UNIVERSIDADE FEDERAL FLUMINENSE

PABLO LUIZ ARAÚJO MUNHOZ

DATA GATHERING IN SENSOR NETWORKS WITH DATA MULES: GLOBAL AND LOCAL APPROACHES

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Thesis presented to the Computing Graduate Program of the Universidade Federal Fluminense in partial fulfillment of the requirements for the degree of Doctor of Science. Area: Algorithms and Optimization

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Abstract

A usual way to collect data in a Wireless Sensor Network (WSN) is by the support of a special agent, called data mule, that moves between sensor nodes and performs all communication between them. Using this problem as base, we tackled two versions of the problem: the first one where the mule has a global view, i.e., has the complete knowledge of all sensors and possible routes between them, and the second one where the mule must to decide its route based only on local informations obtained from the neighbors of the current visited sensor. The first version dealt with the Data Mule Scheduling Problem (DMSP). The DMSP is $\mathcal{NP}$-hard since it is a generalization of the Traveling Salesman Problem. In DMSP, in addition to the Data Mule Routing, it is necessary to plan the speed that this mule will use and also to schedule the attendance of the sensors in this route. Exact mathematical programming models and sequential heuristic algorithms for the problem are studied. Two different formulations using mixed integer linear programming and methods based on the GRASP and GVNS metaheuristics were proposed, in addition we generated instances for their validation. In the second version, the focus is on the construction of the route that the data mule must follow to serve all nodes in the WSN. This second version deals with the case when the data mule does not have a global view of the network, i.e., a prior knowledge of the network as a whole. Thus, at each node, the data mule makes a decision about the next node to be visited based only on a limited local knowledge of the WSN. Considering this realist scenario, two locality sensitive heuristics are proposed. These heuristics differ by the criterion of choice of the next visited node, while the first one uses a simpler greedy choice, the second one uses the geometric concept of convex hull. They were executed in instances of the literature and their results were compared both in terms of route length and in number of sent messages as well. For this version, some theoretical results, a mathematical formulation, and some lower bounds for the global view scenario are also proposed, in order to provide some parameters to evaluate the quality of the solutions given by the locality sensitive heuristics.

Keywords: Wireless Sensor Networks; Data Mule Routing; Locality Sensitive Heuristics;

Resumo

Uma maneira usual de coletar dados em uma Rede de Sensores sem Fio (*Wireless Sensor Networks* – WSN) é atráves de um agente especial, chamado mule de dados, que se move entre os nós sensores e realiza toda a comunicação entre eles. Ao se tratar da coleta de dados em uma WSN utilizando a mula de dados como meio de comunicação entre os sensores da rede, foram escolhidas duas abordagens para esse problema: a primeira onde a mula de dados tem uma visão global, ou seja, tem o conhecimento completo de todos os sensores e possíveis rotas entre eles; e a segunda onde a mula deve decidir sua rota baseada apenas em informações locais obtidas dos vizinhos do sensor que está sendo visitado em dado momento. A primeira abordagem tratou o Problema de Sequenciamento de Mula de Dados (*Data Mule Scheduling Problem* – DMSP). O DMSP é um problema classificado como $\mathcal{NP}$-Difícil, uma vez que é uma generalização do Problema do Caixeiro Viajante (*Traveling Salesman Problem*). Ao tratarmos o DMSP, além de realizar a definição da rota, é necessário planejar a velocidade que esta mula utilizará em seu trajeto e também sequenciar o atendimento dos sensores nesta rota. São estudados modelos de programação matemática e algoritmos heurísticos sequenciais para o problema. Foram propostas formulações matemáticas utilizando programação linear inteira mista e métodos baseados nas metaheurísticas GRASP e GVNS. Além disso, instâncias para a validação dos métodos foram geradas. Na segunda abordagem, o foco está na construção da rota que a mula de dados deve seguir para atender todos os nós na WSN. Esta segunda versão aborda o caso em que a mula de dados não possui uma visão global da rede, ou seja, um conhecimento prévio da rede como um todo. Assim, em cada nó, a mula de dados toma uma decisão sobre o próximo nó a ser visitado com base apenas em um conhecimento local limitado do WSN. Considerando este cenário realista, duas heurísticas sensíveis à localidade são propostas. Estas heurísticas diferem entre si pelo critério de escolha do próximo nó visitado, enquanto a primeira usa uma escolha gulosa mais simples, a segunda usa o conceito geométrico de envoltória convexa. Eles foram testadas em instâncias da literatura e seus resultados foram comparados tanto em termos de duração da rota quanto em número de mensagens enviadas. Para esta versão, alguns resultados teóricos, uma formulação matemática e alguns limites inferiores para o cenário de visão global também são propostos, a fim de fornecer alguns parâmetros para avaliar a qualidade das soluções fornecidas pelas heurísticas sensíveis à localidade.

Palavras-chave:Rede de Sensores sem Fio; Roteamento de Mula de Dados; Heurísticas Sensíveis à Localidade.

Résumé étendu

Un moyen habituel de collecter des données dans un réseau de capteurs sans fil (Wireless Sensor Network - WSN) est le soutien d'un agent spécial, appelé mule de données, qui se déplace entre les noeuds et effectue toutes les communications entre eux. En utilisant ce problème comme base, nous avons abordé deux versions du problème: la première où la mule a une vue globale, c'est à dire, a la connaissance complète de tous les capteurs et les routes possibles entre eux, et le second où la mule doit décider son itinéraire repose uniquement sur des informations locales obtenues des voisins du noeud visité actuel.

Dans la première version, elle traite du DMSP (Data Mule Scheduling Problem). Le DMSP est NP-dur puisqu'il s'agit d'une généralisation du problème du voyageur de commerce. Dans DMSP, en plus du routage de la mule, il est nécessaire de planifier la vitesse que ce mulet utilisera et aussi de programmer la présence des capteurs dans cette route.

Dans cette première version, on considère trois formes d'approche de vitesse. Dans la première, la vitesse est considérée comme constante, donc il n'y a pas de changement dans sa valeur dans l'ensemble du route de la mule. Dans la seconde, il existe un ensemble discret de vitesses définies. Ainsi, la mule peut, à chaque partie du trajet, choisir une des vitesses possibles afin que son itinéraire puisse être réduit dans le temps, mais en maintenant la présence de tous les capteurs de noeuds du réseau. Dans la dernière approche, la vitesse est définie dans un intervalle continu, c'est-à-dire que seule une valeur de vitesse minimale et maximale est définie pour le mulet de données, et dans cette plage de vitesse, le mule peut choisir n'importe quelle valeur de vitesse. Pour tous les cas, les modèles de programmation mathématique sont étudiés, et des formulations utilisant une programmation linéaire entière mixte sont proposées.

Pour le cas où la vitesse est constante, des techniques heuristiques basées sur les métaheuristiques GRASP (*Greedy randomized adaptive search procedure*) et GVNS (*General Variable Neigborhood Search*) ont été développées. Afin de définir l'heuristique finale, des heuristiques constructives et des recherches locales ont été effectuées afin de trouver

la meilleure combinaison qui obtiendrait le meilleur résultat final. En heuristique constructive, deux méthodes ont été proposées, l'une basée sur la recherche des plus proches voisins (IMB) et l'autre basée sur le route le plus long (CML). Dans l'IMB, au lieu de considérer seulement la distance comme critère de choix du prochain noeud, un ratio entre la distance et la capacité de service de chaque choix a été pris en compte. Ainsi, les noeuds de capteurs qui ont la distance la plus courte et qui contribuent le mieux au service des noeuds capteurs du réseau ont la préférence de choix. Dans CML, une longue route est créée à l'aide de tous les noeuds capteurs. Comme l'objectif est de réduire le temps de l'itinéraire, l'idée est d'enlever les noeuds à longue distance et qui contribuent moins au service réseau, de sorte qu'avec cette suppression la solution reste viable, c'est-à-dire que tous les noeuds du réseau continuent être assisté.

Trois recherches locales, Swap, Shift et Swap21 ont été développées, et toutes ont été testées par deux façons d'explorer l'espace de solution: Best and First Improvement. Ces options ont ensuite été testées pour toutes les instances proposées, et les méthodes les plus performantes ont été choisies. Ces méthodes ont été combinées à travers l'heuristique *Variable Neighborhood Descent* (VND) avec un ordre d'exploration aléatoire.

Ainsi, grâce aux composants précédemment testés, deux heuristiques ont été développées, une basée sur la métaheuristique GRASP et une autre basée sur la métaheuristique VNS. Les deux heuristiques ont été comparées aux résultats de la formulation mathématique. Lorsque nous avons testé les instances à partir de 21 noeuds dans le réseau, la formulation mathématique commence à ne pas trouver des solutions optimales dans un délai de 1 heure d'exécution. Ainsi, l'utilisation d'heuristiques définies est justifiée.

Dans la deuxième version, l'accent est mis sur la construction de l'itinéraire que la mule de données doit suivre pour desservir tous les noeuds dans le WSN. La deuxième version traite du cas où la mule de données n'a pas une vue globale du réseau, c'est à dire, une connaissance préalable du réseau dans son ensemble. Ainsi, à chaque noeud, la mule prend une décision concernant le noeud suivant à être visité en se basant uniquement sur une connaissance locale limitée du WSN. Compte tenu de ce scénario réaliste, deux heuristiques sensibles à la localité sont proposées. Ces heuristiques diffèrent par le critère de choix du noeud visité suivant, tandis que le premier utilise un choix glouton, plus simple, le second utilise le concept géométrique de la enveloppe convexe. Ils ont été exécutés dans des cas de la littérature et leurs résultats ont été comparés à la fois en termes de longueur de route et en nombre de messages envoyés ainsi.

List of Figures

2.1 Example of Sparce Ad hoc Network 4

2.2 Subproblems of do DMSP [42] 7

3.1 Problem representation 14

3.2 Representation of solution s 16

3.3 Neighborhood Structures examples 21

5.1 Graph G obtained from U and S. 44

5.2 $Q = \{p_0, p_1, \ldots, p_8\}$ and the corresponding $CH(Q)$ in dashed line 51

5.3 Graham's scan first steps example 54

List of Tables

2.1 Data mule based algorithms 11

3.1 Average GAP between NIH × LIH and the mathematical formulation . . . 26

3.2 Average GAPs of Local Searches 27

3.3 Average IMPs 27

3.4 Computational experiments of GRVND and GVNS-RVND 29

3.5 EQUAL and IMP comparison between GRVND and GVNS-RVND 31

5.1 Connected Dominant Set based algorithms 42

5.2 Local Time and Memory Complexities 56

5.3 Computational results – Global view 58

5.4 Computational results – locality sensitive heuristics 59

5.5 Maximum data mule local time 60

1 Instances with 6 nodes and Central Base Station position 69

2 Instances with 6 nodes and Eccentric Base Station position 70

3 Instances with 6 nodes and Random Base Station position 71

4 Instances with 7 nodes and Central Base Station position 72

5 Instances with 7 nodes and Eccentric Base Station position 73

6 Instances with 7 nodes and Random Base Station position 74

7 Instances with 8 nodes and Central Base Station position 75

8 Instances with 8 nodes and Eccentric Base Station position 76

9 Instances with 8 nodes and Random Base Station position 77

10 Instances with 9 nodes and Central Base Station position 78

11 Instances with 9 nodes and Eccentric Base Station position 79

12 Instances with 9 nodes and Random Base Station position 80
13 Instances with 10 nodes and Central Base Station position 81
14 Instances with 10 nodes and Eccentric Base Station position 82
15 Instances with 10 nodes and Random Base Station position 83
16 Instances with 11 nodes and Central Base Station position 84
17 Instances with 11 nodes and Eccentric Base Station position 85
18 Instances with 11 nodes and Random Base Station position 86
19 Instances with 16 nodes and Central Base Station position 87
20 Instances with 16 nodes and Eccentric Base Station position 88
21 Instances with 16 nodes and Random Base Station position 89
22 Instances with 21 nodes and Central Base Station position 90
23 Instances with 21 nodes and Eccentric Base Station position 91
24 Instances with 21 nodes and Random Base Station position 92
25 Instances with 6 nodes and Central Base Station position 94
26 Instances with 6 nodes and Eccentric Base Station position 95
27 Instances with 6 nodes and Random Base Station position 96
28 Instances with 7 nodes and Central Base Station position 97
29 Instances with 7 nodes and Eccentric Base Station position 98
30 Instances with 7 nodes and Random Base Station position 99
31 Instances with 8 nodes and Central Base Station position 100
32 Instances with 8 nodes and Eccentric Base Station position 101
33 Instances with 8 nodes and Random Base Station position 102
34 Instances with 9 nodes and Central Base Station position 103
35 Instances with 9 nodes and Eccentric Base Station position 104
36 Instances with 9 nodes and Random Base Station position 105
37 Instances with 10 nodes and Central Base Station position 106

38 Instances with 10 nodes and Eccentric Base Station position 107

39 Instances with 10 nodes and Random Base Station position 108

40 Instances with 11 nodes and Central Base Station position 109

41 Instances with 11 nodes and Eccentric Base Station position 110

42 Instances with 11 nodes and Random Base Station position 111

43 Instances with 16 nodes and Central Base Station position 112

44 Instances with 16 nodes and Eccentric Base Station position 113

45 Instances with 16 nodes and Random Base Station position 114

46 Instances with 21 nodes and Central Base Station position 115

47 Instances with 21 nodes and Eccentric Base Station position 116

48 Instances with 21 nodes and Random Base Station position 117

49 Swap – Average GAPs 119

50 Shift – Average GAPs 120

51 Swap21 – Average GAPs 121

52 Swap – Average IMPs 122

53 Shift – Average IMPs 123

54 Swap21 – Average IMPs 124

55 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 6 nodes and Central Base Station position 126

56 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 6 nodes and Eccentric Base Station position 127

57 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 6 nodes and Random Base Station position 128

58 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 7 nodes and Central Base Station position . . . 129

59 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 7 nodes and Eccentric Base Station position . . . 130

60 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 7 nodes and Random Base Station position . . . 131

61 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 8 nodes and Central Base Station position . . . 132

62 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 8 nodes and Eccentric Base Station position . . . 133

63 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 8 nodes and Random Base Station position . . . 134

64 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 9 nodes and Central Base Station position . . . 135

65 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 9 nodes and Eccentric Base Station position . . . 136

66 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 9 nodes and Random Base Station position . . . 137

67 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 10 nodes and Central Base Station position . . . 138

68 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 10 nodes and Eccentric Base Station position 139

69 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 10 nodes and Random Base Station position 140

70 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 11 nodes and Central Base Station position . . . 141

71 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 11 nodes and Eccentric Base Station position 142

72 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 11 nodes and Random Base Station position 143

73 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 16 nodes and Central Base Station position . . . 144

74 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 16 nodes and Eccentric Base Station position 145

75 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 16 nodes and Random Base Station position 146

76 Computational experiments of mathematical formulation, GRVND and GVNS- RVND – Instances with 21 nodes and Central Base Station position . . . 147

Contents

1 Introduction **1**

1.1 Motivation . . . 2

1.2 Objectives . . . 2

1.2.1 Main objectives . . . 2

1.2.2 Specific objectives . . . 2

1.3 Organization . . . 3

2 Data Mule Scheduling Problem **4**

2.1 Introduction . . . 4

2.2 Definition and related works . . . 6

2.2.1 Data Mule Scheduling Problem . . . 6

2.2.2 Related Works . . . 7

3 Data Mule Scheduling Problem with Constant Speed **13**

3.1 Problem definition and mathematical formulation . . . 13

3.2 Proposed heuristics . . . 16

3.2.1 Solution Representation . . . 16

3.2.2 Constructive Heuristic . . . 16

3.2.3 RVND . . . 21

3.2.4 Developed heuristics . . . 22

3.3 Computational Experiments . . . 24

3.3.1 Instances . . . 24

3.3.2 Constructive heuristics 25
3.3.3 Local Searches 26
3.3.4 Proposed heuristics 28

4 Other proposed models for solving the Data Mule Scheduling Problem 33

4.1 DMSP with Discrete Speeds 33
4.2 DMSP with Continuous Speeds 35

5 Data Mule Routing Problem 38

5.1 Introduction 38
5.2 Related Work 39
5.2.1 Connected Dominating Set based Algorithms 40
5.3 Theoretical Remarks 43
5.3.1 Lower Bounds 45
5.3.2 Mathematical Formulation 46
5.4 Algorithms for Data Mule with Local View 48
5.4.1 Algorithm based on number of uncovered neighbours – AlgNUN . . 48
5.4.2 Algorithm based on convex-hull – AlgCH 51
Background 51
5.4.2.1 Data mule Algorithm 54
5.4.3 Complexity Analysis 56
5.5 Computational experiments and Analysis 56

6 Conclusions 61

References 63

Appendix A: Complete test results 68

.1 Local Search Tests 68

.1.1 Best Improvement Tests 68
.1.2 First Improvement Tests 93
.1.3 Average GAP's 118
.1.4 Average Improvements 121
.2 Proposed heuristics tests 124

Chapter 1

Introduction

Wireless Sensor Networks, WSN, have received much attention in last decades due to its flexibility and its easy and fast deployment capability. In addition, there are many practical applications where WSN can be used, as, for example, environmental monitoring and military applications [21, 37]. In this kind of network, communication is exclusively wireless and information exchange is accomplished when there is intersection between sensors spatial coverages. The information routing is one of the main problems of WSN [34, 39]. In some cases, a mobile agent, called date mule, is responsible for performing the network communication. Data mule is a mobile agent that has greater processing, memory capacities and energy availability than regular sensors of the WSN. It is responsible for collecting data from all sensors and take them to a base station, reducing the number of exchanged messages in the network and, consequently, the spent energy for data transmission.

Thus, in this work two ways of dealing with the problem are studied: a global approach, where all the information about the location of the sensor nodes, the amount of demand of each sensor node, and the size of the network are previously known; and a local approach, where the data mule has no previous knowledge about the network, and yet must attend the demands of all nodes. To do this, the mule must make decisions using only the information from the sensors on which it can communicate at any moment.

For the global approach, the problem is formally defined, and mathematical formulation and heuristics, based in GRASP and GVNS, are proposed in order to generate good solutions to the problem. Each component of the two proposed heuristics are exhaustive testing in order to define their final versions. The results of the two proposed heuristics were compared with the results of the exact method and some analysis are made. Besides that, two extended version of the global approach are defined, and mathematical formulations are proposed to represent this cases.

For the local approach, a mathematical formulation and lower bound definitions were proposed, in addiction to theoretical contributions for the problem. Two locality sensitive heuristics are proposed, in such way that they differ by the criterion of choice of the next visited node, while the first one uses a simpler greedy choice, the second one uses the geometric concept of convex hull. They were executed in instances of the literature and their results were compared both in terms of route length and in number of sent messages as well.

1.1 Motivation

Using data mules to perform a communication between all sensor nodes in a Wireless Sensors Network (WSN) is a problem with wide application in the area of networks in theoretical and real applications. In this case of WSN, a wide range of characteristics can be found, including the use of more than one data mule for collecting the information, the sensors can move, restrictions on storage space of both sensor and mule messages, energy use restrictions, among others. In addition, because it is a problem of the $\mathcal{NP}$-hard class, developing efficient algorithms to solve it in an acceptable computational time is a great challenge, and despite the importance of the problem.

1.2 Objectives

1.2.1 Main objectives

This work aims to develop efficient global and local methodologies for solving the communication in Wireless Sensors Network using Data Mules, using both exact and heuristic techniques. It also seeks to identify the various definitions found for this same class of problems that use mobile agents to perform the communication in a wireless sensor network, unifying the works with a single definition, thus making theoretical and practical contributions in the theme.

1.2.2 Specific objectives

1. Study of state-of-the-art publications regarding problems using Data Mules to perform the communication between the sensors of the network;

2. Identification of different variants of the literature;
3. Development of efficient mathematical formulations for the studied problems;
4. Development of heuristics to solve the problems studied;
5. Study and application of distributed programming techniques, aiming to tackle the problem with local view characteristics;
6. Propose instances to evaluate the algorithms;
7. Evaluation of the quality of the algorithms developed;
8. Submission of the results obtained in periodicals and international conferences of good quality.

1.3 Organization

This thesis is divided into six chapters, including this introduction, where the use of data mules in Wireless Sensor Networks is contextualized. In Chapter 2 the Data Mule Scheduling Problem (DMSP) is defined and a literature review is presented. In Chapter 3 the DMSP with Constant Speed is defined and a proposed mathematical formulation and heuristics to deal with the problem is shown. Tests are performed to evaluate the proposed methods and some analysis are made. In Chapter 4 two extended versions of the DMSP where presented, defined and mathematical formulations are proposed to represent each case. In Chapter 5 the Data Mule Routing Problem is defined. In this chapter a literature review is made, theoretical contributions to the problem, and two locality sensitive heuristics are presented. In addition, computational experiments and analyzes are showed. Finally, in Chapter 6, conclusions are presented for the problems tackled.

Chapter 2

Data Mule Scheduling Problem

2.1 Introduction

A sparse mobile ad hoc network is a class of MANET (Mobile Ad hoc Network) where the deployment of the sensors is sparse and thus the exchange of information between these sensors does not occur frequently. Thus the network formed can remain partitioned over a long period of time. Typically, a Store-Carry-and-Forward model is used where a sensor broadcast the source information to the destination sensors in one or more hops, in such a way that a sensor receives the previous sensor information and stores it. This sensor maintains this information for a time until it can contact other sensors and broadcast this information. Systems that depend on the movement of each sensor are called “passive”, while systems in which sensors move proactively to create a new communication bridge are called “active”. An example of a sparse mobile ad hoc network can be seen in Figure 2.1.

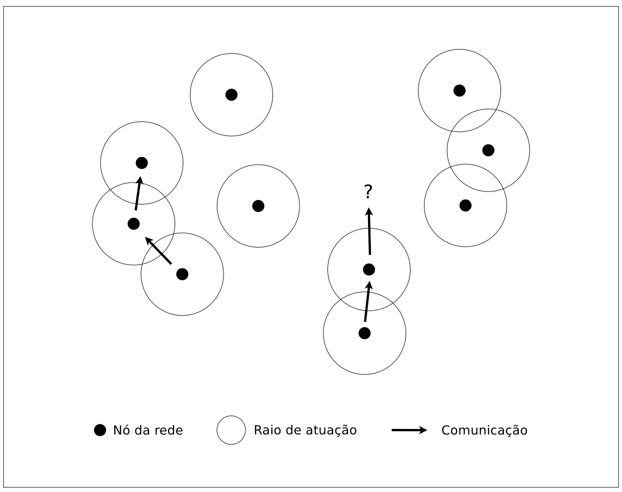

Figure 2.1: Example of Sparce Ad hoc Network

Data MULEs (Mobile Ubiquitous LAN Extensions), defined by [38], differ from other active systems that operate in sparse networks by having mobile agents called Data Mules, which are used to make easier the connections between the other sensors. The role of these agents is to visit the sensors of the network and perform the data delivery between them or the collection of data to a base station.

This model using data mules is quite attractive because it has the characteristic of performing end-to-end data deliveries explicitly, i.e., there are no intermediate sensors between the origin and the destination. In addition, by performing this task, the extra activity of forwarding messages is removed from the other sensors in the network, which may be desirable if these sensors have little capacity for data storage and power [4].

Thus, the network sensors are classified in two ways, the regular sensors, or simply sensors, and a single special sensor called the data mule. Regular sensors generate data in form of messages to other sensors in the network or to a base station, that can be interested in receiving messages from other sensors. The data mule is responsible for performing the communication between the sensors using a route that must be defined within the area where the sensors are present.

The main problem of this model that uses data mules is the generation of routes to collect all network information. This decision may include some restrictions about the paths that the mule can pass, the definition of the speed that this mule will move in the route, respect a maximum value of messages delays in the network, communication guarantee of the mule and sensors, among others.

2.2 Definition and related works

2.2.1 Data Mule Scheduling Problem

In the Data Mule Scheduling Problem, both sensors and the data mule have radio equipment to exchange information, and may have equipment with different ranges. The communication occurs only when the distance between the sensor and the mule is within the range of communication of their equipment, we say that the sensor and the data mule are in `contact`.

During each contact, the mule can upload messages destined for this sensor and download the messages that this sensor wants to send. This process is called `service`, and the mule can execute only one service at a time. Each sensor can also have a buffer of messages to be sent and a buffer of received messages (buffer receive), each with its own capacity.

The Data Mule Scheduling Problem (DMSP) was proposed by [42] and deals with the planning of the data mules attendance. This planning covers three phases: Path Selection, Speed Control and Job Scheduling.

The Path Selection phase attempts to define a route to the data mule to collect information from each of the sensors in the network, which means that there must be at least one contact between the Data Mule and the other sensors. In the Speed Control phase, the speed management during the route created by Path Selection is the focus. The data mule can change the speed during the route in order to stay in contact the time enough to exchange all information with each sensor. The Job Scheduling phase is important when the mule is in contact with more than one sensor simultaneously, because the mule should serves only one sensor at a time. A scheduling of services must be done, analyzed both path and speed of the data mule. These three steps can be seen in Figure 2.2.

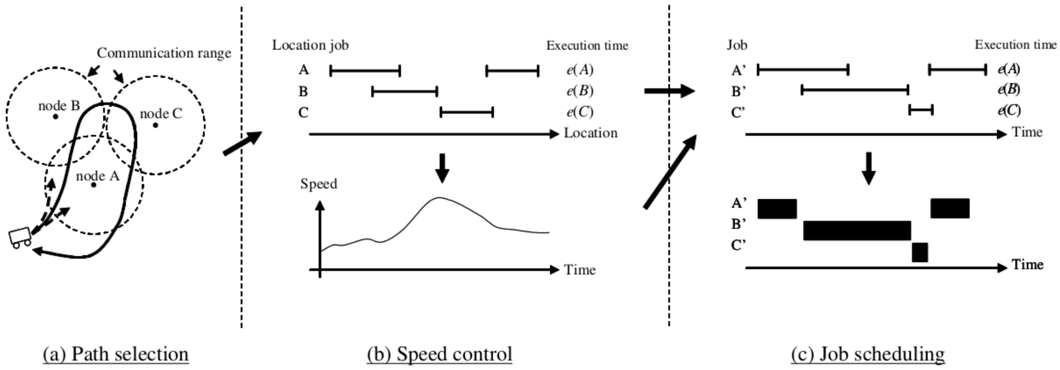

Figure 2.2: Subproblems of do DMSP [42]

In example presented in Figure 2.2 the mule needs to serve three sensors arranged in the plane and having communication ranges as in Figure 2.2(a). In the first phase, Path Selection, one route needs to be defined. In the example, the mule performs the path described by the black arrow, starting and stopping in the same place, defined as base station. Given this route in Path Selection phase (Figure 2.2a), it is possible to create a Gantt chart, Figure 2.2(b)(above), with the visiting order and the distance that the mule will stay in contact with each node. After the construction of the Gantt chart, a definition of the mule speed in each part of the route is made, Figure 2.2(b)(bellow), ending the Speed Control phase. Using the visiting order, the distances and the speeds defined in the second phase, its possible to create another Gantt chart, Figure 2.2(c)(above). But now, the chart is representing the contact time of the mule, given the visiting order. The higher the speed in Speed Control, the shorter the contact time in Job Scheduling, which occur with the node C', for instance. The scheduling starts with this chart, in order to remove the service intersection, which occur with node A' and B', Figure 2.2(c)(above), for instance. After solving the conflict of services, Figure 2.2(c)(bellow), the Job Scheduling phase is finished.

2.2.2 Related Works

The mobile ad hoc networks are extensively studied in the literature. Thus, it is possible to find several works in the literature dealing with the different characteristics of these types of network, such as definition of a better location of the sensors, type of communication used, network security, QoS, type of traffic transmitted by sensors, attendance method, if the sensors are static or dynamic, among other characteristics. In this bibliographic review, the focus will be given mainly on ad hoc mobile networks that use an agent responsible for performing data traffic between the other sensors, being the responsible of performing all communications between them.

For this problem different definitions can be found for this mobile agent responsible for communication. In addition to Data Mule ([38]), the following definitions are also found: Message Ferrying ([51, 52]), Mobile Routers ([22]), Actor ([1]), Actuator ([32, 30]), Mobile Sinks ([29, 44, 3, 19, 23]) and Mobile Elements ([15, 48, 28]).

In [51] the Message Ferrying is defined as the agent responsible for collecting and transmitting the information between the other sensors. In this paper, it is proved that the problem of routing the Message Ferrying (Data Mule) is $\mathcal{NP}$-hard through a generalization of the Traveling Salesman Problem (TSP [13]). The objective is minimizing the average delay in message deliveries. An algorithm has been developed for the TSP with a refinement phase that applies movements to reduce the delay messages exchanges.

In [52] the problem defined in [51] is also tackled. But, here, it uses multiple Message Ferries that can communicate with each other. The communication redundancy provided by the multiple Message Ferries introduces a fault tolerance mechanism in that scenario. Tests were executed considering different types of communication between the ferries (restricted or free), and a unique route or different routes.

A problem using a data mule that can choose between various speeds and where the sensors can move was treated in [4]. Besides those previously described features, the difficulty of the problem has increased because the network sensors move arbitrarily within a predetermined area, and it is necessary to define the speed of the data mule which will allow for it to serve all sensors. Because it is not possible to guarantee that the mule will be in contact with the sensors, an algorithm was proposed, using a model of movement of the sensors in order to define a contact probability to exchange information.

In [49], a robot that collects sensor data and returns to the base station is used. The communication range of the antennas of each sensor is determined by the amount of battery that each sensor has, and reduces with the use of the battery. The problem is a generalization of the Traveling Salesman Problem with Neighborhoods ([16]), where customers are willing to meet with the traveling salesman within a certain distance of their residence. A two-phase evolutionary algorithm was developed. The first phase solves the TSP, using the position of the sensors, and the second phase defines the best meeting points within the communication range of each sensor.

In [24], a problem with only one data mule, named SenCar, and static sensors is addressed. This problem considers multi-hop communication, i.e., sensors can transmit their messages through other sensors. A heuristic algorithm based on clustering to balance the distance traveled by SenCar and the traffic load was proposed, in order to increase the network lifetime. The algorithm works both in connected and disconnected networks and it was evaluated by simulations.

In [48], a problem with multiple data mules and multi-hop communication is presented. Concentrator sensors, called *rendezvous points* (RP), are defined and only they must be served by the data mule. Thus, the mule does not have to travel long distances to collect the data of all sensors. The authors developed two heuristics to address this problem. In the first algorithm the mules choose the RP when they are moving in the routing tree, while in the second algorithm, RP are chosen by considering the maximum energy saving and travel distance ratios.

In [35] there is no prior knowledge of the location of the sensors which must be served, so the data mule executes a location collection procedure to establish which sensors will be used to define the service route. There is also the possibility of communication between the sensors using a k-hop communication, where k defines the highest degree of communication between sensors, i.e., how many sensors a message can pass before reaching the data mule. The solutions are evaluated considering the delay for data transmission and energy efficiency. A heuristic based on the Ant Colony meta-heuristic was developed and tests were carried out in a network simulator.

In [31], multiple data mules were used, each one moving in an independent route at constant or variable speeds. In this work, the sensors are static, but each of them receives a weight that defines their priority to be served. The weights are collected by the data mules and can be updated at each service according the necessity to visit the sensor. A sequential and distributed versions of a probabilistic algorithm, based on a TSP approach, were developed.

In [42] and [43], the Data Mule Scheduling Problem is presented. In this problem, two more perspectives are added to the basic problem of routing: speed control and the order of sensors serving. They developed a mathematical model to treat perspective separately, and heuristics that solve the problems independently.

In [45], sensor nodes send the information to sinks where the data mule, here called mobile sink, must pass to collect the information from the network. There is a motion restriction because the mobile sink is viewed as an unmanned aerial vehicle (UAV), thus the route should be smooth, according to the turning constraints that the UAV is capable of doing. A constructive heuristics was proposed to deal with this problem and the results are compared with a classical TSP solution and a traditional in-network communication routing.

In [25], the data mule, called an M-collector, must start and return to the data sink (base station) collecting all data from the network. So, pooling points where data is transmitted from sensor nodes to the data mule are defined. The problem consists in defining the best pooling points and the best route between them. The candidate pooling points can be defined either by the network nodes themselves or by a previous stage where one or more M-collectors explore the network by searching for points where there is communication with some node of the network. The final path of the M-collector is formed by the set of pooling points that it passes to serve all the nodes of the network. A mathematical formulation and a greedy two-phase heuristic are proposed. The case where multiple M-collectors can be used was also treated.

A summary of the related work that uses a data mule is presented in Table 2.1.

Table 2.1: Data mule based algorithms

Authors	Sensors Movement	Data Mule	Characteristics		Algorithm
			Dest.	Communication	
Zhao and Ammar (2003)[51]	Static	Single	Sensors	End-to-end	Exact algorithm
Zhao *et al.* (2005)[52]	Static	Multiple	Sensors	End-to-end	Assign and route algorithm for TSP
Bin Tariq *et al.* (2006)[4]	Dynamic	Single	Sensors	End-to-end	Optimized Waypoints
Yuan *et al.* 2007[49]	Static	Single	Base Station	End-to-end	Evolutionary Algorithm
Ma and Yang (2007)[24]	Static	Single	Base Station	End-to-end	Clustering Algorithm
Xing *et al.* (2008)[48]	Static	Single	Sinks	Multi-hop	Routing tree with pickup points
Rao *et al.* (2008)[35]	Dynamic	Single	Base Station	Multi-hop	Ant colony
Ngai *et al.* (2009)[31]	Static	Multiple	Base Station	End-to-end	Spanning tree based Algorithm
Sugihara *et al.* (2010)[42]	Static	Single	Base Station	End-to-end	Mathematical Formulation
Sugihara *et al.* (2011)[43]	Static	Single	Base Station	End-to-end	Shortest Path
Wichmann (2012) [45]	Static	Single	Sinks	End-to-end	Constructive heuristics
Ma *et al.* (2013)[25]	Static	Multiple	Base Station	End-to-end	Spanning tree covering algorithm

After analyzing the variants, it was decided to deal with the DMSP with the following characteristics: the sensors do not have move or send/receive buffer, all having a fixed range radius, being serviced by a single Data Mule, which will have a set K of possible constant velocities that can be assigned to each arc of the solution. In addition, the sensors will have a fixed transmission rate within their radius of action and their messages are destined to a Base Station, using only end-to-end communication. In addition, the Data Mule can only perform one service at a time, i.e., only one sensor can transmit data to the data mule at a same time.

Chapter 3

Data Mule Scheduling Problem with Constant Speed

3.1 Problem definition and mathematical formulation

The purpose of the DMSP is to serve the demand of all sensors. In order to do this the mule must stay in the communication range of the sensors enough time to be able to exchange all the required data. Thus, the mule does not necessarily have to visit directly all sensors.

The intersections of communication between sensors are parts of the path where the mule can serve more than one sensor. The attendance can be divided in this intersection area, but it should respect the constraint that the mule cannot connect to more than one sensor at a time. In order to highlight the attendance areas, fictitious nodes were added to the problem representation at each time that the possible path of the mule intercept the border of the radius range of a sensor, as shown in Figure 3.1. Thus the edges can be divided in edges where the mule can serve a node, $\{(a, 4), (4, d), (e, 1), ...\}$, and edges where the mule cannot attend any node, $\{(BS, a), (d, e), ...\}$.

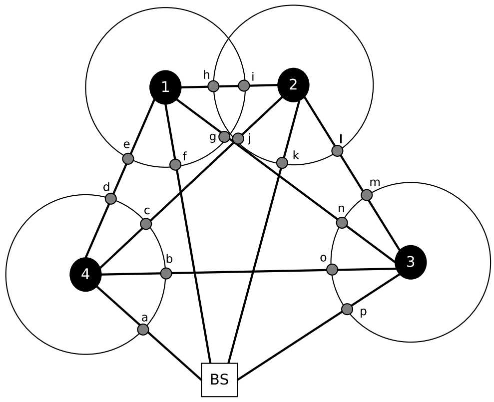

Figure 3.1: Problem representation

The DMSP can be defined as follows. Let $G = (V, E)$ be a complete graph without adding fictitious nodes, where $V = \{0, 1, 2, ..., n\}$ is the set of $n+1$ nodes of the network, and $E = \{(i, j) : i, j \in V, i \neq j\}$ the set of edges. Node 0 represents the Base Station, from where the data mule departs. Each node $i \in V \setminus \{0\}$ has a demand s_i, a communication range r_i radius and a $rate_i$ which is the amount of data that this node can transmit per unit of time. After adding fictitious nodes V_f, a new graph $G' = (V', E')$, where $V' = \{V \cup V_f\}$ and $E' = \{(p, q) : p, q \in V', p \neq q\}$, is created and used as the input of the problem. The set E' can be partitioned into two subsets W and U, representing the edges from which the data mule can and cannot connect to some nodes, respectively. To each edge $(p, q) \in E'$ is associated a non-negative cost c_{pq}, which represents the distance between these nodes, and a pre-calculation of the time which the mule can stay in a edge $(p, q) \in E'$ is made, $T_{pq} = \frac{c_{pq}}{K}$, where K represents the constant speed which the mule uses in its path. In addition, two sets are defined: $A_i = \{(p, q) \in E' : (p, q) \text{ can attend the node } i \in V\}$ and $Fict_{pq} = \{i \mid \text{node } i \in V \text{ can be attended in } (p, q)\}$. The first set consists of all edges $(p, q) \in E'$ that are able to serve a given node $i \in N$. The second set consists of all edges $(p, q) \in E'$ which correspond to the edge $(i, j) \in E$, that is, all edges (p, q) which are contained in the edge $(i, j) \in E$. The decision variables are: $x_{pq}, \forall (p, q) \in E'$, equal to one if the edge (p, q) is used in the solution, zero otherwise; $z_{pq}, \forall (p, q) \in E'$ is a flow variable related of each edge; $y_p, \forall p \in V'$, equal to one if the node p is used in the solution, zero otherwise; and H^i_{pq} is the time spend by the mule in edge $(p, q) \in E'$ serving the sensor $i \in V$. The proposed mathematical formulation is given by:

$$min \sum_{(p,q)\in W} \sum_{i \in V} H^i_{pq} + \sum_{(p,q)\in U} \sum_{i \in V} H^i_{pq} \tag{3.1}$$

$$s.t.$$

$$\sum_{p\in V'} x_{pl} + \sum_{q\in V'} x_{lq} = 2y_l \qquad \forall l \in V' \tag{3.2}$$

$$\sum_{q\in V'} z_{0q} = 1 \tag{3.3}$$

$$\sum_{q\in V'} z_{lq} = \sum_{p\in V'} z_{pl} + y_l \qquad \forall l \in V' \setminus \{0\} \tag{3.4}$$

$$\sum_{p\in V'} z_{p0} = \sum_{p\in V'} y_p + 1 \tag{3.5}$$

$$x_{pq} \leq \frac{z_{pq}}{2} \qquad \forall (p,q) \in E' \mid p \neq 0 \tag{3.6}$$

$$x_{pq} \geq \frac{z_{pq}}{|V'| + 1} \qquad \forall (p,q) \in E' \tag{3.7}$$

$$x_{0q} = z_{0q} \qquad \forall q \in E' \tag{3.8}$$

$$\sum_{i\in Fict_{pq}} H^i_{pq} = T_{pq} x_{pq} \qquad \forall (p,q) \in E' \tag{3.9}$$

$$\sum_{i\in V} H^i_{pq} = T_{pq} x_{pq} \qquad \forall (p,q) \in U \tag{3.10}$$

$$\sum_{(p,q)\in A_i} rate_i H^i_{pq} \geq s_i \qquad \forall i \in V \tag{3.11}$$

$$x_{pq} \in \{0,1\} \qquad \forall (pq) \in E' \tag{3.12}$$

$$y_p \in \{0,1\} \qquad \forall p \in N' \tag{3.13}$$

$$z_{pq} \geq 0 \qquad \forall (p,q) \in E', z_{pq} \in \mathbb{Z}^+ \tag{3.14}$$

$$H^i_{pq} \geq 0 \qquad \forall (p,q) \in E', i \in V, H^i_{pq} \in \mathbb{R}^+ \tag{3.15}$$

The objective function (3.1) aims to minimize the time spent by the data mule to serve all sensors. Constraints (3.2) ensures that if a node is used in the solution, only one edge must enter and another edge must leave this node. The set of constraints (3.3-3.5) represent the flow restrictions that define a path and avoid sub-cycles formation. Constraints (3.6-3.8) make the connection between the flow variables z_{pq} and the solution variables x_{pq}. Constraints (3.9) define the time spent by the mule if the mule use this edge $(p, q) \in E'$ in its path. The demand attendance is guaranteed through constraints (3.11) and constraints (3.12-3.15) ensure integrity and non-negativity of the variables.

3.2 Proposed heuristics

In this section we present the two proposed heuristics, GRVND and GVNS-RVND, for the Data Mule Scheduling Problem.

3.2.1 Solution Representation

A vector was used as a solution representation for the DMSP in the heuristics. In this vector, the value 0 represents the beginning and the end of the route of the mule. When a node is not present in the solution, it is added to the end of the vector, after the last 0. The treatment of the intersection attendance is done greedily, using the information of possible nodes that can be served by the edge and choosing the node which requires that more data are transmitted to be served.

The example solution $s = [0, 4, 2, 3, 0, 1]$ represents the route made by the Data Mule. In this route, the mule leaves Base Station (0), goes to node 4 using the edge (0,4), then to node 2, using the edge (4,2), and return to the Base Station (0). How Node 1 is not part of the route, it will appear after the last 0, represented by this solution. A graphical representation of this solution can be seen in Figure 3.2.

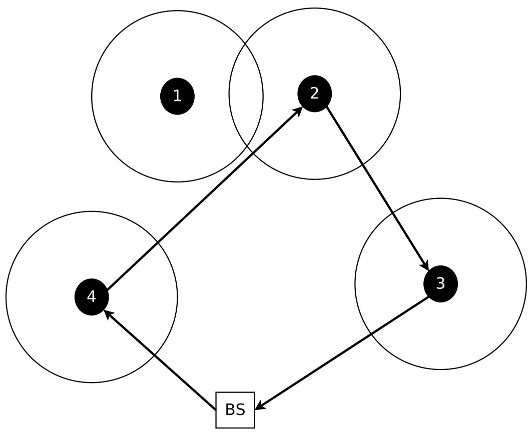

Figure 3.2: Representation of solution s

3.2.2 Constructive Heuristic

The construction of the initial solution is based on the two classical algorithms, Nearest Insertion and Longest Insertion ([36]) proposed for the Traveling Salesman Problem. In the Nearest Insertion the adaptation was made with the change of the criterion of choice, from the shortest distance to a proportion given by the $\frac{attendance}{distance}$ of an edge. Thus, the insertion will prioritize the insertion of nodes that have a greater contribution with the demand attendance and a smaller contribution with the distance that the data mule will go through. In the Longest Insertion, a second phase which aims to reducing the path without the solution becoming infeasible. To deal with this, the method attempt to remove the nodes using a inverse proportion $\frac{distance}{attendance}$, thus the method try to remove nodes that has a small contribution of attendance and a great contribution in the distance path.

The pseudo-code of the proposed constructive heuristic based in the Nearest Insertion, denominated NIH, is presented in the Algorithm 1. The algorithm starts with a list of candidate sensors for insertion L (line 1 of Algorithm 1). A initial solution s containing only the base station is created (line 2 of Algorithm 1) and a random node i is choose, inserted in s and removed from L (lines 3–4 of Algorithm 1). After that, in each iteration, the idea is take the sensor $i \in L$ which most contributes with the attendance and least contributes with the distance traveled by mule and insert it in the current solution s. For this, in each iteration, all nodes $i \in L$ are tested in every possible insert position in the route formed by the current solution s, generating for each insert position a value of attendance capacity given by the $\frac{attendance}{distance}$ (line 7 of Algorithm 1). The highest attendance capacity value calculated for the sensor i is assigned to $capMax_i$ (line 8 of Algorithm 1) and the insertion position that generated the $capMax_i$ value is attributed to $posAdd_i$ (line 9 of Algorithm 1). After these calculations are made, the algorithm select the sensor $i \in L$ with the highest $capMax_i$, insert this sensor in the current solution s at the $posAdd_i$ position and removes i from L (lines 11–14 of Algorithm 1). This procedure is repeated until the demand of all sensors are attended. At the end, the constructed solution s is returned (line 16 of Algorithm 1).

Algorithm 1: Constructive heuristic based in Nearest Insertion

Input: Sets N

1 $L \leftarrow N$;
2 $s \leftarrow$ Solution composed only by Base Station (0) ;
3 Randomly select a node $i \in L$ node and add it to the current solution s ;
4 $L \leftarrow L \setminus \{i\}$;
5 **while** *All demands are not served* **do**
6   **foreach** $i \in L$ **do**
7   Calculate the attendance capacity for each insertion position in the current solution ;
8         $capMax_i \leftarrow$ store the highest capacity of service of the node $i \in N$;
9         $posAdd_i \leftarrow$ store the position of insertion that generated the greatest capacity of attendance ;
10   **end**
11   Select from all $capMax_i$, the i which has the highest capacity of service ;
12   Add the sensor i in the current solution s in position $posAdd_i$;
13   Update the served demand after the new insertion;
14     $L \leftarrow L \setminus \{i\}$;
15 **end**
16 **return** s

The pseudo-code of the proposed constructive heuristic based in the Longest Insertion, denominated LIH, is presented in the Algorithm 2. This algorithm is divided in two phases: the first phase builds one big route in terms of distance (lines 1–13 of Algorithm 2); and the second phase try to remove some sensors of the route made in the first phase in order to reduce the distance traveled by the mule but maintaining the attendance feasibility of the solution (lines 14–25 of Algorithm 2). In the first phase, a set L containing all sensors are defined. A new solution s is initialized with the base station (line 2 of Algorithm 2) and a random sensor $i \in L$ is choose, inserted in s and removed from L (lines 3–4 of Algorithm 2). Thereafter, the idea is insert all sensors in the mule's rote, trying to, in each iteration, insert the sensor with the greatest distance from the current solution possible. So, in each iteration a calculation of the large distance from the current solution s for every $i \in L$ in all possible insert point is made and the bigger value found is assigned to $distMax_i$ (line 7 of Algorithm 2). The insertion position that generates the $distMax_i$ value is associated to $posAdd_i$ variable (line 8 of Algorithm 2). After all calculations, the algorithm selects the sensor i with the highest distance ($distMax_i$) from the current solution s, insert this sensor i in the $posAdd_i$ position and remove it from L (lines 10–12 of Algorithm 2). These steps are repeated until all sensors being part of the solution s, ending the first phase.

The second phase starts with the solution s given by the first phase. The purpose of this second phase is trying to remove some sensors from s, preserving the solution feasibility and reducing the total distance traveled by the mule. So, this phase begins calculating the attendance capacity for each path partition of the current solution s (line 15 of Algorithm 2). This information allows the calculation of the amount of attendance reduction if the sensor $i \in L$ is removed from s (line 17 of Algorithm 2). After this, the algorithm tests if there is some sensor removal that maintain the feasibility of the solution s (line 19). If exists, a sensor i which the greater proportion $\frac{distance_i}{attendance_i}$ is chose (line 20 of Algorithm 2), this value represents the sensor i with lowest reduce the attendance capacity of the solution and highest reduce the total path travelled by the mule. This sensor is removed from s (line 21 of Algorithm 2) and this process is repeated until the removal of new sensors became possible, and the phase two is ended (line 23 of Algorithm 2). At the end, the constructed solution s is returned (line 26 of Algorithm 2).

Algorithm 2: Constructive heuristic based in Longest Path

Input: Sets N

// Phase 1 – Constructing one longest route

1 $L \leftarrow N$;

2 $s \leftarrow$ Solution composed only by Base Station (0) ;

3 Randomly select a $i \in L$ node and add it to the current solution s ;

4 $L \leftarrow L \setminus \{i\}$;

5 **while** $L \neq \emptyset$ **do**

6   **foreach** $i \in L$ **do**

7         $distMax_i \leftarrow$ stores the highest distance obtained by testing all possible insertion position in current solution ;

8         $posAdd_i \leftarrow$ stores the position of insertion that generated the greatest $distMax_i$;

9   **end**

10   Select from all $distMax_i$, the i which has the highest distance ;

11   Add the sensor i in the current solution s in position $posAdd_i$;

12     $L \leftarrow L \setminus \{i\}$;

13 **end**

// Phase 2 – Trying to remove some sensors

14 **while** *true* **do**

15   Calculate the attendance capacity for the current solution s ;

16   **foreach** $i \in L$ **do**

17         $possibleRemove_i \leftarrow$ stores the reduction of the attendance capacity if the sensor i is removed ;

18   **end**

19   **if** *there is a removal in* $possibleRemove_i$ *in which the solution remains feasible* **then**

20   Select from all $possibleRemove_i$, the sensor i with the highest proportion $\frac{distance_i}{attendance_i}$;

21   Remove the sensor i from the current solution s ;

22   **else**

23   break ;

24   **end**

25 **end**

26 **return** s

3.2.3 RVND

The method chosen as local search is the Variable Neighborhood Descent heuristic [27] and it was used with random neighborhood ordering (RVND) [41]. Three neighborhood structures were developed: N^{Swap}: swapping two sensors on the solution, including sensors that are not in the route; N^{Shift}: reallocating a sensor to another point of the route; and $N^{Swap(2,1)}$: swapping two consecutive sensors and another sensor in the solution. All neighborhoods structures consider movements using nodes that are not in the route.

An example of each neighborhood structure is shown in Figure 3.3. The Figure 3.3 (a) represents the base solution where the neighborhoods are applied. The Figure 3.3 (b) shows the new solution s' after a N^{Swap} applied between the sensors 2 and 1. In s', although the sensor 2 is not in the mule's route, the solution pass through its communication range, allowing the mule to serve the sensor 2. In Figure 3.3 (c) the N^{Shift} is shown, the solution s'' represents the reallocation of sensor 1 between sensors 4 and 2. Finally, in Figure 3.3 (d), the $N^{Swap(2,1)}$ is presented. The solution s''' represents the exchange between the nodes (3,0) and the node 1, putting the node 1 in the mule's route.

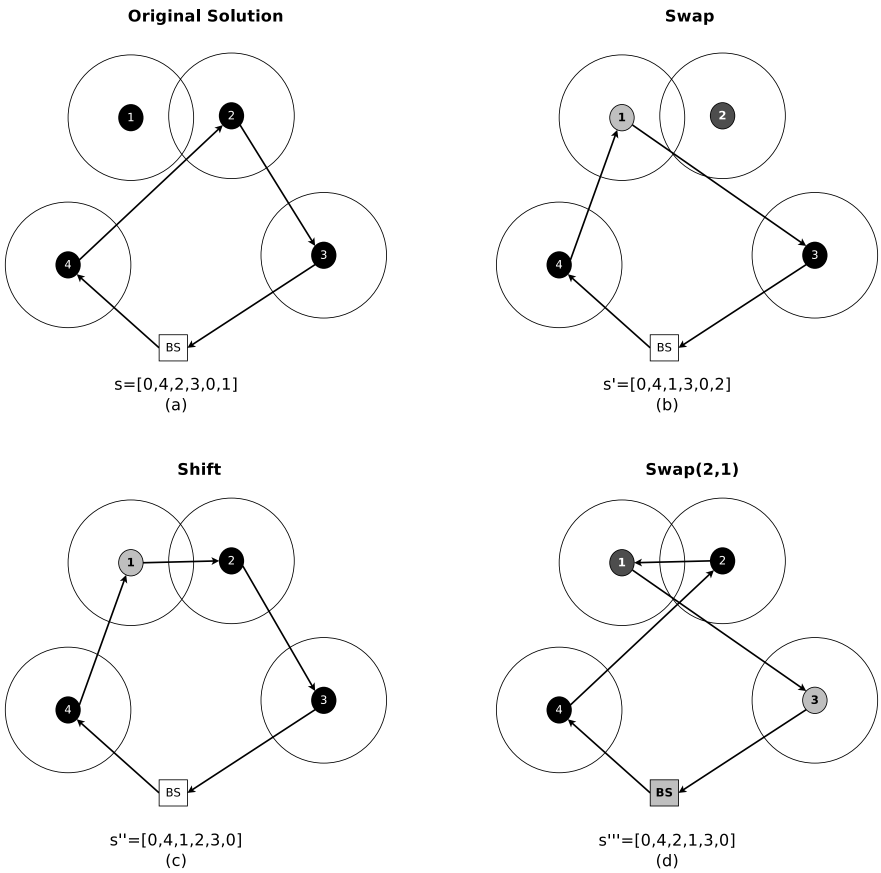

Figure 3.3: Neighborhood Structures examples

The pseudo-code of the RVND is presented in Algorithm 3. The RVND receives as input the three neighborhood structures in a random order and a solution s. The N^k represents the k-th neighborhood structure in this given randomized order. The method starts setting k as the first structure (line 1 of Algorithm 3). In the next step a new solution s' is defined finding the best neighbor of the k-th structure (line 3 of Algorithm 3). If the new solution s' is worse then the current solution s, the method moves to the next neighborhood structure (line 8 of Algorithm 3) and try to find a better solution using this new structure. Otherwise, the current solution s is updated to the new solution s' (line 5 of Algorithm 3) and the neighborhood exploration returns to the first neighborhood structure (line 6 of Algorithm 3). This process is repeated while the solution is improved by some neighborhood structures (line 2 of Algorithm 3). The RVND returns the best solution of the three structures simultaneously (line 11 of Algorithm 3).

Algorithm 3: RVND

Input: neighbours N^{Swap}, N^{Shift} and $N^{Swap(2,1)}$ in a random order, Solution s

1 $k \leftarrow 1$;
2 **while** $k \leq 3$ **do**
3   Find the best neigbour $s' \in N^k(s)$;
4   **if** $f(s') < f(s)$ **then**
5         $s \leftarrow s'$;
6         $k \leftarrow 1$;
7   **else**
8         $k \leftarrow k + 1$;
9   **end**
10 **end**
11 **return** s

3.2.4 Developed heuristics

We developed two heuristics, GRVND and GVNS-RVND, based on Greedy Randomized Adaptive Search Procedure (GRASP) [10] and General Variable Neighborhood Search (GVNS) [27], respectively.

The GRVND is an iterative method that has two phases: construction and local search. Its pseudo-code is presented in Algorithm 4. The GRVND construction phase builds a solution using the Nearest Insertion heuristic (line 4 of Algorihtm 4), and the neighborhood is explored by RVND (line 5 of Algorithm 4). This two phases are performed until $IterMaxWithoutImp$ iterations are executed (line 3 of Algorithm 4). A counter of the number of sequential iterations without improvement ($IterWithoutImp$) is used to control the method (lines 8–10 of Algorithm 4). The best solution over all $IterMaxWithoutImp$ iterations is returned (line 13 of Algorithm 4).

Algorithm 4: GRVND Heuristic

```
   Input: IterMaxWithoutImp, f()
1  IterWithoutImp ← 0;
2  s* ← ∅;
3  while IterWithoutImp < IterMaxWithoutImp do
4      s ← NIH();
5      s' ← RVND(s);
6      if f(s') < f(s*) then
7          s* ← s';
8          IterWithoutImp ← 0;
9      else
10         IterWithoutImp ← IterWithoutImp + 1;
11     end
12 end
13 return s*
```

The VNS is a method whose basic idea is the systematic change of neighborhood structures within the local search algorithm. This metaheuristic uses a shake procedure that applies random movements and not get stuck in a local optimum.. The GVNS is an extended version of the basic VNS which uses more than one neighborhood in a local search, in our case the RVND.

The pseudo-code of the GVNS-RVND is presented in Algorithm 5. The method starts creating a solution s_0 with the Nearest Insertion heuristic (line 1 of Algorithm 5) and refining this initial solution with the RVND local search (line 2 of Algorithm 5). After that, $IterMaxWithoutImp$ iterations are executed. In each iterations a $Shake$ procedure is executed in the best current solution s^* generating a new diversified solution s' (line 5 of Algorithm 5). A RVND local search is applied in s' (line 6 of Algorithm 5) and if the refined solution s'' improves the best current solution s^*, the s^* is updated (line 8 of Algorithm 5) and a counter of number of iterations without improved ($IterWithoutImp$) is reset (line 9 of Algorithm 5). Otherwise this is a non improvement iteration and the counter is increased (line 11 of Algorithm 5). The best solution over all $IterMaxWithoutImp$

iterations is returned (line 14 of Algorithm 5).

Algorithm 5: GVNS-RVND Heuristic

Input: $IterMaxWithoutImp$, $f(), shakePerc$

1 $s_0 \leftarrow NIH()$;
2 $s^* \leftarrow RVND_{BI}(s_0)$;
3 **while** $IterWithoutImp < IterMaxWithoutImp$ **do**
4     $s' \leftarrow s^*$;
5     $s' \leftarrow Shake(s', shakePerc)$;
6     $s'' \leftarrow RVND(s')$;
7   **if** $f(s'') < f(s^*)$ **then**
8         $s^* \leftarrow s''$;
9         $IterWithoutImp \leftarrow 0$;
10   **else**
11         $IterWithoutImp \leftarrow IterWithoutImp + 1$;
12   **end**
13 **end**
14 **return** s^*

In the *Shake* phase of GVNS-RVND (line 5 of Algorithm 5), the algorithm applies $2 + p$ times a random movement of one of the three neighbourhood structures, N^{Swap}, N^{Shift} or $N^{Swap(2,1)}$, randomly selected too. The value of p is initially defined as 0, and it is increased by two units at each $shakePerc\%$ of total $IterMaxWithoutImp$. The idea is, with the increasing of the iterations without improvement the method will try to increase the diversify the current solution, growing up the p in the *Shake* phase. In order to compare this two heuristics, the stop criteria choose for both algorithms was the same: 50 iterations without improvement.

3.3 Computational Experiments

In this section, a set of proposed instances are presented and the performance of constructive heuristics, local searches e proposed heuristics are evaluated.

3.3.1 Instances

For the validation of the proposed methods, a new set of instances was created, having between 6 and 21 sensors. In these instances, the coordinates of the sensors were randomly defined within a *grid* (0, 300) × (0, 300). The Base Station was positioned in three distinct configurations for each instance: `Central`, in the center of the *grid* (150, 150); `Eccentric`, in the corner of *grid* (0, 0); and `Random`, at a random point on the *grid*. The other sensors were positioned randomly. The radius range, r_i, transmission rate, $rate_i$, and service demands, s_i, were randomly selected in the intervals (1, 50), (1, 10) and (1, 20), respectively . Thus, instances with 6, 7, 8, 9, 10, 11, 16 and 21 sensors were created, and for each number of sensors and for each Base Station position, 50 instances were generated, totaling 1200 used for the test.

The tests were performed on a computer with Intel Core i7-4770 3.40GHz processor with 16GB of RAM and Linux Ubuntu 14.04 operating system. For the execution of the exact method, the mathematical solver CPlex version 12.5.1 was used in its default configuration, That is, none of its preprocessing and heuristic functions that assist in solving the model have been deactivated. Thus, the exact method was run for all instances with a timeout of 1 hour (3600 seconds).

3.3.2 Constructive heuristics

The two proposed constructive heuristics were compared and the one that obtained the best results was used in the other phases of the tests. In the Table 3.1 the tests performed with the two constructive heuristics, NIH and LIH, are presented. For each instance the heuristics were executed 10 times and the average results in relation to the mathematical formulation solution are presented. The # **Sensors** column shows the number of sensors, the **Base Station** column identifies base station configuration, `Central`, `Eccentric` or `Random`. The **GAP** and **Time (s)** columns present the average GAP of the solutions found by the constructive methods and the average time required for generate the solution, respectively. The GAP is calculated using the Equation (3.16), where $f_{Constructive}$ represents the cost of the solution found by the tested constructive heuristic and f_{Exact} represents the cost of solution found by the exact method.

$$GAP = \frac{(f_{Constructive} - f_{Exact})}{f_{Exact}} \tag{3.16}$$

Table 3.1: Average GAP between NIH × LIH and the mathematical formulation

# Sensors	Base Station	NIH		LIH	
		GAP	Time (s)	GAP	Time (s)
	central	32.99%	0.000	54.54%	0.000
6	eccentric	32.84%	0.000	46.85%	0.000
	random	37.01%	0.000	54.77%	0.000
	central	39.69%	0.000	57.31%	0.000
7	eccentric	32.43%	0.000	37.91%	0.000
	random	39.77%	0.000	60.35%	0.000
	central	33.44%	0.000	52.82%	0.000
8	eccentric	35.71%	0.000	44.45%	0.000
	random	31.14%	0.000	53.18%	0.000
	central	42.19%	0.000	62.46%	0.000
9	eccentric	43.08%	0.000	57.28%	0.000
	random	45.59%	0.000	60.90%	0.000
	central	54.36%	0.000	74.34%	0.000
10	eccentric	49.20%	0.000	60.67%	0.000
	random	37.01%	0.000	54.77%	0.000
	central	63.51%	0.000	85.40%	0.000
11	eccentric	57.04%	0.000	68.95%	0.000
	random	60.80%	0.000	78.23%	0.000
	central	85.29%	0.001	88.12%	0.000
16	eccentric	90.04%	0.001	90.72%	0.000
	random	99.78%	0.001	103.48%	0.000
	central	89.12%	0.002	149.95%	0.000
21	eccentric	90.71%	0.002	159.69%	0.000
	random	89.17%	0.002	151.28%	0.000

We can observe that for all sets of tested instances the construct heuristic NIH presents better results, reaching a difference of up to 60.83% in relation to the LIH, the instance with 21 nodes. Both constructive heuristics have a low computational time to generate a solution, so this criterion was not used as priority. Thus, analyzing the results presented, we chose to use only the NIH constructive heuristic in the rest of the tests.

3.3.3 Local Searches

In this section, the three different local searches that we developed: Swap, Shift, and Swap21 are tested. For each of the local searches, tests were done using the two forms of neighborhood exploration: Best Improvement and First Improvement [18].

In the results below, in addition to the GAPs in relation to the reported optimal solutions found by the exact method, we also presents a solution improvement rate from the solution generated by the constructive heuristic NIH. For each instance, the local searches were executed 10 times.

In Table 3.2 a summary of the gaps presented by the three local searches both using Best Improvement and First Improvement is presented. In this table the **LS** column identifies which local search is tested, the columns **MIN**, **AVG** and **T (s)** represent the gaps of the best and average solutions found by the local searches in relation to exact solutions, and the average time, in seconds, represents the time spent to find each solution, respectively.

Table 3.2: Average GAPs of Local Searches

LS	Best Improvement				First Improvement			
	MIN	T MIN(s)	AVG	T AVG(s)	MIN	T MIN(s)	AVG	T AVG(s)
Swap	5.47%	0.298	15.03%	0.394	7.17%	0.197	17.02%	0.325
Shift	0.71%	0.556	6.61%	0.716	2.21%	0.155	9.34%	0.245
Swap21	3.06%	0.414	11.11%	0.573	3.87%	0.166	12.46%	0.344

In Table 3.3 the average improvements of the local searches are presented in relation to the initial solutions generated by NIH heuristic, MELHORAR both for the execution of the local searches using Best and First Improvement. In this table the columns **MAX** and **AVG** represent the average maximum improvements and the average of average improvements of the solutions, respectively.

Table 3.3: Average IMPs

	Best Improvement		First Improvement	
	MAX	AVG	MAX	AVG
Swap	46.40%	35.03%	45.25%	34.12%
Shift	48.32%	38.64%	47.47%	37.54%
Swap21	46.76%	36.01%	46.48%	35.30%

We can observe that, both by analyzing the GAPS averages, Table 3.2, when analyzing the average of improvements over the initial solutions, Table 3.3, local searches using Best Improvement have performed better than First Improvement local searches. Although they has a heavy processing time than local searches in First Improvement, this time is still relatively small, not exceeding, on average, 1 second of processing time.

3.3.4 Proposed heuristics

The two proposed heuristics, GRVND and GVNS-RVND, were tested in a set of instances that have 6, 7, 8, 9, 10, 11, 16 and 21 nodes, with three different positions of the Base Station, `central`, `eccentric` and `random`, totaling 1100 instances used for the test. Three metrics were used for the comparison: *GAP*, *EQUAL* and *IMP*. The GAP measures the distance of the solution found by the GRVND with the solution found by the mathematical method, and its formula is presented in Equation (3.17), where $f_{Heuristic}$ represents the value of the objective function of the solution found by the proposed heuristics and f_{Exact} represents the solution found by the mathematical model executed with a time limit of 1 hour (3600 seconds). If the time exceeded the given limit, the CPLEX is interrupted and the best solution found is reported. Each heuristic was executed 10 times for each instance.

$$GAP = \frac{(f_{Heuristic} - f_{Exato})}{f_{Exato}} \tag{3.17}$$

The *EQUAL* metric counts the number of instances where the proposed heuristics found the same solution reported by the exact method, whereas the *IMP* metric counts the number of instances where better solutions are found, in comparison with the result reported by mathematical formulation. Cases where the proposed heuristics finds better solutions than the mathematical method could occur when within the time limit of 1 hour, the exact method could not find the optimal solution of the problem and the reported solution was worse than the heuristic one.

Table 3.4 presents the results of the two proposed heuristics compared to the mathematical formulation executed with a time limit of 1 hour. If the time is exceeded, the mathematical method was reached and the solution found by the model until the interrupt was reported. The proposed heuristics was executed in each instance 10 times. In this table, the first and second columns represent the number of nodes of the instance and the position where the Base Station is, respectively. The columns $\boldsymbol{Sol_{min}}$ and $\boldsymbol{Sol_{avg}}$ represent the average of the *GAP* for the best solutions and for the average solutions found by the heuristics, respectively. The columns **T (s)** shows the average time to find the solutions. The results highlighted in boldface represents that in all 50 instances, grouped by number of sensors and base station configuration, the heuristic was able to find the optimal solution in all 10 executions per instance. The results is underlined if the heuristics obtained a improvement solution in relation of the mathematical formulation one. In this cases the mathematical formulation was not able to prove the optimal solution in 3600 seconds, and the solution reported by it in this limited time was worst then the solution obtained by the heuristic.

Table 3.4: Computational experiments of GRVND and GVNS-RVND

# Sensors	Base Station	GRVND – AVG GAP				GVNS-RVND – AVG GAP			
		Sol_{min}	T(s)	Sol_{avg}	T(s)	Sol_{min}	T(s)	Sol_{avg}	T(s)
	central	0.13%	0.085	0.22%	0.092	**0.00%**	0.082	**0.00%**	0.087
6	**eccentric**	**0.00%**	0.081	0.03%	0.092	**0.00%**	0.013	**0.00%**	0.014
	random	0.23%	0.081	0.27%	0.088	**0.00%**	0.012	**0.00%**	0.014
	central	0.01%	0.152	0.26%	0.173	**0.00%**	0.162	**0.00%**	0.173
7	**eccentric**	**0.00%**	0.158	0.25%	0.173	**0.00%**	0.024	**0.00%**	0.026
	random	**0.00%**	0.162	0.05%	0.181	**0.00%**	0.025	**0.00%**	0.027
	central	**0.00%**	0.269	0.19%	0.306	**0.00%**	0.288	**0.00%**	0.312
8	**eccentric**	**0.00%**	0.278	0.38%	0.324	**0.00%**	0.043	**0.00%**	0.046
	random	0.02%	0.281	0.40%	0.324	**0.00%**	0.044	**0.00%**	0.047
	central	0.02%	0.413	0.42%	0.486	**0.00%**	0.449	**0.00%**	0.489
9	**eccentric**	0.21%	0.409	0.36%	0.480	**0.00%**	0.065	**0.00%**	0.069
	random	0.01%	0.415	0.15%	0.489	**0.00%**	0.067	**0.00%**	0.072
	central	0.05%	0.697	0.16%	0.799	**0.00%**	0.449	**0.00%**	0.489
10	**eccentric**	**0.00%**	0.683	0.22%	0.804	**0.00%**	0.098	**0.00%**	0.106
	random	0.02%	0.739	0.13%	0.833	**0.00%**	0.102	**0.00%**	0.111
	central	0.14%	1.068	0.43%	1.276	**0.00%**	0.510	**0.00%**	0.554
11	**eccentric**	**0.00%**	1.007	0.31%	1.284	**0.00%**	0.156	**0.00%**	0.170
	random	0.03%	1.071	0.12%	1.266	**0.00%**	0.154	0.01%	0.167
	central	0.07%	6.063	0.24%	7.033	**0.00%**	0.712	0.02%	0.838
16	**eccentric**	0.02%	6.208	0.11%	7.119	**0.00%**	0.692	**0.00%**	0.803
	random	0.04%	6.060	0.09%	7.050	**0.00%**	0.714	0.01%	0.805
	central	-1.50%	22.424	-1.40%	25.822	-1.54%	2.097	-1.44%	2.737
21	**eccentric**	-0.44%	10.305	-0.31%	12.421	-0.51%	2.094	-0.46%	2.663
	random	-0.29%	10.524	-0.18%	12.534	-0.35%	2.102	-0.29%	2.675
Average		-0.05%	2.901	0.12%	3.394	-0.10%	0.465	-0.09%	0.562

When looking at the GAPs obtained by the best GRVND solutions ($\boldsymbol{Sol_{min}}$ column), it is noted that, for all tested instances, the GAPs were not higher than 0.23%, on average. Since only in 4 cases, this average value exceeded 0.1% in relation to the values reported by the exact method. In addition, for instances with 21 nodes, it is observed that GRVND can improve the results of the exact methods, obtaining a GAP of -1.50%, -0.44% and -0.29% in average, respectively . However, analyzing the results of the best GVNS-RVND solution ($\boldsymbol{Sol_{min}}$ column), we found all exact solution and also improve the instances with 21 nodes. This behavior are also presented in average GVNS-RVND solutions, showing that this heuristic is very robust.

In relation to the average solutions of the GRVND $\boldsymbol{Sol_{avg}}$ column), a result is very close to the results obtained by the best solutions ($\boldsymbol{Sol_{min}}$ column), with a maximum GAP of 0.43%, and a total average of 0.12%, but with worse results compared with the GVNS-RVND, that obtain almost all proved optimal solutions, excepted by instances 11-random, 16-central and 16-random. But even in these cases, the gaps are very close to 0.00%. This shows that in the 500 tests executed by each combination node and base station position, the average gap presents this small results.

Thus GVNS-RVND outperforms GRVND in terms of both $\boldsymbol{Sol_{min}}$ and $\boldsymbol{Sol_{avg}}$, being able to find the optimal solutions in all instances until 16 sensors, except in one instance in the average measure. Both methods are capable of improving the solutions from 21 nodes, but the GVNS-RVND has a smaller gain when compared to GRVND. The time results clearly show that the heuristics are capable of obtaining good quality solutions in lower computational times when compared with the mathematical formulation. As the methods are using the same constructive and local search modules, it is evident the importance of the shake phase of the GVNS-RVND, allowing to significantly improve the results in relation of the GRVND.

In the Table 3.5 the metrics **IMP** and **EQUAL** are used to compare the proposed heuristics. In this table the first two columns identify the number of sensors and the position of the base station, respectively. The results are grouped in 4 columns that represents the number of how many identical solutions to the exact method were found, **EQUAL**, and how many solutions were improved over the exact method, **IMP**, both in relation to the best solutions found ($\boldsymbol{Sol_{min}}$) and the average of the solutions ($\boldsymbol{Sol_{avg}}$) for each heuristic compared to the mathematical formulation ones. Note that this numbers may vary between 0 and 50, total number of instances in each group formed by the number of sensors and the position of the base station, represented by each row of the table. Thus, in the **EQUAL** column, the closer this number is from 50 show us the capacity of the heuristics to find optimal solutions, and in column **IMP**, how higher is this value, the greater the capacity of the heuristics to prove that they are able to obtain good solutions where the mathematical formulation starts to be inefficient in terms of computational time.

Table 3.5: EQUAL and IMP comparison between GRVND and GVNS-RVND

# Sensors	Base Station	GRVND Sol_{min} EQUAL	GRVND Sol_{min} IMP	GRVND Sol_{avg} EQUAL	GRVND Sol_{avg} IMP	GVNS-RVND Sol_{min} EQUAL	GVNS-RVND Sol_{min} IMP	GVNS-RVND Sol_{avg} EQUAL	GVNS-RVND Sol_{avg} IMP
	central	48	0	47	0	**50**	0	**50**	0
6	**eccentric**	**50**	0	49	0	**50**	0	**50**	0
	random	49	0	48	0	**50**	0	**50**	0
	central	**50**	0	47	0	**50**	0	**50**	0
7	**eccentric**	49	0	47	0	**50**	0	**50**	0
	random	**50**	0	49	0	**50**	0	**50**	0
	central	**50**	0	45	0	**50**	0	**50**	0
8	**eccentric**	**50**	0	45	0	**50**	0	**50**	0
	random	49	0	46	0	**50**	0	**50**	0
	central	49	0	40	0	**50**	0	**50**	0
9	**eccentric**	48	0	42	0	**50**	0	**50**	0
	random	**50**	0	48	0	**50**	0	**50**	0
	central	49	0	44	0	**50**	0	**50**	0
10	**eccentric**	**50**	0	46	0	**50**	0	**50**	0
	random	49	0	46	0	**50**	0	**50**	0
	central	47	0	39	0	**50**	0	**50**	0
11	**eccentric**	**50**	0	41	0	**50**	0	**50**	0
	random	49	0	47	0	**50**	0	49	0
	central	47	0	44	0	**50**	0	49	0
16	**eccentric**	48	0	45	0	**50**	0	**50**	0
	random	49	0	46	0	**50**	0	**50**	0
	central	31	<u>18</u>	27	<u>18</u>	31	<u>19</u>	30	<u>19</u>
21	**eccentric**	39	<u>9</u>	35	<u>9</u>	41	<u>9</u>	41	<u>8</u>
	random	38	<u>11</u>	34	<u>10</u>	31	<u>11</u>	39	<u>11</u>

We observe that the GRVND is not only able to find the solution reported by the exact method in 24 of the 1200 tested instances, when analyzing the best GRVND solutions and 116 of the 1200 for the average GRVND solutions. In addition, we observed that for the 21-node instances, the results of 38 instances were improved in the best GRVND solutions, and 37 in the average solution. However the results of GRVND is greatly outperformed by GVNS-RNVD. The GNVS-RVNS was able to obtain all optimal solutions proved by the exact method in the best GVNS-RVND solutions and almost the same result for the average GVNS-RVND solutions. Besides that, in the 21-node instances, the results of 39 instances were improved, one instance more than the GRVND.

The Table 3.5 reinforce the results presented in Table 3.4, but to validate the statistical significance of all results, we performed a pairwise Wilcoxon test [46] comparing the GAP values, between GRVND and GVNS-RVND, calculated for each instance . This test led to a value $p < 2.2 \times 10^{-16}$, which indicates a significant difference of performance. These tests confirmed that GVNS-RVNS is significantly better than the GRVND, so it can be considered an excellent choice for solving the DMSP, as it can achieve very good solutions in a small computation time.

Chapter 4

Other proposed models for solving the Data Mule Scheduling Problem

In this section, two more problems are defined, the Data Mule Scheduling Problem with Discrete Speeds and the Data Mule Scheduling Problem with Continuous Speeds. This problems are a extension of the Data Mule Scheduling Problem with Constant Speed, the first one introducing a set of discrete speeds which the mule can choose for each edge presented in its path, and the second one where only a lower and upper bound of speeds are defined, leaving the choice of speed as a decision of the problem. One mathematical formulation is proposed for each problem. The idea is begin the studies of this extended versions, making the formal definitions and presenting a initial mathematical formulation for each version.

4.1 DMSP with Discrete Speeds

For this speed case, the DMSP with Discrete Speeds, the data mule can choose between a set $K = \{v_1, v_2, v_3, ..., v_k\}$ of speeds at each edge $e \in E$. All the another assumptions and definitions of this model follows the DMSP with Constant speeds, shown in Section 3.1.

From the input data is possible to generate more two definitions: t^k_{pq}, time required to traverse the edge $(p, q)_k \in E'$, using the speed v_k, represented by the Equation (4.1); and d^k_{pq}, representing the maximum amount of data that can be collected at the edge $(p, q) \in E'$ using the speed v_k, represented by the Equation (4.2).

$$t^k_{pq} = \frac{c_{pq}}{v_k} \qquad \forall (p,q) \in E', \forall v_k \in K \tag{4.1}$$

$$d^k_{pq} = t^k_{pq}\, rate_i \qquad \forall i \in N, \forall (p,q) \in A_i, \forall v_k \in K \tag{4.2}$$

The following decision variables are defined for this model: $x^k_{pq}, \forall (p,q) \in E'$, $k \in K$, equal to one if the edge (p,q) is used in the solution with speed $k \in K$, zero otherwise; $z^k_{pq}, \forall (p,q) \in E'$ is a flow variable related of each edge $(p,q) \in E'$ and each speed $k \in K$; $y_p, \forall p \in V'$, equal to one if the node p is used in the solution, zero otherwise.

The formulation proposed for the resolution of the DMSP with Discrete Speeds is presented by Equations (4.3) to (4.15).

$$min \sum_{k\in K}\sum_{p\in V'}\sum_{q\in V'} t^k_{pq} \times x^k_{pq} \tag{4.3}$$

$$s.t.$$

$$\sum_{k\in K}\sum_{p\in V'} x^k_{pl} + \sum_{k\in K}\sum_{q\in N'} x^k_{lq} = 2y_l \qquad \forall l \in V' \tag{4.4}$$

$$\sum_{k\in K}\sum_{q\in V'} z^k_{0q} = 1 \tag{4.5}$$

$$\sum_{k\in K}\sum_{q\in V'} z^k_{lq} = \sum_{k\in K}\sum_{p\in V'} z^k_{pl} + y_l \qquad \forall l \in V' \setminus \{0\} \tag{4.6}$$

$$\sum_{k\in K}\sum_{p\in V'} z^k_{p0} = \sum_{p\in V'} y_p + 1 \tag{4.7}$$

$$x^k_{pq} \le z^k_{pq} \qquad \forall (p,q) \in E', k \in K \tag{4.8}$$

$$x^k_{pq} \ge \frac{z^k_{pq}}{|V'|+1} \qquad \forall (p,q) \in E', k \in K \tag{4.9}$$

$$\sum_{k\in K} x^k_{pq} \le 1 \qquad \forall (p,q) \in E' \tag{4.10}$$

$$x^k_{pq} = x^k_{p'q'} \qquad \forall (i,j) \in E, \; \forall (p,q) \in Fict_{ij}, \forall (p',q') \in Fict_{ij} \; |(p,q) \neq (p',q') \; \forall k \in K \tag{4.11}$$

$$\sum_{k\in K}\sum_{(p,q)\in A_i} d^k_{pq} x^k_{pq} \ge s_i \qquad \forall i \in V \tag{4.12}$$

$$x^k_{pq} \in \{0,1\} \qquad \forall (p,q) \in E', k \in K \tag{4.13}$$

$$y_p \in \{0,1\} \qquad \forall p \in V' \tag{4.14}$$

$$z_{pq}^k \geq 0 \qquad \forall (p,q) \in E', k \in K, z_{pq}^k \in \mathbb{Z}^+ \tag{4.15}$$

The objective function (4.3) minimizes the travel time of the Data Mule between the sensors. The constraints (4.4) ensure that if a node of the graph G' is used in the solution, it must have degree 2. The set of constraints (4.5 - 4.7) has the role of eliminating solutions that have a disconnected subcycle from the origin. The constraints (4.5) define that the initial flow, which leaves the Base Station (node 0), must be equal to 1, the constraints (4.6) ensure that if a node is used ($y_l = 1$), some flow needs to pass through it. The set of constraints (4.7) ensure that the final flow, which arrives at the Base Station (node 0), is equal to the number of nodes used in the solution plus one unit of the initial flow ($\sum_{p \in N'} y_p + 1$). The constraints (4.8) and (4.9) bind the flow variables z_{pq}^k with the variables x_{pq}^k, by setting the value of $x_{pq}^k = 1$ if there is some flow on that edge, and 0 otherwise. The constraints (4.10) ensure that for each edge only one speed can be used and the constraints (4.11) ensure that the same speed is used on all sub-edges $(p,q)_k \in G'$ that belong to the edge $(i,j) \in G$ of the original graph. The constraints (4.12) ensure that the demands of all nodes are fully satisfied. Finally, the constraints (4.13), (4.14) and (4.15) of integrality and non-negativity are presented.

4.2 DMSP with Continuous Speeds

In this section, the mathematical formulation considers only lower and upper bounds for the speeds of Data Mule ($speed_{min}$ and $speed_{max}$, respectively), thereby leaving the decision of which speed use for each edge to the model. In this formulation let $G'(V', W \cup U)$ be the graph obtained after applying the preprocessing phase in G, where the set of nodes V' represents the original set of nodes V with the artificial nodes added, and the set of edges $E' = W \cup U$ is formed by edges that can attend some nodes (W) and edges that cannot attend any node (U), as in Section 3.1.

Two more definitions are necessary: T_{min}^e, Equation (4.16), and T_{max}^e, Equation (4.17), representing the minimum and the maximum time that the Data Mule can stay in the edge $e \in E'$, respectively.

$$T_{min}^e = \frac{c_e}{speed_{max}} \tag{4.16}$$

$$T_{max}^{e} = \frac{c_e}{speed_{min}} \tag{4.17}$$

Let x_e be 1 if the edge $e \in N'$ is in the solution and 0 otherwise, H_e^i the amount of time spend in edge $e \in E'$ attending the node $i \in V$ and the auxiliary variable z_e is the flow variable used to define the route and avoid sub-cycles without the Base Station. The formulation is given Equations (4.18) to (4.34):

$$min \sum_{e \in W} \sum_{i \in PN_e} H_e^i + \sum_{e \in U} \sum_{i \in PN_e} H_e^i \tag{4.18}$$

$$s.t. \tag{4.19}$$

$$\sum_{p \in N'} x_{pl} + \sum_{q \in N'} x_{lq} = 2y_l \qquad \forall l \in N' \tag{4.20}$$

$$\sum_{q \in N'} z_{0q} = 1 \tag{4.21}$$

$$\sum_{q \in N'} z_{lq} = \sum_{p \in N'} z_{pl} + y_l \qquad \forall l \in N' \setminus \{0\} \tag{4.22}$$

$$\sum_{p \in N'} z_{p0} = \sum_{p \in N'} y_p + 1 \tag{4.23}$$

$$x_{pq} \leq \frac{z_{pq}}{2} \qquad \forall (p,q) \in E' \mid p \neq 0 \tag{4.24}$$

$$x_{pq} \geq \frac{z_{pq}}{|N'| + 1} \qquad \forall (p,q) \in E' \tag{4.25}$$

$$x_{0q} = z_{0q} \qquad \forall q \in E' \tag{4.26}$$

$$\sum_{i \in PN_e} H_e^i \leq T_{max}^e x_e \qquad \forall e \in W \tag{4.27}$$

$$\sum_{i \in PN_e} H_e^i \geq T_{min}^e x_e \qquad \forall e \in W \tag{4.28}$$

$$\sum_{i \in PN_e} H_e^i = T_{min}^e x_e \qquad \forall e \in U \tag{4.29}$$

$$\sum_{e \in A_i} rate_i H_e^i \geq s_i \qquad \forall i \in N \tag{4.30}$$

$$x_e \in \{0,1\} \qquad \forall e \in E' \tag{4.31}$$

$$y_p \in \{0,1\} \qquad \forall p \in N' \tag{4.32}$$

$$z_e \geq 0 \qquad \forall e \in E', z_{pq} \in \mathbb{Z}^+ \tag{4.33}$$

$$H_e^i \geq 0 \qquad \forall e \in E', i \in N, H_e^i \in \mathbb{R}^+ \tag{4.34}$$

The objective function (4.18) aims to minimize the time spent by the mule to transmit the data demand of all nodes. Constraints (4.20) ensures that if a node is used in the solution, only one edge must enter and another edge must leave this node. The set of constraints (4.21 - 4.23) represent the flow restrictions that define a path and avoid the formation of sub-cycles. Constraints (4.24 - 4.26) make the connection between the flow variables z_{pq} and the solution variables x_{pq}. Constraints (4.27-4.29) define the time interval that the mule can spent in each edge $e \in E'$. The demand attendance is guaranteed through constraints (4.30) and constraints (4.31 - 4.34) ensure integrality and non-negativity of the variables.

Chapter 5

Data Mule Routing Problem

5.1 Introduction

This chapter considers that sensors are distributed in a bi-dimensional space and have communication range equal to r. In that scenario, the data mule has to serve each node of the WSN, by sending or receiving data to/from each of them. In the first service, the data mule has no knowledge about the global network and should visit a minimum number of nodes necessary to serve all nodes demands. After that, the mule could storage the position of the nodes and execute a global view algorithm. Thus, with no knowledge, at each node, it has to decide the next one to be visited, aiming at the minimization of the total route. The goal of using a data mule and minimizing its route is to minimize the energy consumption of the WSN. Note that the visited nodes form a connected dominant set. Remark also that at each node, the data mule covers only a limited set of other sensor nodes, and having that limited knowledge about the nodes, it has to choose the best one to be visited next.

Thus, our problem follows the next basic assumptions. Let $G = (V, E)$ be a graph representing a network and the geographical position of a node is given by euclidean coordinates, i.e., $V(G)$ is a set of points placed in an Euclidean plan, and each edge $(i, j) \in E(G)$ between two vertexes i and j exists if the corresponding sensors, that they represent, are within their communication range. The set $N(i)$ contains the neighbour nodes of vertex i, and the corresponding sensor only knows the other sensors in the neighbourhood and their corresponding euclidean coordinates. Edges have no weights. Let $s \in V$ be a vertex, from where the data mule initiates and finishes the route, called here, base station. The data mule moves between nodes, and only serves a node i when located in some node $j \in N(i)$. The data mule can serve every node that is in the neighborhood, and not only the node where it is. When a mule moves to a node from another one, the corresponding edge is included in the route. An edge can be used by the data mule more than once. Each time the edge is used, it is included in the route.

The objective of the problem treated in this work is minimizing the route length traversed by the data mule, that visits a subset of nodes $D \subseteq V$ forming a connected dominant set of G. The remaining of this work is organized as follows.

Related works are presented in Section 5.2. Section 5.3 presents some theoretical remarks on Data Mule Routing problem (DMRP), we show that when the input is allowed to be a general graph even the mule having a global view of the network, DMRP cannot be approximated in polynomial time to within a factor of $(1 - o(1)) \log n$ (unless P=NP). However, we remark that the set of realistic instances treated in this work, in fact, coincides with the Unit Disk Graph class, and then could be approximated in polynomial time to within a constant factor if the mule has a global view, suggesting that the geometric structure of Unit Disk Graphs could be explored to solve our realistic scenario where the mule has only local view. A mathematical formulation for the global view case is also presented in this section. In Section 5.4, we present two heuristics to work on the the realistic scenario where the data mule has only a local view of the network. The heuristics differ from each other in the criterion adopted to choose each next node in the route. The first algorithm adopts a simpler greedy approach, while the second one is based on a geometrical view of the convex-hull of the sub-graph formed by the nodes covered by the data mule at each node. Results and analyses are shown in Section 5.5.

5.2 Related Work

The communication in WSNs can be performed basically either by using virtual backbones and its own network infra-structure, or by using a mobile agent, called data mule. The problem of constructing virtual backbones for communication can be modeled as a Minimum Connected Dominating Set Problem, MCDS, as can be seen in [2, 11, 20, 40].

Papers from related literature of WSN that aim at solving the MCDS, usually present distributed algorithms and consider simultaneous communication among sensor nodes, and local processing at each node. When the communication is performed through a data mule, most works focus on the Data Mule Routing Problem, an $\mathcal{NP}$-hard problem [51]. Usually, those related papers consider that the data mule has the complete knowledge of the WSN. Considering that, mathematical formulations and approximate heuristics were proposed to solve the problem.

Thus, this section is divided in two parts, one that describes the works that consider the problem as a MCDS, and the other that presents papers related only to the Data Mule Routing Problem.

5.2.1 Connected Dominating Set based Algorithms

In this section, related works, in which the data transmission on the network is modeled as the dominant set problem, are presented. When this approach is considered, network nodes themselves are able to transmit their data to the base station, constituting, consequently, a virtual backbone of communication.

In [8] two distributed algorithms, based on a sequential algorithm for solving the Connected Dominating Set Problem (CDSP) [17], applied in undirected graphs are presented. The proposed algorithms consider possibles changes in the networks and are re-executed periodically to keep the connectivity of the current network. They consider that each node has complete knowledge of the network, i.e., it has a copy of the entire graph that represents the network. Those algorithms also employ distributed spanning tree algorithms as building blocks to solve the problem and use shortest path algorithms between all pair of nodes.

In the distributed algorithm proposed in [47], to solve the CDSP, each node broadcasts its set of neighbours. A neighborhood is defined by using a disk unit graph representation. A node defines itself as a dominant, if it has two non-adjacent neighbours. Then, another broadcast round is executed so that the dominant nodes are known by all other nodes. This step occurs using a 2-hop communication between all nodes. After that, there is another step to eliminate redundancies. The algorithm is tested in synthetic instances and its results are compared with the others from the related literature. Moreover, some variations, considering topology changes, like node inclusions, eliminations and movements, are also introduced.

In [2] a distributed algorithm with two phases using a disk unit graph representation was proposed. In the first phase, a maximal independent set (MIS) is created. Although MIS is a dominant set, it is not connected yet. So, in the second phase, a spanning tree algorithm is executed over the MIS, aiming not only to connect those nodes but also to remove eventual extra nodes. The spanning tree algorithm also includes a node defined as base station, even when it does not belong to MIS and only 1-hop communication is allowed.

In [11], the goal of the problem is defining time slots when each node can communicate with the data mule without communication conflicts, i.e, two nodes communicating with the data mule simultaneously. This work uses the coloring approach proposed in [12] to define the connected set and an independent set. It also analyses the relation between the sizes of MIS and Minimum Connected Dominant Set, contributing to define best bounds to several similar problems.

In [20] the CDSP is employed to define virtual backbones for communication in a WSN. For this purpose a 1-hop distributed two-phase algorithm was developed and it is applied in a network represented as a unit disk graph in a Cartesian system. This algorithm uses a color scheme, computation of the convex hull of the nodes and MIS to define a CDS for the network.

In [14] a distributed algorithm is developed for the CDSP where each node of the network has a weight and communication congestions can occur in the network. The objective of the problem is building a CDS with the lowest possible weight. In order to solve this problem, the author uses a 1-hop CONGEST model [33] and proves that the MCDS can be solved by using it.

In [50] a mobile agent is responsible for collecting data from a WSN. In addition to data collection, the cost of transmission according to the capacity of communication channel and the time spent at each point to collect data are taken into account. In this problem, an undirected graph represents the network and some *archor* points must be visited by the data mule in order to attend all nodes' demands. The authors divide the problem in two stages, the first one where the mule decides the *archor* points that it will visit not exceeding a bounded time, and the second one, where, given the mule route, the sensors decide the amount of data that they will transmit to the mule in each *archor* point chosen by the mule in the first stage. For both decisions, mathematical formulations with a global view of the network were proposed.

Table 5.1 summarizes those related works, presenting their main aspects.

Table 5.1: Connected Dominant Set based algorithms

Author	**Graph Rep.**	**Neig. Knowledge**	**Algorithm**
Das and Bharghavan (1997) [8]	Undirected	Global	All pairs shortest path
Wu and Li (1999) [47]	Unit Disk	2-hop	All pairs shortest path for a distributed DS calculation
Alzoubi *et al.* (2002) [2]	Unit Disk	1-hop	MIS and dominating tree
Funke *et al.* (2006) [11]	Unit Disk	1-hop	CDS using distance-2-coloring algorithm
Islam *et al.* (2008) [20]	Unit Disk	1-hop	CDS using convex-hull and MIS
Ghaffari (2014) [14]	Weigth Undirected	1-hop	CONGEST Model based in DS
Zhao *et al.* (2015) [50]	Undirected	Global	Distributed decomposition using Mathematical Formulations

In our work, data are collected from static sensors by a single data mule that starts and finishes its route in a base station, using end-to-end communication. Remark that we consider that the mule's route is a closed walk instead of a hamiltonian cycle (as considered in all related works), i.e, given a route, the mule can visit each vertex more than once.

5.3 Theoretical Remarks

In order to demonstrate how difficult it is to find a route for a data mule, we will first perform an analysis of the problem when the data mule has a global view of the network, that is, the data mule knows the underlying graph G representing the network. In such a scenario, the data mule's aim is to solve the following problem.

	DATA MULE WITH GLOBAL VIEW
Input:	A graph G, and a base station node $v \in V(G)$.
Goal:	Determine a minimum closed walk W of G such that $v \in V(W)$, and for all node $x \in V(G)$, $N[x] \cap V(W) \neq \emptyset$. That is, either $x \in V(W)$ or some neighbor y of x belongs to $V(W)$.

Next result shows that if it is assumed that G is a general graph then it is very unlikely to exist an algorithm to find in polynomial time routes for a data mule with cost near to the optimal solution.

Theorem 1. DATA MULE WITH GLOBAL VIEW *on general graphs cannot be approximated in polynomial time to within a factor of* $(1 - o(1)). \ln n$*, where* $n = |V(G)|$*, unless* $NP \subseteq DTIME(n^{O(\log \log n)})$.

Proof. Given a set of elements $U = 1, 2, \ldots, n$ (universe) and a collection S of m sets whose union equals the universe, the SET COVER problem is to identify the smallest sub-collection of S whose union equals the universe. SET COVER cannot be approximated in polynomial time to within a factor of $(1 - o(1)). \ln |U|$, unless $NP \subseteq DTIME(n^{O(\log \log n)})$ [9].

Now, we present a L-reduction from SET COVER to DATA MULE WITH GLOBAL VIEW. Let $V(G) = \{v_u : u \in U\} \cup \{v_s : S \in S\} \cup \{v\}$. If $u \in S$ then add edge (v_u, v_s) in $E(G)$. Finally add edges in $E(G)$ in order to obtain a clique induced by $\{v_{s'} : S' \in S\} \cup \{v\}$. Figure 5.1 illustrates a graph G constructed from an instance of SET COVER, where G is obtained from $U = \{1, 2, \ldots, 8\}$ and $S = \{1, 2\}, \{1, 3, 5\}, \{4, 7\}, \{5, 6, 7, 8\}$.

If C has a sub-collection C' of size k then $\{v\} \cup \{v_s : S \in C\}$ induces a clique of G of size $k+1$, and then contains a cycle of length $k+1$ such that any vertex $w \notin \{v\} \cup \{v_s : S \in C\}$ has at least one neighbor in such a cycle. Conversely, if G has such a closed walk Q of order $k+1$, without loss of generality Q has no vertex of $\{v_u : u \in U\}$, then $V(Q) \setminus \{v\}$ represent a sub-collection of C of size at most k which is a set cover of U.

To transfer the approximation lower bound of SET COVER to DATA MULE WITH GLOBAL VIEW we need such hardness result on instances of set cover satisfying $ln(|U| + |S|) \approx ln(|U|)$. However, as first observed in [6], it turns out that this is indeed true analyzing of Feige's construction [9].

□

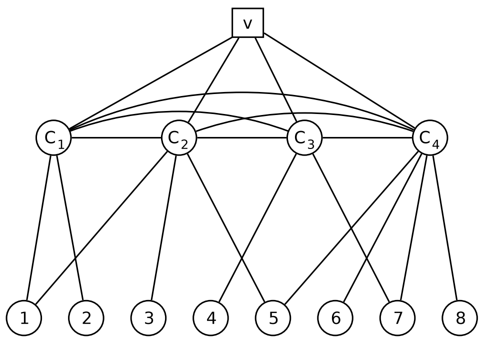

Figure 5.1: Graph G obtained from U and S.

The above result illustrates the hardness of approximate data mule problems on general graphs. Next result shows that the realistic instances of our problem belongs to a very special graph class.

Definition 1. *A* unit disk *graph is the intersection graph of a family of disks of unit size in the Euclidean plane.*

Lemma 1. *Any realistic instance G of* DATA MULE WITH GLOBAL VIEW *is a unit disk graph.*

Proof. Definition 1 is the classical definition of unit disk graph. However, through a isotropic scaling in intersection model it is easy to see that Unit Disk Graphs coincide with the intersection graphs of a family of disks of *same* size in the Euclidean plane.

The instances of our problem are graphs G representing a network node (sensor with the same reachability) whose geographical position is given by euclidean coordinates, i.e., $V(G)$ is a set of points placed in an Euclidean plan, and each edge $(i, j) \in E(G)$ between two vertices i and j exists if the corresponding sensors, that they represent, are within their communication range of each other.

A sensor's communication range can be seen as a disk of radius equal to a constant r, thus data mule instances are composed by graphs with one vertex for each disk, and with an edge between two vertices whenever the corresponding vertices lie within a distance at most r of each other. Such graphs coincide with the intersection graphs of a family of disks of radius equals $\frac{r}{2}$.

□

The next result illustrates an interesting property of our problem in practical instances.

Lemma 2. DATA MULE WITH GLOBAL VIEW *on Unit Disk Graphs admits a* $(2+\epsilon)$-*approximation algorithm,* $\epsilon > 0$.

Proof. Any data mule route contains a connected dominating set. On the other hand, from a connected dominating set S it is easy to obtain a data mule route of size $2|S| - 2$. As CONNECTED DOMINATING SET $(1+\epsilon)$-approximation algorithm [5], then using such algorithm as subroutine we obtain an approximated solution for DATA MULE WITH GLOBAL VIEW to within a factor of $(2+\epsilon)$. □

5.3.1 Lower Bounds

Now, we are interested to recognize some lower bounds for a solution of DATA MULE WITH GLOBAL VIEW that can be found by efficient algorithms.

Given G be a simple graph, and a base station $v \in V(G)$. We denote $d(v,w)$ as the distance between v and w in G, and $d_v = \max_{w \in V(G)} d(v,w)$.

Lemma 3. *Let* $OPT(G,v)$ *be an optimal solution value for* DATA MULE WITH GLOBAL VIEW *on* G *with base station* v. *It holds that* $OPT(G,v) \geq 2(d_v - 1)$.

And such lower bound can be found in $O(m)$ *time.*

Proof. Let w be a vertex of $V(G)$ such that $d_v = d(v,w)$ (w and d_v can be found by a breadth-first search). Clearly the data mule needs to travel through at least $d_v - 1$ edges in order to attend w. After that, the data mule will travel through some edges, and will return to base station which spend at least more $d_v - 1$ steps.

□

Now we present a hierarchy of lower bounds for the problem, whose values and performance to be found depends of an input integer k.

Lemma 4. *Given G, v and an integer $k \geq 1$. Let S be a set composed by the k most distant vertices of v, and T_k be a steiner tree to connect $\{v\} \cup S$. Let $LB_k = |T_k| - k + \min_{w \in S} d(v,w) - 1$. For all $k \geq 1$, it holds that*

$$OPT(G,v) \geq LB_k.$$

Proof. Note that $LB_1 = 2(d_v - 1)$. As previously, the data mule needs to travel through some edges in order to attend all vertices in S, which walks at least $|T_K| - k$ edges. As the data mule must return to base station then at least more $\min_{w \in S} d(v,w) - 1$ steps must be done. □

To compute LB_k, $k > 1$, we have to solve a Steiner instance as subroutine. As Steiner Tree is NP-hard then such strategy is viable only for very small values of k. However even $k = 2$ is already able to improve our previous lower bound. In special, LB_2 can also be quickly found as described below.

Lemma 5. *$LB_{k=2}$ can be computed in $O(m.n)$ time.*

Proof. As $k = 2$ then the Steiner subroutine must connect only three terminals. Thus, at most one vertex, say u, of such Steiner tree has degree greater than two (equal to 3). Hence finding all shortest path between all pair of vertices, which can be done in $O(n.m)$ time, such Steiner tree can be constructed. Note that, given u, if any, the path from a terminal to u is a shortest path, and there exists only $O(n)$ possibilities for u. □

5.3.2 Mathematical Formulation

A mathematical formulation, that considers all the characteristics of the problem is proposed in this subsection. Although the use of mathematical formulation is not the most appropriate approach for the Data Mule Routing Problem, it is a key technique for obtaining bounds. It is important to notice that in the problem solved using the formulation all information about the network is available, allowing to obtain a better path and consequently a reduction in the number of mule movements used to serve all sensor nodes.

Let $G'(V, A)$ be a bidirected graph formed by bidirectiong the edges of original graph $G(V, E)$. The set of vertices $V(G)$ are maintained as points in an Euclidean plane as the original graph. The set of arcs $(i, j) \in A$, represents the possible paths that the mule can choose. Two sets of variables are defined, x_{ij} and y_i. The variables x_{ij} are 1 if the data mule uses the arc (i, j) in his path, and 0 otherwise. The other binary variables y_i are set to 1 if the vertex $i \in V$ are visited by the mule, and 0 if it is attended by another node.

$$\min \quad \sum_{(i,j)\in A} x_{ij} \tag{5.1}$$

$$\text{s.t.} \quad \sum_{j\in N(i)\cup\{i\}} y_j \geq 1, \ \forall i \in V \tag{5.2}$$

$$\sum_{j\in\delta^+(i)} x_{ij} \geq y_i, \ \forall i \in V \tag{5.3}$$

$$\sum_{j\in\delta^-(i)} x_{ji} \geq y_i, \ \forall i \in V \tag{5.4}$$

$$\sum_{j\in\delta^+(i)} x_{ij} = \sum_{j\in\delta^-(i)} x_{ji}, \ \forall i \in V \tag{5.5}$$

$$\sum_{j\in\delta^+(i)} x_{ij} \leq |N(i)| y_i, \ \forall i \in V \tag{5.6}$$

$$\sum_{j\in\delta^-(i)} x_{ji} \leq |N(i)| y_i, \ \forall i \in V \tag{5.7}$$

$$y_0 = 1 \tag{5.8}$$

$$\sum_{i\in\bar{S}} \sum_{j\in S} x_{ij} \geq y_s, \ \forall S \subseteq V \setminus \{0\}, s \in S \tag{5.9}$$

$$x_{ij} \in \{0, 1\}, \ \forall (i, j) \in A \tag{5.10}$$

$$y_i \in \{0, 1\}, \ \forall i \in V \tag{5.11}$$

The objective function (5.1) aims to minimize the number of moves used by the mule to serve all nodes. Constraints (5.2) ensures that all nodes will be attended either by the mule's or by a neighbor in the mule's path. Constraints (5.3) and (5.4) guarantee that if one node is in the mule's path, at least one edge must enter and at least one edge must leave this node. The set of constraints (5.5) ensures that the number of edges entering and leaving one node must be the same. Constraints (5.6) and (5.7) imposes the limits of edges entering and leaving a node i by the number of their neighbours ($N(i)$). The constraint (5.8) ensures that the Base Station belongs in the mule's path. The set of constraints (5.9) eliminate sub-cycles. Finally, constraints (5.10) and (5.11) define the domain of the variables.

5.4 Algorithms for Data Mule with Local View

In this section we present two strategies to deal with the Data Mule Routing Problem, when the data mule does not have a global view, i.e, a prior knowledge of the network as a whole. In the first one, the mule decides his path based on the number of uncovered nodes nearby the current sensor node. In the second, the mule decision is based on the computation of convex-hulls of the current sensor node [20].

5.4.1 Algorithm based on number of uncovered neighbours – AlgNUN

The data mule begins its path in the sensor node that represents the base station s and decides which will be the next sensor to be visited by using a greedy method that will be next explained. The edges traversed by the data mule forms a tree, where the nodes of the tree represent the sensors visited by the data mule.

We consider here that a sensor node can be in one of the following states: (i) *dominator*, when the data mule is or was located in the same position of this sensor node, (ii) *covered*, when the sensor is or was within the communication range of a *dominator*, indicating that it has already been served by the data mule, and (iii) *uncovered*, when it is not in any of the previous described states. Initially, except for the Base Station, all nodes are in the *uncovered* state. In the end of the algorithm, every node will be in either a *dominator* or a *covered* state.

The proposed algorithms, one for the data mule and the other for the regular sensor nodes are described in Algorithms 6 and 7. They use the following types of messages to decide about the data mule moving:

- *msg_request*: contains a request for number of uncovered neighbours, sent from data mule to a regular sensor node
- *msg_numernodes*: contains the number of uncovered neighbours, sent from regular sensor node to data mule
- *msg_serve*: informs that the node can already be served, sent from data mule to regular sensor node

- *msg_served*: informs that the node has been served, sent among regular sensor nodes

The data mule starts and finishes in a Base Station. Initially and upon reaching a sensor node u, the data mule sends the message *msg_serve* to all neighbours $N(u)$, indicating the node can be already served, updating their states to *covered* (lines 11-12 of Algorithm 6). After that, the data mule also sends *msg_request* to them (line 13 of Algorithm 6). Upon receiving that message (line 7 of Algorithm 7), a sensor node replies with the message *msg_numernodes* containing the number of neighbours in *uncovered* state (line 8 of Algorithm 7). The data mule, then, moves to the sensor node with the greatest number of uncovered neighbours (line 18 of Algorithm 6). When the mule arrives at a node u from a node v, if u is not in *dominator* state, it updates its state with *dominator* and the variable $parent(u)$ with v (lines 5-9 of Algorithm 6). In this way, the data mule movement tree is being formed. When the data mule receives messages *msg_numernodes* containing only zeros, indicating that there is no neighbours in *uncovered* state, it moves to the parent of the current node. When this occurs in the Base Station, the data mule stops moving.

Algorithm 6: AlgNUM – Data Mule Algorithm

```
Variables:
    parent ← ∅
    states ← ∅
Upon reaching node u coming from node v
if u is not in dominator state then
    states ← states \ {< u, covered >}
    states ← states ∪ {< u, dominator >}
    parent ← parent ∪ {< u, v >}
end
foreach v ∈ N(u) do
    states ← states ∪ {< v, covered >}
    Send msg_serve to v
    Send msg_request to v
end

Upon receiving all msg_numbernodes of N(u)
if ∃ v ∈ N(u) | numbernodes(v) ≠ 0 then
    Data Mule moves to sensor node t ∈ N(u) with the greatest numbernodes
else
    if u is the Base Station then
        Data Mule stop moving
    else
        v ← get_parent(parent, u)
        Data Mule moves to v
    end
end
```

Regarding the regular sensor node, when it receives the *msg_serve* from data mule, it sends the message *msg_served* to all neighbours (lines 4-6 of Algorithm 7). A sensor node when receives *msg_served*, decreases its variable containing the number of uncovered neighbours (lines 10-12 of Algorithm 7). These steps allow for each sensor to keep the number of uncovered neighbours updated.

Algorithm 7: Regular Sensor Node u Algorithm

```
Variables:
    uncoveredNodes ← |N(u)|
Upon receiving a message M
case M = msg_serve
  | Send msg_served to all N(u)
end
case M = msg_request
  | Send msg_numbernodes(uncoveredNodes) to mule
end
case M = msg_served
  | uncoveredNodes−−
end
```

5.4.2 Algorithm based on convex-hull – AlgCH

The second proposed approach, AlgCH, follows the same steps of AlgNUM. However the criterion used to decide the data mule's movement is based on the convex-hull algorithm, next described.

Background

The convex hull of a set Q of points, called $CH(Q)$, is the smallest convex polygon P for which each point in Q is either on the boundary of P or in its interior. It is assumed that all points in Q are unique and that Q contains at least three no co-linear points [7]. An example of Q and the corresponding $CH(Q)$ are shown in Figure 5.2.

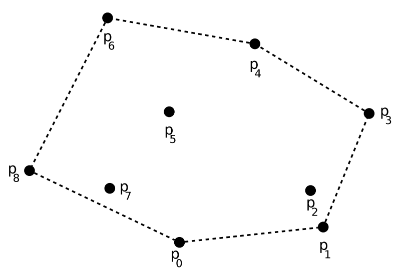

Figure 5.2: $Q = \{p_0, p_1, \ldots, p_8\}$ and the corresponding $CH(Q)$ in dashed line

In this work, Graham's scan algorithm, presented in Algorithm 8, was used to calculate the convex-hull. Its running time is $O(n\ lg\ n)$, where n is the total number of points [7]. It uses a stack S to keep the points of the convex-hull. Initially, the algorithm chooses a point p_0 as the point with the lowest y-coordinate, picking the leftmost point (lowest x-coordinate) in case of a tie (line 2 of Algorithm 8). Then, p_0 is pushed onto S (line 3 of Algorithm 8). After that, the remaining $n-1$ nodes are sorted by the corresponding polar angle formed with p_0 in counterclockwise order, resulting in the ordered set $\langle p_1, p_2, ..., p_{n-1} \rangle$ (line 4 of Algorithm 8). So, points p_1 and p_2 are also pushed onto S (lines 6-7 of Algorithm 8). Note that in this algorithm, a point already pushed onto S can be popped from it depending on the next calculated polar angles. The popping decision is based on the polar angle formed between $\overrightarrow{p_i p_{\text{next}}}$ and $\overrightarrow{p_i p_{top}}$, that uses the procedures *Proc_ top(S)* and *Proc_ next(S)*, to obtain the first (top) and second elements (next) from the top of S, respectively. If the polar angle indicates a non left turn, *top* is popped from S. This procedure is repeat until a left turn is found, when then p_i is pushed onto S. An example of the algorithm execution is shown in Figure 5.3. Consider the scenario where p_0, p_1 are p_2 have already been pushed onto S, Figure 5.3(a). The new candidate point is p_3. As $p_{top} = p_2$ and $p_{\text{next}} = p_1$, the polar angle between $\overrightarrow{p_3 p_1}$ and $\overrightarrow{p_3 p_2}$ is calculated. Observe that in Figure 5.3(b) the angle indicates a nonleft turn, so p_2 is popped from S. After that, p_{top} and p_{next} are updated with p_1 and p_0, respectively. The polar angle between $\overrightarrow{p_3 p_0}$ and $\overrightarrow{p_3 p_1}$ is then calculated, indicating a left turn, Figure 5.3(c), that results in the pushing of p_3 onto S, Figure 5.3(d). The algorithm continues until all the nine points are verified, Figure 5.3(e).

Algorithm 8: Graham's Scan($\boldsymbol{Q}$) based on [7]

$n \leftarrow |Q|$

Let p_0 be the point in Q with the minimum y-coordinate, or the leftmost such point in caso of a tie

$PUSH(p_0, S)$

Let $\langle p_1, p_2, ..., p_{n-1} \rangle$ be the remaining points in Q sorted by polar angle in counterclockwise order around p_0;

Let S be an empty stack

$PUSH(p_1, S)$

$PUSH(p_2, S)$

for $i = 3$ **to** $n - 1$ **do**

  while *the angle formed by points* $Proc\_next(S)$, $Proc\_top(S)$ *and* p_i *makes a nonleft turn* **do**

    $POP(S)$

  end

  $PUSH(p_i, S)$

end

Set $CH \leftarrow$ elements of stack S

return CH

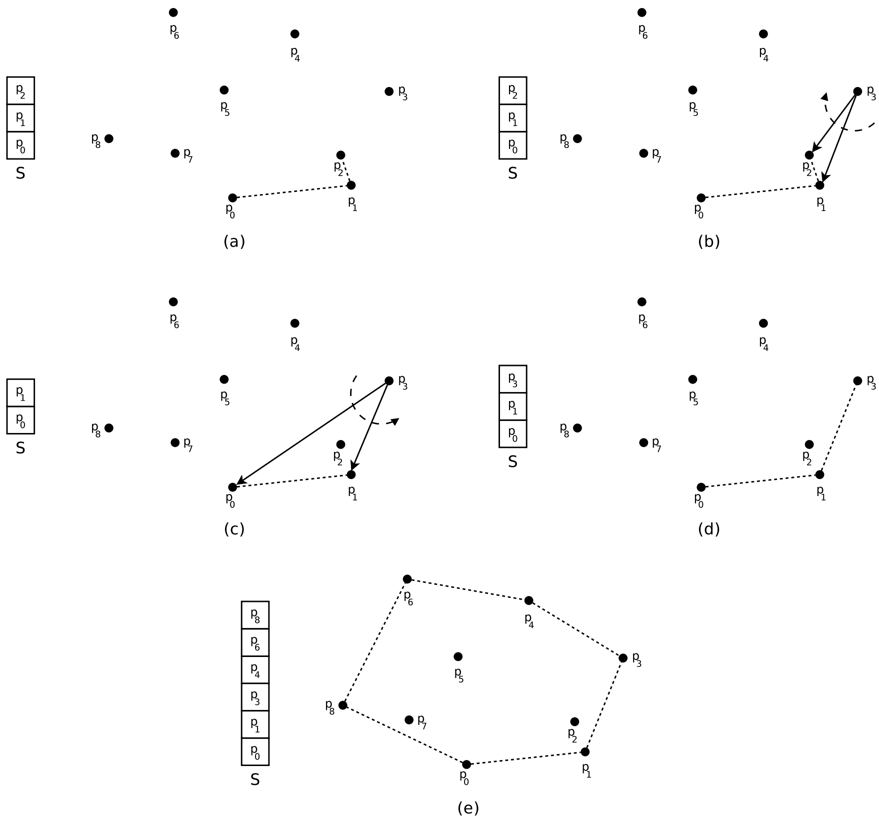

Figure 5.3: Graham's scan first steps example

5.4.2.1 Data mule Algorithm

In AlgCH approach, regular sensor nodes execute also Algorithm 7, described in Subsection 5.4.1. Messages exchanged among the data mule and sensor nodes are the same previously used in AlgNUM. Only the data mule algorithm is modified, as presented in Algorithm 9. In both data mule algorithms, upon reaching a sensor node u, the date mule sends the message *msg_serve* to all nodes in $N(u)$, updating their status to *covered* (lines 11-14 of Algorithm 9). However, in AlgCH before sending the next messages *msg_request*, the mule calculates the convex-hull of $N(u) \cup \{u\}$ (line 15 of Algorithm 9), by using Algorithm 8. Here, the mule only sends *msg_request* to the regular sensors of the convex-hull (lines 16-18 of Algorithm 9), which, in turn, reply with the number of uncovered neighbors. The mule, as in the previous algorithm, will move to the sensor that replied with the larger number of uncovered neighbours.

That approach aims at reducing the number of exchanged message between the data mule and sensor nodes. That happens because nodes inside the convex-hull do not receive *msg_request*. Another desired effect is the reduction in the number of data mule movements. The idea is that the data mule could cover more sensor nodes, with less movements, if it moved on the boundary of the convex-hull.

Algorithm 9: AlgCH – Data Mule Algorithm

```
Variables:
    parent ← ∅
    states ← ∅
    CHnodes ← ∅
Upon reaching node u coming from node v
    if u is not in dominator state then
        states ← states \ {< u, covered >}
        states ← states ∪ {< u, dominator >}
        parent ← parent ∪ {< u, v >}
    end
    foreach v ∈ N(u) do
        states ← states ∪ {< v, covered >}
        Send msg_serve to v
    end
    CHnodes ← Graham's Scan(N(u) ∪ {u})
    foreach v ∈ CHnodes do
        Send msg_request to v
    end
end
Upon receiving all msg_numbernodes of CHnodes
    if ∃ v ∈ CHnodes | numbernodes(v) ≠ 0 then
        Data Mule moves to sensor node t ∈ CHnodes with the greatest
        numbernodes
    else
        if u is the Base Station then
            Data Mule stop moving
        else
            v ← get_parent(parent, u)
            Data Mule moves to v
        end
    end
end
```

5.4.3 Complexity Analysis

Table 5.2 presents memory and time asymptotic complexities both for the data mule and for the regular sensor node algorithms. The data mule stores two types of information: (i) a pair of integers (8 bytes) containing the node identification and its status, for each one of the n nodes of the WSN and (ii) a pair of integers (8 bytes) containing the node identification and its parent identification, for each one of the p visited nodes by the data mule, which forms the data mule movement tree. Thus, the memory complexity is $8(n+p)$ *bytes*. Because p can be equal to $n-1$ in the worst case, the memory asymptotic complexity is $\mathcal{O}(n)$ *bytes*.

Each regular sensor node u also stores two types of information: (i) an integer (4 *bytes*) containing the number of neighbours not covered yet and (ii) a list with $|N(u)|$ elements (each with 4 *bytes*) containing the neighbours identifications . Thus, the memory complexity is $4(|N(u)|+1)$ *bytes*. Because $|N(u)|$ can be equal to $n-1$ in the worst case, the asymptotic memory complexity is $\mathcal{O}(n)$ *bytes*.

Concerning the local time complexity, in AlgNUM the procedure with the biggest complexity is the one executed to select the node with the greatest number of uncovered neighbours, $\mathcal{O}(n)$, while, in AlgCH, the procedure to compute the convex hull is $\mathcal{O}(n \lg n)$. Regular sensor nodes only send messages and execute arithmetic operations, presenting local time complexity equal to $\mathcal{O}(1)$.

Table 5.2: Local Time and Memory Complexities

Complexity	**Mule**		**Regular Sensor u**
	AlgNUM	**AlgCH**	
Memory	$\mathcal{O}(n)$ bytes	$\mathcal{O}(n)$ bytes	$\mathcal{O}(n)$ bytes
Time	$\mathcal{O}(n)$	$\mathcal{O}(n \lg n)$	$\mathcal{O}(1)$

5.5 Computational experiments and Analysis

The experiments aims to evaluate the locality sensitive proposed algorithms, when the data mule has no knowledge of the network, with the global view results. This comparison is not straightforward, since that the solution obtained with global view will always be a lower bound to the optimal one obtained with local view. On the other hand, these results show us how efficient was the no knowledge algorithms for the first time the mule go through the network.

In order to evaluate the proposed algorithms, we used instances generated for the Close-enough Traveling Salesman Problem [26]. We selected ten instances that respect our problem assumptions: (i) nodes are located in an Euclidean plan, (ii) nodes have the same acting range, in our case, communication range, and (iii) the instances are connected graphs. The number of nodes of the selected instances varies from 100 to 1000.

We implemented the heuristics in two scenarios. In the first one, the data mule waits for an acknowledgment, from each sensor node to which it sent a *msg_serve*, before sending *msg_request*. In its turn, the sensor node waits for acknowledgements, from all sensors to which it sent *msg_served*, to send the corresponding acknowledgments to the data mule. Note that, in this scenario, all sent messages *msg_serve* and *msg_served* are delivered and processed, and, consequently, every sensor knows the correct number of covered nodes, when it receives a *msg_request*. The second scenario is the same described in Section 5.4.1 and 5.4.2, and no acknowledgment message is employed.

We also implemented the mathematical formulation and the algorithm for calculating a lower bound, as presented in sections 5.3.2 and 5.3.1. Those results are used as baseline to evaluate the quality of results and execution times of the proposed heuristics.

The heuristics were implemented in the programming language C++, and used MPI for message-passing. The mathematical formulation was implemented in the programming language C++ and used IBM ILOG CPLEX Optimizer v12.5.1 as mixed integer programming solver. The algorithm to calculate the lower bound (LB_3) calculation was implemented in C++ and used a graph library, LEMON[1]. Our tests were executed in a Intel Core i7 3.6 Ghz computer, with 16 GB of RAM and Linux Mint 18 as its operating system.

Table 5.3 presents the results obtained by the methods that have the global view of the network. It shows instance names in column **Inst.**; the lower bounds, in column $\boldsymbol{Sol_{LB_3}}$, found by using the Steiner Tree with $k = 3$, as presented in Lemma 4; the results obtained by the mathematical formulation are presented in columns, **LR**, linear relaxation on root node, $\boldsymbol{T_{LR}(s)}$, time to obtain this linear relaxation, $\boldsymbol{Sol_{Mat}}$, solution of integer formulation presented in Section 5.3.2, and the corresponding time, **T(s)**.

[1]LEMON – Library for Efficient Modeling and Optimization in Networks, available on https://lemon.cs.elte.hu

Table 5.3: Computational results – Global view

Inst.	$\boldsymbol{LB_3}$		**Mathematical Formulation**			
	$\boldsymbol{Sol_{LB_3}}$	**T(s)**	**LR**	$\boldsymbol{T_{LR}(s)}$	$\boldsymbol{Sol_{Math}}$	**T(s)**
kro100	4	0.01	3	0.01	4	1.31
rat195	4	0.07	3	0.02	4	4.27
team2_200	4	0.06	4	0.03	5	14.35
team3_300	32	0.09	19	0.07	74^{α}	17996.7
lin318	4	0.18	3.67	0.27	5^{α}	6012.51
rd400	6	0.28	5	0.97	6	7336.95
pcb442	6	0.38	4.14	0.88	6	37180.6
team6_500	3	0.66	3	2.20	3	225.29
dsj1000	6	3.00	4	2.50	8^{α}	24842.1
bonus1000	8	2.12	7.86	38.46	$22^{\alpha\beta}$	86400

$^{\alpha}$ the mathematical formulation used as input the best solution found by the four heuristics

$^{\beta}$ the optimal solution was not found in a time limit of 24 hours

It was not possible to prove the optimality of solution found for instance bonus1000, so only the feasible solution found was presented in the table. The calculated lower bound allows us to know the interval at which the best solution is, that can help us to evaluate the quality of solutions found by the heuristics. Note that the results showed that very good lower bounds were generated, matching with the optimal solutions in 5 of 10 instances and presenting better results concerning the linear relaxation of the mathematical formulation. Those results indicate that the lower bound algorithm gives good solutions, that can be also used as baseline to analyse heuristics results, in smaller times.

Table 5.4 summarizes the results obtained by the proposed heuristics. Column **Inst.** also presents instance names and the other columns present the obtained results by **AlgNum** and **AlgCH** and the corresponding number of exchanged messages, **msgs**. Note that in **Case 2 – Without ACK**, the results are averages of 10 executions, because, as the algorithms do not use messages of acknowledgments, different solutions can be found at each execution.

Remark that the mathematical formulation has complete knowledge of the network while the heuristics are locality sensitive and have incomplete knowledge. Then, it was already expected that the results given by the heuristics were worse than the ones given by the mathematical formulation.

Table 5.4: Computational results – locality sensitive heuristics

Inst.	**Case 1 – With ACK**				**Case 2 – Without ACK**			
	Sol_{NUM}	**msgs**	Sol_{CH}	**msgs**	Sol_{NUM}	**msgs**	Sol_{CH}	**msgs**
kro100	6	11108	6	10538	10.0	6664.7	15.3	5852.4
rat195	4	43006	4	42108	6.4	23040.8	10.4	21795.9
team2_200	10	30562	12	29016	14.6	17515.6	18.4	15212.2
team3_300	74	21742	74	19556	94.2	13586.5	88.6	10876.1
lin318	8	94250	10	91874	13.2	51019.1	13.4	46772.0
rd400	14	112694	14	108482	22.8	62300.5	17.2	54981.5
pcb442	12	169950	12	165778	17.4	90869.9	17.8	85027.3
team6_500	6	312252	6	307818	12.0	164828.5	9.8	154971.2
dsj1000	8	837514	10	828926	17.8	431716.1	19.9	418260.2
bonus1000	22	450712	26	441438	36.4	238016.4	35.4	222859.8

Results presented in Table 5.4 show that the scenario **With ACK** produces better results, concerning the number of edges of the data mule path, than its counterpart. This occurs because in this scenario the data mule makes decisions based on a consistent state of the network. On the other hand, the number of exchanged messages increases thanks to ACK messages. In the scenario **With ACK**, *AlgNum* outperforms *AlgCH* in four instances and gives the same results in the other six, using, however, a greater number of messages. In the scenario **Without ACK**, *AlgNum* outperforms *AlgCH* in seven instances. However, *AlgCH* finds better solutions in three instances. Here, *AlgCH* also employs less messages than *AlgNum*.

Heuristics gave the optimal solutions in six cases (4 in AlgNUM and 2 in AlgCH) and they presented an average worsening percentage of 61.10% and 164.87% in **With ACK** and **Without ACK** cases, respectively, when compared with the mathematical formulation results. The results obtained by the proposed locality sensitive heuristics are good, since the mathematical formulation results were obtained in an unrealistic scenario where the data mule had the complete knowledge of the network.

Table 5.5 presents the average time for a data mule to make a decision about the next sensor node to be visited. This time includes the sending of *msg_request*, the receipt of *msg_numbernodes*, and in case of AlgCH, the time to calculate the convex hull, additionally. The results are averages of 10 executions.

Table 5.5: Maximum data mule local time

Inst.	**Case 1 – With ACK**		**Case 2 – Without ACK**	
	AlgNUM	**AlgCH**	**AlgNUM**	**AlgCH**
kro100	0.13	0.20	0.22	0.07
rat195	1.15	1.43	0.53	0.45
team2_201	0.36	0.73	0.86	0.85
team3_301	0.20	0.33	0.38	0.37
lin318	0.75	2.21	1.73	1.12
rd400	2.18	3.09	1.25	1.56
pcb442	1.72	2.27	1.73	1.60
team6_501	3.84	4.25	3.31	2.47
dsj1000	789.72	1213.97	290.25	242.11
bonus1001	9.13	7.91	6.30	3.62

It can be observed that in **With ACK** scenario, the calculus of the convex hull increases the time for the data mule to make a decision about the next sensor a lot. On the other hand, in **Without ACK** scenario, the opposite occurs, i.e., the data mule spends less time when executing the convex hull algorithm. It is due to the smaller number of *msg_request* messages sent in *AlgCH* than in *AlgNUM*, and consequently the reduction in waiting time for receiving the corresponding *msg_numbernodes* messages. It means that waiting for more messages is worse than calculating the convex hull in the tested instances.

Chapter 6

Conclusions

In this thesis, two different approaches for the problem where the data mule is used to perform the communication in networks of wireless sensors were considered, global and local view. In the first approach, the problem considered has a global view of the network, that is, the input data provide the geographic position of all the nodes, the possible paths that the data mule can use to perform its service and the demands of each node. In the second approach, the problem considered the data mule has only the local view of the network, that is, it does not have prior knowledge of the position of the nodes, their quantity or the demand for service of each one. The mule relies only on the information you can get through the range of your antenna to make your choices.

In the global approach, we presented the Data Mule Scheduling Problem (DMSP), and a mathematical formulation and two heuristics are proposed for deal with the problem with Constant Speed. Besides that, two extensions of the DMSP are defined. The first one uses a set of Discrete Speeds, and the second one uses only a lower and upper bounds of speed, leaving the speed as a decision for the problem.

For the Data Mule Scheduling Problem with Constant Speed, we propose a mathematical formulation and two heuristics, GRVND and GVNS-RVND, based in GRASP and Variable Neighborhood Search metaheuristics. The comparative experiments show that the GVNS-RVND provides results of great quality in comparison with the GRASP based heuristic. This conclusions are made not only by the numerical results but also validated by a Wilcoxon pairwise test, which indicates a significant difference of performance between then. For the mathematical formulations, the model starts to fail in prove the optimal solutions in instances with 21 sensors, setting a limit for the use of the exact method. This occurs mainly due to the pre-processing phase which greatly increases the number of sensors, adding the fictitious nodes in the solution representation.

The second approach, the local view, dealt with the Data Mule Routing Problem, in a scenario where the data mule has only a local view of the WSN. Two locality sensitive heuristics *AlgNUM* e *AlgCH* were proposed and tested in instances of a related problem from the literature. They were compared in two different approaches, with and without the complete updating of the local knowledge, before making a decision about the next node to be visited. Experimental results showed that both approaches can be helpful depending on the main goal to be reached, i.e., to obtain the smallest data mule route, more messages must be exchanged by the sensor nodes and data mule, otherwise, the route can be a little worsened by reducing the number of exchanged messages. The proposed mathematical formulation and lower bounds showed to be important not only to define the problem when the data mule has the whole knowledge of the WSN, but to offer some parameters to analyze the quality of solutions given by the locality heuristics as well. The proposed heuristics presented good results in reasonable times when analyzed considering those parameters.

As future works, studies to extend the heuristics for the DMSP with Discrete and Continuous speeds may be done. Since they have good results with Constant Speed, it is expected that as this two versions has a greater complexity, a better improvement is possible with respect to the mathematical formulation. For the DMRP, new compatible instances can be tested in order to explore other network characteristics and verify the behavior of the two algorithms. In addition, real tests can be done in order to observe the behavior of these algorithms in a fully distributed scenario.

References

[1] Akyildiz, I. F.; Kasimoglu, I. H. Wireless sensor and actor networks: research challenges. *Ad Hoc Networks 2*, 4 (2004), 351–367.

[2] Alzoubi, K. M.; Wan, P.-J.; Frieder, O. New distributed algorithm for connected dominating set in wireless ad hoc networks. In *System Sciences, 2002. HICSS. Proceedings of the 35th Annual Hawaii International Conference on* (2002), IEEE, pp. 3849–3855.

[3] Basagni, S.; Carosi, A.; Melachrinoudis, E.; Petrioli, C.; Wang, Z. M. Controlled sink mobility for prolonging wireless sensor networks lifetime. *Wireless Networks 14*, 6 (Dec. 2008), 831–858.

[4] Bin Tariq, M. M.; Ammar, M.; Zegura, E. Message ferry route design for sparse ad hoc networks with mobile nodes. In *Proceedings of the 7th ACM international symposium on Mobile ad hoc networking and computing* (New York, NY, USA, 2006), MobiHoc '06, ACM, pp. 37–48.

[5] Cheng, X.; Huang, X.; Li, D.; Wu, W.; Du, D.-Z. A polynomial-time approximation scheme for the minimum-connected dominating set in ad hoc wireless networks. *Networks 42*, 4 (2003), 202–208.

[6] Chlebík, M.; Chlebíková, J. Approximation hardness of dominating set problems in bounded degree graphs. *Information and Computation 206*, 11 (2008), 1264 – 1275.

[7] Cormen, T. H.; Stein, C.; Rivest, R. L.; Leiserson, C. E. *Introduction to Algorithms*, 2nd ed. McGraw-Hill Higher Education, 2001.

[8] Das, B.; Bharghavan, V. Routing in ad-hoc networks using minimum connected dominating sets. In *Communications, 1997. ICC'97 Montreal, Towards the Knowledge Millennium. 1997 IEEE International Conference on* (1997), vol. 1, IEEE, pp. 376–380.

[9] Feige, U. A threshold of ln n for approximating set cover. *J. ACM 45*, 4 (July 1998), 634–652.

[10] Feo, T. A.; Resende, M. G. Greedy randomized adaptive search procedures. *Journal of global optimization 6*, 2 (1995), 109–133.

[11] Funke, S.; Kesselman, A.; Meyer, U.; Segal, M. A simple improved distributed algorithm for minimum cds in unit disk graphs. *ACM Trans. Sen. Netw. 2*, 3 (Aug. 2006), 444–453.

[12] Gandhi, R.; Parthasarathy, S. Fast distributed well connected dominating sets for ad hoc networks. Tech. rep., University of Maryland, CS-TR-4559, 2004.

[13] Gendreau, M.; Hertz, A.; Laporte, G. New insertion and postoptimization procedures for the traveling salesman problem. *Operations Research 40*, 6 (1992), 1086–1094.

[14] Ghaffari, M. *Near-Optimal Distributed Approximation of Minimum-Weight Connected Dominating Set.* Springer Berlin Heidelberg, Berlin, Heidelberg, 2014, pp. 483–494.

[15] Gu, Y.; Bozdag, D.; Ekici, E.; Özgüner, F.; Lee, C. Partitioning based mobile element scheduling in wireless sensor networks. *SECON* (2005).

[16] Gudmundsson, J.; Levcopoulos, C. A fast approximation algorithm for tsp with neighborhoods and red-blue separation. *Nordic Journal of Computing 6* (1997), 6–469.

[17] Guha, S.; Khuller, S. Approximation Algorithms for Connected Dominating Sets. Tech. Rep. 3660, UM Computer Science Department, University of Maryland (College Park, Md.), June 1996.

[18] Hansen, P.; Mladenović, N. First vs. best improvement: An empirical study. *Discrete Applied Mathematics 154*, 5 (2006), 802 – 817. IV ALIO/EURO Workshop on Applied Combinatorial Optimization.

[19] Hashish, S.; Karmouch, A. Deployment-based solution for prolonging network lifetime in sensor networks. In *Wireless Sensor and Actor Networks II*, A. Miri, Ed., vol. 264 of *IFIP – The International Federation for Information Processing*. Springer US, 2008, pp. 85–96.

[20] Islam, K.; Akl, S. G.; Meijer, H. A constant factor localized algorithm for computing connected dominating sets in wireless sensor networks. In *Parallel and Distributed Systems, 2008. ICPADS'08. 14th IEEE International Conference on* (2008), IEEE, pp. 559–566.

[21] Jang, H.-C.; Lien, Y.-N.; Tsai, T.-C. Rescue information system for earthquake disasters based on manet emergency communication platform. In *Proceedings of the 2009 International Conference on Wireless Communications and Mobile Computing: Connecting the World Wirelessly* (New York, NY, USA, 2009), IWCMC '09, ACM, pp. 623–627.

[22] Kansal, A.; Somasundara, A. A.; Jea, D. D.; Srivastava, M. B.; Estrin, D. Intelligent fluid infrastructure for embedded networks. In *In Proc. ACM MobiSys'04* (2004).

[23] Li, X.; Nayak, A.; Stojmenovic, I. Sink mobility in wireless sensor networks. In *Wireless Sensor and Actuator Networks: Algorithms and Protocols for Scalable Coordination and Data Communication*, A. Nayak and I. Stojmenovic, Eds. John Wiley & Sons, Inc., 2010, ch. 6, pp. 153–184.

[24] Ma, M.; Yang, Y. SenCar: An Energy-Efficient Data Gathering Mechanism for Large-Scale Multihop Sensor Networks. *IEEE Transactions on Parallel and Distributed Systems 18*, 10 (Oct. 2007), 1476–1488.

[25] Ma, M.; Yang, Y.; Zhao, M. Tour planning for mobile data gathering mechanisms in wireless sensor networks. *IEEE Transactions on Vehicular Technology 62*, 4 (2013), 1472–1483.

[26] Mennell, W. K. *Heuristics for Solving Three Routing Problems: Close-Enough Traveling Salesman Problem, Close-Enough Vehicle Routing Problem, Sequence-Dependent Team Orienteering Problem.* Tese de Doutorado, University of Maryland (College Park, Md.), College Park, Maryland, USA, 2009.

[27] Mladenović, N.; Hansen, P. Variable neighborhood search. *Computers & operations research 24*, 11 (1997), 1097–1100.

[28] Moazzez-Estanjini, R.; Paschalidis, I. On delay-minimized data harvesting with mobile elements in wireless sensor networks. *Ad Hoc Networks 10*, 7 (2012), 1191–1203.

[29] Nesamony, S.; Vairamuthu, M.; Orlowska, M. On optimal route of a calibrating mobile sink in a wireless sensor network. In *Networked Sensing Systems, 2007. INSS '07. Fourth International Conference on* (2007), pp. 61–64.

[30] Ngai, E. C.-H.; Liu, J.; Lyu, M. R. An Adaptive Delay-Minimized Route Design for Wireless Sensor-Actuator Networks. In *2007 IEEE Internatonal Conference on Mobile Adhoc and Sensor Systems* (Oct. 2007), vol. 58, IEEE, pp. 1–9.

[31] Ngai, E. C. H.; Liu, J.; Lyu, M. R. An adaptive delay-minimized route design for wireless sensor-actuator networks. *IEEE Trans. Vehicular Technology 58*, 9 (2009), 5083–5094.

[32] Ngai, E. C.-H.; Zhou, Y.; Lyu, M.; Liu, J. Reliable reporting of delay-sensitive events in wireless sensor-actuator networks. In *Mobile Adhoc and Sensor Systems (MASS), 2006 IEEE International Conference on* (2006), pp. 101–108.

[33] Peleg, D. *Distributed Computing: A Locality-sensitive Approach.* Society for Industrial and Applied Mathematics, Philadelphia, PA, USA, 2000.

[34] Puccinelli, D.; Haenggi, M. Wireless sensor networks: applications and challenges of ubiquitous sensing. *IEEE Circuits and Systems Magazine 5* (2005), 2005.

[35] Rao, J.; Wu, T.; Biswas, S. Network-Assisted Sink Navigation Protocols for Data Harvesting in Sensor Networks. *2008 IEEE Wireless Communications and Networking Conference* (Mar. 2008), 2887–2892.

[36] Rosenkrantz, D. J.; Stearns, R. E.; II, P. M. L. Approximate algorithms for the traveling salesperson problem. In *15th Annual Symposium on Switching and Automata Theory, New Orleans, Louisiana, USA, October 14-16, 1974* (1974), pp. 33–42.

[37] Sahin, C. S.; Urrea, E.; Uyar, M. U.; Conner, M.; Hokelek, I.; Bertoli, G.; Pizzo, C. Uniform distribution of mobile agents using genetic algorithms for military applications in manets. In *Military Communications Conference, 2008. MILCOM 2008. IEEE* (2008), IEEE, pp. 1–7.

[38] Shah, R. C.; Roy, S.; Jain, S.; Brunette, W. Data mules: modeling and analysis of a three-tier architecture for sparse sensor networks. *Ad Hoc Networks 1*, 2–3 (2003), 215–233.

[39] Sharma, S.; Bansal, R. K.; Bansal, S. Issues and challenges in wireless sensor networks. In *Machine Intelligence and Research Advancement (ICMIRA), 2013 International Conference on* (2013), IEEE, pp. 58–62.

[40] Stojmenovic, I.; Seddigh, M.; Zunic, J. Dominating sets and neighbor elimination-based broadcasting algorithms in wireless networks. *IEEE Trans. Parallel Distrib. Syst. 13*, 1 (Jan. 2002), 14–25.

[41] Subramanian, A.; Drummond, L.; Bentes, C.; Ochi, L.; Farias, R. A parallel heuristic for the vehicle routing problem with simultaneous pickup and delivery. *Computers & Operations Research 37*, 11 (2010), 1899 – 1911. Metaheuristics for Logistics and Vehicle Routing.

[42] Sugihara, R.; Gupta, R. K. Speed control and scheduling of data mules in sensor networks. *ACM Transactions on Sensor Networks 7*, 1 (Aug. 2010), 4:1–4:29.

[43] Sugihara, R.; Gupta, R. K. Path planning of data mules in sensor networks. *ACM Transactions on Sensor Networks 8*, 1 (Aug. 2011), 1:1–1:27.

[44] Vincze, Z.; Vass, D.; Vida, R.; Vidács, A.; Telcs, A. Adaptive sink mobility in event-driven densely deployed wireless sensor networks. *Ad Hoc & Sensor Wireless Networks 3* (2007), 255–284.

[45] Wichmann, A.; Chester, J.; Korkmaz, T. Smooth path construction for data mule tours in wireless sensor networks. In *GLOBECOM* (2012), pp. 86–92.

[46] Wilcoxon, F. Individual comparisons by ranking methods. *Biometrics bulletin 1*, 6 (1945), 80–83.

[47] Wu, J.; Li, H. On calculating connected dominating set for efficient routing in ad hoc wireless networks. In *Proceedings of the 3rd International Workshop on Discrete Algorithms and Methods for Mobile Computing and Communications* (New York, NY, USA, 1999), DIALM '99, ACM, pp. 7–14.

[48] Xing, G.; Wang, T.; Xie, Z.; Jia, W. Rendezvous Planning in Wireless Sensor Networks with Mobile Elements. *IEEE Transactions on Mobile Computing 7*, 12 (2008), 1430–1443.

[49] Yuan, B.; Orlowska, M.; Sadiq, S. On the Optimal Robot Routing Problem in Wireless Sensor Networks. *IEEE Transactions on Knowledge and Data Engineering 19*, 9 (Sept. 2007), 1252–1261.

[50] Zhao, M.; Gong, D.; Yang, Y. Network cost minimization for mobile data gathering in wireless sensor networks. *IEEE Transactions on Communications 63*, 11 (2015), 4418–4432.

[51] Zhao, W.; Ammar, M. Message ferrying: Proactive routing in highly-partitioned wireless ad hoc networks. *The Ninth IEEE Workshop on Future Trends of Distributed Computing Systems, 2003. FTDCS 2003. Proceedings.* (2003), 308–314.

[52] Zhao, W.; Ammar, M.; Zegura, E. Controlling the mobility of multiple data transport ferries in a delay-tolerant network. In *Proceedings IEEE 24th Annual Joint Conference of the IEEE Computer and Communications Societies.* (2005), vol. 2, IEEE, pp. 1407–1418.

Appendix A: Complete test results

In this chapter the complete test results are presented for proposed methods.

.1 Local Search Tests

Three different local searches were developed: Swap, Shift, and Swap21. For each of the local searches, tests were done using the two forms of neighborhood exploration: Best Improvement and First Improvement. In this section we present the complete tests for each instance using both forms of neighborhood exploration.

.1.1 Best Improvement Tests

In Tables 1–24 the results of the three local searches using the Best Improvement were presented. In this tables, the column **Inst.** identifies the tested instance, the columns **Min** and **Avg** show the best solution and the average solution obtained by each method in 10 executions for each instance, respectively. The columns **T (s)** shows the time spend for each method to obtain the presented solutions.

Table 1: Instances with 6 nodes and Central Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
6_0	546647	0.000	546647	0.000	546114	0.001	546114	0.001	560786	0.000228	565968.8	0.000
6_1	479082	0.000	480044.5	0.000	476885	0.001	476885	0.001	479082	0.000404	479907.3	0.000
6_2	835931	0.000	835931	0.000	835637	0.000	835637	0.000	835637	0.000174	835813.4	0.000
6_3	583501	0.000	583503.4	0.000	583501	0.001	583501	0.001	583501	0.000448	586258.5	0.001
6_4	393982	0.000	404261.8	0.000	393830	0.000	393830	0.001	440072	0.000304	442007.3	0.000
6_5	534464	0.000	600540.2	0.000	533556	0.001	533556	0.001	573862	0.00029	584068	0.000
6_6	630865	0.000	631462	0.000	630865	0.000	630865	0.001	621491	0.000197	629835.4	0.000
6_7	612379	0.000	612729	0.000	612364	0.001	612364	0.001	612364	0.000216	626275.6	0.001
6_8	520829	0.000	522265.8	0.001	520829	0.001	520829	0.001	520829	0.000393	536842	0.001
6_9	470066	0.000	470066	0.000	470066	0.001	470066	0.001	495577	0.000378	495577	0.000
6_10	639134	0.000	639642	0.000	639134	0.001	639134	0.001	656555	0.000189	656555	0.000
6_11	619915	0.000	620734.7	0.000	619894	0.001	619894	0.001	619894	0.000224	624779.8	0.000
6_12	522721	0.000	545269.4	0.000	522721	0.001	525440.7	0.001	522721	0.00039	525848.2	0.001
6_13	364167	0.000	367360	0.000	364167	0.001	364167	0.001	364167	0.000244	369189.8	0.000
6_14	611143	0.000	612831.4	0.000	611143	0.001	611143	0.001	611143	0.000308	643859.8	0.000
6_15	818863	0.000	818863	0.000	818863	0.000	818863	0.000	843193	0.000187	843193	0.000
6_16	821989	0.000	839720.8	0.000	821989	0.000	823700.5	0.001	821989	0.000208	864961.3	0.001
6_17	660660	0.000	666431.1	0.000	660660	0.001	660660	0.001	660660	0.000299	714933.8	0.000
6_18	840727	0.000	846210.6	0.000	840727	0.001	840727	0.001	860270	0.000296	860270	0.000
6_19	715997	0.000	715997	0.000	715997	0.000	738321.4	0.000	715997	0.000168	761094.6	0.000
6_20	549152	0.000	549734.4	0.001	549152	0.001	549152	0.001	549984	0.000399	549984	0.001
6_21	713937	0.000	731526.6	0.000	713937	0.000	720533.1	0.000	713937	0.000169	729614.2	0.000
6_22	591211	0.000	602744.7	0.000	591211	0.000	591211	0.001	591211	0.000151	602681.1	0.000
6_23	524522	0.000	547899.5	0.000	524522	0.001	546811.4	0.001	524522	0.000484	551443	0.001
6_24	866253	0.000	869010.9	0.001	866253	0.001	866253	0.001	866253	0.000455	868613.4	0.001
6_25	635749	0.000	636061.5	0.000	635598	0.001	635598	0.001	635598	0.000323	691800.2	0.000
6_26	544356	0.000	546246.7	0.001	538351	0.001	538351	0.001	545418	0.000392	550619.4	0.001
6_27	795024	0.000	809509.5	0.000	795024	0.000	829060.8	0.000	795024	0.000181	851204.7	0.000
6_28	638259	0.000	639202.8	0.000	638259	0.000	638259	0.000	641405	0.000282	648556.8	0.000
6_29	610599	0.000	611865.2	0.000	610599	0.000	610599	0.001	610599	0.000258	614946.7	0.000
6_30	465915	0.000	488684.6	0.000	465915	0.001	469519.5	0.001	465915	0.000332	483883	0.000
6_31	684259	0.000	684259	0.000	683706	0.001	683706	0.001	683706	0.000198	699338.5	0.000
6_32	537562	0.001	537562	0.001	537562	0.001	537562	0.001	537562	0.000422	557994.1	0.001
6_33	815377	0.000	815377	0.000	815377	0.000	815377	0.000	815377	0.000168	815377	0.000
6_34	735356	0.000	753466.4	0.000	732237	0.001	744467.1	0.001	735356	0.00019	746230.2	0.000
6_35	772559	0.000	772559	0.000	772559	0.000	772559	0.000	791978	0.000181	792018.5	0.000
6_36	510537	0.000	557487.4	0.000	510537	0.001	510537	0.001	510537	0.00042	523372.2	0.000
6_37	467336	0.000	477404	0.000	467336	0.001	467336	0.001	487472	0.000307	504111.5	0.000
6_38	428160	0.000	431901.6	0.000	421521	0.001	421521	0.001	428160	0.000546	436521.4	0.001
6_39	565619	0.000	571541	0.001	565619	0.001	565619	0.001	583749	0.000418	583749	0.000
6_40	573112	0.000	575558.8	0.000	573112	0.000	573112	0.001	573112	0.000291	576813.2	0.000
6_41	654673	0.000	671513.2	0.000	654673	0.001	654673	0.001	654673	0.000422	663691.4	0.001
6_42	761059	0.000	823799.2	0.000	761059	0.001	761059	0.001	834505	0.000285	850360.3	0.000
6_43	747812	0.000	763614.8	0.000	747812	0.000	817600.8	0.000	747812	0.000258	749659.4	0.000
6_44	497265	0.000	502698.4	0.000	491016	0.001	491016	0.001	491016	0.000309	498021.5	0.000
6_45	558647	0.000	579361.4	0.000	558558	0.000	561156.2	0.001	558647	0.000269	576772.1	0.000
6_46	493725	0.000	524584.2	0.000	491839	0.001	491839	0.001	543998	0.000393	545233.3	0.001
6_47	605053	0.000	609811.4	0.000	605053	0.000	605053	0.000	668567	0.000273	675707.8	0.000
6_48	505033	0.000	505033	0.000	505033	0.001	505033	0.001	597461	0.000178	597461	0.000
6_49	481597	0.000	481597	0.000	481588	0.001	481588	0.001	481588	0.000326	482015.2	0.000

Table 2: Instances with 6 nodes and Eccentric Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
6_0	746543	0.000	747933.1	0.000	746543	0.001	746543	0.001	746543	0.000	758413.9	0.001
6_1	791604	0.000	791604	0.000	791604	0.000	791604	0.001	791604	0.000	793433.8	0.000
6_2	916760	0.000	923317.2	0.000	916760	0.000	923258.4	0.001	916760	0.000	925578.8	0.000
6_3	741533	0.000	762999.2	0.001	741533	0.000	741533	0.001	741533	0.000	760893.6	0.000
6_4	470349	0.000	473734.5	0.001	470349	0.001	470394.3	0.001	470500	0.000	473330.6	0.000
6_5	631759	0.000	640939	0.000	631759	0.001	631759	0.001	631759	0.000	643908.2	0.000
6_6	904104	0.000	904178.6	0.000	903109	0.001	903109	0.001	903109	0.000	914084.2	0.000
6_7	705643	0.000	706393.4	0.000	705643	0.001	705643	0.001	705643	0.000	710517.6	0.000
6_8	716674	0.000	716674	0.000	696168	0.001	696168	0.001	719963	0.000	719963	0.000
6_9	568526	0.000	574102	0.000	567748	0.001	567748	0.001	567748	0.000	567748	0.001
6_10	691493	0.000	692186	0.000	691493	0.000	691493	0.000	691493	0.000	692120.7	0.000
6_11	905862	0.000	905862	0.000	904670	0.001	904670	0.001	904670	0.000	911068	0.000
6_12	640630	0.000	640808.2	0.001	640630	0.000	640630	0.001	640630	0.000	640630	0.001
6_13	535258	0.000	537911.6	0.000	535258	0.000	537820.4	0.001	535258	0.000	535921.4	0.001
6_14	708404	0.000	709529.6	0.000	702463	0.001	702463	0.001	702463	0.000	705965	0.000
6_15	952253	0.000	959212.7	0.000	952253	0.000	952253	0.001	952253	0.000	952253	0.000
6_16	969532	0.000	969532	0.000	949830	0.000	949830	0.001	966945	0.000	1103433.9	0.000
6_17	914878	0.000	926013.8	0.000	899054	0.001	899054	0.001	899054	0.000	920504.9	0.000
6_18	935330	0.000	946161.5	0.000	935330	0.001	935330	0.001	935330	0.000	939961.4	0.000
6_19	844611	0.000	844611	0.000	844611	0.001	844611	0.001	950108	0.000	950108	0.000
6_20	785541	0.000	792595.4	0.000	785541	0.001	785541	0.001	785541	0.000	789258.5	0.000
6_21	841903	0.000	843422.8	0.000	841903	0.000	841903	0.001	866696	0.000	866696	0.000
6_22	691130	0.000	694218	0.000	691130	0.001	691130	0.001	691130	0.000	698358.8	0.000
6_23	645265	0.000	660655.8	0.000	645265	0.001	646515.3	0.001	645265	0.000	674570.5	0.001
6_24	983997	0.000	987096.3	0.000	983997	0.000	983997	0.001	983997	0.000	989115.4	0.001
6_25	800280	0.000	800280	0.001	809517	0.001	815631.2	0.001	840088	0.000	840243.2	0.000
6_26	693289	0.000	695031	0.000	693289	0.001	693289	0.001	693289	0.000	698086.4	0.001
6_27	808294	0.000	812845.2	0.000	808294	0.000	808294	0.001	808294	0.000	815129.8	0.000
6_28	891397	0.000	891397	0.000	891397	0.000	901792.2	0.000	962915	0.000	963122.4	0.000
6_29	734012	0.000	736755.3	0.000	734012	0.000	734012	0.000	734012	0.000	735971.5	0.000
6_30	704966	0.000	718888	0.000	685765	0.000	696149.2	0.001	685765	0.000	708253.8	0.000
6_31	732864	0.000	733261.1	0.000	732864	0.001	732864	0.001	745396	0.000	748543.5	0.000
6_32	734563	0.000	735454.8	0.001	734563	0.001	734695	0.001	734563	0.000	735633.1	0.001
6_33	842181	0.000	842186.4	0.000	842181	0.000	842181	0.000	842181	0.000	952263.2	0.000
6_34	763132	0.000	766110	0.000	763132	0.001	763132	0.001	770577	0.000	773986.7	0.000
6_35	833773	0.000	836977.4	0.000	833773	0.000	833773	0.001	833773	0.000	839214.8	0.000
6_36	823479	0.000	845767.2	0.000	822349	0.001	838703.2	0.001	822349	0.000	853886.8	0.001
6_37	754106	0.000	754106	0.000	754106	0.001	754106	0.001	770372	0.000	770372	0.001
6_38	741217	0.000	752703.4	0.000	741217	0.000	742027.4	0.001	741217	0.000	745605.6	0.000
6_39	756234	0.000	763594	0.001	756234	0.001	756234	0.001	756234	0.000	756234	0.000
6_40	733223	0.000	733392.6	0.000	733223	0.001	733223	0.001	741159	0.000	759294.5	0.000
6_41	815773	0.000	816529	0.000	815641	0.001	815641	0.001	815773	0.000	817178.6	0.000
6_42	935718	0.000	935718	0.000	935718	0.001	935718	0.001	1022699	0.000	1022699	0.000
6_43	874902	0.000	881881.4	0.000	874902	0.000	874902	0.000	870408	0.000	870408	0.000
6_44	659085	0.000	659087.4	0.000	652836	0.001	652836	0.001	652836	0.000	655336	0.000
6_45	668894	0.000	673284	0.000	668894	0.001	668894	0.001	677629	0.000	677629	0.000
6_46	816966	0.000	831154.8	0.001	815080	0.001	815080	0.001	815080	0.000	827847	0.001
6_47	640348	0.000	640443	0.000	637378	0.001	637378	0.001	721322	0.000	721322	0.000
6_48	593176	0.000	593225.6	0.000	593176	0.000	593176	0.001	593176	0.000	613314.8	0.000
6_49	816418	0.000	816418	0.000	815000	0.000	815000	0.000	815000	0.000	817220	0.000

Table 3: Instances with 6 nodes and Random Base Station position

	Swap – Best Improvement				Shift – Best Improvement				Swap21 – Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
6_0	563033	0.000	563459.4	0.000	563033	0.001	563033	0.001	563033	0.000	563246.2	0.000
6_1	498775	0.000	506771.2	0.000	498775	0.001	498775	0.001	498775	0.000	510730.9	0.000
6_2	801107	0.000	801120.8	0.000	801107	0.000	801107	0.000	801107	0.000	812312	0.000
6_3	708729	0.000	714912.6	0.000	708729	0.001	708729	0.001	708729	0.000	711820.8	0.000
6_4	513512	0.000	513542.4	0.000	513512	0.000	513512	0.000	513512	0.000	520636.9	0.000
6_5	568203	0.000	590325.3	0.000	567295	0.001	567295	0.001	567295	0.000	576460.8	0.000
6_6	631196	0.000	631992	0.000	631196	0.001	631196	0.001	631196	0.000	632091.5	0.000
6_7	759734	0.000	759743	0.000	759234	0.001	759234	0.001	759249	0.000	759491.5	0.000
6_8	645802	0.000	662206.8	0.000	645802	0.000	645802	0.001	645802	0.000	663086.1	0.001
6_9	656406	0.001	659566.8	0.001	656406	0.001	656406	0.001	686312	0.000	686440.4	0.000
6_10	818134	0.000	818134	0.000	818134	0.001	818134	0.001	818134	0.000	818134	0.000
6_11	683207	0.000	683207	0.000	682015	0.001	682015	0.001	682015	0.000	682015	0.000
6_12	546882	0.000	546882	0.000	554700	0.000	572141.1	0.001	546882	0.000	552321.4	0.001
6_13	386383	0.000	386383	0.000	379749	0.001	379749	0.001	382952	0.000	384193.4	0.001
6_14	813985	0.000	817237.9	0.000	811171	0.001	811171	0.001	811171	0.000	816858.4	0.000
6_15	786583	0.000	790471.8	0.000	786583	0.000	786583	0.001	786583	0.000	821827.4	0.000
6_16	824867	0.000	869753.4	0.000	805165	0.001	805165	0.001	805165	0.000	842552.6	0.000
6_17	668535	0.000	675411.7	0.000	665984	0.001	665984	0.001	668535	0.000	669138.3	0.000
6_18	859515	0.000	859515	0.000	859515	0.000	859515	0.000	867026	0.000	883299.2	0.000
6_19	736186	0.000	738626.8	0.000	736186	0.001	736186	0.001	744322	0.000	783258	0.000
6_20	576287	0.000	577243.6	0.000	574901	0.001	574901	0.001	574901	0.001	580453.1	0.001
6_21	689819	0.000	755066.7	0.000	689819	0.000	689819	0.000	689819	0.000	712614.5	0.000
6_22	621260	0.000	621260	0.001	621048	0.001	621048	0.001	621048	0.000	628661.5	0.001
6_23	586199	0.000	588642.2	0.000	586199	0.001	586199	0.001	586199	0.000	588413	0.001
6_24	855959	0.000	855959	0.001	845628	0.001	845628	0.001	847274	0.001	851003.6	0.001
6_25	641441	0.000	641441	0.000	640665	0.001	640665	0.001	640665	0.000	664949.7	0.001
6_26	546768	0.000	548118.5	0.001	540763	0.001	540763	0.001	540763	0.000	549017.3	0.001
6_27	766084	0.000	766084	0.000	753218	0.001	753218	0.001	753218	0.000	758122.5	0.000
6_28	787948	0.000	822379	0.000	787948	0.000	829265.2	0.000	787948	0.000	836948.2	0.000
6_29	694788	0.000	695367.2	0.000	694788	0.001	694788	0.001	720551	0.000	720551	0.000
6_30	479487	0.000	551027.1	0.000	479487	0.001	479487	0.001	498688	0.000	498688	0.000
6_31	713564	0.000	726148.4	0.000	716736	0.000	716736	0.000	766013	0.000	766013	0.000
6_32	682876	0.000	687334.4	0.000	682876	0.000	707014	0.001	682876	0.000	710617	0.001
6_33	769271	0.000	771068.8	0.000	769271	0.000	769271	0.000	899375	0.000	899375	0.000
6_34	765705	0.000	783354	0.000	765705	0.000	801003	0.000	765705	0.000	809827.5	0.000
6_35	834834	0.000	837421.8	0.000	834834	0.001	834834	0.001	867327	0.000	867327	0.000
6_36	515440	0.000	525045	0.000	513643	0.001	513643	0.001	515440	0.000	558662.5	0.000
6_37	580264	0.000	595262.5	0.000	580264	0.000	602710	0.001	580609	0.000	595504	0.000
6_38	494637	0.000	503864.4	0.000	487998	0.000	487998	0.001	487998	0.000	502463.2	0.000
6_39	596675	0.000	612875.8	0.000	596675	0.000	596675	0.001	596675	0.000	596694.2	0.000
6_40	527069	0.000	527796.5	0.000	527069	0.001	527069	0.001	531732	0.000	553749.7	0.000
6_41	643222	0.000	652257	0.000	643222	0.000	643222	0.001	643222	0.000	671090.9	0.000
6_42	758854	0.000	758854	0.000	757340	0.000	757340	0.000	757340	0.000	757945.6	0.000
6_43	743108	0.000	743108	0.000	743108	0.000	743108	0.000	743108	0.000	743108	0.000
6_44	624859	0.000	626660.4	0.000	624859	0.000	624859	0.001	649282	0.000	649282	0.000
6_45	554492	0.000	558206.5	0.000	527529	0.001	527529	0.001	527529	0.000	543902.7	0.000
6_46	752770	0.000	771332.8	0.001	750884	0.001	750884	0.001	750884	0.001	770201.2	0.001
6_47	598092	0.000	598686	0.000	598092	0.000	598092	0.000	661606	0.000	661606	0.000
6_48	633299	0.000	640047.6	0.000	633299	0.000	633299	0.001	650133	0.000	650133	0.000
6_49	560037	0.000	585701.1	0.000	560037	0.000	560037	0.001	560037	0.000	560037	0.000

Table 4: Instances with 7 nodes and Central Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
7_0	553284	0.001	577616	0.001	552984	0.002	552984	0.002	552984	0.001	570197.6	0.001
7_1	511053	0.001	546307.2	0.001	506579	0.001	506579	0.002	506579	0.001	514803.2	0.001
7_2	797105	0.000	800429	0.001	797105	0.001	805751.6	0.001	797105	0.000	811084.5	0.001
7_3	798622	0.000	814848.2	0.001	798622	0.001	802950.4	0.001	813050	0.000	838706	0.001
7_4	489293	0.001	497256.9	0.001	489293	0.001	489293	0.002	489293	0.001	528922	0.001
7_5	429124	0.001	440179.6	0.001	411217	0.001	417603.6	0.002	429124	0.000	462691.5	0.001
7_6	701586	0.000	702710	0.001	670402	0.001	693888.4	0.001	704396	0.000	726510.1	0.001
7_7	719924	0.000	721440	0.001	715776	0.001	715776	0.001	719924	0.000	749243.2	0.001
7_8	527657	0.000	548353.3	0.001	527657	0.000	542637.1	0.001	527657	0.001	537272	0.001
7_9	657261	0.000	669010.5	0.001	657259	0.001	677665.6	0.001	657261	0.000	675988.5	0.001
7_10	714773	0.001	733274.7	0.001	714773	0.001	714773	0.002	728692	0.001	738905.3	0.001
7_11	796508	0.000	800832.2	0.000	801188	0.000	806543.4	0.001	801188	0.000	840159.2	0.000
7_12	547930	0.001	556865.6	0.001	547930	0.001	555605.5	0.002	547930	0.001	579424.9	0.001
7_13	637412	0.001	655345.8	0.001	637412	0.002	646387.4	0.002	637412	0.001	661241.4	0.001
7_14	959440	0.000	960408.4	0.001	956263	0.001	958169.2	0.001	959440	0.000	977653.1	0.001
7_15	343071	0.000	348239.9	0.001	343071	0.001	343071	0.002	343071	0.001	348291	0.001
7_16	633964	0.001	639367.9	0.001	633817	0.001	633817	0.002	633817	0.001	642137.6	0.001
7_17	959654	0.000	971959.6	0.000	959654	0.001	964994.2	0.001	959654	0.001	975676.9	0.001
7_18	497988	0.000	527268.8	0.001	497988	0.001	500447	0.002	497988	0.001	514387.6	0.001
7_19	731815	0.000	774706.2	0.001	730268	0.001	730268	0.001	745508	0.001	774763.2	0.001
7_20	841998	0.000	857943.2	0.001	841998	0.001	851912	0.001	843991	0.000	880266.8	0.001
7_21	719618	0.000	765338.3	0.000	719618	0.001	726944.1	0.001	721039	0.000	752080.1	0.001
7_22	787260	0.000	847996.2	0.000	785388	0.001	833247	0.001	837895	0.000	877142.4	0.001
7_23	764756	0.001	781111.9	0.001	764756	0.001	764756	0.001	772345	0.001	798996.5	0.001
7_24	908946	0.000	928895.6	0.000	908946	0.000	922475	0.001	908946	0.000	972425.9	0.000
7_25	714706	0.000	733092.4	0.001	714706	0.001	714706	0.001	714706	0.000	734533.1	0.001
7_26	669347	0.001	690738.2	0.001	667947	0.001	675551.5	0.001	669347	0.000	696421.2	0.001
7_27	577316	0.000	591572.6	0.001	577316	0.001	578452.8	0.001	585098	0.000	614722.1	0.001
7_28	578061	0.001	601040.2	0.001	578061	0.001	578061	0.002	578061	0.001	618139.9	0.001
7_29	603449	0.000	635343.8	0.000	603449	0.000	625402.2	0.001	603449	0.000	648370.6	0.000
7_30	731101	0.001	740583.8	0.001	731101	0.001	731101	0.002	731101	0.001	752012.2	0.001
7_31	710037	0.000	717573.5	0.001	710037	0.001	710037	0.001	710037	0.001	741426.7	0.001
7_32	525426	0.000	575097.3	0.000	525426	0.001	525426	0.001	525426	0.000	583722.1	0.001
7_33	749125	0.000	753813.1	0.000	749125	0.001	752951.5	0.001	749125	0.000	770317.6	0.001
7_34	720549	0.001	720634.2	0.001	720549	0.002	720549	0.002	720549	0.001	722180.9	0.001
7_35	900893	0.000	924175.3	0.000	873530	0.001	881361.8	0.001	873530	0.000	894880.1	0.001
7_36	825401	0.000	843937.2	0.001	825401	0.001	858015.8	0.001	825401	0.000	915350.6	0.001
7_37	667188	0.001	676388.9	0.001	666921	0.001	670390.1	0.002	667188	0.001	693720.1	0.001
7_38	519494	0.000	547737.6	0.001	519494	0.000	519494	0.001	519494	0.001	536827.3	0.001
7_39	641626	0.000	657189.5	0.001	641626	0.001	654535.1	0.002	652155	0.000	685548.7	0.001
7_40	931176	0.000	940641.8	0.000	931176	0.001	944063.4	0.001	958756	0.000	982663.1	0.001
7_41	695816	0.000	695889.2	0.001	670362	0.001	670362	0.001	670362	0.001	690638.6	0.001
7_42	731566	0.000	733100.6	0.000	731539	0.001	731539	0.002	731539	0.000	739617.4	0.001
7_43	753888	0.000	755753.2	0.000	753888	0.000	753888	0.001	753946	0.000	773643.8	0.001
7_44	525665	0.001	532984.2	0.001	525665	0.001	531438.3	0.001	525665	0.001	544353	0.001
7_45	827703	0.000	880430.6	0.000	827318	0.001	827318	0.001	827318	0.000	893877.1	0.001
7_46	606546	0.000	609028.8	0.001	604949	0.001	605318.3	0.002	604949	0.001	617777.2	0.001
7_47	691063	0.001	696729.4	0.001	689082	0.001	689082	0.002	689082	0.001	703685	0.001
7_48	612820	0.001	623434.1	0.001	612820	0.001	614124.4	0.001	612820	0.000	621161.2	0.001
7_49	686159	0.000	686159	0.001	652825	0.001	652825	0.002	652825	0.001	674266.9	0.001

Table 5: Instances with 7 nodes and Eccentric Base Station position

	Swap – Best Improvement				Shift – Best Improvement				Swap21 – Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
7_0	841098	0.001	847221.5	0.001	841098	0.001	841098	0.002	841098	0.001	841181.6	0.001
7_1	682429	0.000	696817.9	0.001	682429	0.001	683320	0.002	682429	0.001	697705.4	0.001
7_2	819608	0.000	824135.4	0.001	819608	0.001	819608	0.001	819608	0.000	819759.8	0.001
7_3	910034	0.001	942951.6	0.001	910034	0.001	942504	0.002	913992	0.001	948295.7	0.001
7_4	760182	0.001	766891.5	0.001	760182	0.002	760182	0.002	760182	0.001	779703.7	0.001
7_5	762675	0.001	766384.6	0.001	744768	0.001	744768	0.002	744768	0.001	771192.8	0.001
7_6	905231	0.000	946182.7	0.001	905231	0.001	905231	0.002	905231	0.001	942264.1	0.001
7_7	944431	0.000	946171	0.001	942536	0.001	943178	0.001	942536	0.001	971574	0.001
7_8	911108	0.000	921857	0.001	911108	0.000	919203.6	0.001	913126	0.000	928546.7	0.001
7_9	805816	0.000	846091	0.001	796780	0.001	796780	0.001	796780	0.000	819203.2	0.001
7_10	906532	0.001	918591.6	0.001	906532	0.001	906532	0.002	906532	0.001	923770.1	0.001
7_11	832198	0.000	861679.9	0.000	832198	0.001	850532.7	0.001	832198	0.000	886062.9	0.000
7_12	688733	0.000	709026.9	0.001	712394	0.001	712394	0.001	688733	0.000	726021	0.001
7_13	739740	0.001	761177.1	0.001	739740	0.001	742934.8	0.001	739740	0.001	763345.4	0.001
7_14	1070175	0.000	1073159.6	0.000	1069398	0.001	1069398	0.001	1069398	0.000	1073230.5	0.000
7_15	661359	0.001	679896.1	0.001	661359	0.001	667755	0.002	661359	0.001	681342.2	0.001
7_16	826900	0.001	831819.4	0.001	826900	0.001	826900	0.002	826900	0.001	833159.6	0.001
7_17	1000184	0.000	1005012	0.000	1000184	0.001	1005392.5	0.001	1000184	0.000	1007348.4	0.000
7_18	799641	0.001	802573.8	0.001	799067	0.001	800305	0.002	799067	0.001	808345.8	0.001
7_19	845116	0.000	870638	0.000	843569	0.001	861918.7	0.001	843569	0.000	873981.5	0.001
7_20	887061	0.000	899625.7	0.000	886660	0.001	886660	0.001	886697	0.000	905273.5	0.001
7_21	809218	0.001	821345.5	0.001	803270	0.001	808484.9	0.001	803270	0.000	829841.9	0.001
7_22	889640	0.000	901024	0.001	876857	0.001	881221.4	0.001	929011	0.000	951973.6	0.001
7_23	836711	0.000	854430	0.001	836621	0.001	836621	0.001	842887	0.000	876390.1	0.001
7_24	959916	0.000	976172	0.000	959916	0.000	959916	0.001	959916	0.000	1009420.2	0.000
7_25	842003	0.000	867101.7	0.001	833577	0.001	844056.3	0.001	833577	0.001	857427.8	0.001
7_26	795252	0.000	811191.6	0.001	795252	0.001	808005.2	0.001	795323	0.001	821564.5	0.001
7_27	807620	0.000	859583.9	0.000	807620	0.001	823265.2	0.001	807620	0.000	841142.1	0.001
7_28	922925	0.001	924439.1	0.001	879656	0.002	879656	0.003	879656	0.001	894085.4	0.002
7_29	865189	0.000	893486.2	0.001	865189	0.001	954983.5	0.001	889099	0.000	970807	0.001
7_30	793206	0.000	806145	0.001	791334	0.001	795535	0.001	791334	0.001	794738.7	0.001
7_31	979597	0.000	1009015.5	0.000	977635	0.001	997531.4	0.001	979597	0.000	994095.6	0.001
7_32	784632	0.000	805557.7	0.001	784632	0.001	798353	0.001	784632	0.001	813567.8	0.001
7_33	847917	0.000	851394.8	0.000	847917	0.001	862390.6	0.001	847917	0.000	896065.1	0.001
7_34	947311	0.001	952202.5	0.001	947208	0.001	958996.8	0.002	947208	0.000	961050.1	0.001
7_35	871626	0.000	896660.7	0.001	871357	0.001	875480.8	0.001	871357	0.001	889721.3	0.001
7_36	902495	0.000	912099.6	0.001	902220	0.001	943022.4	0.001	902220	0.001	940297.5	0.001
7_37	753306	0.000	762601.3	0.001	753039	0.001	753039	0.002	753039	0.001	772121.5	0.001
7_38	825313	0.000	827144.7	0.001	825313	0.001	825313	0.001	825313	0.000	845843.2	0.001
7_39	776551	0.001	789744	0.001	776551	0.001	777868	0.002	776551	0.000	856644.7	0.001
7_40	905713	0.000	937642.1	0.001	905713	0.001	905713	0.001	913178	0.001	943816.1	0.001
7_41	742008	0.000	767070	0.001	742008	0.001	763076.2	0.001	767462	0.000	791734.4	0.001
7_42	775608	0.000	779228.7	0.001	775608	0.001	775608	0.001	775608	0.001	784814.7	0.001
7_43	952347	0.000	981872.5	0.001	952347	0.001	986238.2	0.002	952405	0.001	978916.4	0.001
7_44	558840	0.000	568010.6	0.001	558840	0.001	559108.2	0.001	558840	0.000	570177.9	0.001
7_45	972786	0.000	998684.9	0.001	972401	0.001	972401	0.001	972401	0.000	1026123.6	0.001
7_46	811394	0.000	812352.2	0.001	811394	0.001	812711.5	0.001	811394	0.001	812640.9	0.001
7_47	757313	0.000	771686.1	0.001	757313	0.001	761436.8	0.001	757313	0.001	761195.5	0.001
7_48	744859	0.000	745795	0.001	744859	0.001	744859	0.001	747467	0.000	754156.2	0.001
7_49	827960	0.000	838135.2	0.001	827960	0.001	857849.2	0.001	827960	0.000	863396.7	0.001

Table 6: Instances with 7 nodes and Random Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
7_0	571952	0.001	575982.2	0.001	571155	0.001	579874.2	0.002	571155	0.001	581682.1	0.001
7_1	535544	0.000	560709.2	0.001	521552	0.001	521552	0.002	525855	0.001	529795	0.001
7_2	790865	0.001	803750.6	0.001	790865	0.001	790865	0.002	790865	0.000	830471	0.001
7_3	828313	0.001	846876.6	0.001	828313	0.001	854145.4	0.002	828313	0.001	859608.9	0.001
7_4	757684	0.000	771885.1	0.001	757684	0.001	757684	0.002	757684	0.001	770351.8	0.001
7_5	421309	0.000	432312.7	0.001	403402	0.001	406994.2	0.002	403402	0.000	448360.7	0.001
7_6	680002	0.000	703364.8	0.001	648818	0.001	648818	0.002	648818	0.000	688782.8	0.001
7_7	715096	0.000	762297	0.001	710948	0.001	710948	0.001	733290	0.000	847480.3	0.001
7_8	534672	0.001	535924.6	0.001	527384	0.001	529263.8	0.002	527384	0.001	543006	0.001
7_9	625812	0.000	645085.5	0.000	625810	0.001	625810	0.001	625810	0.000	638568.6	0.001
7_10	704420	0.001	750553.8	0.001	704420	0.001	714816.4	0.002	704420	0.001	753536.5	0.001
7_11	952954	0.000	961506.3	0.000	952954	0.000	968566.6	0.001	957818	0.000	1011960.3	0.000
7_12	550935	0.001	564830.8	0.001	550935	0.001	550935	0.001	552509	0.001	588557.8	0.001
7_13	719069	0.001	757648.4	0.001	719069	0.001	719069	0.002	719069	0.001	749010.5	0.001
7_14	950457	0.000	969886.2	0.001	950457	0.001	990881.3	0.001	950457	0.000	966066.7	0.001
7_15	361454	0.001	366610.2	0.001	358357	0.002	358357	0.002	358357	0.001	367334.3	0.001
7_16	638618	0.001	644218.3	0.001	632527	0.001	632527	0.002	632527	0.000	640982.1	0.001
7_17	961175	0.000	979019.3	0.001	961175	0.000	961175	0.001	961175	0.000	983492.5	0.001
7_18	514049	0.001	524869.8	0.001	513475	0.002	514275	0.002	513475	0.001	520165.1	0.001
7_19	797137	0.000	807805	0.001	793571	0.001	793571	0.002	793571	0.000	804815.4	0.001
7_20	818118	0.000	818278.4	0.000	818118	0.000	818118	0.001	818118	0.000	824696.5	0.000
7_21	712292	0.001	725728.7	0.001	712292	0.001	713032	0.001	750059	0.000	789182	0.001
7_22	762060	0.000	829281.5	0.000	731989	0.001	731989	0.001	733861	0.000	822531.2	0.001
7_23	784922	0.000	784922	0.001	778746	0.001	778746	0.001	778746	0.001	823865.8	0.001
7_24	884405	0.000	907622.9	0.000	884405	0.001	884405	0.001	884405	0.000	948305.9	0.000
7_25	709621	0.000	748801.3	0.000	709621	0.001	709621	0.001	709621	0.000	743993.2	0.001
7_26	716465	0.000	726079.5	0.001	707794	0.001	707794	0.002	707794	0.001	715498	0.001
7_27	548868	0.001	571459.7	0.001	548868	0.001	559471	0.002	548868	0.000	579111.9	0.001
7_28	610509	0.001	628453.5	0.001	604108	0.002	604108	0.002	604108	0.001	624444.2	0.001
7_29	634227	0.000	690185.9	0.000	609603	0.001	609603	0.001	609626	0.000	641922	0.000
7_30	750410	0.001	755526.6	0.001	750410	0.001	752423.2	0.002	750410	0.001	763067.5	0.001
7_31	718517	0.000	726333.5	0.001	718517	0.001	718517	0.001	718517	0.000	745209.4	0.001
7_32	672887	0.000	688417.2	0.001	653942	0.001	653942	0.002	683289	0.001	709718.3	0.001
7_33	827013	0.000	835830.6	0.001	827013	0.001	835934	0.001	837855	0.000	879545.9	0.001
7_34	735201	0.000	736623.4	0.001	735201	0.001	738001.8	0.001	735201	0.000	748468.2	0.001
7_35	884032	0.000	914375.3	0.001	856669	0.001	874382.6	0.001	856669	0.001	899060.9	0.001
7_36	822946	0.000	831624	0.001	822946	0.001	871934	0.001	822946	0.000	858623.6	0.001
7_37	704625	0.000	723911.2	0.001	704358	0.001	710908.3	0.002	704358	0.001	732386.6	0.001
7_38	657577	0.001	659699.2	0.001	657577	0.001	657577	0.002	661114	0.001	714433	0.001
7_39	640435	0.000	673851.7	0.001	630646	0.001	635540.5	0.002	630646	0.000	685301.5	0.001
7_40	850499	0.000	887164.8	0.001	850499	0.001	850499	0.001	850499	0.001	874542.6	0.001
7_41	696470	0.000	716147.6	0.001	696470	0.001	723259.7	0.001	696470	0.000	712791.8	0.001
7_42	772821	0.000	798471.4	0.001	772794	0.001	790112.2	0.002	783947	0.001	810271.7	0.001
7_43	731317	0.000	749707	0.001	731317	0.001	731317	0.002	731317	0.000	758621.1	0.001
7_44	547198	0.000	562926.2	0.001	547198	0.001	547198	0.002	547198	0.001	586894.3	0.001
7_45	798048	0.000	847046.5	0.000	798048	0.001	801250	0.001	798048	0.000	849780.8	0.001
7_46	654822	0.000	658213.9	0.001	654822	0.001	654822	0.002	654822	0.000	665252.7	0.001
7_47	700321	0.000	730523.5	0.001	700321	0.001	705425.6	0.001	700321	0.000	715730.2	0.001
7_48	722665	0.001	722721.4	0.001	722665	0.001	722691.8	0.001	722665	0.000	765162.1	0.001
7_49	655045	0.000	685877.5	0.001	655045	0.000	655045	0.002	655045	0.000	662640.4	0.001

Table 7: Instances with 8 nodes and Central Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
8_0	571952	0.001	575982.2	0.001	571155	0.001	579874.2	0.002	571155	0.001	581682.1	0.001
8_1	535544	0.000	560709.2	0.001	521552	0.001	521552	0.002	525855	0.001	529795	0.001
8_2	790865	0.001	803750.6	0.001	790865	0.001	790865	0.002	790865	0.000	830471	0.001
8_3	828313	0.001	846876.6	0.001	828313	0.001	854145.4	0.002	828313	0.001	859608.9	0.001
8_4	757684	0.000	771885.1	0.001	757684	0.001	757684	0.002	757684	0.001	770351.8	0.001
8_5	421309	0.000	432312.7	0.001	403402	0.001	406994.2	0.002	403402	0.000	448360.7	0.001
8_6	680002	0.000	703364.8	0.001	648818	0.001	648818	0.002	648818	0.000	688782.8	0.001
8_7	715096	0.000	762297	0.001	710948	0.001	710948	0.001	733290	0.000	847480.3	0.001
8_8	534672	0.001	535924.6	0.001	527384	0.001	529263.8	0.002	527384	0.001	543006	0.001
8_9	625812	0.000	645085.5	0.000	625810	0.001	625810	0.001	625810	0.000	638568.6	0.001
8_10	704420	0.001	750553.8	0.001	704420	0.001	714816.4	0.002	704420	0.001	753536.5	0.001
8_11	952954	0.000	961506.3	0.000	952954	0.000	968566.6	0.001	957818	0.000	1011960.3	0.000
8_12	550935	0.001	564830.8	0.001	550935	0.001	550935	0.001	552509	0.001	588557.8	0.001
8_13	719069	0.001	757648.4	0.001	719069	0.001	719069	0.002	719069	0.001	749010.5	0.001
8_14	950457	0.000	969886.2	0.001	950457	0.001	990881.3	0.001	950457	0.000	966066.7	0.001
8_15	361454	0.001	366610.2	0.001	358357	0.002	358357	0.002	358357	0.001	367334.3	0.001
8_16	638618	0.001	644218.3	0.001	632527	0.001	632527	0.002	632527	0.000	640982.1	0.001
8_17	961175	0.000	979019.3	0.001	961175	0.000	961175	0.001	961175	0.000	983492.5	0.001
8_18	514049	0.001	524869.8	0.001	513475	0.002	514275	0.002	513475	0.001	520165.1	0.001
8_19	797137	0.000	807805	0.001	793571	0.001	793571	0.002	793571	0.000	804815.4	0.001
8_20	818118	0.000	818278.4	0.000	818118	0.000	818118	0.001	818118	0.000	824696.5	0.000
8_21	712292	0.001	725728.7	0.001	712292	0.001	713032	0.001	750059	0.000	789182	0.001
8_22	762060	0.000	829281.5	0.000	731989	0.001	731989	0.001	733861	0.000	822531.2	0.001
8_23	784922	0.000	784922	0.001	778746	0.001	778746	0.001	778746	0.001	823865.8	0.001
8_24	884405	0.000	907622.9	0.000	884405	0.001	884405	0.001	884405	0.000	948305.9	0.000
8_25	709621	0.000	748801.3	0.000	709621	0.001	709621	0.001	709621	0.000	743993.2	0.001
8_26	716465	0.000	726079.5	0.001	707794	0.001	707794	0.002	707794	0.001	715498	0.001
8_27	548868	0.001	571459.7	0.001	548868	0.001	559471	0.002	548868	0.000	579111.9	0.001
8_28	610509	0.001	628453.5	0.001	604108	0.002	604108	0.002	604108	0.001	624444.2	0.001
8_29	634227	0.000	690185.9	0.000	609603	0.001	609603	0.001	609626	0.000	641922	0.000
8_30	750410	0.001	755526.6	0.001	750410	0.001	752423.2	0.002	750410	0.001	763067.5	0.001
8_31	718517	0.000	726333.5	0.001	718517	0.001	718517	0.001	718517	0.000	745209.4	0.001
8_32	672887	0.000	688417.2	0.001	653942	0.001	653942	0.002	683289	0.001	709718.3	0.001
8_33	827013	0.000	835830.6	0.001	827013	0.001	835934	0.001	837855	0.000	879545.9	0.001
8_34	735201	0.000	736623.4	0.001	735201	0.001	738001.8	0.001	735201	0.000	748468.2	0.001
8_35	884032	0.000	914375.3	0.001	856669	0.001	874382.6	0.001	856669	0.001	899060.9	0.001
8_36	822946	0.000	831624	0.001	822946	0.001	871934	0.001	822946	0.000	858623.6	0.001
8_37	704625	0.000	723911.2	0.001	704358	0.001	710908.3	0.002	704358	0.001	732386.6	0.001
8_38	657577	0.001	659699.2	0.001	657577	0.001	657577	0.002	661114	0.001	714433	0.001
8_39	640435	0.000	673851.7	0.001	630646	0.001	635540.5	0.002	630646	0.000	685301.5	0.001
8_40	850499	0.000	887164.8	0.001	850499	0.001	850499	0.001	850499	0.001	874542.6	0.001
8_41	696470	0.000	716147.6	0.001	696470	0.001	723259.7	0.001	696470	0.000	712791.8	0.001
8_42	772821	0.000	798471.4	0.001	772794	0.001	790112.2	0.002	783947	0.001	810271.7	0.001
8_43	731317	0.000	749707	0.001	731317	0.001	731317	0.002	731317	0.000	758621.1	0.001
8_44	547198	0.000	562926.2	0.001	547198	0.001	547198	0.002	547198	0.001	586894.3	0.001
8_45	798048	0.000	847046.5	0.000	798048	0.001	801250	0.001	798048	0.000	849780.8	0.001
8_46	654822	0.000	658213.9	0.001	654822	0.001	654822	0.002	654822	0.000	665252.7	0.001
8_47	700321	0.000	730523.5	0.001	700321	0.001	705425.6	0.001	700321	0.000	715730.2	0.001
8_48	722665	0.001	722721.4	0.001	722665	0.001	722691.8	0.001	722665	0.000	765162.1	0.001
8_49	655045	0.000	685877.5	0.001	655045	0.000	655045	0.002	655045	0.000	662640.4	0.001

Table 8: Instances with 8 nodes and Eccentric Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
8_0	666234	0.001	710528	0.002	666234	0.003	669900.7	0.004	666234	0.001	711284.6	0.002
8_1	847597	0.001	881136	0.001	847597	0.001	855146.7	0.002	883365	0.001	950004.8	0.001
8_2	828816	0.001	842206.6	0.001	828816	0.002	835092.6	0.002	828934	0.001	841135.4	0.001
8_3	930397	0.001	940854.7	0.002	930397	0.002	931646.8	0.004	930397	0.002	940554.9	0.002
8_4	845671	0.001	868160.4	0.001	845671	0.003	845890.5	0.003	845752	0.001	870260.4	0.002
8_5	901411	0.001	992332.6	0.001	901411	0.001	911495.6	0.002	926465	0.001	961855.6	0.001
8_6	1010940	0.001	1061778.5	0.001	1010940	0.001	1024291.1	0.003	1067436	0.001	1093598.2	0.001
8_7	822472	0.001	881124.2	0.002	820056	0.001	820056	0.003	820056	0.001	875829.5	0.002
8_8	756609	0.001	775437.2	0.001	756355	0.001	787022.2	0.002	777141	0.001	801609.1	0.001
8_9	797788	0.001	827444.8	0.001	797788	0.001	812920.9	0.002	818514	0.001	860019.6	0.001
8_10	1047341	0.000	1073743	0.001	1044721	0.002	1044721	0.002	1047341	0.000	1094815	0.001
8_11	911549	0.001	945220.3	0.001	908475	0.002	963217.6	0.003	919730	0.001	953988.7	0.002
8_12	728984	0.001	739847.6	0.001	728984	0.002	742880	0.003	728984	0.001	772028	0.001
8_13	655193	0.001	704311.5	0.002	655193	0.002	660353	0.003	655193	0.001	684656.1	0.002
8_14	1076910	0.001	1122884.3	0.001	1076910	0.001	1156390.2	0.002	1083961	0.001	1142447.8	0.001
8_15	760427	0.001	814945.1	0.001	760427	0.001	760427	0.002	785978	0.000	855530.9	0.001
8_16	1019179	0.001	1074889	0.001	1019179	0.002	1044104.8	0.003	1020719	0.001	1091394.5	0.001
8_17	794978	0.001	833755.2	0.002	794978	0.001	827405.1	0.003	796116	0.001	851408.5	0.002
8_18	818357	0.001	866091.2	0.001	818357	0.002	828898.2	0.003	818357	0.001	880152.6	0.001
8_19	776896	0.001	817124.8	0.001	776896	0.001	776896	0.002	776896	0.001	793895.7	0.001
8_20	781246	0.001	783416.5	0.002	781246	0.001	782562.5	0.003	781246	0.001	782068.3	0.003
8_21	808264	0.001	818492.7	0.002	808264	0.002	810110.3	0.003	810386	0.001	844438	0.001
8_22	984607	0.001	1000905.4	0.002	980081	0.002	996074.3	0.003	980081	0.001	1009310.7	0.002
8_23	958051	0.001	1020456.1	0.001	958051	0.001	1021927.7	0.002	958051	0.001	1036810.1	0.001
8_24	845683	0.001	875638.3	0.002	845548	0.003	849417.7	0.004	845683	0.001	884682.7	0.002
8_25	931115	0.001	934396.2	0.001	919924	0.003	919924	0.003	919924	0.001	925864.6	0.001
8_26	767814	0.001	780511.7	0.001	767814	0.001	767814	0.003	767814	0.001	816058.8	0.001
8_27	1046091	0.000	1076871.4	0.001	1046091	0.001	1047111.5	0.001	1046091	0.000	1067880.2	0.001
8_28	935195	0.001	970633.7	0.001	930531	0.002	940333.1	0.003	935195	0.001	976435.3	0.002
8_29	892496	0.001	967897.4	0.001	892496	0.001	942232.4	0.002	931245	0.001	972633.9	0.001
8_30	951959	0.001	957476.6	0.002	951920	0.002	954584.6	0.004	951920	0.001	956683.8	0.002
8_31	880611	0.001	922751.5	0.001	876864	0.002	884407.4	0.002	880814	0.001	944225.4	0.001
8_32	813344	0.001	867075.7	0.002	813344	0.002	817835.7	0.003	813344	0.001	847491	0.002
8_33	865898	0.002	890433.2	0.002	862890	0.002	870865.6	0.004	862890	0.002	876508.3	0.002
8_34	970444	0.001	1016563.2	0.001	970444	0.002	986300.2	0.003	977339	0.001	1040452	0.002
8_35	872804	0.001	876721.6	0.001	872804	0.002	911360	0.002	872804	0.001	885090.5	0.001
8_36	839482	0.001	844794.1	0.001	839482	0.002	839482	0.002	839482	0.001	842501.3	0.002
8_37	889967	0.001	1003830.9	0.001	889775	0.002	924094.6	0.002	889775	0.001	958241.4	0.002
8_38	1008729	0.001	1019833.5	0.001	1008729	0.002	1033710.3	0.003	1008729	0.001	1058783.7	0.001
8_39	792703	0.001	804036.3	0.001	792703	0.001	824110.6	0.003	792703	0.001	821303.7	0.002
8_40	926963	0.000	996783.6	0.001	912065	0.001	945166.7	0.002	912065	0.001	940515.8	0.001
8_41	991375	0.001	1005433.9	0.001	990368	0.003	994326	0.003	991375	0.001	1009885	0.002
8_42	785772	0.001	806035.8	0.001	785772	0.001	785772	0.002	785772	0.001	786629	0.001
8_43	979484	0.000	991884.4	0.001	968958	0.001	1013062.8	0.002	987525	0.001	1049091.2	0.001
8_44	761545	0.001	766301.1	0.002	761545	0.001	763448.5	0.002	761545	0.001	774561.1	0.002
8_45	770821	0.001	779668.1	0.002	770283	0.001	770283	0.003	770283	0.002	785644	0.002
8_46	847021	0.000	858545.1	0.001	843248	0.001	851446.4	0.002	847021	0.000	960819.6	0.001
8_47	787044	0.001	807325.7	0.001	787044	0.001	787044	0.003	787044	0.001	806858.1	0.002
8_48	909573	0.001	916920.7	0.001	908778	0.001	922076.7	0.002	910258	0.001	942449.3	0.001
8_49	802898	0.001	835353.2	0.002	802898	0.001	831529.1	0.003	802898	0.001	834967.4	0.002

Table 9: Instances with 8 nodes and Random Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
8_0	650601	0.001	688542.6	0.002	636554	0.002	639410.1	0.004	636554	0.001	665659.4	0.002
8_1	726007	0.001	761970.7	0.001	725989	0.001	737756	0.002	725989	0.001	766941.8	0.001
8_2	833036	0.001	837321.3	0.001	833036	0.001	850626	0.002	835609	0.001	847317	0.001
8_3	907170	0.001	930485.7	0.002	907170	0.002	953495.1	0.003	907170	0.001	957767.9	0.002
8_4	783711	0.001	800382.6	0.001	783711	0.001	784518.3	0.003	785906	0.001	800123.8	0.001
8_5	808765	0.001	826556.9	0.001	802860	0.001	843178.8	0.002	822841	0.000	910744.7	0.001
8_6	832065	0.001	856991.1	0.001	832065	0.002	837953.1	0.002	832065	0.001	862800	0.002
8_7	701377	0.001	784872.1	0.001	701314	0.002	721659.8	0.003	701314	0.001	797454.8	0.002
8_8	749621	0.001	750884.1	0.001	729089	0.001	746738.1	0.002	729089	0.000	785644	0.001
8_9	682912	0.001	686043.4	0.001	673660	0.002	673660	0.002	682912	0.001	698522.3	0.001
8_10	943925	0.001	977184.4	0.001	941305	0.001	941305	0.002	943925	0.000	974361.8	0.001
8_11	720053	0.000	729238.6	0.001	720053	0.001	722230.4	0.002	720053	0.000	742214	0.001
8_12	690241	0.000	720650.6	0.001	690241	0.002	690241	0.003	716609	0.001	761842.4	0.001
8_13	471898	0.001	526217.5	0.002	471898	0.003	476788.4	0.004	484020	0.002	514238.5	0.002
8_14	914222	0.001	945028.5	0.001	914222	0.002	926078.2	0.002	920858	0.001	948613.4	0.001
8_15	692888	0.001	747319.3	0.001	692888	0.001	692888	0.002	718330	0.001	791390.8	0.001
8_16	818047	0.000	855561.6	0.001	804057	0.001	804057	0.002	816507	0.000	859909.1	0.001
8_17	767636	0.001	817084.9	0.001	767000	0.002	826323.6	0.003	769621	0.001	854076.4	0.001
8_18	726454	0.000	742033.4	0.001	726454	0.001	726454	0.002	726454	0.000	752755.7	0.001
8_19	718905	0.001	764997	0.001	685652	0.002	688573.1	0.002	709116	0.001	786724.8	0.001
8_20	742238	0.000	746248.3	0.002	742238	0.003	742238	0.004	742238	0.000	745037.6	0.002
8_21	717761	0.001	748468.1	0.002	717647	0.001	754111.2	0.003	717647	0.001	723458.8	0.002
8_22	727227	0.001	732133.6	0.002	705567	0.002	705567	0.003	710093	0.001	732630.4	0.002
8_23	700661	0.001	736386.1	0.001	700661	0.001	744025.4	0.002	728531	0.001	744466.7	0.001
8_24	727831	0.001	731671	0.001	695449	0.002	696738.9	0.003	695449	0.001	724903.7	0.001
8_25	799305	0.001	802678.6	0.001	799305	0.001	799305	0.003	799305	0.001	801914.1	0.002
8_26	716624	0.001	749420	0.002	716624	0.002	729980.4	0.003	716624	0.001	780495.7	0.002
8_27	987543	0.000	987543	0.001	987543	0.001	989589.6	0.001	987543	0.000	1009176.4	0.001
8_28	844912	0.001	861119.5	0.001	841134	0.002	842151	0.003	841134	0.001	964292.5	0.001
8_29	744720	0.000	806632.4	0.001	744720	0.001	749814	0.002	744720	0.000	803190.6	0.001
8_30	783634	0.001	802615.6	0.002	783634	0.002	783634	0.003	783667	0.001	819279.8	0.002
8_31	724383	0.000	744542.7	0.001	717267	0.002	717836.7	0.002	724383	0.001	758667.1	0.001
8_32	706391	0.001	725535.9	0.001	706391	0.002	711036.2	0.003	717452	0.001	742348.9	0.002
8_33	680498	0.001	704380.5	0.002	680498	0.003	687923.4	0.004	680498	0.001	694322	0.002
8_34	870273	0.001	878451	0.001	870273	0.002	877599.1	0.002	870288	0.001	890253.8	0.001
8_35	795951	0.001	809373.8	0.001	795951	0.001	822320.8	0.002	795951	0.001	816246.7	0.001
8_36	885511	0.000	898844.8	0.001	874127	0.001	878779	0.002	874127	0.000	925496.4	0.001
8_37	794015	0.000	814675.4	0.001	794015	0.001	794015	0.002	794404	0.001	849824.9	0.001
8_38	807203	0.001	852372.8	0.001	789386	0.002	804137.5	0.003	829814	0.001	853069.9	0.001
8_39	853403	0.001	898068.7	0.002	853403	0.002	853526	0.003	853403	0.001	871188.3	0.002
8_40	806764	0.001	842474.3	0.001	818304	0.001	857876.3	0.002	801347	0.001	858658.6	0.001
8_41	871568	0.001	871568	0.002	854812	0.003	854812	0.004	854940	0.001	864647	0.002
8_42	594210	0.001	604780.5	0.002	594210	0.001	605649.6	0.003	594210	0.001	620035.3	0.002
8_43	738511	0.000	781010.6	0.001	719944	0.001	719944	0.002	738581	0.000	808248.1	0.001
8_44	685895	0.001	722941.7	0.002	685895	0.002	696041.6	0.004	685895	0.001	709759.4	0.002
8_45	574001	0.001	622690.3	0.002	573463	0.003	573463	0.004	573463	0.002	628474.2	0.002
8_46	624371	0.001	691526.8	0.001	624371	0.001	627588.5	0.002	650014	0.001	697602.5	0.001
8_47	703136	0.001	710054.2	0.001	702768	0.002	702768	0.003	702768	0.001	717078	0.001
8_48	767550	0.001	788760.7	0.001	767250	0.002	772212.7	0.003	767250	0.001	819653	0.001
8_49	604260	0.001	627076.3	0.002	604260	0.002	606941.5	0.003	604260	0.001	604817.4	0.002

Table 10: Instances with 9 nodes and Central Base Station position

	Swap – Best Improvement				Shift – Best Improvement				Swap21 – Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
9_0	618196	0.001	635583.7	0.001	614266	0.002	617017	0.003	637842	0.001	654197	0.002
9_1	616958	0.001	649881	0.002	616958	0.002	636428.3	0.004	618662	0.002	650007.3	0.002
9_2	869040	0.002	887081.3	0.003	868155	0.003	876642.3	0.006	868155	0.002	946019.5	0.003
9_3	872223	0.001	911615.3	0.001	857801	0.002	862831.6	0.004	868598	0.001	876976.6	0.002
9_4	932596	0.001	974928.3	0.001	902448	0.002	945871.7	0.003	922245	0.001	962855.5	0.002
9_5	937349	0.001	958642.2	0.002	937349	0.003	957182	0.004	937349	0.002	970281.4	0.003
9_6	672407	0.001	761597.2	0.002	671444	0.003	745105.9	0.004	698952	0.001	801324.8	0.002
9_7	834113	0.001	868976.8	0.001	834113	0.001	876719.5	0.002	834113	0.001	897099.1	0.001
9_8	766381	0.001	790020.1	0.001	766381	0.003	770341.8	0.003	766381	0.001	779712	0.002
9_9	728911	0.001	763305.4	0.001	728911	0.002	728911	0.002	732147	0.001	787110.5	0.001
9_10	520251	0.002	563626.9	0.002	537755	0.002	562110.3	0.004	577342	0.001	625495.8	0.002
9_11	650536	0.002	673182.6	0.003	646881	0.006	646881	0.007	646881	0.003	673638.7	0.004
9_12	889070	0.001	976212.7	0.001	883236	0.002	940813.8	0.004	889070	0.001	1044461.4	0.001
9_13	489939	0.002	523297	0.003	489939	0.003	496317.5	0.004	489939	0.002	550255.8	0.003
9_14	726587	0.001	760753.6	0.002	711205	0.003	739140.4	0.005	711205	0.002	741641.6	0.003
9_15	731958	0.002	764223.1	0.003	731958	0.005	746666.8	0.007	738989	0.002	768581.3	0.004
9_16	787078	0.002	825143	0.003	763903	0.002	813010.2	0.004	786807	0.002	813050.8	0.003
9_17	720475	0.001	763210.9	0.002	720474	0.003	720474	0.004	732796	0.001	798893.4	0.002
9_18	946869	0.001	1041133.1	0.002	935266	0.003	965873.5	0.005	965015	0.002	996524	0.003
9_19	859085	0.001	877352.7	0.001	831353	0.001	856892.6	0.002	842632	0.001	875869.7	0.001
9_20	675743	0.001	712476.2	0.002	675685	0.003	681116.9	0.005	683390	0.001	731510.8	0.002
9_21	874883	0.001	931276.2	0.002	873362	0.003	918933.7	0.004	873362	0.002	902685.1	0.002
9_22	788476	0.002	831510	0.002	757371	0.003	790163.8	0.005	820667	0.002	862737.3	0.002
9_23	879349	0.001	921552.9	0.002	879349	0.003	903497.2	0.003	879349	0.001	932779.6	0.002
9_24	730931	0.001	758157.9	0.002	717108	0.004	727138	0.005	717108	0.002	789593.7	0.003
9_25	803891	0.001	824250.9	0.002	802998	0.002	821013.7	0.003	803891	0.001	857627.9	0.002
9_26	825197	0.000	840813.5	0.001	825197	0.001	825197	0.002	825197	0.001	858910.2	0.001
9_27	776960	0.001	798556	0.002	776960	0.002	779362.6	0.003	776960	0.001	809528.2	0.002
9_28	693839	0.001	724667.4	0.002	693839	0.003	707012.2	0.004	693839	0.001	748850.7	0.002
9_29	840656	0.001	883414.9	0.002	840656	0.004	845748.8	0.005	864111	0.001	875901.8	0.002
9_30	523259	0.001	588806	0.002	523174	0.002	526389.4	0.003	523174	0.001	569135	0.002
9_31	890986	0.001	936638.5	0.002	890882	0.003	943171	0.004	905752	0.001	956977.6	0.002
9_32	889642	0.001	925746.9	0.001	869228	0.002	885888.6	0.004	890492	0.001	940520.6	0.001
9_33	778086	0.001	812493.3	0.002	778086	0.003	800742.4	0.004	778086	0.001	818499	0.002
9_34	619774	0.001	677722.3	0.002	619774	0.003	632473.8	0.005	619774	0.002	716469.3	0.003
9_35	741453	0.002	773749.2	0.003	738470	0.003	738470	0.005	738470	0.001	785251.4	0.003
9_36	873604	0.001	962966.4	0.001	873604	0.002	911592.4	0.002	873604	0.001	932372.5	0.002
9_37	987365	0.001	1033359.1	0.001	986772	0.002	991450	0.003	988310	0.001	1045787.8	0.002
9_38	847007	0.001	941086.3	0.001	845112	0.002	914280.2	0.003	845112	0.001	905964	0.001
9_39	834797	0.001	870727.7	0.002	823458	0.003	824682.8	0.005	823458	0.002	864966.6	0.003
9_40	628050	0.001	652549.5	0.001	608580	0.003	614836.8	0.004	628486	0.001	671561.6	0.002
9_41	653078	0.001	701534.5	0.002	653016	0.002	688180.3	0.004	653016	0.002	721517.4	0.003
9_42	817999	0.001	895498.6	0.001	817780	0.002	841900	0.003	856368	0.001	908997.4	0.002
9_43	865855	0.002	915407.4	0.003	865855	0.005	908268	0.006	865855	0.003	917123.6	0.004
9_44	949986	0.001	1028524.6	0.002	935627	0.002	951617	0.004	935627	0.001	1022998.4	0.002
9_45	972298	0.002	981610	0.003	951296	0.003	973456.7	0.006	951386	0.002	1000323.4	0.003
9_46	630721	0.002	642679.4	0.004	630721	0.005	638685.1	0.007	631437	0.004	641429.9	0.005
9_47	679230	0.001	709877.2	0.002	634601	0.001	657192	0.004	679230	0.001	722892.9	0.002
9_48	844922	0.001	887278.7	0.002	840329	0.003	840329	0.004	844922	0.002	893933.5	0.002
9_49	680167	0.001	722142.4	0.002	680167	0.002	694247	0.004	692808	0.001	715829.9	0.002

Table 11: Instances with 9 nodes and Eccentric Base Station position

	Swap – Best Improvement				Shift – Best Improvement				Swap21 – Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
9_0	795056	0.001	798880.1	0.001	783925	0.002	784774.1	0.003	796624	0.001	815891	0.002
9_1	746997	0.001	770873.6	0.002	746997	0.002	771303.9	0.004	746997	0.001	768226.5	0.002
9_2	995435	0.002	1055301.3	0.003	994252	0.005	999792.7	0.006	1013544	0.002	1072618.1	0.003
9_3	958252	0.001	1098607.4	0.002	935609	0.004	939530.6	0.005	947835	0.002	1047350.4	0.002
9_4	992131	0.001	1048970.1	0.002	984256	0.003	993252.4	0.004	986125	0.001	1011317.5	0.002
9_5	1031944	0.001	1050475.3	0.002	1030525	0.003	1058011.9	0.004	1030525	0.001	1113676.9	0.003
9_6	881470	0.001	998175.6	0.002	881429	0.003	917962.6	0.005	881442	0.001	1016126.2	0.002
9_7	917587	0.001	983959.8	0.001	917587	0.001	933697.1	0.003	922070	0.001	1001168.7	0.001
9_8	912593	0.001	988470	0.002	912593	0.002	931554.8	0.004	931116	0.001	1003812.3	0.002
9_9	761791	0.001	815029.5	0.001	760994	0.002	762203	0.003	769478	0.001	817465.2	0.001
9_10	847636	0.001	891131.7	0.003	847636	0.004	850949.7	0.005	847636	0.002	939745.1	0.003
9_11	953644	0.001	955837	0.003	941064	0.004	941064	0.006	944719	0.001	977472.9	0.003
9_12	971903	0.001	977539.4	0.001	962773	0.003	1007469.1	0.004	1037618	0.001	1111728	0.002
9_13	869488	0.001	922293.5	0.002	869488	0.002	874801	0.005	869488	0.001	883096.2	0.003
9_14	843380	0.002	880703.7	0.002	826909	0.003	831247.6	0.006	827998	0.002	891959.4	0.003
9_15	906962	0.000	928578.5	0.002	902947	0.003	918184	0.006	928509	0.002	943842.7	0.003
9_16	826186	0.001	857119.5	0.002	826186	0.004	866954.3	0.005	849361	0.001	893327.7	0.002
9_17	911845	0.001	940142.4	0.002	911844	0.003	916772.8	0.004	924685	0.002	967250.8	0.002
9_18	946400	0.001	990768.4	0.002	943129	0.003	966951.8	0.004	943129	0.001	1032956.9	0.003
9_19	903105	0.001	941771.6	0.002	903105	0.003	917143.9	0.004	903105	0.002	967403.4	0.002
9_20	793986	0.002	817883.8	0.002	793622	0.005	793622	0.006	793622	0.002	815854	0.003
9_21	993113	0.001	1004509	0.002	993113	0.003	1012393.8	0.004	1001499	0.002	1060382.3	0.002
9_22	833819	0.002	855374.5	0.002	833819	0.002	835992.5	0.005	833819	0.001	882852.2	0.003
9_23	966479	0.001	1016178.4	0.002	966479	0.002	1000552.4	0.004	975569	0.001	1045450.1	0.003
9_24	828349	0.001	883709.5	0.002	825224	0.003	825224	0.006	825224	0.002	855166.6	0.002
9_25	864465	0.001	873405.6	0.002	864459	0.003	885830.6	0.004	878918	0.001	914502	0.002
9_26	882448	0.001	900189.2	0.002	882448	0.003	882448	0.003	913738	0.001	985829.1	0.002
9_27	972594	0.001	998668.9	0.001	960502	0.002	980279.5	0.003	961512	0.001	1019969.4	0.002
9_28	917286	0.001	947428.2	0.002	916966	0.003	959573	0.005	916966	0.002	972214	0.003
9_29	873803	0.001	921250.2	0.001	873803	0.002	912315.8	0.003	908464	0.001	939527.4	0.002
9_30	741853	0.000	767878.1	0.001	741853	0.001	751439.8	0.004	741853	0.001	762719.1	0.002
9_31	903742	0.001	914865.7	0.002	888976	0.002	902855.2	0.004	912361	0.001	963257.1	0.002
9_32	982125	0.001	1041418.5	0.001	982125	0.002	1002354.7	0.003	982125	0.001	1079490.4	0.002
9_33	1011445	0.001	1042636.8	0.002	1007137	0.002	1062193.6	0.004	1007137	0.001	1077030.1	0.002
9_34	718625	0.001	729947.5	0.002	718625	0.003	735461.8	0.004	718625	0.001	757484.2	0.002
9_35	957548	0.001	1010819.4	0.002	954565	0.003	972743.3	0.004	979813	0.001	1025590.6	0.002
9_36	914201	0.001	959963.5	0.002	914201	0.002	921855.4	0.003	923722	0.001	1020825.4	0.002
9_37	989659	0.001	992446.7	0.002	988714	0.003	988986.4	0.004	990567	0.001	1042048.3	0.002
9_38	1035103	0.001	1069354.9	0.002	1033208	0.003	1054290	0.003	1033208	0.001	1067543.9	0.002
9_39	959387	0.001	979178.8	0.002	959387	0.004	960305.6	0.005	959387	0.002	1014311.9	0.003
9_40	869194	0.001	887418.5	0.001	855188	0.002	863474.1	0.004	879584	0.001	914118.5	0.002
9_41	869508	0.001	914409.2	0.002	866869	0.002	869685	0.004	870389	0.001	947768.6	0.002
9_42	962783	0.001	972349.7	0.001	962564	0.001	970089.6	0.003	992924	0.001	1050701.5	0.002
9_43	1107080	0.003	1157914.1	0.004	1104956	0.005	1105229.4	0.006	1115694	0.002	1193460.7	0.003
9_44	988722	0.001	1039213.1	0.002	988104	0.003	992107.2	0.005	988104	0.001	1053269.1	0.002
9_45	1131965	0.001	1139826.3	0.002	1117078	0.003	1117078	0.006	1119227	0.003	1142893.7	0.004
9_46	827015	0.001	851117.3	0.003	827015	0.001	829126.1	0.004	827015	0.001	827986.7	0.003
9_47	798732	0.001	821220.5	0.002	798625	0.002	802942.2	0.004	798732	0.002	842191.6	0.002
9_48	960945	0.001	1035315.3	0.002	960945	0.002	1011782.1	0.004	978564	0.001	1050500.5	0.002
9_49	811997	0.001	847617.5	0.002	798112	0.003	800928	0.005	811997	0.001	874433.6	0.002

Table 12: Instances with 9 nodes and Random Base Station position

	Swap – Best Improvement				Shift – Best Improvement				Swap21 – Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
9_0	651262	0.001	656042.9	0.001	644739	0.002	652885.6	0.003	670426	0.001	686358.6	0.002
9_1	603190	0.001	623249.7	0.002	603190	0.002	617172.7	0.003	603190	0.001	638331.5	0.002
9_2	862080	0.002	871874.1	0.003	862080	0.004	870499.6	0.005	862080	0.003	909021.9	0.004
9_3	890764	0.001	956028.7	0.001	878815	0.003	880100.8	0.005	878815	0.002	923685.6	0.002
9_4	899383	0.000	957433.3	0.001	898831	0.001	942368.2	0.003	899383	0.001	945022.1	0.001
9_5	930731	0.001	976895.1	0.002	929312	0.002	941739.4	0.004	984098	0.001	1010099.8	0.002
9_6	720107	0.001	787277.7	0.002	720079	0.003	727345.9	0.004	720079	0.001	812432.5	0.002
9_7	982583	0.001	1010966.2	0.002	982583	0.001	1001447.3	0.003	982646	0.001	1051491.9	0.002
9_8	762965	0.001	811837.4	0.002	762845	0.002	827906.6	0.003	762845	0.001	812341.5	0.002
9_9	816367	0.001	849714.3	0.002	813131	0.001	854544.1	0.003	815570	0.001	922372.9	0.002
9_10	617279	0.001	704218.8	0.002	617213	0.002	639500	0.004	617213	0.001	712303.9	0.002
9_11	697756	0.003	705375	0.004	689749	0.004	690184.2	0.007	697756	0.002	713223.1	0.004
9_12	885829	0.001	944599.5	0.001	885829	0.002	911540.8	0.003	887024	0.001	1022576.2	0.001
9_13	444818	0.002	460971.6	0.003	437449	0.002	462238.6	0.004	437449	0.001	455562.3	0.003
9_14	729338	0.001	781813	0.002	684500	0.002	709362	0.004	684500	0.001	773502.1	0.002
9_15	754433	0.003	766932.2	0.004	750274	0.003	757499.6	0.006	750274	0.003	768685.9	0.004
9_16	853835	0.002	905839	0.003	876739	0.003	897064.1	0.004	853835	0.002	947039	0.003
9_17	720304	0.001	801914.1	0.002	720303	0.003	720303	0.004	748804	0.001	822743.9	0.002
9_18	953315	0.001	1021694.9	0.002	944030	0.004	964875.4	0.005	944030	0.003	986190.2	0.004
9_19	842956	0.001	887004.1	0.002	840734	0.003	864801.8	0.004	874179	0.002	905450	0.002
9_20	724853	0.001	743342	0.002	680695	0.005	680695	0.006	680695	0.002	756605.6	0.003
9_21	884284	0.001	910713.3	0.002	882864	0.003	882864	0.004	902337	0.001	938504.8	0.002
9_22	869566	0.002	905915	0.002	869566	0.004	885333.9	0.005	869566	0.002	928513.6	0.003
9_23	859389	0.001	904255.2	0.002	854354	0.003	861827.6	0.004	885783	0.001	904267.8	0.002
9_24	684379	0.001	704264	0.002	684295	0.004	684295	0.005	684379	0.002	736581.9	0.002
9_25	767737	0.001	791421.4	0.002	767737	0.003	771392.1	0.004	799644	0.001	838938.3	0.002
9_26	764223	0.001	787992.2	0.001	764223	0.001	764223	0.003	764223	0.001	807880.8	0.001
9_27	814404	0.001	860259.1	0.002	814398	0.002	817271.2	0.004	814398	0.001	879296.1	0.002
9_28	721821	0.002	753554	0.003	694588	0.005	704621.2	0.006	711757	0.002	746487.4	0.003
9_29	873940	0.001	903757.2	0.002	855246	0.004	855246	0.005	882398	0.002	938644	0.002
9_30	586861	0.001	644869.1	0.002	586861	0.002	641978.3	0.004	591012	0.001	662069.8	0.002
9_31	910582	0.001	921112.4	0.002	895712	0.003	902275.2	0.004	910582	0.001	932126.1	0.002
9_32	870208	0.001	908057.7	0.001	849050	0.002	859341.9	0.003	849050	0.001	920812.1	0.002
9_33	772452	0.001	805456.2	0.002	772452	0.003	784281.4	0.004	780721	0.001	812249.8	0.002
9_34	686574	0.001	702889.4	0.002	679352	0.003	684566.7	0.005	695092	0.002	758201.5	0.002
9_35	776503	0.001	782861.1	0.002	748090	0.003	748090	0.005	773520	0.002	804084.6	0.002
9_36	825681	0.001	873412.1	0.002	825681	0.002	838027.2	0.003	834278	0.001	927605.3	0.002
9_37	973968	0.001	1005596	0.001	973375	0.003	973375	0.004	974913	0.001	1081741.4	0.001
9_38	823474	0.001	840531	0.001	823474	0.003	823474	0.003	823474	0.001	878813	0.002
9_39	819017	0.002	879907.5	0.003	814113	0.003	817697.5	0.004	816517	0.002	882956.9	0.002
9_40	633866	0.001	698418.3	0.002	620490	0.003	641211.3	0.004	620490	0.001	684725.9	0.002
9_41	666597	0.001	680942.6	0.002	666571	0.003	674169.8	0.004	666571	0.002	698367.3	0.003
9_42	880506	0.001	926979.2	0.001	880287	0.001	890640.6	0.002	880506	0.001	932507.4	0.001
9_43	870132	0.002	929396.3	0.003	869391	0.004	869761.5	0.005	873430	0.002	931518.5	0.003
9_44	894478	0.001	942003.1	0.002	894478	0.001	916138.8	0.003	894478	0.001	933296.8	0.001
9_45	987300	0.001	999037.3	0.002	963389	0.002	983040.1	0.005	985293	0.002	991798.9	0.003
9_46	715272	0.002	775798.7	0.003	702325	0.006	703223.8	0.007	702325	0.003	717179.4	0.004
9_47	877903	0.001	895237.8	0.002	839884	0.003	851021.5	0.005	839884	0.002	922700	0.003
9_48	799293	0.001	845574.8	0.002	799293	0.003	822398.6	0.005	807824	0.002	889808.6	0.003
9_49	670444	0.001	724340.3	0.002	656559	0.002	656559	0.004	656559	0.001	727132	0.002

Table 13: Instances with 10 nodes and Central Base Station position

	Swap − Best Improvement				Shift − Best Improvement				Swap21 − Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
10_0	844627	0.001	872383.6	0.002	828229	0.003	830500	0.006	832561	0.002	915537.5	0.003
10_1	722468	0.002	762899.3	0.002	722468	0.004	727711.8	0.005	740173	0.002	813637.1	0.003
10_2	731002	0.002	778038	0.003	719509	0.004	723715.5	0.005	731002	0.003	759151.5	0.004
10_3	898618	0.002	918666.7	0.003	898392	0.005	928975.8	0.007	904858	0.002	949471.1	0.004
10_4	699446	0.002	714468.4	0.004	699445	0.003	715727.1	0.006	699445	0.003	729567.5	0.004
10_5	861324	0.002	924631.8	0.003	823373	0.005	865138.2	0.007	823373	0.003	894153.6	0.004
10_6	716711	0.002	773135.1	0.003	706920	0.004	744085.6	0.005	740066	0.002	808845.2	0.003
10_7	944430	0.003	995818.4	0.004	942493	0.005	988427.6	0.007	947974	0.003	1013136.7	0.005
10_8	869681	0.001	973141.5	0.002	854315	0.004	872880.4	0.005	854315	0.002	943653.2	0.002
10_9	1007515	0.002	1041976.8	0.002	1007069	0.004	1012037.9	0.005	1033768	0.002	1075876.6	0.003
10_10	944759	0.001	994414.5	0.002	942886	0.004	993086.3	0.004	969234	0.001	994876.2	0.002
10_11	793339	0.002	838900.6	0.003	793339	0.005	807854.7	0.006	844838	0.003	878652.5	0.004
10_12	537919	0.003	577061.5	0.004	537919	0.004	552986.2	0.007	537919	0.003	551187.2	0.004
10_13	610261	0.004	661504.4	0.006	610006	0.006	615381.5	0.009	610006	0.003	651254.3	0.007
10_14	650929	0.001	678440.1	0.002	666662	0.004	666662	0.005	650576	0.002	681191.6	0.002
10_15	809305	0.002	858906.9	0.003	796231	0.005	796231	0.006	833717	0.002	863582.3	0.004
10_16	789975	0.001	832308.9	0.002	789975	0.003	914925.9	0.004	834936	0.001	879841.8	0.002
10_17	1096841	0.001	1133505.7	0.002	1087310	0.003	1102779.1	0.004	1112489	0.001	1175869.5	0.002
10_18	778132	0.001	804098	0.002	776608	0.003	797534.9	0.004	794655	0.002	823953.3	0.003
10_19	651658	0.001	739530.2	0.003	651658	0.004	658349	0.007	660404	0.002	746561.2	0.004
10_20	979325	0.001	1071089	0.002	977782	0.002	1034665.2	0.004	1036001	0.001	1070372	0.002
10_21	708566	0.002	727311	0.004	708373	0.006	708373	0.008	708373	0.004	720508.4	0.005
10_22	612907	0.003	677134.2	0.004	612424	0.005	622423.4	0.008	671465	0.002	729828.2	0.005
10_23	738789	0.002	762653.1	0.004	737688	0.004	766064.6	0.007	762286	0.002	810120.6	0.004
10_24	519531	0.002	558219.4	0.004	518419	0.006	524532.2	0.008	518419	0.002	594212.2	0.004
10_25	699889	0.002	734448.1	0.003	696834	0.003	706923.2	0.006	696834	0.003	740702.4	0.004
10_26	665115	0.002	696678.2	0.003	658875	0.005	712083.2	0.006	691015	0.002	715650	0.004
10_27	869872	0.002	947005.5	0.003	863251	0.005	915643.9	0.006	864757	0.003	940148.6	0.004
10_28	1001120	0.002	1055073.8	0.002	996114	0.004	1023704.6	0.005	999410	0.002	1071601.5	0.003
10_29	633351	0.002	641790.7	0.003	630719	0.005	634632.4	0.006	633370	0.002	678080.9	0.003
10_30	713819	0.002	769052.7	0.003	710663	0.004	711949.5	0.006	713819	0.003	818425.4	0.003
10_31	885851	0.002	958367.7	0.003	866449	0.006	899285.7	0.008	866449	0.002	953440.3	0.004
10_32	939601	0.001	1018632.6	0.003	891422	0.004	969778.4	0.007	891422	0.002	1002694.2	0.004
10_33	923800	0.002	975397.8	0.004	923800	0.003	951503.9	0.007	928276	0.003	975313.8	0.004
10_34	801525	0.003	859631	0.003	784263	0.004	821925.3	0.006	833809	0.003	853092.4	0.004
10_35	830850	0.002	872644	0.003	828550	0.004	846010.5	0.006	853194	0.003	877177.2	0.004
10_36	815167	0.003	857536.9	0.004	815167	0.004	841641.3	0.007	827764	0.003	874738.7	0.005
10_37	546129	0.001	608549.2	0.004	545452	0.004	546997.6	0.007	545452	0.003	576018.1	0.005
10_38	687030	0.002	693486.3	0.003	650149	0.005	666256.5	0.007	654154	0.002	705753.5	0.003
10_39	850125	0.003	908838	0.004	836311	0.006	846375.3	0.008	836434	0.003	926409.4	0.005
10_40	999453	0.001	1098278.1	0.003	963155	0.006	971718.4	0.007	967732	0.002	1024302	0.003
10_41	925891	0.002	984188.5	0.003	918988	0.003	949978.4	0.007	918988	0.001	955369.7	0.004
10_42	826904	0.002	882681.1	0.003	826904	0.004	839693.1	0.005	826904	0.002	883698.3	0.003
10_43	876788	0.001	933471.7	0.003	876788	0.004	906525.2	0.006	876788	0.002	951084	0.003
10_44	878728	0.002	889954.2	0.004	805367	0.006	824729.5	0.008	799914	0.003	885432.3	0.005
10_45	1076064	0.001	1117339.5	0.002	1047014	0.003	1090612.6	0.005	1073502	0.002	1129430.1	0.003
10_46	820865	0.001	919350.9	0.002	798872	0.004	799801.9	0.005	809692	0.001	891824.3	0.002
10_47	826666	0.002	884570.6	0.003	816733	0.006	818235.6	0.009	816733	0.003	841163.8	0.005
10_48	655040	0.001	689301.2	0.002	654464	0.004	657462.2	0.006	655040	0.002	695311.8	0.002
10_49	891636	0.001	924142.4	0.002	864020	0.004	867153.2	0.006	887854	0.001	926537.6	0.003

Table 14: Instances with 10 nodes and Eccentric Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
10_0	840001	0.001	922413.6	0.003	839991	0.004	853398	0.005	841880	0.002	892750.6	0.004
10_1	885945	0.002	940003	0.002	874311	0.003	875854.5	0.005	926079	0.002	1012906.1	0.003
10_2	847304	0.002	899980.6	0.003	834660	0.005	843465	0.006	843915	0.002	892616.7	0.004
10_3	1113870	0.003	1145479.6	0.004	1060094	0.005	1083328.9	0.009	1068121	0.004	1108275.5	0.005
10_4	861802	0.002	871098	0.004	857215	0.007	865978.7	0.008	861802	0.002	896853.5	0.004
10_5	950671	0.002	1030728.3	0.003	950671	0.004	989671.6	0.006	1003117	0.002	1060203	0.003
10_6	871953	0.002	974325.4	0.004	886404	0.001	953523.9	0.005	873476	0.002	969385.9	0.003
10_7	1181113	0.002	1222565	0.003	1145851	0.005	1187947.4	0.008	1125485	0.002	1222145.3	0.005
10_8	987465	0.002	1003420.9	0.002	969140	0.005	992918	0.006	1003679	0.002	1018353.4	0.003
10_9	1032472	0.002	1067320.4	0.003	1030144	0.004	1053759.6	0.006	1039657	0.002	1079682.2	0.003
10_10	958232	0.002	978646.3	0.002	958232	0.003	958232	0.004	958232	0.002	998823.8	0.003
10_11	935756	0.002	1008148.6	0.003	899439	0.004	947708.9	0.006	879416	0.003	967219.9	0.003
10_12	756079	0.003	805290.3	0.004	758506	0.004	769730.3	0.007	758506	0.003	796802	0.005
10_13	751197	0.004	796054.6	0.006	747152	0.003	770938.5	0.009	764629	0.003	833625.9	0.006
10_14	903130	0.002	960079.7	0.004	899106	0.006	937833.1	0.007	905913	0.003	943712.1	0.005
10_15	881795	0.001	915101.2	0.003	870479	0.003	920958	0.005	870479	0.003	932435.4	0.004
10_16	810435	0.001	859382.4	0.002	808019	0.003	815959.4	0.005	808019	0.002	852874.8	0.002
10_17	1075013	0.001	1180110.1	0.002	1075013	0.003	1094658.7	0.005	1178728	0.001	1263299.3	0.002
10_18	929183	0.001	970776.2	0.002	927281	0.002	963583	0.004	927399	0.002	968694.1	0.002
10_19	967849	0.002	992840.7	0.003	967449	0.006	967449	0.008	967449	0.002	1034949.5	0.003
10_20	1052694	0.001	1130455.3	0.003	1023091	0.003	1029927.8	0.005	1031228	0.002	1144580.4	0.003
10_21	837317	0.004	862697.6	0.005	837100	0.002	845620	0.007	837100	0.003	842566.7	0.005
10_22	823187	0.002	881155.9	0.004	817234	0.005	835104.3	0.008	818088	0.003	874383	0.004
10_23	955263	0.002	962433.8	0.004	941423	0.005	949825.9	0.007	941423	0.002	970957.9	0.005
10_24	720161	0.002	773776.9	0.003	718415	0.004	724405.8	0.007	718415	0.002	776672.8	0.003
10_25	986529	0.001	1015767.2	0.002	981300	0.003	985648.7	0.006	981300	0.002	1033046.6	0.003
10_26	776495	0.002	799101.3	0.004	763815	0.006	792593.8	0.008	784111	0.003	819825.7	0.005
10_27	869252	0.002	897748.4	0.003	868855	0.004	868855	0.006	869022	0.002	898459	0.003
10_28	1013964	0.002	1092414.4	0.003	1012108	0.004	1059464.9	0.006	1012108	0.001	1052065.1	0.003
10_29	804657	0.002	882533.2	0.003	787517	0.004	829054.1	0.006	804657	0.003	860248.6	0.004
10_30	1036971	0.002	1076583.8	0.003	1028667	0.004	1031480.8	0.006	1031823	0.001	1097271.5	0.002
10_31	897204	0.002	935374.9	0.003	896235	0.004	896747.4	0.007	901359	0.002	926146.4	0.004
10_32	909529	0.001	966995.8	0.003	909529	0.002	947468.5	0.006	909529	0.002	979690.3	0.004
10_33	1099506	0.002	1144411.6	0.004	1082746	0.005	1133493.3	0.008	1082746	0.002	1139735.6	0.004
10_34	985926	0.002	1073744.9	0.003	985926	0.004	1012125.9	0.006	1020131	0.003	1079735.1	0.004
10_35	959609	0.001	1090687.6	0.002	956548	0.005	999096.1	0.006	957309	0.003	1047596.8	0.004
10_36	1012517	0.002	1072013	0.004	971414	0.005	1050060.9	0.007	1009345	0.003	1050021.2	0.005
10_37	970522	0.001	1016492.9	0.003	925384	0.004	966600.4	0.006	960972	0.002	1026630.3	0.004
10_38	767603	0.003	802427.6	0.004	766544	0.005	776419.2	0.008	771060	0.002	817505.2	0.004
10_39	1063849	0.002	1144386.7	0.004	1050158	0.004	1130049.2	0.007	1050158	0.002	1226966.7	0.004
10_40	963068	0.001	1058111.3	0.003	962844	0.004	1001638.9	0.007	963045	0.002	1100323.8	0.003
10_41	963787	0.003	1000050.5	0.004	951783	0.005	959612.4	0.009	956884	0.005	1011526.6	0.006
10_42	950609	0.002	1034853.3	0.003	950609	0.003	1029400.9	0.005	980358	0.002	1019530.8	0.003
10_43	968990	0.001	1028080.6	0.002	967400	0.005	992550.8	0.006	1000685	0.002	1060423.9	0.003
10_44	930043	0.001	1011153.5	0.003	929986	0.002	1022857.4	0.006	929986	0.002	999249.9	0.003
10_45	1195980	0.002	1318601.6	0.003	1136682	0.005	1154362.2	0.006	1170122	0.002	1247890.1	0.004
10_46	953390	0.001	996451.4	0.002	919244	0.004	951292.1	0.005	953506	0.002	1013438.6	0.003
10_47	842965	0.002	870790.9	0.003	842965	0.002	857209.6	0.006	842965	0.001	851080.3	0.004
10_48	780465	0.001	856683.5	0.003	771828	0.003	791843.5	0.006	771828	0.003	841256.9	0.004
10_49	890516	0.003	921743.6	0.004	887654	0.006	909382	0.007	890516	0.002	968835.8	0.004

Table 15: Instances with 10 nodes and Random Base Station position

	Swap − Best Improvement				Shift − Best Improvement				Swap21 − Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
10_0	807038	0.001	874685.2	0.003	794823	0.005	832565.5	0.007	807116	0.002	877868.8	0.004
10_1	698690	0.001	726431.6	0.003	680010	0.004	689856	0.006	680010	0.002	762542.9	0.003
10_2	752377	0.002	854676.9	0.003	742608	0.004	758010.2	0.006	763356	0.002	846296.8	0.004
10_3	885832	0.002	897376.9	0.003	881128	0.006	887782	0.006	905136	0.002	913227.7	0.003
10_4	705739	0.001	716374.2	0.003	701984	0.004	713129.5	0.006	704757	0.002	714676.6	0.004
10_5	829770	0.002	893342	0.003	803685	0.005	856390.9	0.007	809128	0.001	883897.7	0.003
10_6	683847	0.001	736926	0.002	673230	0.003	680576.4	0.005	716993	0.002	759192.7	0.003
10_7	967124	0.003	986568.6	0.004	918282	0.006	938469.8	0.009	918282	0.003	989010.9	0.004
10_8	837322	0.001	915594.1	0.002	837322	0.004	837322	0.006	837322	0.002	972261.7	0.003
10_9	1031940	0.001	1094511.3	0.002	1021504	0.005	1034487.2	0.006	1052569	0.001	1106016.3	0.003
10_10	972041	0.001	996032.4	0.002	933915	0.002	954578.7	0.004	938152	0.002	959904.8	0.003
10_11	805821	0.002	860533.9	0.002	805821	0.004	860316.5	0.005	847128	0.001	875308.4	0.003
10_12	540404	0.002	576866.5	0.004	538366	0.005	541463.3	0.007	538366	0.004	548233.7	0.006
10_13	639334	0.004	678855.5	0.005	639334	0.004	652517.5	0.010	639334	0.004	648508.3	0.007
10_14	774954	0.002	793393.7	0.003	774520	0.004	774520	0.007	774520	0.002	787876.9	0.004
10_15	924839	0.001	956839.1	0.002	882251	0.004	895788	0.006	882251	0.002	975983.8	0.003
10_16	922573	0.001	993764.3	0.002	922521	0.003	928735.5	0.005	922830	0.002	1010855.1	0.003
10_17	1034408	0.001	1078740.7	0.002	1034408	0.003	1050767.7	0.004	1038074	0.002	1153542	0.002
10_18	840443	0.001	883468.9	0.002	837062	0.003	864108.4	0.005	837062	0.001	897278.5	0.003
10_19	953016	0.002	975371.7	0.003	903482	0.005	913182.6	0.008	912173	0.002	959250.3	0.004
10_20	904727	0.002	954503	0.003	904727	0.003	922874.4	0.005	908732	0.001	998305.3	0.003
10_21	715031	0.002	756997.6	0.003	715031	0.004	720898.1	0.007	715031	0.003	722229.4	0.005
10_22	691376	0.002	730809.5	0.004	691376	0.004	713636	0.007	704186	0.003	763176.3	0.004
10_23	784607	0.002	829195	0.003	771191	0.003	787972.9	0.007	771743	0.003	814357.4	0.005
10_24	666222	0.003	686104.8	0.004	664476	0.005	672451.2	0.008	666222	0.003	706780.2	0.004
10_25	722513	0.002	781485.7	0.003	719458	0.002	727859.4	0.005	724182	0.002	743025	0.003
10_26	709653	0.003	736314.5	0.004	688020	0.006	697042.8	0.008	692338	0.003	741356	0.005
10_27	899918	0.001	938024.2	0.002	886632	0.004	923341.2	0.006	887609	0.002	939465	0.003
10_28	978538	0.002	1049830.3	0.003	969860	0.003	1010415.6	0.005	982215	0.002	1038537.8	0.004
10_29	683947	0.003	756513.7	0.003	681387	0.006	684632.6	0.008	706012	0.003	830515	0.003
10_30	979530	0.002	1037566.4	0.003	969941	0.005	970455.6	0.007	973097	0.002	1029097.3	0.004
10_31	867236	0.002	919938	0.003	812507	0.006	813019.4	0.008	812507	0.003	893840.9	0.005
10_32	920151	0.002	942786.1	0.003	920151	0.006	920151	0.008	878265	0.003	944419	0.004
10_33	922091	0.003	937038.7	0.004	917577	0.005	929830.9	0.008	922053	0.003	949706.7	0.004
10_34	955576	0.001	1017556.2	0.002	859329	0.005	907062.3	0.006	876883	0.003	959178.3	0.003
10_35	835088	0.002	883298.1	0.003	832788	0.004	867457	0.007	884640	0.002	930103.7	0.003
10_36	816899	0.002	889652.1	0.004	816899	0.004	848216.6	0.008	817169	0.003	874106.7	0.005
10_37	613728	0.001	653265.6	0.003	611860	0.003	636902.8	0.006	613728	0.003	677511.2	0.004
10_38	662741	0.001	713572.3	0.002	656677	0.004	656677	0.007	660284	0.002	728599.3	0.004
10_39	836797	0.003	904879.5	0.004	836797	0.008	857189.6	0.009	878065	0.004	912260.7	0.005
10_40	926003	0.001	1122959.5	0.002	916920	0.005	944008.5	0.007	929278	0.001	1037489.2	0.003
10_41	914999	0.003	975700.2	0.003	902995	0.006	902995	0.008	906473	0.004	966489	0.005
10_42	894359	0.001	967576.7	0.002	894359	0.004	913926.4	0.005	948521	0.001	1001963.3	0.002
10_43	866551	0.001	938203	0.003	866551	0.005	875915.3	0.006	880714	0.002	953599.8	0.003
10_44	784138	0.003	840851.9	0.004	767091	0.005	796576.2	0.007	784138	0.002	850415	0.004
10_45	1026425	0.001	1080630.1	0.002	983672	0.004	1003686.8	0.006	984743	0.002	1043290.8	0.003
10_46	818936	0.001	883884.3	0.002	807763	0.004	828079	0.005	807763	0.002	891400.1	0.003
10_47	994082	0.002	1025456.4	0.004	991891	0.003	1042463.9	0.006	991891	0.002	1058642.2	0.005
10_48	593639	0.001	625718.3	0.002	593639	0.003	600328.7	0.006	593639	0.001	629554.5	0.003
10_49	833974	0.003	886387	0.003	830381	0.004	839780.6	0.006	880357	0.002	951900.2	0.003

Table 16: Instances with 11 nodes and Central Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
11_0	915831	0.002	971330	0.003	894909	0.006	907607.4	0.008	916481	0.001	1021616.9	0.003
11_1	927346	0.002	991397.1	0.003	895268	0.004	965016.3	0.007	902356	0.003	958031.5	0.005
11_2	948431	0.004	1016337.6	0.005	945392	0.008	970176.2	0.011	1008725	0.003	1044956.1	0.005
11_3	864438	0.004	992714.3	0.005	832957	0.007	832957	0.009	864438	0.003	949095.3	0.006
11_4	650146	0.003	704608.2	0.005	622738	0.009	637144.9	0.011	638045	0.004	716315.7	0.006
11_5	972887	0.002	1019541.2	0.003	944070	0.006	956676.1	0.008	972887	0.002	1031232.8	0.004
11_6	1007174	0.005	1040518.2	0.007	1001525	0.009	1012207	0.012	1007174	0.003	1059866.9	0.008
11_7	808507	0.002	842641.5	0.004	796808	0.005	809235.1	0.007	820089	0.004	872137.1	0.004
11_8	1195424	0.001	1270677.3	0.002	1177088	0.004	1215332.1	0.006	1244141	0.001	1318979.2	0.003
11_9	947329	0.002	1054322.7	0.004	935997	0.007	945663.2	0.010	936992	0.004	1048760.9	0.006
11_10	863685	0.005	932656	0.006	841634	0.009	883577.4	0.012	868223	0.006	927042.7	0.008
11_11	816444	0.006	840374.5	0.007	815549	0.009	839500.2	0.011	815549	0.005	897074.6	0.007
11_12	718590	0.002	798040.3	0.005	745793	0.007	766990.3	0.011	728696	0.004	817170.5	0.007
11_13	978751	0.004	1002660	0.005	966999	0.006	968301	0.009	968859	0.003	1021353.9	0.007
11_14	877663	0.002	917427.9	0.005	853141	0.007	881980.6	0.010	853141	0.006	953856.8	0.007
11_15	778485	0.003	805661.2	0.005	774656	0.008	777828.8	0.009	783518	0.003	807446.1	0.005
11_16	777476	0.003	836594.6	0.006	777476	0.007	810219.8	0.009	790460	0.004	880020.1	0.006
11_17	596445	0.002	683799.5	0.003	596445	0.006	624497.5	0.008	625258	0.002	698049.8	0.005
11_18	1051951	0.002	1127632.4	0.003	1041929	0.004	1086537	0.007	1044563	0.003	1126912.3	0.005
11_19	710881	0.006	807712.9	0.008	710835	0.008	732736.8	0.013	764401	0.006	813763.7	0.009
11_20	972141	0.003	1051953.4	0.004	954445	0.007	994610	0.008	981076	0.003	1044870.7	0.005
11_21	1090081	0.003	1177927.5	0.004	1084552	0.007	1106592.6	0.011	1100599	0.005	1150355.3	0.006
11_22	839491	0.004	903549.6	0.005	836408	0.006	836903.8	0.010	836418	0.002	880438.1	0.006
11_23	788199	0.004	843501.5	0.005	786811	0.007	811064	0.009	838770	0.005	871267.2	0.006
11_24	862567	0.003	939510.4	0.004	850395	0.007	863778.1	0.008	907730	0.004	946509.3	0.005
11_25	797678	0.004	857203.3	0.006	795461	0.007	820928	0.011	795461	0.005	903288.9	0.007
11_26	743077	0.002	801265.4	0.004	733634	0.007	739014.8	0.008	771119	0.003	818311.6	0.005
11_27	742452	0.006	796814.7	0.008	731156	0.006	732634.2	0.011	731156	0.004	783202.8	0.007
11_28	966920	0.004	1009950.7	0.006	940558	0.007	979257.9	0.010	965182	0.004	1024661.2	0.005
11_29	886377	0.004	939493.2	0.005	886187	0.008	898950	0.011	893916	0.005	948616.1	0.006
11_30	683119	0.004	749401.8	0.006	655363	0.007	733660.2	0.010	657916	0.004	763867.4	0.007
11_31	752114	0.002	812040.9	0.003	710364	0.007	748688	0.008	752114	0.001	856025.2	0.004
11_32	642633	0.004	709298.5	0.006	620856	0.005	690236.6	0.010	631131	0.003	694591.5	0.007
11_33	668857	0.004	713878.2	0.007	668646	0.006	701497.5	0.010	669550	0.006	722330.2	0.008
11_34	924693	0.002	951638.5	0.004	923434	0.007	933250.7	0.009	924693	0.004	973317.2	0.006
11_35	615066	0.005	686870.4	0.008	613869	0.008	627902.4	0.013	615066	0.006	676937.3	0.008
11_36	847938	0.003	917398.1	0.005	805299	0.007	876602.3	0.008	862465	0.002	956868.6	0.005
11_37	724956	0.004	768880.2	0.006	724956	0.005	759401.1	0.009	754626	0.003	798881.5	0.007
11_38	787806	0.003	812721.6	0.004	783780	0.005	834530.6	0.008	813086	0.002	882793.9	0.004
11_39	1017068	0.002	1073318.4	0.003	985485	0.005	1009247.2	0.007	1011996	0.002	1122461	0.003
11_40	816767	0.002	869017	0.004	777223	0.007	781328.1	0.008	821255	0.003	902980	0.005
11_41	936235	0.004	990174.3	0.005	935560	0.007	944553	0.010	967627	0.003	1013786.1	0.006
11_42	875315	0.003	927913.7	0.005	875315	0.007	897285.7	0.010	885978	0.005	935928	0.007
11_43	800174	0.005	826301.8	0.006	771394	0.009	771394	0.012	799117	0.003	862763.4	0.006
11_44	879032	0.003	943899.8	0.004	872871	0.006	904037.8	0.008	910532	0.003	957754.2	0.005
11_45	857840	0.002	905844.8	0.004	855215	0.007	874677.4	0.010	874292	0.003	946993.4	0.005
11_46	695857	0.003	725849.1	0.005	690887	0.007	730927.4	0.009	695857	0.005	754918.1	0.008
11_47	655590	0.004	694029.2	0.006	654949	0.003	657012.9	0.011	656801	0.004	688528.8	0.007
11_48	811329	0.002	888345.9	0.005	811329	0.007	858602.9	0.009	843553	0.005	902705.7	0.007
11_49	1014885	0.002	1087808.1	0.004	989781	0.004	1031860.4	0.008	1014885	0.004	1099517.8	0.005

Table 17: Instances with 11 nodes and Eccentric Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
11_0	903786	0.003	1045213.6	0.005	891275	0.008	895535	0.009	891313	0.005	976932.8	0.006
11_1	1084793	0.002	1172633.6	0.003	1068995	0.005	1117115.1	0.006	1085552	0.002	1168014.6	0.004
11_2	1005392	0.002	1050595.1	0.004	1033704	0.005	1037387.4	0.009	986065	0.003	1062265.5	0.005
11_3	880214	0.003	961541.5	0.004	880214	0.004	940821	0.009	944120	0.003	1004549	0.005
11_4	900666	0.004	936916.2	0.006	847585	0.011	848359.5	0.013	869379	0.003	915202.6	0.008
11_5	999356	0.002	1065909.6	0.003	996058	0.006	1001864	0.006	996552	0.003	1092219.1	0.004
11_6	998474	0.003	1043510.4	0.006	998474	0.006	1055417.8	0.010	998474	0.004	1058368	0.007
11_7	771174	0.002	817494.7	0.004	763492	0.005	769429.2	0.009	763511	0.003	804626.8	0.005
11_8	1147968	0.002	1177379.5	0.003	1147968	0.004	1158046.2	0.007	1172370	0.001	1271050	0.004
11_9	964684	0.003	1017924.5	0.006	963336	0.007	963336	0.010	963577	0.004	1029195.2	0.006
11_10	881363	0.002	914515.9	0.007	881224	0.005	988553.7	0.009	881224	0.004	949780.3	0.008
11_11	1035211	0.003	1126597.3	0.005	1020182	0.005	1057971.2	0.010	1035211	0.004	1130764.7	0.008
11_12	889535	0.003	942300.3	0.005	885846	0.009	899836.9	0.012	896911	0.004	971741.3	0.007
11_13	1004379	0.002	1018321.4	0.004	992712	0.004	1015806.7	0.008	992712	0.003	1022320.1	0.006
11_14	956779	0.002	1032223.5	0.003	920383	0.007	924239.5	0.008	956779	0.004	1052803.4	0.006
11_15	875199	0.002	914984.1	0.004	867507	0.005	889070.8	0.009	867627	0.004	933137.4	0.006
11_16	923808	0.002	982357.6	0.005	920046	0.007	936665.7	0.010	920046	0.004	984717.7	0.006
11_17	757707	0.003	835315.1	0.005	749253	0.006	784140.1	0.008	777717	0.004	876632.6	0.005
11_18	1057330	0.001	1150914.6	0.002	1044749	0.003	1076050.7	0.007	1062919	0.002	1136624.6	0.004
11_19	850510	0.005	952136	0.008	849438	0.006	867598.8	0.013	875382	0.004	941254.4	0.009
11_20	1016182	0.003	1118650.1	0.004	1011095	0.007	1147897.9	0.008	1056134	0.002	1126586.3	0.005
11_21	1174127	0.004	1281498.3	0.005	1155634	0.007	1238346.8	0.008	1156939	0.005	1251243.6	0.006
11_22	1006952	0.003	1106899.7	0.005	987399	0.006	1080862.3	0.010	1008857	0.004	1129901.6	0.006
11_23	879554	0.003	974704.3	0.004	857981	0.009	876995	0.010	858466	0.003	927478	0.006
11_24	1001758	0.003	1112937.1	0.005	989993	0.007	1041903.7	0.010	1026864	0.005	1119137.7	0.007
11_25	892515	0.003	1010737.6	0.005	882765	0.007	968086.8	0.010	883910	0.004	960537.3	0.008
11_26	795580	0.002	971997.5	0.004	787202	0.007	790794	0.009	787552	0.005	852359.3	0.006
11_27	1011947	0.004	1075768.8	0.006	1010356	0.006	1035322.1	0.012	1010356	0.005	1107877.2	0.008
11_28	923641	0.003	943385.7	0.005	923615	0.004	948474.2	0.007	923615	0.002	996861.7	0.005
11_29	963919	0.003	1076538.4	0.006	963729	0.006	988711.8	0.010	963729	0.005	1031422.6	0.007
11_30	752566	0.004	808527.1	0.006	750317	0.008	771612.2	0.011	751662	0.003	831475.9	0.005
11_31	949210	0.003	1060047.6	0.004	861302	0.006	886445.3	0.008	883919	0.003	994656.8	0.005
11_32	878941	0.003	946269.4	0.005	878941	0.007	928478.8	0.010	881633	0.004	953590.6	0.006
11_33	772240	0.004	789621.3	0.006	772240	0.008	776843.9	0.011	776657	0.004	819503.8	0.008
11_34	1090527	0.004	1201129.2	0.005	1075631	0.006	1113653.2	0.011	1089312	0.003	1182403.5	0.007
11_35	858077	0.004	995829.4	0.006	856880	0.008	893609.6	0.011	856880	0.005	976145	0.007
11_36	980342	0.003	1087997	0.005	977286	0.006	995425.3	0.009	1038101	0.005	1105751.6	0.006
11_37	826696	0.003	909638.1	0.005	826696	0.006	838814.1	0.007	830365	0.003	897955.9	0.005
11_38	889196	0.002	944370.4	0.004	888872	0.006	914183.2	0.008	909741	0.003	985485.8	0.005
11_39	1032983	0.001	1048212.5	0.003	1005524	0.005	1026267.7	0.008	1036432	0.002	1145081.6	0.003
11_40	833979	0.002	878806.8	0.004	813135	0.005	827320.5	0.008	822948	0.003	876222.7	0.005
11_41	925683	0.004	940753.7	0.006	924153	0.007	925012.2	0.009	924153	0.003	986418.6	0.006
11_42	925140	0.003	947226.7	0.005	925123	0.007	930084	0.010	945822	0.005	966383.6	0.006
11_43	861952	0.002	898333.4	0.005	861952	0.005	868188.7	0.010	868258	0.005	903847.7	0.008
11_44	896498	0.003	970566.3	0.005	896429	0.005	920267.9	0.008	896455	0.003	947542.5	0.005
11_45	1125615	0.004	1183615.4	0.006	1106538	0.007	1149511.8	0.009	1130279	0.005	1184452.1	0.007
11_46	818511	0.003	896295	0.005	813541	0.006	860148.2	0.009	818511	0.006	905762.6	0.007
11_47	774418	0.004	826331.4	0.007	774418	0.007	786808.8	0.012	781483	0.004	810057	0.007
11_48	956216	0.004	1011040.8	0.005	924920	0.008	963012.1	0.010	927841	0.004	1010709.6	0.006
11_49	1089286	0.003	1187344.6	0.004	1074240	0.005	1101880.2	0.009	1089286	0.004	1151596.4	0.005

Table 18: Instances with 11 nodes and Random Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
11_0	963230	0.002	983719.4	0.004	958033	0.003	1011621.3	0.007	973767	0.002	1049494.9	0.004
11_1	1058888	0.002	1084064.3	0.003	1032899	0.004	1061969.6	0.006	1057211	0.002	1112796.8	0.004
11_2	990456	0.003	1030394.6	0.005	978915	0.008	999829.4	0.010	938097	0.004	1002339.4	0.007
11_3	848566	0.001	967218.3	0.003	839860	0.007	842133.8	0.010	871304	0.002	949142.5	0.005
11_4	633274	0.004	704900.4	0.005	621242	0.008	648711.9	0.011	630903	0.003	711677.3	0.006
11_5	984242	0.002	1001572.6	0.003	966077	0.004	1002580.1	0.006	986030	0.001	1072763.3	0.003
11_6	1012259	0.004	1022179.8	0.007	977771	0.009	1003542.6	0.011	1020921	0.005	1054585.7	0.007
11_7	769868	0.002	803108.4	0.004	767458	0.004	791133.8	0.007	782042	0.003	840977.6	0.004
11_8	1094470	0.002	1137882.3	0.003	1094470	0.003	1123410.6	0.006	1094470	0.002	1150395.9	0.003
11_9	953764	0.002	1026806.2	0.004	942553	0.007	942553	0.010	952316	0.003	1058967.6	0.005
11_10	849222	0.004	915598.9	0.007	845383	0.011	895200	0.013	852528	0.006	939470.2	0.008
11_11	813639	0.004	894164.8	0.005	813639	0.009	833457.1	0.011	813639	0.004	871139.9	0.007
11_12	851072	0.004	901094.6	0.006	831139	0.009	836723.8	0.011	831518	0.003	929148.8	0.007
11_13	1038501	0.003	1115852.4	0.005	1024700	0.007	1053069	0.008	1036408	0.004	1106295	0.006
11_14	882065	0.004	901476.5	0.005	882065	0.007	888469.7	0.010	882072	0.004	932806.8	0.007
11_15	936157	0.003	1003213.7	0.004	924262	0.007	933603.7	0.011	927320	0.004	989871.7	0.007
11_16	860593	0.002	934912	0.005	857908	0.007	871329.1	0.010	857908	0.004	935590.5	0.006
11_17	686327	0.003	768378.6	0.004	691755	0.005	712135.2	0.009	701443	0.004	784310.6	0.005
11_18	1185852	0.002	1260750.9	0.003	1143732	0.005	1173665.1	0.008	1190634	0.004	1268344.3	0.005
11_19	719382	0.004	768102.4	0.007	719382	0.010	735765.4	0.014	719136	0.007	765413.2	0.010
11_20	1002280	0.001	1108794.3	0.004	983788	0.007	1028467	0.009	1002280	0.003	1102136.4	0.005
11_21	1057358	0.003	1175853.1	0.005	1051129	0.006	1072491	0.008	1069622	0.003	1173323.2	0.007
11_22	745166	0.003	799128.7	0.004	745116	0.007	751464.3	0.008	745116	0.003	799254.9	0.005
11_23	843807	0.004	929235.1	0.005	793493	0.006	817293.9	0.009	810882	0.004	891439.6	0.007
11_24	824742	0.002	894105	0.004	833712	0.006	913356.5	0.008	834658	0.003	953797.3	0.005
11_25	887785	0.005	989903.3	0.008	870284	0.007	943395.2	0.011	886459	0.005	930248.8	0.007
11_26	712444	0.004	748078.5	0.005	709530	0.006	725205	0.009	732504	0.003	775631.3	0.006
11_27	732136	0.004	764192.6	0.007	731641	0.009	732189.8	0.012	731641	0.005	764157.3	0.008
11_28	905702	0.003	992578.9	0.005	905025	0.005	945434.8	0.008	905025	0.003	939754.8	0.005
11_29	823730	0.003	867089.5	0.005	816291	0.006	838111.2	0.010	821238	0.005	868960.9	0.007
11_30	883842	0.004	930497.1	0.006	831047	0.008	859220.8	0.012	859752	0.004	914559.3	0.008
11_31	844563	0.003	936364.8	0.004	802813	0.006	881102.1	0.008	845614	0.004	947289.8	0.005
11_32	619988	0.004	703481.4	0.005	619159	0.005	630885.9	0.010	629434	0.005	698987.6	0.007
11_33	736852	0.003	779991.5	0.007	734005	0.008	757756	0.011	736517	0.005	765189.2	0.009
11_34	899458	0.003	931059.4	0.004	893992	0.003	911448.8	0.009	918528	0.003	985624.5	0.005
11_35	669065	0.005	699313.7	0.007	667758	0.008	692274	0.012	670309	0.006	744835	0.009
11_36	801017	0.003	865342.6	0.005	787571	0.007	810824.2	0.009	815334	0.003	891410.5	0.005
11_37	735468	0.001	754280.8	0.005	724710	0.005	772638.7	0.008	724710	0.003	760051.1	0.006
11_38	846376	0.001	888500.8	0.003	837655	0.004	861368	0.006	837952	0.002	897261.4	0.004
11_39	1048814	0.002	1205339.6	0.004	1047120	0.005	1047120	0.009	1059700	0.002	1190970.8	0.004
11_40	721213	0.002	804228.3	0.004	721213	0.007	721213	0.009	721213	0.002	820862.4	0.004
11_41	921209	0.005	958285.4	0.006	908234	0.009	908571	0.011	908234	0.004	953098.6	0.007
11_42	873017	0.004	975463.5	0.006	871205	0.008	880665.2	0.012	891827	0.005	930496.7	0.007
11_43	796903	0.002	805810.2	0.006	770268	0.010	771128.2	0.012	792815	0.004	818809.6	0.007
11_44	882031	0.003	938241.7	0.005	878431	0.004	891758.2	0.007	884367	0.003	959391.2	0.004
11_45	893519	0.003	914194.7	0.005	872184	0.008	900810.6	0.010	874584	0.003	965970.5	0.007
11_46	762597	0.004	802326.6	0.006	757627	0.007	776252.8	0.011	797975	0.006	871513.5	0.008
11_47	618335	0.002	655764.8	0.006	617694	0.007	625308	0.010	617694	0.004	649289.2	0.007
11_48	933826	0.004	973946.9	0.006	918733	0.006	959524.2	0.010	942060	0.004	996198	0.007
11_49	995895	0.003	1030434.3	0.004	959587	0.007	964857.5	0.008	1003890	0.003	1088692.4	0.004

Table 19: Instances with 16 nodes and Central Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
16_0	1055213	0.012	1162588.2	0.017	1056496	0.023	1108183.8	0.029	1113355	0.013	1191851.8	0.020
16_1	1039584	0.018	1173458.1	0.027	1043881	0.037	1093662.1	0.051	1061390	0.019	1092718.4	0.036
16_2	1119097	0.015	1217835.5	0.020	1039727	0.036	1069842.9	0.045	1050928	0.018	1173190.8	0.026
16_3	1033226	0.018	1228393.1	0.022	995386	0.035	1108437.4	0.042	1022843	0.012	1168727.7	0.024
16_4	1050701	0.014	1195107.3	0.020	995894	0.025	1090365.4	0.033	1024576	0.015	1168728.3	0.023
16_5	1129812	0.012	1220159.6	0.017	1101438	0.027	1157334.6	0.035	1188592	0.011	1316168.4	0.019
16_6	1140938	0.013	1197518.2	0.017	1099342	0.030	1175996.1	0.037	1089030	0.017	1214925.7	0.021
16_7	891595	0.017	967182.7	0.021	885427	0.027	941403.4	0.038	908302	0.021	950184	0.030
16_8	1117536	0.012	1239209.8	0.018	1023035	0.026	1091142	0.033	1056535	0.019	1159390.2	0.025
16_9	906884	0.017	1037020.1	0.021	901779	0.028	944340.6	0.040	914141	0.019	983057.1	0.026
16_10	1103549	0.015	1242523.9	0.023	1082413	0.036	1139345.8	0.045	1075901	0.022	1212492.6	0.033
16_11	1169059	0.013	1275918	0.018	1167026	0.028	1195795.6	0.035	1186951	0.016	1263192.6	0.022
16_12	1119922	0.010	1241964.2	0.015	1049190	0.026	1110653.4	0.030	1044310	0.011	1140632	0.019
16_13	699467	0.016	765282.3	0.026	589803	0.027	629650.6	0.043	638847	0.023	686283.7	0.035
16_14	1021805	0.013	1201623.5	0.019	989038	0.020	1112628.2	0.030	1092040	0.019	1209888.2	0.025
16_15	870766	0.014	984930	0.023	814948	0.031	858786.5	0.041	827313	0.021	894586.9	0.028
16_16	1215977	0.011	1382030.5	0.015	1168997	0.022	1274902.7	0.030	1255908	0.017	1331925	0.021
16_17	1074855	0.015	1199269.2	0.020	1014320	0.030	1049761	0.038	1063825	0.012	1192560.4	0.022
16_18	921437	0.016	1043204.6	0.020	918428	0.036	955673.3	0.043	924854	0.018	1003372.2	0.027
16_19	1203034	0.016	1277924.7	0.023	1214109	0.027	1253621.8	0.042	1238505	0.022	1302074.2	0.030
16_20	875685	0.015	1004179	0.021	849413	0.030	910487.9	0.039	882333	0.020	980006.6	0.029
16_21	1084414	0.011	1204375.2	0.016	998468	0.020	1059090.3	0.025	1098650	0.011	1203129.9	0.016
16_22	979355	0.013	1073720.5	0.019	962992	0.025	1020428	0.034	1036424	0.013	1118423.6	0.021
16_23	899914	0.016	1012431.2	0.020	850694	0.029	918422.8	0.039	854274	0.018	979875	0.026
16_24	1051997	0.010	1189396.8	0.016	1041237	0.018	1119523.1	0.027	1078933	0.016	1157293.1	0.023
16_25	960867	0.014	1071466.5	0.018	910015	0.021	981460.4	0.030	993995	0.013	1092509.4	0.022
16_26	981105	0.015	1084458.6	0.020	941509	0.026	1015605.5	0.039	975988	0.018	1042661.8	0.029
16_27	993805	0.014	1213494.1	0.021	946986	0.032	1009563.1	0.041	1011621	0.014	1114437.2	0.025
16_28	1028363	0.013	1119734.2	0.019	1018955	0.022	1067757.5	0.036	1053052	0.018	1108751.6	0.023
16_29	1128184	0.014	1200675.8	0.017	1112742	0.017	1135792.1	0.033	1141311	0.016	1203338.1	0.022
16_30	896824	0.019	1017029.4	0.021	865491	0.020	963706.2	0.032	804947	0.016	939418.7	0.026
16_31	921925	0.015	986873.2	0.024	826569	0.034	896193.6	0.044	871132	0.015	943806.2	0.028
16_32	1161686	0.021	1219427.4	0.025	1064769	0.034	1137893	0.048	1120048	0.021	1225633.4	0.029
16_33	959222	0.014	1087011.8	0.019	951696	0.021	1018218.3	0.031	1028045	0.009	1113724.5	0.017
16_34	1319768	0.013	1434616.2	0.017	1230203	0.024	1322130.1	0.034	1310249	0.018	1376428.4	0.022
16_35	898102	0.019	1010497	0.024	839054	0.025	916475.1	0.042	923551	0.017	991599.8	0.024
16_36	1021048	0.012	1116205.9	0.020	1015087	0.024	1079912.6	0.033	1015087	0.017	1089095	0.023
16_37	1023876	0.014	1193380.9	0.020	1100171	0.020	1176374.9	0.035	1016175	0.015	1127553.7	0.028
16_38	995917	0.013	1126286.5	0.020	992611	0.023	1080856.3	0.034	991507	0.009	1143685.4	0.023
16_39	919596	0.010	1048149.3	0.019	890843	0.026	933293.6	0.032	917574	0.006	1005078.9	0.020
16_40	1150210	0.017	1200509	0.022	1071499	0.028	1113008	0.037	1099586	0.022	1228748	0.028
16_41	1180972	0.009	1332330.4	0.012	1189080	0.019	1264239.7	0.025	1188596	0.013	1321157.3	0.018
16_42	923262	0.014	989397.5	0.019	924261	0.016	961592	0.032	936152	0.016	1020077.1	0.021
16_43	1085297	0.009	1154187.3	0.016	1041656	0.025	1113193.5	0.031	1069610	0.014	1130694.2	0.019
16_44	1082807	0.013	1201680.7	0.019	1069472	0.018	1084889.9	0.036	1124876	0.019	1178328.7	0.027
16_45	894922	0.015	976872.5	0.020	866208	0.026	904344.8	0.035	871396	0.015	1006590.8	0.026
16_46	908088	0.014	1030428.2	0.017	894459	0.015	956482.5	0.032	891611	0.006	1043830.4	0.018
16_47	999701	0.022	1117831.2	0.030	992898	0.021	1031411.8	0.041	1016942	0.025	1097962.7	0.033
16_48	931226	0.010	1081674.2	0.020	901169	0.021	1001511.4	0.036	938877	0.009	1070867.6	0.024
16_49	1095014	0.014	1231893.2	0.020	1079880	0.030	1166347.9	0.038	1143956	0.017	1249384	0.024

Table 20: Instances with 16 nodes and Eccentric Base Station position

	Swap – Best Improvement				Shift – Best Improvement				Swap21 – Best Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
16_0	1133708	0.008	1264490.3	0.014	1112665	0.023	1161506.1	0.029	1160628	0.015	1275811.2	0.019
16_1	1138440	0.017	1313931.4	0.027	1137544	0.019	1175982.2	0.046	1166727	0.026	1291616.8	0.036
16_2	1224993	0.013	1426853.8	0.022	1194988	0.026	1241967.2	0.044	1253273	0.017	1356134.4	0.028
16_3	1061689	0.013	1211508.2	0.023	1002810	0.026	1111064	0.043	1056815	0.018	1187510.9	0.030
16_4	995195	0.014	1299571.8	0.019	981692	0.019	1153001.5	0.030	1073759	0.016	1198202.5	0.024
16_5	1199362	0.012	1301772.1	0.016	1143048	0.024	1247238.1	0.032	1198931	0.015	1317557.4	0.020
16_6	1073975	0.018	1172215.6	0.021	1073974	0.027	1167323.1	0.038	1112921	0.014	1201197.5	0.024
16_7	1150161	0.016	1313001.4	0.026	1096896	0.037	1178891.5	0.049	1141118	0.019	1277034.5	0.030
16_8	1176818	0.014	1346934.9	0.019	1082035	0.028	1159726.2	0.036	1170322	0.020	1260535.7	0.028
16_9	1046170	0.013	1156959.3	0.021	1036245	0.020	1079864	0.039	1059510	0.020	1154884.8	0.028
16_10	1087983	0.011	1197937.4	0.022	1087983	0.034	1175198.5	0.045	1102462	0.019	1177073.6	0.029
16_11	1223608	0.015	1307237.2	0.019	1185053	0.027	1217899.9	0.033	1252661	0.011	1333197.6	0.023
16_12	1149948	0.013	1313358.7	0.017	1124115	0.015	1276028.1	0.032	1152446	0.011	1278764.7	0.020
16_13	884833	0.018	1000891.9	0.029	884689	0.035	892299.8	0.058	929194	0.025	961836.5	0.034
16_14	1130523	0.016	1342409.7	0.021	1091921	0.027	1190511.8	0.039	1105242	0.023	1259978.6	0.028
16_15	1071532	0.014	1144112.6	0.021	1051395	0.033	1098311.9	0.043	1113442	0.019	1169752.3	0.027
16_16	1226661	0.013	1442029.9	0.018	1204669	0.028	1300531.9	0.035	1251056	0.017	1307575.1	0.023
16_17	1053417	0.013	1226843.9	0.020	1086687	0.023	1138557.8	0.038	1087225	0.020	1156195.7	0.033
16_18	1013535	0.019	1115340.1	0.026	1006873	0.036	1074067.1	0.047	1024022	0.014	1093217.5	0.028
16_19	1196483	0.017	1324704.3	0.020	1229588	0.028	1280534.5	0.046	1185076	0.016	1270998.8	0.033
16_20	966762	0.015	1131287	0.021	959478	0.033	1027687.7	0.040	1055857	0.018	1159062.2	0.026
16_21	1286879	0.011	1471318.3	0.016	1188300	0.020	1250544.3	0.031	1242234	0.017	1352173.8	0.022
16_22	1086683	0.015	1328676.5	0.024	1074473	0.025	1156792.3	0.039	1125438	0.023	1281760.4	0.027
16_23	1016060	0.011	1191009.5	0.017	984795	0.028	1044432.7	0.036	1004976	0.018	1097648.6	0.027
16_24	1104512	0.014	1183659	0.018	1072921	0.025	1127299.8	0.032	1088026	0.013	1230411.8	0.020
16_25	1035817	0.014	1191633.4	0.019	1016020	0.021	1112301.3	0.029	1063642	0.017	1188100	0.022
16_26	998762	0.014	1142294.2	0.023	989464	0.037	1091813.5	0.052	989464	0.023	1088465.4	0.037
16_27	948739	0.014	1168659.2	0.026	941190	0.023	941190	0.043	952548	0.020	1124952.5	0.029
16_28	1107720	0.015	1204657.6	0.021	1073226	0.029	1126464.9	0.039	1115232	0.018	1174805.7	0.025
16_29	1046338	0.016	1063367.9	0.019	1038710	0.023	1131107	0.032	1049647	0.012	1186101.2	0.024
16_30	1106754	0.015	1259435.5	0.019	1042976	0.027	1141117.4	0.040	1060949	0.017	1136468.9	0.026
16_31	1050526	0.016	1180094.6	0.024	1018895	0.040	1114060.9	0.048	1146941	0.021	1211709.6	0.028
16_32	1169011	0.016	1246992	0.024	1058612	0.027	1136327.7	0.045	1085123	0.019	1176664.2	0.033
16_33	983496	0.010	1076083.3	0.016	959814	0.015	1030581	0.026	1001464	0.013	1126516.1	0.020
16_34	1436021	0.011	1492897.3	0.016	1327193	0.025	1441840.1	0.032	1375941	0.016	1472413.7	0.024
16_35	1050849	0.011	1205776	0.020	933857	0.028	1119575.4	0.041	1016254	0.022	1134662.4	0.027
16_36	1219684	0.015	1271981.9	0.021	1110655	0.028	1170202.5	0.039	1147831	0.019	1262922.3	0.026
16_37	1077012	0.012	1266122.1	0.019	1058835	0.024	1160375.6	0.033	1060259	0.015	1196172	0.024
16_38	1083359	0.015	1191373	0.019	1063460	0.018	1158338.6	0.031	1097019	0.017	1202663.2	0.023
16_39	1082092	0.015	1293585.8	0.021	1064843	0.022	1228931.2	0.037	1085749	0.014	1253688.2	0.021
16_40	1160789	0.013	1243115.5	0.021	1088720	0.037	1237887.1	0.043	1109352	0.021	1214060.4	0.029
16_41	1206368	0.010	1438559.8	0.016	1157798	0.017	1259658.4	0.025	1252441	0.015	1334908.5	0.020
16_42	1141317	0.014	1266071.7	0.022	1095616	0.027	1139741.6	0.036	1144884	0.019	1212341.9	0.026
16_43	1262540	0.010	1393243.6	0.016	1190349	0.020	1271155.3	0.030	1233666	0.013	1327691.2	0.020
16_44	1063464	0.013	1183477.1	0.019	1037247	0.019	1117956.5	0.035	1061537	0.019	1175548.7	0.024
16_45	1092098	0.014	1218606	0.022	1044945	0.015	1123050.5	0.038	1050133	0.017	1157854	0.025
16_46	1137375	0.012	1270670.6	0.019	1044867	0.028	1160045.7	0.033	1129872	0.015	1217393.1	0.021
16_47	1047665	0.022	1134748.4	0.026	1045801	0.027	1101269.4	0.047	1089255	0.019	1235364.4	0.032
16_48	1071639	0.014	1233128.1	0.019	1026188	0.033	1092222.8	0.039	1035711	0.019	1144277.9	0.029
16_49	1217039	0.015	1323067.4	0.020	1114926	0.028	1248386.1	0.034	1213550	0.019	1258190.3	0.026

Table 21: Instances with 16 nodes and Random Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
16_0	1048213	0.016	1164127.3	0.022	1048383	0.026	1095179.1	0.035	1048720	0.018	1125768.8	0.024
16_1	1098733	0.021	1246239	0.027	1054202	0.026	1148657.2	0.045	1071533	0.022	1150645.4	0.036
16_2	1058792	0.010	1229377.6	0.020	994553	0.027	1021420.6	0.041	1045324	0.018	1164875.9	0.028
16_3	1040285	0.014	1282401.4	0.023	969186	0.033	1131880.5	0.044	986372	0.028	1114870.1	0.032
16_4	1084201	0.013	1335517	0.018	936773	0.029	1080380.6	0.035	1012047	0.017	1247206.6	0.023
16_5	1090388	0.012	1188466.6	0.015	1054108	0.016	1127346.9	0.029	1090388	0.015	1168045.3	0.021
16_6	1032868	0.012	1129469	0.018	1058488	0.027	1152893.3	0.032	1012650	0.015	1150482.1	0.023
16_7	900677	0.019	1007571.7	0.022	936580	0.033	1004590.6	0.043	891614	0.021	975620.3	0.031
16_8	1105866	0.012	1140161.4	0.017	1004588	0.031	1038615.1	0.035	1021493	0.015	1132866.5	0.022
16_9	957121	0.014	1041916.6	0.021	949646	0.022	1028785.5	0.036	1002709	0.016	1096108	0.029
16_10	1062042	0.014	1241071.4	0.021	1042436	0.031	1166197.5	0.042	1090561	0.021	1258186.8	0.027
16_11	1189472	0.013	1303309.2	0.019	1163742	0.022	1241767.1	0.029	1215302	0.017	1288804.9	0.025
16_12	1077867	0.013	1196540.9	0.016	1027170	0.024	1141651.7	0.032	1114355	0.014	1205951.7	0.020
16_13	693235	0.025	759602.2	0.028	597269	0.037	646215.5	0.048	649135	0.024	706113.2	0.037
16_14	1055430	0.016	1206714.9	0.020	984863	0.029	1046082.1	0.039	1023359	0.023	1188565.4	0.028
16_15	857206	0.017	922911.9	0.024	846339	0.030	881097.4	0.038	910623	0.022	984309.2	0.026
16_16	1199660	0.014	1292495.2	0.018	1181626	0.021	1274618.5	0.029	1228724	0.013	1332822.7	0.021
16_17	1003962	0.018	1102862.5	0.022	985809	0.019	1039855.8	0.040	1056103	0.022	1124447.9	0.030
16_18	1006311	0.017	1127508.7	0.023	970909	0.027	1037304.5	0.041	935293	0.019	1021536.7	0.028
16_19	1255402	0.019	1345889.4	0.025	1186155	0.038	1254527.1	0.045	1264127	0.019	1337678.4	0.032
16_20	1025173	0.018	1145812.4	0.022	896988	0.024	1049980.2	0.040	912691	0.024	1060786.1	0.030
16_21	1141095	0.012	1264243.9	0.017	1081463	0.027	1181641.7	0.033	1132083	0.017	1230512	0.023
16_22	1088692	0.014	1191449.3	0.018	992726	0.027	1046280.4	0.036	1101365	0.013	1175218.3	0.023
16_23	899172	0.014	970828.8	0.022	838646	0.028	847305.7	0.039	872438	0.021	962711.3	0.026
16_24	1055348	0.014	1203508.4	0.019	1017075	0.030	1088996	0.035	1067330	0.015	1155650.2	0.023
16_25	1041085	0.010	1107457.9	0.016	922093	0.022	983174.9	0.031	1022405	0.012	1179427.1	0.017
16_26	990744	0.019	1164427.2	0.025	948487	0.039	1042271.2	0.052	951460	0.028	1047588.4	0.042
16_27	981209	0.019	1192443.5	0.024	924920	0.031	974418.3	0.044	1057094	0.018	1241528.5	0.028
16_28	1008411	0.013	1118864.9	0.020	989868	0.030	1062075.3	0.040	1043348	0.016	1134607.4	0.024
16_29	1067002	0.010	1177026.2	0.017	1047733	0.019	1128216.4	0.029	1047785	0.018	1158496.1	0.024
16_30	912176	0.008	1085753	0.019	860685	0.022	983420.5	0.039	867216	0.022	940890.1	0.029
16_31	884162	0.018	1015804.7	0.023	854483	0.027	904603.7	0.040	927648	0.022	961050.5	0.030
16_32	1074642	0.019	1190810.7	0.026	1046262	0.041	1096153.8	0.053	1063408	0.014	1138061.1	0.030
16_33	973490	0.016	1091051	0.020	933626	0.027	1019228.2	0.035	1007033	0.016	1066734.9	0.026
16_34	1219915	0.014	1386324.3	0.020	1191885	0.027	1253128.3	0.035	1216730	0.018	1339234.9	0.027
16_35	887052	0.017	1039815.4	0.020	871426	0.031	934239.8	0.048	921100	0.018	1009329.8	0.026
16_36	1151026	0.018	1256335.3	0.020	1008643	0.024	1166776.6	0.038	1052444	0.019	1219381.6	0.025
16_37	1054340	0.015	1204259.8	0.020	1021428	0.026	1095269.8	0.038	1021577	0.018	1134119.7	0.026
16_38	969749	0.012	1097574.5	0.019	925367	0.021	970989.3	0.038	963139	0.009	1081972.8	0.024
16_39	891687	0.013	1030178.8	0.020	874276	0.032	929519.8	0.038	996547	0.017	1104070.3	0.024
16_40	1135451	0.019	1200804.8	0.024	1026171	0.026	1105615.8	0.039	1092757	0.022	1197696.4	0.033
16_41	1177078	0.012	1316904	0.015	1111868	0.023	1223660.2	0.031	1136771	0.011	1261888.8	0.020
16_42	989642	0.012	1095331.5	0.017	917917	0.018	986981.6	0.032	972523	0.017	1055524.9	0.021
16_43	1084751	0.012	1176869.6	0.016	1043871	0.014	1124273.8	0.028	1111648	0.014	1192706.8	0.019
16_44	1026650	0.017	1227220.1	0.021	963071	0.026	1021764	0.038	970647	0.014	1148782.8	0.028
16_45	1030652	0.013	1173228.3	0.021	924675	0.018	1016604.8	0.032	944947	0.014	1087565	0.025
16_46	998262	0.012	1108815.3	0.018	858361	0.018	936729.8	0.028	924498	0.015	1006765.5	0.022
16_47	1084267	0.018	1172183.7	0.027	978891	0.021	1049662.1	0.045	999727	0.019	1088017.9	0.032
16_48	1068966	0.013	1247556.3	0.018	1019100	0.019	1097199.5	0.035	1095860	0.014	1177025.6	0.022
16_49	1101769	0.015	1217829.7	0.020	1064766	0.034	1160077	0.037	1104802	0.013	1207337	0.025

Table 22: Instances with 21 nodes and Central Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
21_0	1171866	0.024	1290280.8	0.054	988188	0.106	1130243.3	0.124	1098448	0.071	1219294.5	0.087
21_1	1212855	0.040	1401429.7	0.065	1174669	0.091	1246125.1	0.123	1243443	0.077	1309364.9	0.090
21_2	1168128	0.029	1289256.2	0.064	1118920	0.109	1205249.8	0.132	1114042	0.048	1242834.4	0.083
21_3	1138927	0.035	1365216.9	0.055	1096488	0.076	1202751.8	0.108	1197521	0.045	1263228.6	0.064
21_4	1292580	0.055	1527208.4	0.067	1083411	0.118	1193580.1	0.155	1101258	0.091	1323126.7	0.110
21_5	1021769	0.033	1163713.1	0.059	983005	0.062	1088342.4	0.103	1005972	0.061	1122766.1	0.086
21_6	1051357	0.078	1155740.1	0.099	920415	0.148	1057303.7	0.182	981175	0.083	1059088.1	0.158
21_7	1188021	0.041	1269455.2	0.054	1093292	0.089	1202087	0.112	1142281	0.060	1236971.3	0.076
21_8	1221405	0.033	1473333.8	0.047	1171191	0.070	1283396.6	0.093	1342343	0.036	1485973	0.053
21_9	1163926	0.048	1326366.1	0.061	1064636	0.108	1248987.3	0.124	1122549	0.055	1273849	0.080
21_10	1180876	0.053	1384980.4	0.087	1090035	0.119	1163028.4	0.152	1119029	0.069	1269495.8	0.110
21_11	1226347	0.051	1325523.3	0.060	1111713	0.046	1245407.9	0.104	1188004	0.061	1340607.7	0.075
21_12	1284766	0.052	1473073.9	0.060	1209530	0.089	1362512.4	0.133	1341687	0.068	1456528	0.092
21_13	1109121	0.039	1244428.1	0.066	954530	0.125	1080723	0.151	1092981	0.075	1177316.6	0.101
21_14	1039274	0.044	1215557.6	0.068	969061	0.106	1064818.8	0.120	1005777	0.070	1092958.1	0.097
21_15	1055440	0.034	1233191.5	0.053	981825	0.093	1098052.6	0.110	1070297	0.043	1202176.5	0.063
21_16	1154455	0.053	1379741.5	0.069	1180792	0.094	1292841.8	0.133	1286291	0.064	1405027.2	0.095
21_17	1197409	0.045	1410396.6	0.067	1172150	0.104	1257409.8	0.131	1176430	0.088	1262313.4	0.112
21_18	1195649	0.049	1279696.6	0.061	1015749	0.079	1079653.4	0.109	1083406	0.037	1193498.2	0.072
21_19	1382455	0.043	1472499	0.064	1272768	0.096	1391498.9	0.128	1319112	0.059	1422488	0.084
21_20	980549	0.042	1148356.4	0.068	936365	0.108	1103355.6	0.130	1001051	0.065	1089474.9	0.099
21_21	1196922	0.043	1385651.3	0.057	1175812	0.060	1246681.1	0.101	1219183	0.039	1337171.8	0.070
21_22	1219267	0.038	1345476.7	0.052	1113037	0.057	1291845.1	0.104	1203903	0.052	1309774.7	0.069
21_23	1081645	0.052	1178001.8	0.063	1043207	0.058	1093592.3	0.105	1083481	0.043	1147827.8	0.083
21_24	1117454	0.048	1415010.6	0.064	1050895	0.060	1205591.3	0.106	1075426	0.035	1347474.6	0.072
21_25	1088153	0.037	1302059.4	0.044	1053977	0.044	1237463.2	0.082	1100107	0.049	1202859.8	0.059
21_26	1098540	0.053	1259866.8	0.085	1049256	0.080	1127259.2	0.157	1049888	0.083	1137167.9	0.113
21_27	1303803	0.036	1448779.1	0.050	1166433	0.066	1286351.1	0.110	1201996	0.041	1391600.9	0.066
21_28	1130752	0.041	1288997.5	0.065	1060360	0.102	1138857.4	0.131	1139208	0.044	1245907.8	0.090
21_29	1308579	0.044	1487866.4	0.067	1185254	0.091	1262198	0.121	1223081	0.047	1364434.8	0.092
21_30	1304125	0.035	1444934.4	0.044	1186330	0.068	1294179.4	0.090	1275722	0.039	1349563.9	0.057
21_31	1032580	0.041	1193814.3	0.071	1006955	0.069	1072710.2	0.102	1015844	0.051	1090551.4	0.082
21_32	1235793	0.040	1413324.9	0.053	1179072	0.058	1290781.3	0.100	1212894	0.052	1339869	0.075
21_33	1126122	0.058	1416392.9	0.074	1063400	0.127	1131608.7	0.148	1094799	0.067	1235891.8	0.100
21_34	1098472	0.068	1309312.7	0.085	1001416	0.113	1087408.9	0.152	1040148	0.047	1229968.2	0.096
21_35	1243572	0.039	1443959.9	0.054	1180481	0.088	1287981.3	0.112	1211941	0.056	1344981.7	0.082
21_36	1272590	0.039	1466798.7	0.050	1120556	0.069	1243677.2	0.101	1254780	0.035	1366537.2	0.065
21_37	1280090	0.035	1408199.3	0.050	1185527	0.086	1304898.1	0.114	1242834	0.053	1359779.2	0.065
21_38	1227948	0.055	1384792.9	0.081	1167335	0.111	1246226.8	0.152	1243161	0.077	1317979.7	0.098
21_39	1162324	0.057	1391515.5	0.074	1128683	0.068	1199962.7	0.128	1124354	0.063	1271305.4	0.080
21_40	1187747	0.042	1385501	0.064	1103293	0.073	1273894.8	0.110	1215820	0.055	1342077.7	0.076
21_41	1177952	0.054	1343118.3	0.066	1167841	0.077	1254796.1	0.116	1255244	0.045	1343430.3	0.084
21_42	1272681	0.044	1382828.6	0.059	1253169	0.106	1340846.4	0.126	1236826	0.068	1368671.3	0.088
21_43	1321159	0.040	1437609.7	0.050	1318513	0.072	1397286.5	0.087	1307292	0.055	1466482.9	0.067
21_44	1030215	0.041	1155992	0.064	930219	0.105	1142219.2	0.134	964119	0.054	1133718.7	0.102
21_45	1229412	0.041	1405218.8	0.053	1181280	0.062	1306457.6	0.099	1276063	0.054	1405991.7	0.067
21_46	1141436	0.054	1213074.9	0.079	1020703	0.117	1085125.1	0.155	1024381	0.066	1088824.9	0.110
21_47	1375866	0.055	1522533.2	0.076	1310215	0.119	1384524.5	0.145	1316522	0.066	1391673.3	0.115
21_48	1147928	0.033	1266142.1	0.048	1127866	0.051	1178297.2	0.094	1097006	0.043	1226749.9	0.068
21_49	1376336	0.028	1542778.8	0.042	1203654	0.074	1408149.1	0.106	1387417	0.060	1475640	0.073

Table 23: Instances with 21 nodes and Eccentric Base Station position

	Swap − Best Improvement				**Shift − Best Improvement**				**Swap21 − Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
21_0	1138649	0.041	1380903.8	0.051	1125637	0.090	1195363.7	0.106	1136345	0.050	1318160.2	0.070
21_1	1457271	0.039	1558780	0.058	1262745	0.075	1458260.6	0.110	1386994	0.061	1543104.9	0.080
21_2	1388941	0.032	1475430	0.059	1199038	0.068	1360789.3	0.111	1200126	0.062	1346213.4	0.087
21_3	1220776	0.036	1396351.2	0.050	1087386	0.069	1233383.3	0.100	1166498	0.058	1243330.7	0.075
21_4	1164948	0.051	1488062.7	0.071	1078247	0.084	1243857.3	0.148	1118272	0.078	1401310.6	0.103
21_5	1079685	0.032	1367381.5	0.076	1120770	0.087	1238716.6	0.119	1167572	0.060	1271319.3	0.089
21_6	1075809	0.073	1252432.5	0.091	1022914	0.127	1103171.1	0.203	1069779	0.102	1164982.2	0.137
21_7	1301098	0.046	1381713.9	0.058	1162190	0.069	1282386.7	0.115	1250826	0.063	1344384.1	0.081
21_8	1211548	0.029	1526463.4	0.044	1183811	0.078	1356956.3	0.098	1274373	0.043	1488958.9	0.065
21_9	1218316	0.038	1355810.7	0.051	1162232	0.092	1280590.8	0.114	1211461	0.041	1322833.1	0.070
21_10	1221283	0.048	1376442.9	0.071	1166188	0.094	1258962.3	0.133	1193199	0.070	1317001.8	0.105
21_11	1223363	0.038	1454576.5	0.058	1206405	0.077	1292366.7	0.111	1309714	0.068	1400290.6	0.086
21_12	1251377	0.042	1397041.1	0.061	1150642	0.084	1347853.6	0.119	1176713	0.062	1332070.4	0.090
21_13	1297362	0.053	1362668	0.074	1106007	0.062	1263512.7	0.127	1153686	0.049	1311707.2	0.100
21_14	1106211	0.061	1303211.9	0.082	1072529	0.099	1196015.9	0.147	1128190	0.059	1308819.4	0.094
21_15	1201697	0.042	1357603.8	0.053	1080828	0.072	1178477.5	0.124	1232314	0.046	1326543.9	0.078
21_16	1320617	0.045	1466426.9	0.057	1279718	0.084	1364331.4	0.125	1255861	0.051	1474835.9	0.078
21_17	1350447	0.042	1562471.5	0.073	1346626	0.082	1423806.8	0.143	1331277	0.058	1495726.4	0.093
21_18	1202107	0.059	1352504.2	0.072	1116322	0.100	1203052.3	0.126	1185736	0.050	1313703	0.086
21_19	1468236	0.035	1690278	0.063	1457207	0.115	1532267.2	0.132	1469230	0.072	1608968.3	0.099
21_20	1142702	0.046	1274791.9	0.062	1022131	0.114	1163900.1	0.147	1086255	0.063	1234582.2	0.086
21_21	1422196	0.051	1633649.4	0.065	1355092	0.087	1482751.1	0.121	1355385	0.062	1459218.7	0.084
21_22	1292806	0.044	1478642	0.060	1181799	0.070	1329493.3	0.117	1210648	0.057	1368095.2	0.076
21_23	1080705	0.043	1274238.2	0.054	1089412	0.063	1158688.6	0.124	1114897	0.034	1171420.3	0.072
21_24	1173150	0.046	1543915.6	0.056	1123678	0.102	1244290.9	0.120	1176259	0.066	1369571.7	0.086
21_25	1141320	0.029	1336380.2	0.042	1127936	0.062	1265032.1	0.080	1109407	0.037	1285230.7	0.052
21_26	1171890	0.061	1301279.3	0.090	1115249	0.130	1206958.3	0.175	1157171	0.067	1263434.6	0.111
21_27	1280278	0.028	1541468.3	0.049	1232645	0.070	1378141.3	0.120	1373067	0.060	1487196	0.082
21_28	1310292	0.042	1441922.4	0.065	1213635	0.080	1281388	0.116	1301764	0.056	1444975.3	0.081
21_29	1197847	0.039	1469539	0.060	1139311	0.074	1365091	0.129	1310242	0.042	1412709.4	0.092
21_30	1324558	0.029	1526022.7	0.047	1338735	0.067	1411065.8	0.084	1320383	0.049	1436487.6	0.059
21_31	1094265	0.044	1265025.9	0.068	1077377	0.084	1242354.8	0.119	1105724	0.058	1209139.8	0.087
21_32	1265647	0.039	1476928.7	0.055	1216267	0.070	1372548.1	0.109	1329265	0.045	1484158.5	0.072
21_33	1379670	0.056	1604146	0.073	1240450	0.119	1350760.3	0.150	1393076	0.069	1500972.8	0.105
21_34	1150059	0.046	1481318.9	0.073	1188945	0.087	1332000.6	0.133	1096555	0.047	1338749	0.090
21_35	1227010	0.043	1462463.5	0.062	1149078	0.096	1275015.4	0.115	1327579	0.057	1488290.3	0.086
21_36	1268161	0.031	1535034.1	0.050	1164163	0.083	1299864.7	0.106	1261125	0.037	1487292.5	0.073
21_37	1179676	0.033	1511710.4	0.051	1176131	0.062	1343139.2	0.110	1270491	0.063	1408430.1	0.080
21_38	1222643	0.038	1346554.4	0.060	1184052	0.049	1306665.3	0.099	1184710	0.049	1228313.3	0.085
21_39	1316781	0.032	1515993.9	0.064	1157036	0.103	1260026.5	0.129	1197830	0.049	1440400.6	0.089
21_40	1472339	0.062	1627907.4	0.078	1256508	0.122	1412550.7	0.150	1200969	0.063	1497466.4	0.101
21_41	1455537	0.034	1612686.7	0.060	1263697	0.079	1428672.3	0.116	1298225	0.065	1416573.9	0.086
21_42	1322117	0.041	1481112.6	0.056	1192244	0.069	1337562.3	0.111	1206696	0.057	1420119.5	0.084
21_43	1472182	0.034	1623323.7	0.046	1271264	0.072	1477616.6	0.090	1436245	0.048	1551003	0.066
21_44	1248405	0.046	1453563.7	0.070	1106315	0.113	1299676.4	0.142	1182833	0.064	1366464.2	0.096
21_45	1154399	0.035	1375042.1	0.057	1117177	0.065	1268238.1	0.111	1167197	0.051	1269598	0.073
21_46	1119672	0.037	1309943.7	0.071	1122007	0.085	1244671.1	0.120	1170569	0.065	1232755.8	0.083
21_47	1421486	0.046	1630089	0.087	1328438	0.074	1480460.5	0.141	1301319	0.087	1423250.7	0.118
21_48	1323402	0.045	1499307.3	0.063	1095177	0.074	1276459.8	0.115	1127163	0.059	1259662.8	0.080
21_49	1318371	0.031	1515543.6	0.047	1310009	0.065	1402925.4	0.100	1369714	0.048	1467034.1	0.069

Table 24: Instances with 21 nodes and Random Base Station position

	Swap – Best Improvement				**Shift – Best Improvement**				**Swap21 – Best Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
21_0	1091510	0.043	1286735.5	0.051	986526	0.103	1113206.3	0.118	1136666	0.037	1235519.9	0.073
21_1	1227024	0.043	1401581.2	0.062	1112761	0.078	1199583.1	0.116	1103459	0.050	1312212.5	0.077
21_2	1283266	0.044	1458677.5	0.063	1126283	0.090	1249926.2	0.111	1180932	0.071	1336179.7	0.085
21_3	1155016	0.038	1299301.1	0.054	1058055	0.081	1145147.1	0.100	1112074	0.050	1250622.7	0.071
21_4	1113720	0.050	1385905.8	0.062	1067960	0.128	1246456.4	0.160	1140390	0.054	1304536.6	0.086
21_5	1181452	0.046	1347692	0.072	981738	0.097	1107586	0.137	1030001	0.069	1129180.7	0.098
21_6	1085278	0.073	1185651	0.096	883937	0.143	1061754.9	0.194	1006772	0.070	1117056.3	0.123
21_7	1237022	0.042	1340707.8	0.054	1072846	0.099	1175582.9	0.122	1151331	0.065	1245905.1	0.091
21_8	1189647	0.034	1505286	0.045	1102090	0.073	1238158	0.103	1200400	0.039	1418226.2	0.062
21_9	1157583	0.033	1289797.8	0.044	1121497	0.074	1253249.7	0.100	1133733	0.043	1287487.3	0.071
21_10	1158841	0.042	1289380.2	0.068	1069966	0.096	1112107.6	0.136	1132028	0.052	1208381.3	0.100
21_11	1288450	0.031	1363511.5	0.053	1186575	0.085	1252939.3	0.122	1173803	0.035	1365464.6	0.071
21_12	1256699	0.044	1437068.6	0.057	1155281	0.108	1323904.9	0.128	1295227	0.080	1408980.7	0.095
21_13	1069742	0.045	1213683.9	0.069	925918	0.042	1063314.2	0.124	1043628	0.075	1141063.5	0.098
21_14	1161223	0.062	1260772.9	0.071	943996	0.091	1029935.7	0.137	959767	0.077	1082372.3	0.108
21_15	1116674	0.040	1322903.1	0.057	1000909	0.060	1154698.8	0.103	1008004	0.062	1171818.1	0.073
21_16	1232890	0.058	1453714.6	0.076	1036847	0.090	1258331.1	0.146	1067467	0.077	1289426	0.099
21_17	1196828	0.047	1310955.9	0.067	1136434	0.113	1224299.5	0.137	1204273	0.080	1275127.1	0.099
21_18	1114110	0.036	1211170.3	0.061	990247	0.066	1130759.8	0.118	1085293	0.040	1230225.4	0.078
21_19	1394041	0.056	1540099.8	0.072	1311521	0.096	1455407.4	0.130	1332048	0.067	1467985.1	0.094
21_20	937609	0.059	1163232	0.076	915622	0.108	1102629.3	0.135	923972	0.065	1025047.5	0.112
21_21	1302669	0.035	1491363.5	0.061	1240846	0.118	1323732.6	0.140	1257223	0.062	1374044	0.100
21_22	1247744	0.042	1357110.7	0.058	1089605	0.083	1244492.4	0.125	1123808	0.044	1326549	0.086
21_23	1059575	0.047	1210212.9	0.065	1001066	0.095	1058798.3	0.125	1047576	0.076	1113507.8	0.090
21_24	1268193	0.036	1426499.2	0.051	1038512	0.096	1183022.6	0.111	1045397	0.066	1289177.4	0.080
21_25	1177864	0.034	1485891.7	0.042	1112607	0.053	1338578.5	0.086	1219976	0.043	1352468.4	0.055
21_26	1212752	0.056	1327680	0.079	1095215	0.151	1201473.7	0.177	1097378	0.093	1207707	0.117
21_27	1279738	0.037	1474496.2	0.058	1185981	0.080	1325056.7	0.109	1300625	0.075	1416604.1	0.088
21_28	1267287	0.043	1443904.4	0.060	1221782	0.079	1291915.3	0.118	1235830	0.069	1317924.2	0.092
21_29	1426435	0.043	1551995.7	0.059	1094414	0.098	1204443.9	0.143	1180671	0.079	1345114.7	0.090
21_30	1217230	0.030	1360136.2	0.042	1121970	0.062	1257970.2	0.080	1257202	0.045	1332656.8	0.060
21_31	989671	0.041	1178813.6	0.062	965361	0.040	1084339.5	0.100	1015381	0.044	1141380.1	0.088
21_32	1217810	0.046	1411752.7	0.058	1158723	0.081	1396381.2	0.109	1207724	0.044	1351383.4	0.087
21_33	1238284	0.046	1383589.1	0.068	1039228	0.122	1099612.6	0.145	1126504	0.078	1229698.8	0.103
21_34	981893	0.072	1194168.4	0.090	1014491	0.089	1174191.5	0.125	1005321	0.073	1155229.8	0.111
21_35	1108275	0.044	1340221.7	0.058	1084828	0.056	1229982.6	0.099	1165747	0.052	1274876.5	0.083
21_36	1244176	0.036	1380445.2	0.058	1354363	0.098	1409180.9	0.121	1142422	0.041	1308400.3	0.076
21_37	1156906	0.035	1359193.7	0.051	1097535	0.091	1261482.5	0.102	1177326	0.033	1291511.7	0.062
21_38	1166409	0.055	1378389.5	0.076	1130925	0.087	1243096.3	0.134	1122843	0.061	1214414	0.095
21_39	1154584	0.040	1376373.4	0.068	1078151	0.104	1192986.6	0.129	1196595	0.078	1338793.2	0.092
21_40	1170120	0.046	1469728.1	0.062	1146991	0.082	1311918.4	0.130	1168391	0.068	1428372.8	0.097
21_41	1284349	0.047	1487682.6	0.063	1098069	0.093	1200352.1	0.125	1200036	0.055	1284597.8	0.085
21_42	1286469	0.045	1492882.1	0.064	1288058	0.078	1408037.8	0.116	1193013	0.073	1377560.3	0.095
21_43	1318507	0.031	1467480.5	0.053	1162000	0.088	1331004.8	0.100	1388050	0.038	1513558.6	0.064
21_44	1012681	0.040	1209878.3	0.061	1023706	0.091	1138643.9	0.114	995490	0.084	1099372.2	0.106
21_45	1140885	0.031	1333867.5	0.063	1086351	0.072	1266606.7	0.099	1176732	0.053	1273391.8	0.088
21_46	1126833	0.049	1206641	0.073	1039777	0.083	1099255.4	0.135	1066381	0.065	1138926.1	0.096
21_47	1408539	0.068	1576993.9	0.078	1260413	0.094	1450362.8	0.128	1328800	0.069	1505971.2	0.107
21_48	1055027	0.033	1380808.8	0.049	1039552	0.100	1126511.2	0.112	1050016	0.056	1258063.6	0.071
21_49	1382610	0.030	1539704.7	0.052	1289430	0.066	1456296.4	0.104	1337135	0.051	1510613.7	0.065

.1.2 First Improvement Tests

In Tables 25–48 the results of the three local searches using the First Improvement were presented. In this tables, as in the Best Improvement results, the column **Inst.** identifies the tested instance, the columns **Min** and **Avg** show the best solution and the average solution obtained by each method in 10 executions for each instance, respectively. The columns **T (s)** shows the time spend for each method to obtain the presented solutions.

Table 25: Instances with 6 nodes and Central Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
6_0	546647	0.000	551714.7	0.000	546114	0.001	546114	0.001	596791	0.000	596897.6	0.000
6_1	490121	0.000	490121	0.000	476885	0.000	476885	0.001	476885	0.000	476885	0.001
6_2	835931	0.000	835931	0.000	835637	0.000	835637	0.000	835637	0.000	835842.8	0.000
6_3	583504	0.000	592681.5	0.000	583501	0.001	583501	0.001	583501	0.000	584895.4	0.000
6_4	393982	0.000	405975.1	0.000	393830	0.000	393830	0.000	393830	0.000	426199.4	0.000
6_5	534464	0.000	571173	0.000	533556	0.000	533556	0.000	534464	0.000	593198.4	0.000
6_6	631860	0.000	639683	0.000	630865	0.000	630865	0.000	631860	0.000	646256.4	0.000
6_7	612879	0.000	612879	0.000	612364	0.000	612364	0.001	612364	0.000	647068	0.000
6_8	528010	0.000	538601.2	0.000	520829	0.001	520829	0.001	520829	0.000	541023.5	0.000
6_9	470844	0.000	497763	0.000	470066	0.001	470066	0.001	495577	0.000	495577	0.000
6_10	639134	0.000	639261	0.000	639134	0.000	639134	0.001	656555	0.000	656555	0.000
6_11	621086	0.000	621086	0.000	619894	0.000	619894	0.001	619894	0.000	636814.8	0.000
6_12	531042	0.000	550154.8	0.000	522721	0.001	528567.9	0.001	522721	0.000	538513	0.001
6_13	364167	0.000	365763.5	0.000	364167	0.001	364167	0.001	364167	0.000	369189.8	0.000
6_14	613957	0.000	616902.5	0.000	611143	0.000	611143	0.001	611143	0.000	647747	0.000
6_15	818863	0.000	818863	0.000	818863	0.000	818863	0.000	843193	0.000	843193	0.000
6_16	821989	0.000	831840	0.000	821989	0.000	861362.5	0.000	917641	0.000	938612.3	0.000
6_17	665222	0.000	687113.6	0.000	660660	0.000	660660	0.001	660660	0.000	724516.1	0.000
6_18	840727	0.000	846210.6	0.000	840727	0.000	840727	0.001	860270	0.000	877713	0.000
6_19	715997	0.000	728753.8	0.000	715997	0.000	735132.2	0.000	715997	0.000	749820.2	0.000
6_20	549152	0.000	563207.2	0.000	549152	0.001	549152	0.001	549984	0.000	549984	0.001
6_21	735924	0.000	735924	0.000	713937	0.000	722731.8	0.000	713937	0.000	734093.4	0.000
6_22	591211	0.000	599581.9	0.000	591211	0.000	591211	0.001	591211	0.000	606319.1	0.000
6_23	550497	0.000	570004	0.000	524522	0.001	524522	0.001	524522	0.000	608308.4	0.000
6_24	872154	0.000	875830.8	0.000	866253	0.001	866253	0.001	866253	0.000	870383.7	0.000
6_25	635749	0.000	649803.7	0.000	635598	0.001	635598	0.001	635598	0.000	670430.1	0.000
6_26	544356	0.000	545706.5	0.000	538351	0.000	538351	0.001	545418	0.000	549541.2	0.000
6_27	811119	0.000	822425.1	0.000	837570	0.000	837570	0.000	857447	0.000	859598.9	0.000
6_28	638259	0.000	638573.6	0.000	638259	0.000	638259	0.001	641405	0.000	648556.8	0.000
6_29	610719	0.000	613107.4	0.000	610599	0.000	610599	0.001	616810	0.000	625882	0.000
6_30	465915	0.000	478926.2	0.000	465915	0.000	473124	0.001	497045	0.000	497045	0.000
6_31	684259	0.000	684259	0.000	683706	0.000	683706	0.000	683706	0.000	702465	0.000
6_32	594488	0.000	594717.8	0.000	537562	0.001	537562	0.001	543797	0.000	569681	0.001
6_33	815377	0.000	815377	0.000	815377	0.000	815377	0.000	815377	0.000	815377	0.000
6_34	735356	0.000	761709.6	0.000	732237	0.000	744467.1	0.000	735356	0.000	755705.6	0.000
6_35	772559	0.000	772559	0.000	772559	0.000	780326.6	0.000	791978	0.000	792032	0.000
6_36	510537	0.000	523235.6	0.000	510537	0.001	510537	0.001	524643	0.000	546646	0.000
6_37	467336	0.000	496505	0.000	467336	0.001	467336	0.001	487472	0.000	510428.3	0.000
6_38	437514	0.000	445667.6	0.000	421521	0.001	421521	0.001	421521	0.000	460091	0.000
6_39	579258	0.000	585646.4	0.000	565619	0.001	565619	0.001	583749	0.000	601183.9	0.000
6_40	534631	0.000	543142.8	0.000	534631	0.000	553871.5	0.001	577190	0.000	577190	0.000
6_41	661469	0.000	671580.4	0.000	654673	0.000	658951.6	0.001	661804	0.000	676023.4	0.000
6_42	761059	0.000	831842.2	0.000	761059	0.000	768252.2	0.000	852122	0.000	852122	0.000
6_43	774150	0.000	774150	0.000	747812	0.000	791430	0.000	747812	0.000	775479.6	0.000
6_44	497265	0.000	503474.6	0.000	491016	0.000	491016	0.001	498778	0.000	502527.4	0.000
6_45	558558	0.000	563754.4	0.000	558558	0.000	583444.5	0.000	558647	0.000	576772.1	0.000
6_46	493725	0.000	519441	0.000	491839	0.001	492347.9	0.001	543271	0.000	544571.4	0.001
6_47	616949	0.000	651756.5	0.000	605053	0.000	605053	0.001	668567	0.000	673922.6	0.000
6_48	505033	0.000	505033	0.000	505033	0.000	505033	0.000	597461	0.000	597461	0.000
6_49	481597	0.000	481597	0.000	481588	0.001	481588	0.001	483006	0.000	483012.3	0.000

Table 26: Instances with 6 nodes and Eccentric Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
6_0	747076	0.000	750214.4	0.000	746543	0.001	746543	0.001	747076	0.000	757793.9	0.001
6_1	791604	0.000	796172.4	0.000	791604	0.000	791604	0.000	791604	0.000	798204.2	0.000
6_2	916760	0.000	946267.4	0.000	916760	0.000	923258.4	0.000	916760	0.000	938807	0.000
6_3	766175	0.000	766175	0.000	741533	0.000	741533	0.001	741533	0.000	761598.2	0.000
6_4	470349	0.000	470425	0.000	470500	0.000	470500	0.000	470500	0.000	472896.7	0.000
6_5	647059	0.000	647059	0.000	631759	0.001	631759	0.001	632725	0.000	644230.6	0.000
6_6	904104	0.000	904104	0.000	903109	0.000	903109	0.000	904104	0.000	914780.7	0.000
6_7	706143	0.000	707852.1	0.000	705643	0.001	705643	0.001	705643	0.000	717119.6	0.000
6_8	696168	0.000	712572.8	0.000	696168	0.001	696168	0.001	716674	0.000	718318.5	0.000
6_9	575496	0.000	575496	0.000	567748	0.001	567748	0.001	608598	0.000	608909.2	0.000
6_10	691493	0.000	692178.6	0.000	691493	0.000	691493	0.000	691493	0.000	693462.3	0.000
6_11	905862	0.000	905862	0.000	904670	0.001	904670	0.001	904670	0.000	949456	0.000
6_12	640630	0.000	650758.6	0.000	640630	0.000	640630	0.001	640630	0.000	640630	0.001
6_13	541892	0.000	541892	0.000	535258	0.000	535258	0.001	535258	0.000	538575	0.000
6_14	705277	0.000	710029.8	0.000	702463	0.000	702463	0.000	702463	0.000	707321	0.000
6_15	952253	0.000	952253	0.000	952253	0.000	952253	0.000	952253	0.000	979963.1	0.000
6_16	969532	0.000	969532	0.000	949830	0.001	958387.5	0.001	966945	0.000	1128882.3	0.000
6_17	914878	0.000	942717.5	0.000	899054	0.000	899054	0.001	899054	0.000	941955.8	0.000
6_18	935330	0.000	942551	0.000	935330	0.000	961033.1	0.001	935330	0.000	943063.1	0.000
6_19	844611	0.000	844611	0.000	844611	0.000	844611	0.000	950108	0.000	950108	0.000
6_20	786927	0.000	806011.2	0.000	785541	0.000	785541	0.001	785541	0.000	786372.6	0.000
6_21	841903	0.000	854299.5	0.000	841903	0.000	841903	0.001	846969	0.000	858805.2	0.000
6_22	691130	0.000	691300	0.000	691130	0.000	691130	0.001	706570	0.000	711193.8	0.000
6_23	645265	0.000	649808.6	0.000	645265	0.001	654017.1	0.001	645265	0.000	710174.2	0.000
6_24	983997	0.000	991228.7	0.000	983997	0.001	983997	0.001	983997	0.000	989115.4	0.001
6_25	809554	0.000	809554	0.000	800280	0.000	806745.9	0.001	836679	0.000	837934.5	0.000
6_26	701995	0.000	701995	0.000	693289	0.000	693289	0.001	693289	0.000	703754.6	0.001
6_27	808294	0.000	812845.2	0.000	808294	0.000	808294	0.000	822542	0.000	861976.1	0.000
6_28	891397	0.000	891397	0.000	891397	0.000	891397	0.000	962915	0.000	963226.1	0.000
6_29	734012	0.000	735971.5	0.000	734012	0.000	734012	0.000	734012	0.000	746409.5	0.000
6_30	704966	0.000	718888	0.000	685765	0.000	706533.4	0.001	685765	0.000	696528	0.000
6_31	732864	0.000	733150.5	0.000	732864	0.001	732864	0.001	745396	0.000	748543.5	0.000
6_32	734563	0.000	737390.4	0.000	734563	0.000	735025	0.001	734563	0.000	740556	0.001
6_33	842181	0.000	842183.7	0.000	842181	0.000	842181	0.001	842181	0.000	995332.4	0.000
6_34	763132	0.000	764621	0.000	763132	0.000	763132	0.001	763132	0.000	823320.9	0.000
6_35	833773	0.000	833773	0.000	833773	0.000	868405.9	0.000	841547	0.000	842324.8	0.000
6_36	823479	0.000	823479	0.000	822349	0.001	849606	0.001	822349	0.000	829940.8	0.001
6_37	754106	0.000	767872.4	0.000	754106	0.000	754106	0.000	754106	0.000	758985.8	0.000
6_38	741217	0.000	749635.6	0.000	741217	0.001	741217	0.001	743243	0.000	758829	0.000
6_39	756234	0.000	763190.5	0.000	756234	0.000	756234	0.000	756234	0.000	791083.8	0.000
6_40	733223	0.000	733477.4	0.000	733223	0.000	768588.6	0.000	747995	0.000	760122.2	0.000
6_41	815773	0.000	816907	0.000	815641	0.001	816585.5	0.001	815773	0.000	817003.6	0.000
6_42	935718	0.000	997288.5	0.000	935718	0.000	935718	0.000	1022699	0.000	1022699	0.000
6_43	944696	0.000	944696	0.000	870408	0.000	870408	0.000	870408	0.000	870408	0.000
6_44	659085	0.000	659088.6	0.000	652836	0.000	652836	0.001	652836	0.000	661266.8	0.000
6_45	668894	0.000	668939	0.000	668894	0.000	668894	0.000	669119	0.000	678384.6	0.000
6_46	816966	0.000	831154.8	0.000	815080	0.001	815080	0.001	838728	0.000	840704	0.000
6_47	640348	0.000	640443	0.000	637378	0.001	637378	0.001	721322	0.000	721322	0.000
6_48	593238	0.000	593269.6	0.000	593176	0.000	593176	0.000	593616	0.000	628550.9	0.000
6_49	816418	0.000	816418	0.000	815000	0.000	815000	0.001	815000	0.000	817664	0.000

Table 27: Instances with 6 nodes and Random Base Station position

	Swap – First Improvement				**Shift – First Improvement**				**Swap21 – First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
6_0	563033	0.000	590666	0.000	563033	0.000	563033	0.001	563566	0.000	599279.5	0.000
6_1	500972	0.000	513170.6	0.000	498775	0.000	498775	0.001	500972	0.000	522931.1	0.000
6_2	801107	0.000	809311.8	0.000	801107	0.000	801107	0.001	801107	0.000	827252	0.000
6_3	708729	0.000	716973.8	0.000	708729	0.000	708729	0.001	708729	0.000	718004.4	0.000
6_4	513512	0.000	513627	0.000	513512	0.000	513512	0.000	513512	0.000	513592	0.000
6_5	568203	0.000	575577.1	0.000	567295	0.000	567295	0.000	568203	0.000	568203	0.000
6_6	632191	0.000	658155	0.000	631196	0.000	631196	0.000	632191	0.000	632191	0.000
6_7	759749	0.000	759749	0.000	759234	0.001	759234	0.001	759234	0.000	804305.4	0.000
6_8	645802	0.000	658105.6	0.000	645802	0.000	645802	0.001	645802	0.000	662793	0.000
6_9	662442	0.000	663188.4	0.000	656406	0.001	656406	0.001	656406	0.000	678816.6	0.001
6_10	818134	0.000	818134	0.000	818134	0.000	818134	0.000	818134	0.000	818134	0.000
6_11	683207	0.000	683207	0.000	682015	0.000	682015	0.001	682015	0.000	726841.3	0.000
6_12	546882	0.000	569430.4	0.000	546882	0.000	551572.8	0.001	546882	0.000	553885	0.000
6_13	386383	0.000	387215.8	0.000	379749	0.000	381670.8	0.001	382952	0.000	386055.5	0.001
6_14	813985	0.000	816308.5	0.000	811171	0.000	811171	0.000	815818	0.000	816943.6	0.000
6_15	786583	0.000	790471.8	0.000	786583	0.000	786583	0.001	786583	0.000	847349.8	0.000
6_16	824867	0.000	869753.4	0.000	805165	0.000	818857	0.001	824867	0.000	852921	0.000
6_17	670546	0.000	675612.8	0.000	665984	0.000	665984	0.000	668535	0.000	670020.9	0.000
6_18	859515	0.000	885358.8	0.000	859515	0.000	871429.8	0.000	867026	0.000	903097.7	0.000
6_19	736186	0.000	737813.2	0.000	736186	0.000	736186	0.000	744322	0.000	783258	0.000
6_20	576287	0.000	580113.4	0.000	574901	0.001	574901	0.001	574901	0.000	579836.2	0.001
6_21	689819	0.000	745745.6	0.000	689819	0.000	689819	0.000	689819	0.000	712614.5	0.000
6_22	636275	0.000	636275	0.000	621048	0.001	621048	0.001	621048	0.000	624093.4	0.000
6_23	587345	0.000	593643.2	0.001	586199	0.001	586199	0.001	598525	0.000	607375.2	0.001
6_24	855959	0.000	855959	0.000	845628	0.001	845628	0.001	847274	0.001	854235.4	0.001
6_25	641441	0.000	641441	0.000	640665	0.001	640665	0.001	640665	0.000	657321.6	0.000
6_26	549469	0.000	604008.1	0.000	540763	0.000	540763	0.001	540763	0.000	547072.2	0.001
6_27	766084	0.000	766084	0.000	753218	0.000	753218	0.000	755637	0.000	758045.4	0.000
6_28	787948	0.000	836206.6	0.000	787948	0.000	829265.2	0.000	787948	0.000	837213.8	0.000
6_29	694788	0.000	694788	0.000	694788	0.001	694788	0.001	720551	0.000	720551	0.000
6_30	558976	0.000	558976	0.000	479487	0.000	479487	0.000	498688	0.000	498688	0.000
6_31	713564	0.000	730343.2	0.000	716736	0.000	716736	0.000	766013	0.000	766013	0.000
6_32	694022	0.000	731200.9	0.000	682876	0.000	695598.1	0.001	724264	0.000	733117.9	0.000
6_33	769271	0.000	774664.4	0.000	769271	0.000	769271	0.000	899375	0.000	899375	0.000
6_34	765705	0.000	827476.5	0.000	765705	0.000	818652	0.000	765705	0.000	809827.5	0.000
6_35	834834	0.000	834834	0.000	834834	0.001	834834	0.001	867327	0.000	868578.1	0.000
6_36	515440	0.000	518000.2	0.000	513643	0.001	513643	0.001	515440	0.000	553860	0.000
6_37	580264	0.000	587884	0.000	580264	0.000	595228	0.000	596875	0.000	614337.7	0.000
6_38	487998	0.000	493953.9	0.000	487998	0.000	487998	0.000	491826	0.000	517302	0.000
6_39	596675	0.000	612875.8	0.000	596675	0.001	596675	0.001	596771	0.000	623541	0.000
6_40	527069	0.000	527796.5	0.000	527069	0.000	543080.2	0.001	527069	0.000	548597.4	0.000
6_41	643222	0.000	653273.3	0.000	643222	0.000	646787.5	0.000	643222	0.000	671090.9	0.000
6_42	758854	0.000	758854	0.000	757340	0.000	757340	0.000	757340	0.000	758097	0.000
6_43	743108	0.000	743108	0.000	743108	0.000	743108	0.000	743108	0.000	743108	0.000
6_44	624859	0.000	626660.4	0.000	624859	0.000	624859	0.001	624859	0.000	629682.5	0.000
6_45	534958	0.000	540818.2	0.000	527529	0.000	527529	0.000	550920	0.000	550920	0.000
6_46	750884	0.000	780425.6	0.000	750884	0.001	751102.1	0.001	750884	0.000	788386.8	0.001
6_47	601062	0.000	601062	0.000	598092	0.000	598092	0.000	661606	0.000	661606	0.000
6_48	633299	0.000	640032.6	0.000	633299	0.000	633299	0.001	633374	0.000	658364.5	0.000
6_49	560037	0.000	594255.8	0.000	560037	0.000	560037	0.000	560037	0.000	560037	0.000

Table 28: Instances with 7 nodes and Central Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
7_0	553370	0.000	574109.2	0.001	552984	0.001	552984	0.001	577527	0.000	594620.8	0.001
7_1	519585	0.000	544564.2	0.001	506579	0.001	507869.9	0.001	510882	0.000	535499	0.001
7_2	805131	0.000	805131	0.000	797105	0.001	801428.3	0.001	797105	0.000	822113.8	0.001
7_3	798622	0.000	824467	0.001	798622	0.001	804393.2	0.001	813050	0.000	845599.7	0.001
7_4	489293	0.000	523745.9	0.001	489293	0.001	489293	0.002	512977	0.001	537031.6	0.001
7_5	411217	0.000	443709.1	0.001	411217	0.001	423990.2	0.001	429124	0.000	456350.9	0.001
7_6	673212	0.000	697597.2	0.001	670402	0.000	701717.2	0.001	704396	0.000	724970.8	0.000
7_7	721819	0.000	721819	0.000	715776	0.001	718878.4	0.001	717671	0.000	743657.3	0.001
7_8	540629	0.000	542685.2	0.001	527657	0.000	559009.2	0.001	527657	0.000	556837.8	0.001
7_9	657261	0.000	669936.1	0.000	657259	0.001	661793.8	0.001	657261	0.000	681423.5	0.000
7_10	714773	0.000	733989.2	0.001	714773	0.001	714773	0.001	728692	0.000	747111.5	0.001
7_11	796508	0.000	815392.4	0.000	796508	0.000	810962.8	0.001	801188	0.000	858249	0.000
7_12	549504	0.000	554621.6	0.001	547930	0.001	558164	0.001	547930	0.000	585687.7	0.001
7_13	637412	0.001	654049.7	0.001	637412	0.001	646387.4	0.001	637412	0.001	656024.4	0.001
7_14	961054	0.000	974573.7	0.000	956263	0.001	957851.5	0.001	959440	0.000	980663.2	0.001
7_15	343071	0.001	355630.6	0.001	343071	0.001	343071	0.001	343071	0.001	352695	0.001
7_16	640055	0.000	644674.6	0.001	633817	0.001	640899.6	0.001	633817	0.000	649528.4	0.001
7_17	959654	0.000	972893.2	0.000	959654	0.001	974375.4	0.001	970358	0.000	990065.1	0.000
7_18	498562	0.000	500517.2	0.001	497988	0.001	498060	0.001	497988	0.000	519299.8	0.001
7_19	731815	0.000	740959	0.001	730268	0.001	730268	0.001	747055	0.000	781848.6	0.001
7_20	841998	0.000	868502.6	0.000	841998	0.000	857000	0.001	872002	0.000	884036.2	0.000
7_21	719618	0.000	769865.4	0.000	719618	0.001	758921.1	0.001	721039	0.000	756590.6	0.000
7_22	787260	0.000	886627.8	0.000	785388	0.001	801341	0.001	787260	0.000	853862	0.000
7_23	764756	0.000	807409.4	0.001	764756	0.001	764756	0.001	780545	0.000	817559	0.001
7_24	908946	0.000	935660.1	0.000	908946	0.000	932449.8	0.000	908946	0.000	954993.9	0.000
7_25	737689	0.000	737689	0.001	714706	0.001	714706	0.001	714706	0.000	755240.3	0.001
7_26	669347	0.000	677670.5	0.001	667947	0.001	679563.6	0.001	669346	0.000	712057.6	0.001
7_27	579011	0.000	603035.7	0.001	577316	0.001	586197	0.001	613332	0.000	618307	0.001
7_28	579546	0.000	614440.6	0.001	578061	0.001	578061	0.001	579546	0.001	623189.6	0.001
7_29	603449	0.000	631468.8	0.000	603449	0.000	625402.2	0.000	603449	0.000	638420.6	0.000
7_30	748569	0.001	766651.4	0.001	731101	0.001	731101	0.002	732973	0.001	761659.7	0.001
7_31	711999	0.000	721179.8	0.001	710037	0.001	710037	0.001	712144	0.000	748384.6	0.001
7_32	557366	0.000	579811.7	0.000	525426	0.001	525426	0.001	593801	0.000	618975.8	0.001
7_33	749126	0.000	782843	0.000	749125	0.000	760921.7	0.001	749125	0.000	760632.6	0.000
7_34	720798	0.001	733837.2	0.001	720549	0.001	720549	0.001	720549	0.001	726475.8	0.001
7_35	895323	0.000	914685	0.001	873530	0.000	885651.8	0.001	900883	0.000	911119	0.001
7_36	825401	0.000	835148.6	0.000	825401	0.001	850023.5	0.001	830973	0.000	941952.3	0.000
7_37	667188	0.000	695558.2	0.001	666921	0.001	674705.6	0.001	681808	0.001	705387.3	0.001
7_38	519494	0.000	536142	0.001	519494	0.000	519494	0.001	519494	0.000	562113.1	0.001
7_39	641626	0.001	665486.9	0.001	641626	0.001	646890.5	0.001	652155	0.000	695343.7	0.001
7_40	940227	0.000	957732	0.000	931176	0.001	951219.7	0.001	940227	0.000	962790.1	0.000
7_41	670362	0.000	672944	0.001	670362	0.001	670362	0.001	695999	0.000	700909.1	0.001
7_42	731566	0.000	733284.9	0.001	731539	0.001	731539	0.001	731539	0.000	741173.6	0.001
7_43	753888	0.000	757686.8	0.000	753888	0.001	753888	0.001	758493	0.000	772818	0.000
7_44	541738	0.000	545247.4	0.001	525665	0.001	529953.1	0.001	525665	0.001	539339.1	0.001
7_45	827318	0.000	868738.7	0.000	827318	0.001	834676.1	0.001	827703	0.000	873380	0.001
7_46	608851	0.000	610128.6	0.001	606180	0.001	606180	0.001	606546	0.001	621136.6	0.001
7_47	695767	0.000	707061.9	0.001	689082	0.001	689082	0.001	695767	0.000	712069.6	0.001
7_48	612820	0.000	621935.2	0.001	612820	0.001	614341.8	0.001	612820	0.000	641245.6	0.001
7_49	686159	0.000	698689.4	0.001	652825	0.001	661549.4	0.001	663737	0.000	685654.7	0.001

Table 29: Instances with 7 nodes and Eccentric Base Station position

	Swap – First Improvement				**Shift – First Improvement**				**Swap21 – First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
7_0	841098	0.000	849099.9	0.001	841098	0.001	841098	0.001	841098	0.001	867515.2	0.001
7_1	682581	0.000	692371.6	0.001	682429	0.001	683320	0.001	682429	0.000	690475.4	0.001
7_2	819608	0.000	823100.7	0.000	819608	0.000	819608	0.001	819608	0.000	821894.3	0.001
7_3	913912	0.000	955904	0.001	910034	0.001	916528	0.002	910114	0.001	924364.6	0.001
7_4	760182	0.001	781140.3	0.001	760182	0.001	760182	0.001	778975	0.000	793658.9	0.001
7_5	762675	0.001	766384.6	0.001	744768	0.001	753703	0.001	744768	0.001	773781.1	0.001
7_6	948583	0.000	948583	0.001	905231	0.001	907427	0.001	905231	0.000	955202.1	0.001
7_7	944431	0.000	994948.2	0.000	942536	0.001	943499	0.001	942536	0.000	972412.6	0.001
7_8	913126	0.000	925208.7	0.001	911108	0.000	920747	0.001	911108	0.000	936810.8	0.001
7_9	850566	0.000	853302.2	0.000	796780	0.000	825968.9	0.001	796780	0.000	829124.6	0.000
7_10	906532	0.000	924625	0.001	906532	0.001	906532	0.001	906532	0.001	950919.8	0.001
7_11	832198	0.000	853620	0.000	832198	0.001	851392.8	0.001	832198	0.000	884223.7	0.000
7_12	690307	0.000	702330.2	0.001	712394	0.000	712394	0.001	688733	0.000	710007	0.001
7_13	760198	0.000	810092.3	0.001	739740	0.001	740652.8	0.001	739740	0.000	771607.4	0.001
7_14	1070175	0.000	1076144.2	0.000	1069398	0.001	1069398	0.001	1069398	0.000	1083965.2	0.001
7_15	681775	0.001	681775	0.001	661359	0.001	667755	0.001	661359	0.001	679559.7	0.001
7_16	826900	0.000	829908	0.001	826900	0.001	830046.4	0.001	826900	0.001	831960	0.001
7_17	1000184	0.000	1010827.3	0.000	1000184	0.000	1007475.9	0.001	1000184	0.000	1014084.8	0.001
7_18	799067	0.001	803005.2	0.001	799067	0.001	801519.4	0.001	799067	0.001	815376.6	0.001
7_19	845116	0.000	862353.1	0.000	843569	0.001	848433.9	0.001	843796	0.000	882072.4	0.001
7_20	886660	0.000	892052.7	0.000	886660	0.001	886660	0.001	886697	0.000	906433	0.000
7_21	803270	0.000	818053.8	0.001	820653	0.001	832816.8	0.001	803270	0.001	872049.5	0.001
7_22	876857	0.000	889929.4	0.001	876857	0.001	884494.7	0.001	929011	0.000	951973.6	0.001
7_23	836711	0.000	853931.8	0.001	836621	0.001	864403.7	0.001	836621	0.000	862265.5	0.001
7_24	959916	0.000	1000556	0.000	959916	0.001	959916	0.001	959916	0.000	1013962	0.000
7_25	833577	0.000	857465	0.001	833577	0.001	833577	0.001	833577	0.000	869545.8	0.001
7_26	795323	0.000	806075	0.001	795252	0.001	814131.6	0.001	795252	0.001	800374.3	0.001
7_27	846733	0.000	865837.6	0.000	807620	0.000	841334.2	0.001	807620	0.000	858016	0.001
7_28	923793	0.000	925991.7	0.001	879656	0.001	879656	0.001	881141	0.001	922418.9	0.001
7_29	889099	0.000	889229.8	0.001	865189	0.000	895928.6	0.001	865625	0.000	969570.9	0.000
7_30	808802	0.000	815412.2	0.001	791334	0.001	795535	0.001	799736	0.001	803040.1	0.001
7_31	1003424	0.000	1004332.6	0.000	977635	0.001	995118.1	0.001	979597	0.000	987093.4	0.001
7_32	806712	0.000	811801.6	0.001	784632	0.001	826134.9	0.001	784632	0.000	821974.9	0.001
7_33	847917	0.000	854695.5	0.000	847917	0.001	865393.9	0.001	887887	0.000	910370.1	0.000
7_34	947311	0.001	948706.5	0.001	947208	0.001	958996.8	0.001	947208	0.000	961618.6	0.001
7_35	871357	0.000	879900.8	0.001	871357	0.001	878705.5	0.001	871357	0.000	911699.1	0.001
7_36	902495	0.001	907358.6	0.001	902220	0.001	903435.9	0.001	904219	0.000	952553.4	0.001
7_37	759355	0.000	759355	0.001	753039	0.001	753039	0.001	759088	0.001	791178.2	0.001
7_38	826822	0.000	827470	0.001	825313	0.001	825313	0.001	825313	0.000	858180.1	0.001
7_39	776551	0.001	782031	0.001	776551	0.001	787087	0.001	789721	0.000	827290.9	0.001
7_40	905713	0.000	935206.9	0.001	905713	0.001	944750.2	0.001	905713	0.000	923117.3	0.001
7_41	742008	0.000	773343	0.000	767399	0.001	769413.4	0.001	769917	0.000	808210	0.000
7_42	778998	0.001	782206.7	0.001	775608	0.001	775608	0.001	775608	0.000	790997.6	0.001
7_43	952405	0.000	972517	0.001	952347	0.001	974689.9	0.001	952405	0.000	979658.5	0.001
7_44	558840	0.000	573112	0.001	558840	0.001	560618.4	0.001	559138	0.000	586688.6	0.001
7_45	972401	0.000	992258.1	0.000	972401	0.001	972401	0.001	972401	0.000	993962	0.001
7_46	812991	0.000	813159.1	0.001	811394	0.001	812711.5	0.001	811394	0.000	812823.3	0.001
7_47	757313	0.000	764777.5	0.001	757313	0.001	765560.6	0.001	757313	0.001	763015.6	0.001
7_48	744859	0.000	783434	0.000	744859	0.001	751183.4	0.001	744859	0.001	747502.2	0.001
7_49	828547	0.000	861854.2	0.001	827960	0.000	858684.9	0.001	827960	0.000	843294.7	0.001

Table 30: Instances with 7 nodes and Random Base Station position

	Swap – First Improvement				**Shift – First Improvement**				**Swap21 – First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
7_0	571952	0.001	581583.3	0.001	571155	0.001	574061.4	0.001	571155	0.001	576240.9	0.001
7_1	535544	0.000	567000.5	0.001	521552	0.001	524133.8	0.001	525855	0.000	563172.2	0.001
7_2	792001	0.001	806485.5	0.001	790865	0.001	790865	0.001	790865	0.000	854093.5	0.001
7_3	832191	0.000	855232.4	0.001	828313	0.001	869865.7	0.001	837584	0.000	873694.8	0.001
7_4	757684	0.001	793604.8	0.001	757684	0.001	757684	0.001	757684	0.001	791724	0.001
7_5	421309	0.001	424942.3	0.001	403402	0.001	424955.2	0.001	421309	0.000	463238.4	0.001
7_6	648842	0.000	681857.6	0.001	648818	0.001	648818	0.001	648818	0.000	696512.6	0.001
7_7	715096	0.000	747970.1	0.001	710948	0.001	712887	0.001	819929	0.000	863102.3	0.000
7_8	534672	0.001	538453.6	0.001	527384	0.001	541449.4	0.001	531771	0.001	553204.4	0.001
7_9	625812	0.000	674741.2	0.000	625810	0.001	625810	0.001	625810	0.000	645756.3	0.000
7_10	704420	0.001	731089.3	0.001	704420	0.001	704420	0.001	704420	0.001	755026.4	0.001
7_11	952954	0.000	995950.5	0.000	952954	0.000	966342.5	0.001	957818	0.000	1013079.1	0.000
7_12	578097	0.000	578097	0.001	550935	0.001	553473.4	0.001	550935	0.000	582789.5	0.001
7_13	719069	0.000	751621.9	0.001	719069	0.001	754147.4	0.001	719069	0.000	735127.5	0.001
7_14	960047	0.000	970948.4	0.000	960047	0.001	960047	0.001	950457	0.000	969810.1	0.001
7_15	378135	0.001	378517.8	0.001	358357	0.001	358357	0.002	358357	0.001	374943.7	0.001
7_16	638618	0.000	644032.2	0.001	632527	0.001	638763.4	0.001	632527	0.000	640934	0.001
7_17	961175	0.000	971105.9	0.000	961175	0.000	970280.6	0.001	961175	0.000	1005745.2	0.001
7_18	514049	0.001	520425.8	0.001	513475	0.001	513518.2	0.001	513619	0.001	532881.6	0.001
7_19	793571	0.000	804400.4	0.000	793571	0.001	793571	0.001	793571	0.000	805109.2	0.001
7_20	818118	0.000	833909.4	0.000	818118	0.000	850164.4	0.001	818118	0.000	844980.1	0.000
7_21	714142	0.000	741478.7	0.001	712292	0.001	731874	0.001	712292	0.000	792763.6	0.001
7_22	733861	0.000	778942.4	0.000	731989	0.000	731989	0.001	733861	0.000	826036.8	0.000
7_23	784922	0.000	784922	0.000	778746	0.001	778746	0.001	784922	0.000	824537.7	0.001
7_24	884405	0.000	957312.3	0.000	884405	0.000	884405	0.001	884405	0.000	933477.1	0.000
7_25	732604	0.000	774191.8	0.000	709621	0.001	709621	0.001	709621	0.000	741016.9	0.001
7_26	709194	0.001	718319.8	0.001	707794	0.001	708773.3	0.001	707794	0.000	756326.7	0.001
7_27	558977	0.001	570507.7	0.001	548868	0.001	555540.6	0.001	550563	0.001	585589	0.001
7_28	610509	0.001	624864.6	0.001	604108	0.001	604108	0.001	604108	0.000	642401.4	0.001
7_29	634227	0.000	658241.3	0.000	609603	0.001	609603	0.001	609626	0.000	681464.1	0.000
7_30	754951	0.001	782340.7	0.001	750410	0.001	753528.2	0.001	750410	0.001	772436.1	0.001
7_31	722872	0.000	782636.1	0.001	718517	0.001	718517	0.001	753761	0.000	780350.6	0.001
7_32	672887	0.000	710101.4	0.001	653942	0.001	653942	0.001	663194	0.000	683455.5	0.001
7_33	827013	0.000	840184.5	0.000	827013	0.000	846186.6	0.001	838215	0.000	868660.6	0.000
7_34	735201	0.000	740607	0.001	735201	0.001	743928.3	0.001	735201	0.000	745746.2	0.001
7_35	856669	0.000	919166.2	0.001	856669	0.001	895948	0.001	884022	0.001	884027	0.001
7_36	822946	0.000	919301.8	0.000	822946	0.000	838173.4	0.001	825538	0.000	873637.3	0.000
7_37	710321	0.000	732133.4	0.001	704358	0.001	706005.2	0.001	704358	0.001	727624.5	0.001
7_38	657577	0.001	659345.5	0.001	657577	0.001	657577	0.001	657577	0.001	686340.7	0.001
7_39	630646	0.000	672369.7	0.001	640435	0.001	640435	0.001	667279	0.000	694792.6	0.001
7_40	850499	0.000	908256.7	0.000	850499	0.001	890775.5	0.001	850499	0.000	869322.3	0.001
7_41	696470	0.000	714002.4	0.000	696470	0.000	719432.6	0.001	711702	0.000	730038.1	0.000
7_42	786005	0.000	824683.1	0.001	772794	0.001	772794	0.001	783947	0.001	810763.7	0.001
7_43	735922	0.001	767242	0.001	731317	0.001	731317	0.001	731317	0.000	777206.9	0.001
7_44	567246	0.000	576525.7	0.001	547198	0.001	551486.1	0.001	547198	0.000	568901.3	0.001
7_45	798048	0.000	824576.7	0.000	798048	0.001	814058	0.001	798048	0.000	838818.7	0.000
7_46	654822	0.000	658124.5	0.001	654822	0.001	654822	0.001	654822	0.000	659184.9	0.001
7_47	707006	0.000	742742.7	0.001	700321	0.001	751322.2	0.001	707006	0.000	739861.9	0.000
7_48	722665	0.000	757130.4	0.001	722665	0.001	728221	0.001	722665	0.000	769305.8	0.001
7_49	655045	0.000	721096.1	0.001	655045	0.000	655045	0.001	655045	0.001	665521.6	0.001

Table 31: Instances with 8 nodes and Central Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
8_0	645012	0.001	682275.7	0.001	590280	0.001	615087.1	0.002	590280	0.001	662315.4	0.002
8_1	737016	0.001	754065.2	0.001	687344	0.001	687344	0.002	689184	0.001	754982.3	0.001
8_2	707704	0.001	733836.9	0.001	707704	0.001	717953.6	0.001	724833	0.000	741027.9	0.001
8_3	698668	0.001	709051.6	0.001	692893	0.001	730695.3	0.002	698313	0.001	728333.5	0.001
8_4	770484	0.001	784427.1	0.002	768310	0.001	778895.3	0.002	792229	0.001	808405.6	0.001
8_5	714476	0.000	738536.9	0.001	708571	0.001	708571	0.002	714476	0.001	782822	0.001
8_6	820088	0.000	848082.3	0.001	820088	0.002	832557.7	0.002	820088	0.001	834597.6	0.002
8_7	695901	0.000	728220.8	0.001	688076	0.002	709357.9	0.002	695901	0.001	758897.5	0.001
8_8	727905	0.000	772888.3	0.001	725973	0.001	738882.3	0.001	727905	0.001	781311.9	0.001
8_9	674243	0.001	707199.8	0.001	673868	0.001	673868	0.002	673868	0.001	719542.3	0.001
8_10	945208	0.000	1010588.7	0.001	944077	0.001	964974.8	0.001	945208	0.001	966640.9	0.001
8_11	745509	0.001	794777.8	0.001	742435	0.001	745366.7	0.002	745509	0.001	770635.1	0.001
8_12	691124	0.001	698979.2	0.001	691124	0.001	696600.4	0.002	692404	0.001	717519.7	0.001
8_13	408701	0.001	445730.2	0.002	424829	0.001	459165.5	0.002	418112	0.001	464416.8	0.001
8_14	877656	0.000	914245.8	0.001	866449	0.001	896360.4	0.001	866449	0.001	914705.2	0.001
8_15	728249	0.001	795299	0.001	702807	0.001	832067.6	0.002	728249	0.001	788572.9	0.001
8_16	823867	0.000	869911.5	0.001	822327	0.001	837296.2	0.002	823867	0.001	909903.1	0.001
8_17	721014	0.001	767881.1	0.001	711424	0.001	718742.1	0.002	721014	0.001	782566	0.001
8_18	749420	0.001	769812.5	0.001	733302	0.001	760910.3	0.001	749420	0.001	794441.6	0.001
8_19	722044	0.000	761919	0.001	718002	0.001	739520.6	0.002	746084	0.001	795578.4	0.001
8_20	700291	0.002	706255.4	0.002	700291	0.002	704370.6	0.002	700291	0.001	702929.9	0.002
8_21	736761	0.001	799207.8	0.002	736761	0.001	775316.6	0.002	736761	0.001	797354.2	0.002
8_22	737116	0.001	742817.3	0.001	711051	0.002	711051	0.002	719298	0.001	761401	0.001
8_23	738164	0.001	756258.3	0.001	710236	0.001	741366.2	0.002	742055	0.001	775227.3	0.001
8_24	664936	0.001	689917.8	0.002	664936	0.002	668843.8	0.003	702909	0.001	713082.2	0.002
8_25	719847	0.001	727108.5	0.001	718378	0.001	718378	0.001	718378	0.001	726156	0.001
8_26	743650	0.001	834824.8	0.001	713245	0.001	721123	0.002	769620	0.001	850609.3	0.001
8_27	993321	0.000	1030065.1	0.001	993321	0.001	1000954.4	0.001	1002910	0.000	1055414.1	0.000
8_28	816310	0.001	860364.1	0.001	807868	0.001	851926.6	0.002	842129	0.001	922047.4	0.001
8_29	775644	0.000	793564.6	0.001	736507	0.001	736507	0.001	736507	0.000	819069	0.001
8_30	844420	0.000	860054.8	0.001	819322	0.002	823907.5	0.002	819355	0.001	851906.8	0.002
8_31	780372	0.001	800040.1	0.001	773256	0.001	778383.3	0.002	773256	0.001	802696.3	0.001
8_32	714999	0.000	730714.6	0.001	703938	0.001	715504.4	0.002	703568	0.001	738935	0.001
8_33	557052	0.001	582707.6	0.002	556768	0.002	558826.7	0.002	556768	0.001	607940.9	0.002
8_34	833784	0.000	886899.2	0.001	833784	0.001	859549.5	0.002	833784	0.001	871463.9	0.001
8_35	799950	0.000	804330.1	0.001	783095	0.001	812029.8	0.001	783095	0.001	805153.4	0.001
8_36	933146	0.000	996299.9	0.001	859443	0.001	882709.6	0.001	861523	0.000	929671.7	0.001
8_37	825277	0.000	867752.2	0.001	822364	0.001	831046.8	0.002	822556	0.001	847444.6	0.001
8_38	826706	0.001	854240.2	0.001	825746	0.001	852661.1	0.001	808889	0.001	836816.8	0.001
8_39	717912	0.001	721535.6	0.002	717912	0.002	717912	0.003	717912	0.001	752126.6	0.002
8_40	595246	0.001	607533.1	0.001	595167	0.001	596358.2	0.001	615754	0.001	625348.8	0.001
8_41	840282	0.001	864376	0.001	840154	0.001	845870.1	0.003	840154	0.001	867259	0.001
8_42	569256	0.001	572207.2	0.001	569095	0.001	570812	0.001	569095	0.001	574068.6	0.001
8_43	740917	0.000	800784.4	0.001	722350	0.001	722350	0.001	762219	0.000	816563.7	0.001
8_44	689948	0.001	703367.2	0.002	685529	0.001	685529	0.002	685529	0.001	696075.8	0.002
8_45	594346	0.001	603774.5	0.001	591018	0.001	593977.8	0.002	594346	0.001	608865	0.001
8_46	684507	0.000	732677.5	0.001	668687	0.001	700119	0.001	702243	0.001	770788	0.001
8_47	718686	0.000	736962.1	0.001	716821	0.001	717830.4	0.001	718263	0.001	733135.3	0.001
8_48	767494	0.001	865383.3	0.001	766862	0.002	768988	0.002	766014	0.001	818738.6	0.001
8_49	541118	0.001	552182.7	0.001	541118	0.001	551919.4	0.002	564396	0.001	572335.4	0.001

Table 32: Instances with 8 nodes and Eccentric Base Station position

	Swap – First Improvement				Shift – First Improvement				Swap21 – First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
8_0	681931	0.001	716712.4	0.002	666234	0.001	684523.5	0.002	666234	0.001	694512.4	0.002
8_1	849437	0.001	884762	0.001	847597	0.001	884004.6	0.001	889305	0.001	917590.2	0.001
8_2	833234	0.000	840647	0.001	841373	0.001	858058.2	0.001	828816	0.001	841001.5	0.001
8_3	930398	0.001	953922.3	0.002	930397	0.001	942986.3	0.003	930398	0.001	978331.3	0.002
8_4	845671	0.001	875897.3	0.001	845671	0.001	846549	0.002	845671	0.001	866029.6	0.002
8_5	962158	0.001	1031951.9	0.001	901537	0.001	922249.6	0.002	901537	0.001	947131.8	0.001
8_6	1020082	0.001	1045211.2	0.001	1010940	0.001	1045952.6	0.002	1010940	0.001	1023755	0.001
8_7	822472	0.001	925475	0.001	820056	0.001	820056	0.002	820056	0.001	926201.3	0.001
8_8	756355	0.001	778886.5	0.001	756355	0.001	772616.8	0.002	777141	0.001	816673.2	0.001
8_9	797788	0.001	804413.5	0.001	797788	0.001	809186.7	0.001	798163	0.001	838390.6	0.001
8_10	1047341	0.001	1162424.1	0.001	1044721	0.001	1044721	0.001	1047341	0.001	1098153.4	0.001
8_11	911549	0.001	938580.1	0.001	908475	0.001	950550.7	0.002	929526	0.001	977790.3	0.001
8_12	747304	0.001	752788.6	0.001	728984	0.001	735932	0.002	728984	0.001	788847.3	0.001
8_13	655193	0.001	699434.6	0.001	655193	0.001	675415.1	0.002	665513	0.001	695979.8	0.001
8_14	1076910	0.001	1135749.2	0.001	1076910	0.001	1111467.4	0.001	1098968	0.001	1150136.1	0.001
8_15	785869	0.000	819965.9	0.001	760427	0.001	760427	0.001	785978	0.000	853832.9	0.001
8_16	1086945	0.000	1145757.1	0.001	1019179	0.001	1082573	0.001	1020719	0.001	1063445.2	0.001
8_17	794978	0.001	808352.4	0.002	794978	0.001	871148.4	0.001	794978	0.001	837087.4	0.002
8_18	818357	0.000	848130.5	0.001	818357	0.001	823627.6	0.001	848550	0.001	880357.1	0.001
8_19	776896	0.001	820255.6	0.001	776896	0.001	776896	0.002	777820	0.001	811143.6	0.001
8_20	781246	0.001	782862.2	0.002	782475	0.001	783044.4	0.002	782475	0.001	788714.6	0.002
8_21	808378	0.001	819755.4	0.001	808264	0.002	808688.4	0.002	810386	0.001	827981.3	0.002
8_22	988328	0.001	1001968.9	0.001	1014139	0.001	1018219.6	0.001	980081	0.001	1019908.3	0.001
8_23	967031	0.001	1033519.6	0.001	958051	0.001	1005653.5	0.002	977161	0.001	1005426.8	0.001
8_24	877930	0.001	890027.8	0.001	845548	0.001	886759.6	0.002	845548	0.001	873863.4	0.002
8_25	931115	0.001	951055.2	0.001	919924	0.001	919924	0.002	919924	0.001	937872.5	0.001
8_26	814437	0.001	814437	0.001	767814	0.001	767814	0.002	768107	0.001	816579.6	0.002
8_27	1046091	0.000	1054181.7	0.001	1046091	0.001	1053234.5	0.001	1046091	0.000	1061923.4	0.001
8_28	935195	0.001	986986.5	0.001	930531	0.001	937532.5	0.002	930531	0.001	1001573.8	0.001
8_29	892496	0.000	955617.2	0.001	892496	0.001	941439.3	0.001	913553	0.001	964800.7	0.001
8_30	951959	0.001	971651.4	0.001	951920	0.001	954926.9	0.002	951920	0.001	956936	0.002
8_31	880611	0.001	910876.5	0.001	880611	0.001	891762.7	0.002	880611	0.001	929997.5	0.001
8_32	824405	0.001	851052.1	0.001	813344	0.001	822337.3	0.003	815987	0.001	869002.1	0.001
8_33	863174	0.001	876889.1	0.002	862890	0.002	869775.6	0.002	862890	0.001	897590.7	0.002
8_34	970444	0.001	1019679.7	0.001	977339	0.001	1024882.6	0.001	977339	0.001	1018194	0.001
8_35	873074	0.000	883343.7	0.001	872804	0.001	889227.2	0.001	872804	0.001	885595.4	0.001
8_36	842895	0.001	873285	0.001	839482	0.001	866952	0.002	839482	0.001	908464.5	0.001
8_37	889967	0.001	986598	0.001	889775	0.001	978442.8	0.002	890890	0.001	994762.2	0.001
8_38	1008729	0.001	1031975.5	0.001	1008729	0.001	1069893.6	0.002	1008729	0.001	1052648.1	0.001
8_39	808047	0.000	837275.2	0.001	792703	0.001	803172.2	0.002	792703	0.001	827811.8	0.001
8_40	912144	0.001	992657.9	0.001	912065	0.001	994133.1	0.001	926963	0.001	945931.1	0.001
8_41	1006996	0.001	1011899.3	0.002	990368	0.002	1002008.8	0.003	1006996	0.001	1012519.2	0.001
8_42	794101	0.001	832846.5	0.001	785772	0.001	785772	0.002	785772	0.001	788834.6	0.001
8_43	987525	0.001	994028.7	0.001	968958	0.001	1005177	0.001	979484	0.001	1075138.5	0.001
8_44	761545	0.001	767184.7	0.001	761545	0.001	765562.8	0.002	765774	0.001	795070.4	0.001
8_45	770821	0.001	773147.7	0.001	770283	0.001	799610.8	0.002	770283	0.001	772974.3	0.001
8_46	859068	0.000	860954.5	0.001	843248	0.001	890815.8	0.001	859068	0.000	904430	0.001
8_47	805663	0.001	809453.5	0.001	787044	0.001	798657.3	0.002	787044	0.001	825894.7	0.001
8_48	909573	0.000	917626.5	0.001	908778	0.001	917051.4	0.001	908778	0.001	921551.4	0.001
8_49	805735	0.001	835410	0.001	802898	0.001	828618.4	0.002	817664	0.001	834185.8	0.001

Table 33: Instances with 8 nodes and Random Base Station position

	Swap – First Improvement				Shift – First Improvement				Swap21 – First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
8_0	636554	0.001	676869.6	0.002	636554	0.001	651734.8	0.002	644014	0.001	658263.4	0.002
8_1	728583	0.000	768141.4	0.001	725989	0.001	736308.1	0.002	725989	0.001	766657	0.001
8_2	833036	0.001	837208.1	0.001	835609	0.001	854564.7	0.001	833036	0.001	843479.9	0.001
8_3	954476	0.001	977304.8	0.001	907170	0.001	911376.3	0.003	907171	0.002	926001.4	0.002
8_4	785885	0.001	813450.9	0.001	783711	0.001	786571.9	0.001	783711	0.001	798476	0.001
8_5	823640	0.001	877093.6	0.001	802860	0.001	894946.8	0.001	829545	0.001	909070.3	0.001
8_6	832090	0.001	875509.5	0.001	832065	0.001	851652.6	0.002	835191	0.001	875922.6	0.001
8_7	756521	0.001	772446.2	0.001	701314	0.001	701314	0.002	756521	0.001	806385.5	0.001
8_8	749621	0.000	756043.1	0.001	729089	0.001	746738.1	0.001	749621	0.001	796172.7	0.001
8_9	674035	0.000	719824.6	0.001	673660	0.001	673660	0.001	682912	0.001	694472.1	0.001
8_10	943925	0.000	990802.4	0.001	941305	0.001	959009.6	0.001	943925	0.001	969554.8	0.001
8_11	720053	0.001	731390.7	0.001	720053	0.001	730326.2	0.001	727311	0.000	743381.9	0.001
8_12	707094	0.001	717655.7	0.001	690241	0.001	696917.8	0.002	716609	0.001	751714.2	0.001
8_13	533467	0.001	539302.5	0.002	483091	0.002	505955.3	0.002	499757	0.001	536789.2	0.001
8_14	920858	0.000	941092.1	0.001	914222	0.001	920100.6	0.001	914222	0.001	960196.8	0.001
8_15	718330	0.001	743040.6	0.001	692888	0.001	692888	0.002	692888	0.001	774395	0.001
8_16	818047	0.000	851347.1	0.001	804057	0.001	804057	0.002	816507	0.000	891922	0.001
8_17	769621	0.001	786607	0.001	767000	0.001	811333.3	0.002	769621	0.001	812209.5	0.001
8_18	726454	0.000	762973.7	0.001	726454	0.001	750680.3	0.001	726454	0.001	779512.5	0.001
8_19	718905	0.001	770006.4	0.001	685652	0.001	717118.5	0.002	685652	0.001	785108.1	0.001
8_20	742238	0.000	761942.6	0.001	742238	0.001	744190	0.002	742238	0.000	743564.4	0.002
8_21	717761	0.001	735840.2	0.001	717647	0.001	736727.9	0.001	717647	0.001	782463.6	0.001
8_22	731632	0.001	736013.1	0.001	705567	0.002	705567	0.002	723385	0.001	747507.3	0.002
8_23	728589	0.000	768980.1	0.001	700661	0.001	726178.2	0.001	736434	0.001	763566	0.001
8_24	695584	0.001	717332.2	0.001	695449	0.001	703188.4	0.002	695584	0.001	714302.4	0.001
8_25	799485	0.001	811218.1	0.002	799305	0.001	799305	0.002	799305	0.001	810499.6	0.002
8_26	716624	0.001	743791.9	0.001	716624	0.001	749259.8	0.002	727661	0.001	782480.9	0.002
8_27	987543	0.000	1001961.4	0.001	987543	0.001	993682.8	0.001	987543	0.000	1007077.9	0.001
8_28	845798	0.001	885471.1	0.001	841134	0.001	843846	0.002	841134	0.001	870761.8	0.001
8_29	744720	0.000	802757.5	0.001	744720	0.001	749814	0.001	744720	0.000	801280.3	0.001
8_30	783667	0.001	800777.2	0.001	783634	0.001	783634	0.002	783634	0.001	811019.2	0.001
8_31	724383	0.001	731102.9	0.001	717267	0.001	720115.5	0.002	724383	0.001	760081.3	0.001
8_32	714889	0.001	738037.4	0.001	706391	0.001	710560.8	0.002	706391	0.001	737239	0.001
8_33	683790	0.001	700020	0.001	680498	0.001	696511.2	0.002	680498	0.001	710557	0.002
8_34	870288	0.001	875716.7	0.001	870273	0.001	871640.9	0.002	870288	0.001	883317.7	0.001
8_35	795951	0.001	812415.5	0.001	795951	0.001	829797.3	0.001	795951	0.001	826111.5	0.001
8_36	885511	0.000	921696.2	0.001	874127	0.001	899348.6	0.002	888648	0.001	940513.9	0.001
8_37	795130	0.001	812288.9	0.001	794015	0.001	794015	0.001	794207	0.001	830049.5	0.001
8_38	834485	0.001	866237.9	0.001	789386	0.001	807858.6	0.002	811467	0.001	859542.8	0.001
8_39	853403	0.001	862111.2	0.001	853403	0.001	855183.4	0.002	853403	0.001	874459.9	0.002
8_40	795391	0.000	824225.3	0.001	806685	0.001	853141.3	0.001	815978	0.001	863344.8	0.001
8_41	871568	0.001	871568	0.001	854812	0.002	878350	0.002	854940	0.001	864840	0.002
8_42	594210	0.001	623605.7	0.001	594210	0.001	608319.5	0.002	597169	0.001	619997.6	0.002
8_43	738511	0.000	776230.8	0.001	719944	0.001	748585.6	0.001	738511	0.000	817755.2	0.001
8_44	685895	0.001	726928.6	0.001	685895	0.001	692659.4	0.002	685895	0.001	711151.1	0.002
8_45	576791	0.001	612464.6	0.001	573463	0.002	618805.8	0.003	573463	0.001	607015.9	0.002
8_46	664511	0.000	674768.2	0.001	624371	0.001	650111	0.001	624371	0.001	723231.2	0.001
8_47	707758	0.001	726127.4	0.001	702768	0.001	702768	0.002	702768	0.001	733730.8	0.001
8_48	771089	0.001	826523	0.001	767250	0.001	778095.5	0.002	780160	0.001	814241.6	0.001
8_49	604260	0.001	653809.2	0.001	604260	0.001	612304.5	0.001	604260	0.001	611822.1	0.001

Table 34: Instances with 9 nodes and Central Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
9_0	618310	0.001	632775.4	0.001	614266	0.002	616231	0.003	618196	0.001	643239.6	0.001
9_1	616958	0.001	666494	0.001	616958	0.001	630213.1	0.003	618662	0.001	655414.8	0.002
9_2	869040	0.001	912199.9	0.002	868155	0.003	894012.6	0.004	868155	0.002	941822.2	0.002
9_3	872223	0.001	886572.2	0.001	857801	0.001	863536.8	0.002	862286	0.001	892961.6	0.002
9_4	902448	0.001	963444.3	0.001	902448	0.001	947597.8	0.002	922245	0.001	973016.6	0.001
9_5	938977	0.001	989020.1	0.002	937349	0.002	961182.3	0.002	952567	0.001	990876.9	0.002
9_6	672407	0.001	797841.3	0.001	698952	0.001	706860.8	0.002	671444	0.001	782019.2	0.002
9_7	834113	0.000	851324.7	0.001	834113	0.002	892164.8	0.002	874766	0.001	915885.7	0.001
9_8	769003	0.001	796616.3	0.001	766381	0.002	771332	0.002	766381	0.001	800010.6	0.002
9_9	728911	0.001	784425.8	0.001	728911	0.001	749290.9	0.002	734621	0.001	788063	0.001
9_10	575679	0.002	584485.8	0.003	520251	0.001	585813.8	0.003	559838	0.001	629046.6	0.002
9_11	663116	0.001	714076.4	0.003	646881	0.003	646881	0.004	659461	0.002	698878.4	0.003
9_12	889070	0.001	965018.6	0.001	883236	0.002	894302.7	0.003	1043563	0.001	1108095.6	0.001
9_13	489939	0.001	523902.1	0.002	489939	0.002	508151.6	0.003	489939	0.001	517630	0.002
9_14	756043	0.001	809698.2	0.002	711205	0.002	737828.8	0.002	711205	0.001	778588.4	0.002
9_15	743781	0.002	798687.8	0.002	766468	0.002	768488.5	0.004	731958	0.002	756263.9	0.003
9_16	763903	0.001	842805	0.002	813535	0.002	826191.1	0.002	786807	0.002	820347.5	0.002
9_17	748976	0.001	765691.4	0.002	720474	0.002	726635	0.002	766962	0.001	854148.6	0.001
9_18	983565	0.001	1028472.6	0.002	935266	0.001	959580.3	0.003	965829	0.001	1005774.6	0.002
9_19	862450	0.001	897193.4	0.001	831353	0.001	859720	0.002	871106	0.001	921875.1	0.001
9_20	675743	0.002	694688.4	0.002	675685	0.002	682567.3	0.003	719779	0.001	787553.9	0.002
9_21	886838	0.001	956334.3	0.001	873362	0.002	899971.8	0.003	874883	0.001	906810.2	0.002
9_22	788476	0.001	844218.4	0.002	757371	0.002	804993.8	0.003	788476	0.002	869915.4	0.002
9_23	883442	0.001	928847.3	0.002	879349	0.002	942220.5	0.002	883442	0.001	944502	0.002
9_24	717192	0.001	762043.2	0.002	717108	0.002	724630.5	0.003	783651	0.001	818683.1	0.002
9_25	812743	0.001	850210.9	0.001	802998	0.002	825223.9	0.002	809725	0.001	871275.3	0.001
9_26	825197	0.001	831691.2	0.001	825197	0.001	835944.8	0.002	825197	0.001	870834	0.001
9_27	776960	0.001	809712.3	0.001	776960	0.001	780563.9	0.002	792606	0.001	826141.2	0.001
9_28	697488	0.002	758894.5	0.003	693839	0.003	706660.7	0.003	694159	0.001	733129.3	0.002
9_29	864111	0.001	872001.3	0.002	840656	0.001	845748.8	0.003	848705	0.001	891357.2	0.002
9_30	526278	0.001	610597	0.001	523174	0.001	554941.5	0.002	523174	0.001	583846.4	0.001
9_31	905752	0.001	948198.1	0.001	890882	0.002	955444.8	0.003	903664	0.001	948729.5	0.002
9_32	910800	0.001	933915.6	0.001	869228	0.001	910037.2	0.002	890492	0.001	954040.2	0.002
9_33	780449	0.001	798125.3	0.001	778086	0.001	785693	0.002	836988	0.001	872544.6	0.001
9_34	649552	0.001	703975.5	0.002	619774	0.002	673486.4	0.003	679063	0.001	735313.9	0.002
9_35	754999	0.001	790713.2	0.001	738470	0.002	738470	0.003	741453	0.002	785575.3	0.003
9_36	873604	0.001	939842.2	0.001	873604	0.001	937531.2	0.002	873604	0.001	949354.7	0.001
9_37	988310	0.001	1045535.4	0.001	986772	0.001	991450	0.002	988310	0.001	1050524	0.001
9_38	870728	0.001	928096.3	0.001	845112	0.001	912659.7	0.002	845112	0.001	901513.7	0.001
9_39	834797	0.001	934633.2	0.002	823458	0.003	823611.1	0.004	823458	0.001	923580.5	0.002
9_40	651553	0.001	656643.8	0.002	608580	0.001	635460.9	0.002	645732	0.001	678317.8	0.002
9_41	667974	0.001	719056.7	0.002	653016	0.002	660304.8	0.003	667974	0.001	728318.1	0.002
9_42	857980	0.001	887857.8	0.001	817780	0.001	849940	0.002	857993	0.001	916243.9	0.001
9_43	868910	0.001	945665.4	0.002	865855	0.003	909349	0.003	865855	0.002	930124.9	0.003
9_44	936245	0.001	998691.1	0.001	935627	0.002	942693.6	0.003	935627	0.001	997787.6	0.002
9_45	951386	0.002	985358.8	0.002	951296	0.003	965002.8	0.005	974860	0.001	1014475	0.002
9_46	630721	0.002	652835	0.004	630721	0.003	636759.8	0.004	635592	0.002	654285.7	0.004
9_47	679230	0.001	728990.6	0.001	634601	0.001	651850.6	0.002	676212	0.001	713997.9	0.002
9_48	844922	0.001	901269.1	0.001	840329	0.002	847135	0.003	844922	0.001	916607.6	0.002
9_49	694052	0.001	748174.4	0.002	680167	0.001	682983	0.003	684558	0.001	772776.4	0.001

Table 35: Instances with 9 nodes and Eccentric Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
9_0	795056	0.001	806126	0.001	783925	0.002	787626.6	0.002	795056	0.001	822446.6	0.001
9_1	747058	0.001	787342	0.002	746997	0.002	751659.6	0.002	774908	0.001	792486.3	0.002
9_2	995435	0.001	1041359.4	0.002	1007805	0.002	1024978.8	0.003	1007805	0.002	1071722.2	0.003
9_3	957884	0.001	1019444	0.001	935609	0.002	951295.4	0.002	958252	0.001	1024519.2	0.001
9_4	992095	0.001	1023077.2	0.002	992095	0.001	1045780.5	0.002	992257	0.001	1018585.2	0.001
9_5	1032121	0.001	1114741.5	0.002	1030525	0.002	1082070.9	0.003	1030702	0.001	1106764.7	0.002
9_6	882433	0.001	984114.8	0.001	881429	0.002	934076.4	0.002	909484	0.001	1008613.6	0.002
9_7	917587	0.001	950585.2	0.002	917587	0.001	984700.5	0.002	922070	0.001	984960.8	0.001
9_8	915215	0.001	957518.8	0.001	912593	0.001	962035.2	0.002	912593	0.001	996215.1	0.001
9_9	761791	0.000	794217.9	0.001	760994	0.002	798710	0.002	770275	0.001	823900.4	0.001
9_10	849265	0.001	931387.4	0.002	847636	0.002	888886.2	0.003	847636	0.001	947678.5	0.002
9_11	957299	0.001	980918.1	0.002	941064	0.002	941064	0.003	944719	0.001	971960.2	0.002
9_12	971903	0.001	996476.8	0.001	962773	0.002	992570.4	0.002	985994	0.001	1119461.4	0.001
9_13	869995	0.001	923711.1	0.002	869488	0.001	881506.6	0.002	869488	0.001	916802.4	0.002
9_14	843380	0.001	936088.5	0.002	826909	0.001	843876.3	0.003	827998	0.001	913269.9	0.003
9_15	918785	0.001	944126.3	0.002	926701	0.002	927424.2	0.003	927440	0.001	944332.9	0.003
9_16	829077	0.001	876234.4	0.001	849090	0.001	883296.3	0.002	829077	0.001	866998	0.002
9_17	911845	0.001	937422	0.002	911844	0.002	919237.2	0.002	911845	0.001	940193.1	0.002
9_18	943129	0.002	977802.5	0.002	943129	0.001	958003.5	0.003	943129	0.001	1017281.6	0.002
9_19	903105	0.001	946552.7	0.001	903105	0.001	957215	0.002	948355	0.001	984294.4	0.002
9_20	793628	0.001	822022	0.002	793622	0.002	793622	0.003	793622	0.001	881614.2	0.003
9_21	993113	0.001	1111438.1	0.001	993113	0.002	1044994.4	0.003	993113	0.001	1038728.5	0.002
9_22	833819	0.001	840341.6	0.002	835934	0.002	854768.9	0.002	833819	0.001	864139.9	0.002
9_23	966479	0.001	1060855.7	0.002	971476	0.001	1020920.3	0.002	971476	0.001	1041111.1	0.002
9_24	832954	0.002	881503.3	0.002	825224	0.002	825224	0.003	825224	0.002	917214.3	0.003
9_25	872451	0.001	931121.1	0.001	864459	0.001	906714	0.002	864459	0.001	910149.3	0.001
9_26	882448	0.001	883925.7	0.002	882448	0.001	940950	0.002	882448	0.001	951982.6	0.002
9_27	972594	0.001	972594	0.002	960502	0.002	1018241.2	0.003	972594	0.001	1017532.3	0.001
9_28	917286	0.001	925602.7	0.002	916966	0.003	950586.6	0.004	917286	0.001	1005232.9	0.003
9_29	906749	0.001	952693.2	0.001	873803	0.001	918734.6	0.002	887801	0.001	936121	0.001
9_30	741853	0.001	777728.8	0.001	741853	0.001	741853	0.002	741853	0.001	783409.1	0.002
9_31	903742	0.001	943347.7	0.001	888976	0.002	938276.1	0.003	907368	0.001	953083.5	0.002
9_32	982125	0.001	1067281.7	0.001	982125	0.002	1014471.8	0.002	982125	0.001	1093110.7	0.001
9_33	1013808	0.001	1135948.9	0.001	1007137	0.001	1101578.7	0.003	1007137	0.001	1086174.6	0.001
9_34	720766	0.001	743586.4	0.002	718625	0.001	733541.3	0.003	718625	0.001	771912.6	0.002
9_35	957548	0.001	1026969.3	0.002	979813	0.002	1001046.6	0.002	957548	0.001	1024226.5	0.002
9_36	914201	0.001	1005537.6	0.002	914201	0.002	929509.8	0.002	942952	0.001	1016403.8	0.002
9_37	989659	0.001	1010174.6	0.001	988714	0.002	1001451.7	0.002	990567	0.001	1066153.1	0.002
9_38	1058824	0.001	1068612	0.001	1033208	0.001	1033208	0.002	1033208	0.001	1094907.6	0.002
9_39	970726	0.001	1078235.5	0.002	959387	0.003	959540.1	0.003	959387	0.001	983049.5	0.002
9_40	872434	0.001	895051.1	0.001	855188	0.001	879463.7	0.002	875094	0.001	924785.8	0.002
9_41	870451	0.001	926585.9	0.002	866869	0.002	885200.4	0.003	870389	0.001	943309.9	0.002
9_42	962783	0.001	996860	0.001	962564	0.002	962564	0.003	965959	0.001	1062397.2	0.001
9_43	1115694	0.001	1290807.5	0.002	1104956	0.002	1148622.4	0.003	1104956	0.001	1180736.6	0.003
9_44	1002463	0.001	1032359	0.001	988104	0.002	988104	0.003	988104	0.001	1171952.5	0.002
9_45	1132055	0.002	1132269.9	0.003	1117078	0.002	1164425.7	0.003	1132058	0.001	1168805.1	0.002
9_46	827015	0.000	853726.5	0.002	827015	0.001	827015	0.002	827015	0.001	827015	0.002
9_47	824136	0.001	847838.8	0.001	798625	0.002	807259.4	0.002	798732	0.001	857348	0.002
9_48	960945	0.001	1079287.9	0.001	978471	0.002	1022334.9	0.002	996090	0.001	1082793.9	0.002
9_49	823920	0.001	852330.1	0.002	798112	0.002	798112	0.003	816388	0.001	886479.6	0.002

Table 36: Instances with 9 nodes and Random Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
9_0	650741	0.001	661631.8	0.001	644739	0.001	657177.6	0.002	673012	0.001	698933	0.001
9_1	603190	0.001	633999.6	0.002	603190	0.001	618070.3	0.002	603272	0.001	647880.4	0.001
9_2	872412	0.001	969306.5	0.003	862080	0.002	870499.6	0.003	862080	0.002	886778.2	0.003
9_3	890764	0.001	932042.4	0.001	878815	0.002	904411.2	0.002	894597	0.001	970758.1	0.001
9_4	899383	0.000	974967.4	0.001	924738	0.001	955602.1	0.002	907199	0.001	1003736.6	0.001
9_5	930731	0.001	965585.8	0.001	929312	0.002	979438.9	0.002	947914	0.001	1003607.1	0.001
9_6	720107	0.001	799047.9	0.002	720079	0.002	741879.7	0.002	747600	0.001	807641.7	0.002
9_7	982583	0.001	1003722.1	0.001	982583	0.001	1001447.3	0.002	1004336	0.001	1069594.3	0.001
9_8	765467	0.001	776791	0.001	762845	0.002	823095.6	0.002	765467	0.001	813878.6	0.002
9_9	813131	0.001	831959.2	0.001	813131	0.001	948357.6	0.002	816404	0.001	897389.9	0.001
9_10	656800	0.001	729760.2	0.002	617213	0.002	636157.4	0.003	655137	0.001	736121.3	0.002
9_11	693025	0.002	705602.3	0.003	689749	0.002	692360.2	0.004	697756	0.001	718533.5	0.003
9_12	885829	0.001	984016.1	0.001	885829	0.001	885829	0.002	885829	0.001	1008136.6	0.001
9_13	437933	0.001	458080.1	0.002	437449	0.002	445087.4	0.002	437449	0.001	464213.9	0.002
9_14	729338	0.001	781677.9	0.001	684500	0.002	732815.6	0.003	684500	0.001	753771.1	0.002
9_15	756003	0.001	766982.3	0.003	758929	0.002	758984.3	0.004	762705	0.001	775804.9	0.003
9_16	877010	0.001	996432.8	0.002	922644	0.002	926524.8	0.003	876739	0.001	944299.8	0.002
9_17	748805	0.001	787424.6	0.001	720303	0.001	727696.2	0.002	780288	0.001	860193.2	0.002
9_18	953315	0.001	1025529.2	0.002	944030	0.002	960093.2	0.003	944030	0.002	1032080.6	0.003
9_19	842956	0.001	884952.2	0.001	888712	0.002	915922.7	0.002	842956	0.001	879379.9	0.002
9_20	724853	0.001	798782.8	0.002	680695	0.002	704598	0.003	724795	0.002	758962.2	0.002
9_21	892048	0.001	938956.5	0.002	882864	0.002	907036	0.003	884284	0.001	957593.5	0.002
9_22	892677	0.001	908543.8	0.002	874395	0.002	912241.5	0.003	869566	0.001	937613.3	0.002
9_23	854354	0.001	897066.4	0.002	854354	0.002	915312.4	0.003	854354	0.001	903468	0.002
9_24	692025	0.001	736912.5	0.001	684295	0.002	684295	0.002	684295	0.001	781984	0.002
9_25	775723	0.001	790171.4	0.002	767737	0.002	784707.8	0.003	775723	0.001	850592.3	0.002
9_26	764301	0.001	801330.7	0.001	764223	0.001	803042.4	0.002	794317	0.001	843661.3	0.001
9_27	814404	0.001	836566.1	0.001	814398	0.001	831258.2	0.002	814398	0.001	854432.1	0.002
9_28	722141	0.001	747964.1	0.002	694588	0.002	714654.4	0.003	694588	0.002	753381	0.003
9_29	891522	0.001	938301.9	0.002	855246	0.002	894764.7	0.003	882398	0.001	962076.3	0.002
9_30	623561	0.001	720548.4	0.001	586861	0.002	662824	0.002	591012	0.001	693252.2	0.002
9_31	910582	0.001	913193	0.001	895712	0.001	912785.3	0.002	908494	0.001	965195	0.001
9_32	870208	0.001	916964.5	0.001	849050	0.002	872299.2	0.002	879692	0.001	926650.8	0.001
9_33	772452	0.001	813327.2	0.002	772452	0.002	786298.7	0.002	780721	0.001	823585.7	0.002
9_34	665314	0.001	697876	0.001	665314	0.002	675515.6	0.002	681894	0.001	715375.5	0.002
9_35	776503	0.001	776503	0.002	748090	0.002	748090	0.003	808504	0.001	851050.7	0.002
9_36	825681	0.001	883934.5	0.001	825681	0.001	871242.9	0.002	835564	0.001	901402.3	0.001
9_37	974913	0.001	1012018.4	0.001	973375	0.001	984536.7	0.002	974913	0.001	1067883.8	0.001
9_38	825369	0.001	845860.5	0.002	823474	0.001	823474	0.002	849623	0.001	872448	0.001
9_39	825452	0.001	907901.4	0.002	814113	0.002	814419.2	0.003	814113	0.001	867273.4	0.002
9_40	646217	0.001	698039.3	0.002	633866	0.002	650001.8	0.002	674474	0.001	735902.2	0.002
9_41	681467	0.001	701134.2	0.002	678913	0.002	680411.8	0.003	679625	0.001	714819.5	0.002
9_42	880506	0.001	906166.3	0.001	880287	0.001	911428.8	0.002	905130	0.001	933817.5	0.001
9_43	876090	0.001	958434	0.002	869391	0.002	870057.9	0.002	870132	0.001	935180	0.002
9_44	894478	0.001	916336.6	0.001	894478	0.001	924383.6	0.002	903230	0.001	979994.4	0.001
9_45	987300	0.001	992107.2	0.002	963389	0.002	988577.3	0.003	989676	0.001	1020508.6	0.002
9_46	702326	0.002	756490.4	0.003	702325	0.002	704463.9	0.004	702325	0.002	736678.1	0.003
9_47	877903	0.001	884697.5	0.002	839884	0.001	901599.9	0.002	883279	0.001	937454.2	0.002
9_48	799293	0.001	818667.5	0.002	819574	0.002	930951.3	0.003	819574	0.001	907905.6	0.002
9_49	670444	0.001	729560.9	0.001	656559	0.001	662191	0.003	656559	0.001	748495.6	0.002

Table 37: Instances with 10 nodes and Central Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
10_0	840522	0.001	885882.5	0.002	828229	0.003	829364.5	0.004	841947	0.001	925991.5	0.003
10_1	751807	0.001	779221.5	0.002	722468	0.002	750647.1	0.003	740173	0.001	836294.3	0.002
10_2	737068	0.001	779843	0.003	719928	0.002	728847.5	0.003	733518	0.002	780335.3	0.003
10_3	903096	0.001	923134.4	0.003	898392	0.004	912160.8	0.005	898392	0.002	943456.8	0.003
10_4	703086	0.002	736376	0.004	698499	0.002	723086	0.005	704677	0.002	725462.5	0.006
10_5	828816	0.001	923246.6	0.003	823373	0.003	887132	0.005	823373	0.002	952267.1	0.003
10_6	749857	0.002	828498.4	0.003	706920	0.003	735451.6	0.004	749857	0.002	818692.8	0.002
10_7	964796	0.001	1007188.9	0.003	962859	0.003	989985.2	0.004	996816	0.002	1045611	0.003
10_8	854315	0.001	943801.3	0.002	854315	0.002	880816.8	0.003	886345	0.001	963532.2	0.002
10_9	1007515	0.002	1064139.3	0.002	1023632	0.002	1046400.8	0.004	1014201	0.001	1076418.1	0.002
10_10	947002	0.001	1019608.6	0.002	942886	0.002	1001351	0.003	955786	0.001	986249.2	0.002
10_11	818844	0.001	847170.8	0.002	793339	0.002	840750.4	0.004	843834	0.002	900377.3	0.002
10_12	538227	0.002	559798.5	0.003	537919	0.002	559007.6	0.003	537919	0.002	547340.4	0.003
10_13	637193	0.003	751170	0.005	610006	0.005	630722.2	0.006	610006	0.004	679866	0.007
10_14	646855	0.001	663512.4	0.002	646552	0.002	654596	0.003	648278	0.001	676980.7	0.002
10_15	809305	0.001	893933.5	0.002	796231	0.002	818846.6	0.003	838356	0.001	916735.9	0.002
10_16	790336	0.001	826168.6	0.002	789975	0.002	882822.6	0.003	790284	0.002	889136.8	0.003
10_17	1087310	0.001	1145131.1	0.001	1087310	0.001	1133040.9	0.002	1087310	0.001	1190085.2	0.002
10_18	804080	0.001	811123.2	0.002	776608	0.002	802432.8	0.003	792774	0.001	840610	0.002
10_19	660404	0.002	723355.5	0.002	651658	0.002	699524.1	0.004	651658	0.002	753856.2	0.003
10_20	979325	0.001	1026159.3	0.001	977782	0.002	1002068	0.003	977782	0.001	1089112.4	0.002
10_21	716855	0.002	752649.6	0.003	708373	0.003	710499.7	0.003	708373	0.002	722354.4	0.004
10_22	612907	0.001	685548.5	0.003	612424	0.003	618637.4	0.004	633739	0.002	710871.8	0.003
10_23	737688	0.001	785636.2	0.003	775569	0.002	814336	0.004	762286	0.002	829170.3	0.003
10_24	533087	0.001	630224.2	0.003	518419	0.003	518419	0.005	518419	0.002	591052	0.004
10_25	696834	0.002	747864.8	0.003	696834	0.003	749228.3	0.003	707483	0.001	766789.3	0.002
10_26	695210	0.001	710285	0.003	673076	0.003	696968.9	0.005	702321	0.001	728761	0.003
10_27	916597	0.001	995987.3	0.002	863780	0.002	897803.4	0.003	883039	0.001	931373.5	0.003
10_28	1001120	0.001	1028137.4	0.002	996114	0.002	1015372.4	0.004	1019699	0.001	1078657.4	0.002
10_29	633351	0.002	645787.1	0.003	630719	0.003	646372.6	0.004	647253	0.002	672071.3	0.003
10_30	748528	0.001	826836.8	0.003	710663	0.003	732645.6	0.004	730786	0.002	851230.7	0.002
10_31	871668	0.002	964903.8	0.003	866449	0.003	929087.8	0.006	885851	0.002	986110.3	0.003
10_32	944577	0.001	995104.9	0.002	891422	0.003	972557.5	0.004	940603	0.002	1024351.7	0.003
10_33	928276	0.002	965519.5	0.003	923800	0.003	934509.9	0.004	934362	0.002	977287.7	0.003
10_34	838696	0.001	877006.7	0.003	784263	0.003	834176.4	0.005	826029	0.001	876595	0.003
10_35	830850	0.002	893325.5	0.002	828550	0.003	845107	0.003	830850	0.002	880659.6	0.003
10_36	850471	0.002	913072.1	0.003	826494	0.003	855064	0.004	861047	0.002	901291.6	0.004
10_37	546715	0.001	617392.7	0.003	545452	0.003	547770.4	0.004	546715	0.001	624081	0.003
10_38	650149	0.002	703705.3	0.003	650149	0.002	671513.7	0.004	665879	0.001	716243.3	0.003
10_39	862139	0.002	937326.1	0.003	836311	0.003	844940.3	0.005	877740	0.003	928380.4	0.004
10_40	1083735	0.001	1142032.1	0.002	963155	0.002	971718.4	0.003	1001825	0.001	1077561	0.002
10_41	927615	0.002	993098	0.003	918988	0.003	967633.8	0.005	927466	0.002	981112.7	0.003
10_42	826904	0.001	890238.7	0.003	826904	0.003	867900.5	0.004	826904	0.001	894525.9	0.003
10_43	878311	0.001	946083.4	0.003	876788	0.003	921393.8	0.004	877496	0.001	974877.7	0.003
10_44	847968	0.001	876509.6	0.003	805367	0.003	825365.8	0.004	827491	0.002	867998.9	0.003
10_45	1033311	0.001	1118202.8	0.002	1047014	0.002	1079097.7	0.003	1072177	0.001	1153542.9	0.002
10_46	820865	0.001	852138.2	0.002	798872	0.003	820054.8	0.003	809692	0.001	864366.5	0.002
10_47	827838	0.002	865109.3	0.003	816733	0.003	816733	0.005	816733	0.003	853577.8	0.005
10_48	654686	0.001	707626.3	0.002	654464	0.002	663370.9	0.003	655341	0.002	715493.4	0.002
10_49	903941	0.001	939483.1	0.002	864020	0.002	882819.2	0.003	896187	0.002	953307.7	0.002

Table 38: Instances with 10 nodes and Eccentric Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
10_0	839991	0.001	969537.6	0.002	839991	0.002	866156.2	0.003	846264	0.001	890962.2	0.003
10_1	903650	0.001	969336	0.002	874311	0.002	882028.5	0.003	885945	0.002	945691	0.003
10_2	874309	0.001	918048.2	0.002	843915	0.002	858040.7	0.003	843915	0.002	909320.4	0.003
10_3	1118892	0.002	1188112.6	0.003	1060094	0.003	1077013.6	0.005	1078857	0.003	1118956.6	0.004
10_4	873693	0.002	885471.4	0.004	857538	0.003	898753.3	0.005	857215	0.003	909238.2	0.005
10_5	1024592	0.001	1067543.8	0.002	950671	0.002	1024181	0.003	1003117	0.001	1071073.5	0.002
10_6	885025	0.002	953110.3	0.002	871953	0.002	935091.3	0.003	872477	0.001	950733.6	0.003
10_7	1174327	0.002	1227099.7	0.003	1125485	0.003	1188773.8	0.004	1154150	0.002	1206401.5	0.004
10_8	970301	0.002	1002214	0.003	969140	0.002	1005631.7	0.003	969140	0.001	1019489	0.003
10_9	1032404	0.001	1093485.6	0.002	1030144	0.003	1087098.2	0.004	1032404	0.002	1066140.1	0.003
10_10	958232	0.001	1004268.9	0.002	958232	0.002	995386.7	0.003	975820	0.001	1022152.2	0.002
10_11	935756	0.001	1027383.4	0.002	878007	0.002	951751.6	0.003	878007	0.002	963136.5	0.003
10_12	759113	0.003	804914	0.004	756079	0.003	787981.7	0.004	756079	0.002	792471.4	0.004
10_13	754023	0.003	776622.6	0.005	747152	0.003	786615.9	0.005	761510	0.003	812557.3	0.006
10_14	903130	0.002	1036612.8	0.003	899106	0.002	927361.5	0.004	906266	0.003	937842.7	0.004
10_15	870479	0.001	893827.1	0.003	870479	0.002	909142.2	0.003	886143	0.001	945404.7	0.002
10_16	810435	0.001	830635.7	0.002	808019	0.002	808019	0.003	808071	0.001	843456.1	0.002
10_17	1075013	0.001	1188081.5	0.002	1075013	0.002	1183096.4	0.003	1076873	0.001	1164943.2	0.002
10_18	929376	0.001	991001.2	0.001	927281	0.001	939739.6	0.002	929183	0.001	991239.8	0.002
10_19	978199	0.002	1018246.5	0.003	967449	0.002	985057.2	0.004	970801	0.003	1035650.5	0.004
10_20	1031228	0.001	1166528.6	0.003	1027223	0.003	1070720.6	0.004	1031228	0.001	1164379	0.003
10_21	837318	0.002	899527	0.004	837100	0.003	851793	0.003	837100	0.001	847613.5	0.003
10_22	868370	0.002	909377.1	0.003	817234	0.003	828543.9	0.004	818901	0.002	895216.3	0.003
10_23	941423	0.001	968333.9	0.003	941423	0.003	955193.5	0.004	955263	0.002	998914.8	0.003
10_24	721704	0.001	766188.3	0.003	718415	0.002	737083.4	0.004	753869	0.002	786809.4	0.004
10_25	988124	0.001	1019753.4	0.003	981300	0.003	1002743	0.004	993082	0.002	1044784.2	0.003
10_26	776495	0.003	836501.7	0.004	763815	0.003	785131.8	0.005	784111	0.002	827546.5	0.004
10_27	869252	0.001	908686.1	0.002	868855	0.003	868855	0.004	869252	0.002	923333.5	0.002
10_28	1012108	0.002	1037877.5	0.002	1012108	0.003	1034287.4	0.004	1023023	0.001	1135653.4	0.003
10_29	804657	0.002	844915.3	0.003	802025	0.002	861599.8	0.003	802025	0.002	854949.5	0.003
10_30	1036971	0.001	1066041.8	0.002	1028667	0.002	1031480.8	0.004	1035270	0.001	1115751.8	0.002
10_31	942404	0.002	970156.9	0.003	896235	0.002	897772.2	0.003	896235	0.001	912446.5	0.003
10_32	957708	0.002	972423.1	0.003	909529	0.002	981690.5	0.003	909529	0.001	932680.4	0.002
10_33	1087260	0.001	1146389.5	0.004	1089823	0.003	1166711.8	0.004	1117040	0.001	1156139	0.003
10_34	985926	0.002	1102990.6	0.003	985926	0.002	1016710.5	0.003	985926	0.002	1111379.7	0.004
10_35	958848	0.001	1112267.6	0.002	956548	0.002	975421.3	0.003	959609	0.001	1108316.9	0.002
10_36	1065855	0.001	1117350.8	0.002	971414	0.002	1055017.8	0.003	999920	0.003	1046499.9	0.003
10_37	930894	0.001	1017154.1	0.002	925384	0.002	973686.1	0.003	952729	0.002	1004836.7	0.003
10_38	770001	0.002	806837.1	0.003	766544	0.003	786294.4	0.004	766544	0.001	840468.4	0.003
10_39	1063972	0.001	1238832.6	0.002	1050158	0.002	1115797.1	0.003	1050281	0.002	1206468.1	0.003
10_40	962867	0.001	1102151.4	0.002	962844	0.002	1014290.7	0.004	962844	0.001	1045445.9	0.003
10_41	963787	0.001	1034708.8	0.003	951783	0.003	973320.6	0.005	1006737	0.002	1053977.6	0.004
10_42	980803	0.002	1027669.7	0.003	950609	0.002	977468.9	0.003	980803	0.001	1057692.2	0.002
10_43	988112	0.002	1022732.9	0.003	967400	0.003	984167.2	0.004	987062	0.001	1048794.8	0.002
10_44	949511	0.001	1038524.7	0.002	929986	0.001	995050.2	0.003	929986	0.002	977510	0.003
10_45	1175248	0.002	1324539.4	0.002	1136682	0.002	1191217	0.003	1188591	0.002	1245403.3	0.003
10_46	953506	0.001	1031531.9	0.002	919244	0.002	950350.6	0.003	956935	0.002	1027989.5	0.002
10_47	842977	0.001	877149.1	0.003	843326	0.002	861239.1	0.003	842965	0.002	868928.6	0.003
10_48	808937	0.001	901571.2	0.002	771828	0.003	812440	0.003	773489	0.001	844118.8	0.002
10_49	890516	0.002	964381.8	0.003	887654	0.002	912486	0.003	887654	0.002	1000590.9	0.003

Table 39: Instances with 10 nodes and Random Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
10_0	826256	0.002	909667.1	0.002	794823	0.003	865569.2	0.004	814041	0.001	890882	0.003
10_1	683977	0.001	739160.8	0.002	680010	0.002	698063.2	0.004	698690	0.002	770969.1	0.002
10_2	781429	0.001	846380.6	0.003	751863	0.003	780572.4	0.004	742608	0.001	832018.6	0.003
10_3	885832	0.002	894090.3	0.003	881128	0.003	890551.4	0.004	912415	0.001	928790.9	0.002
10_4	705739	0.001	736394.9	0.003	701984	0.002	732383.7	0.004	705739	0.001	717300	0.004
10_5	809128	0.001	901316.7	0.003	803685	0.003	869042.9	0.004	868664	0.002	908626.3	0.003
10_6	683021	0.001	740821.5	0.002	673230	0.002	678739.8	0.004	706376	0.001	744627.4	0.002
10_7	967124	0.002	996916.7	0.003	918282	0.003	960875	0.005	918282	0.002	989183.7	0.004
10_8	841743	0.001	911854.9	0.002	837322	0.002	854716.4	0.003	932457	0.001	1004886.7	0.002
10_9	1028403	0.001	1103865.3	0.002	1021504	0.003	1069067.9	0.003	1028403	0.001	1083262.9	0.003
10_10	935788	0.001	987177.3	0.002	938136	0.002	1008071.8	0.003	953514	0.001	1031538.5	0.002
10_11	805821	0.002	857100.2	0.003	784383	0.002	861858.5	0.003	810817	0.002	872715.3	0.003
10_12	562829	0.002	594245.3	0.003	570517	0.002	577282.2	0.004	540404	0.003	564432.4	0.003
10_13	669009	0.002	681506.5	0.005	639334	0.004	658496.4	0.005	639334	0.003	656453.9	0.007
10_14	774954	0.002	803580.1	0.002	774520	0.003	821593.8	0.004	774656	0.002	800048.9	0.004
10_15	924839	0.001	976038.1	0.002	882251	0.002	893174.8	0.003	922020	0.002	1027782.2	0.002
10_16	925246	0.001	984973.5	0.002	922521	0.002	971593.1	0.003	922830	0.001	1022923.3	0.002
10_17	1034408	0.001	1097211.4	0.001	1034408	0.002	1075641.4	0.003	1075530	0.001	1184531.3	0.001
10_18	840325	0.001	888940.5	0.002	840325	0.002	854709.8	0.003	840499	0.001	900364	0.002
10_19	953016	0.001	979685.5	0.003	903482	0.003	919811.4	0.006	946611	0.002	975535.6	0.003
10_20	908732	0.001	1042953.3	0.002	904727	0.003	941686.9	0.004	904727	0.001	996691.2	0.003
10_21	726582	0.002	791077.5	0.003	715031	0.001	720898.1	0.003	715031	0.001	743616.1	0.004
10_22	735261	0.002	783140.2	0.002	691376	0.003	721922.1	0.004	731354	0.003	766435.2	0.004
10_23	786060	0.001	845380.1	0.002	771191	0.003	820878.5	0.004	785095	0.001	828607.6	0.004
10_24	680513	0.002	735834	0.003	664476	0.002	664476	0.003	666519	0.002	742616.6	0.003
10_25	719458	0.001	740943	0.003	719458	0.002	737048.9	0.003	727068	0.001	751961.7	0.002
10_26	722566	0.002	765048.9	0.004	706539	0.005	764570.1	0.006	724774	0.002	755897.6	0.003
10_27	893209	0.001	922450.5	0.002	886632	0.002	919746.6	0.003	906657	0.001	974574.9	0.002
10_28	974651	0.001	1017564.2	0.002	969860	0.003	1088663.7	0.004	977947	0.001	1139689.7	0.002
10_29	701516	0.002	814744.6	0.003	681387	0.002	689501	0.004	707281	0.002	781715.5	0.003
10_30	992636	0.001	1100507	0.002	969941	0.003	972580	0.004	969941	0.001	1063549.2	0.003
10_31	867326	0.002	918825	0.003	812507	0.004	814556.6	0.005	858676	0.002	953572.6	0.003
10_32	927446	0.002	958403.9	0.003	877996	0.003	939436.9	0.003	932622	0.002	995414.3	0.003
10_33	922091	0.002	978216	0.003	917577	0.002	933148.4	0.004	934875	0.002	963867.8	0.003
10_34	913762	0.001	971269.6	0.003	893548	0.003	912025	0.004	876883	0.002	1007418.8	0.003
10_35	835849	0.001	897652.4	0.003	832788	0.002	848647.2	0.003	895377	0.002	928364.8	0.003
10_36	844031	0.002	956492.6	0.004	816899	0.003	855691.9	0.004	817169	0.002	895750.8	0.004
10_37	616693	0.001	656668.8	0.002	611860	0.002	624987.8	0.003	620530	0.001	682966.3	0.003
10_38	668402	0.001	717526.8	0.002	656677	0.003	656677	0.004	676202	0.001	709397.5	0.003
10_39	850488	0.002	950670.9	0.003	836797	0.003	855118.9	0.005	873201	0.003	929854.8	0.005
10_40	926003	0.001	1148295.3	0.002	916920	0.003	1050368.8	0.004	929278	0.001	1062950.7	0.002
10_41	914999	0.002	956962.4	0.003	902995	0.003	920639.2	0.004	935722	0.003	1014643.9	0.004
10_42	894359	0.001	1007666.4	0.002	894359	0.002	938768	0.003	926707	0.001	973511.7	0.002
10_43	866551	0.001	986357.4	0.002	866551	0.002	866551	0.003	868359	0.001	954606.4	0.002
10_44	784138	0.002	859060.5	0.003	767091	0.003	809508.5	0.004	767506	0.002	817406	0.003
10_45	1012713	0.001	1073578.1	0.002	983672	0.002	1021960.5	0.003	1023265	0.001	1082666.6	0.002
10_46	841909	0.001	951935.5	0.002	807763	0.002	813638	0.004	807763	0.001	890826.7	0.002
10_47	991891	0.002	1061890.5	0.003	991891	0.002	1018145	0.004	1006901	0.001	1040643.4	0.004
10_48	593639	0.002	626798.9	0.002	593639	0.002	602734	0.004	594516	0.001	623552.5	0.002
10_49	833243	0.001	922403.8	0.002	830381	0.002	852313.4	0.004	830381	0.002	916580.7	0.003

Table 40: Instances with 11 nodes and Central Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
11_0	926523	0.002	981218.4	0.003	894909	0.004	919357.9	0.005	915831	0.002	972223	0.003
11_1	954578	0.001	999196.9	0.002	895268	0.003	991656.8	0.003	943463	0.002	993698.4	0.003
11_2	952448	0.003	1030163	0.004	945392	0.004	945392	0.005	952213	0.003	1048580.5	0.005
11_3	841663	0.003	958670.3	0.004	832957	0.004	862093.2	0.007	855953	0.003	950808.4	0.005
11_4	678071	0.003	755344.7	0.004	622738	0.004	627385	0.006	622738	0.004	701552.7	0.006
11_5	972887	0.001	1032547.3	0.002	944070	0.003	975831.2	0.005	987563	0.002	1049701.7	0.003
11_6	1007181	0.004	1035393.1	0.006	1001525	0.005	1015940.7	0.008	1047089	0.003	1087971.2	0.005
11_7	808581	0.002	877155.8	0.003	796808	0.003	816889.2	0.006	841461	0.002	873561.7	0.003
11_8	1195424	0.001	1280960.8	0.002	1177088	0.003	1190921.3	0.004	1210650	0.002	1279166.8	0.002
11_9	947329	0.002	1070666.8	0.004	935997	0.004	965142.3	0.006	1056148	0.002	1114880.2	0.003
11_10	870742	0.003	949192.5	0.004	841634	0.005	873275.8	0.006	875831	0.003	919665.4	0.005
11_11	858596	0.003	913024.4	0.004	815549	0.005	857571.2	0.007	815549	0.003	888756.7	0.006
11_12	756184	0.003	795289.7	0.004	718590	0.004	755232.6	0.006	744934	0.003	797619	0.005
11_13	982145	0.003	1000399.8	0.004	966999	0.003	977171.8	0.006	990764	0.003	1074324.9	0.006
11_14	912245	0.002	954778	0.003	853141	0.004	887976.9	0.007	900431	0.002	963943.2	0.005
11_15	778485	0.002	831006.1	0.004	774656	0.005	779842	0.006	791285	0.002	821472.6	0.004
11_16	777476	0.002	862937.7	0.004	786698	0.003	794269.1	0.006	787775	0.003	851118.3	0.006
11_17	647167	0.002	692976.2	0.003	596445	0.002	666740.5	0.005	633641	0.002	727635.7	0.003
11_18	1058617	0.001	1124051.4	0.003	1051951	0.003	1116352.2	0.005	1132528	0.002	1200115.4	0.003
11_19	738303	0.004	839592.9	0.007	710835	0.007	764176.1	0.008	758267	0.003	847106	0.006
11_20	976901	0.002	1050268.6	0.003	954445	0.005	999839.6	0.006	1033792	0.002	1063835.7	0.003
11_21	1101419	0.002	1193889.3	0.003	1084552	0.004	1108004.9	0.006	1098853	0.003	1172840.4	0.004
11_22	839541	0.003	902744.9	0.004	836408	0.005	849049.7	0.006	847939	0.002	928251.5	0.005
11_23	788199	0.002	866386.6	0.004	786811	0.004	834794.9	0.006	823989	0.003	876386.4	0.005
11_24	862160	0.002	903860.8	0.003	850395	0.004	869420.5	0.006	862160	0.002	951286.7	0.003
11_25	806356	0.003	890378.2	0.005	837247	0.005	859117.6	0.007	831841	0.003	906433.4	0.005
11_26	738922	0.002	791894.6	0.004	733634	0.004	740360	0.005	748365	0.003	815187.9	0.005
11_27	731165	0.002	780402.8	0.005	731156	0.005	733426.4	0.006	732528	0.002	772056.4	0.006
11_28	957451	0.002	1026750.1	0.004	950529	0.004	986222.6	0.005	972514	0.003	1051226.1	0.004
11_29	893926	0.003	986497.7	0.005	892025	0.005	974028.1	0.006	904007	0.003	962112.5	0.007
11_30	684205	0.003	775697.3	0.004	655363	0.005	713174.2	0.007	657916	0.002	762607.7	0.005
11_31	752114	0.001	858112.8	0.003	710364	0.005	710364	0.006	801061	0.002	906805	0.003
11_32	671922	0.003	711448.3	0.004	620856	0.003	646494.9	0.006	650454	0.002	688384	0.005
11_33	673643	0.003	761517.8	0.006	668646	0.005	692294.6	0.009	672034	0.003	734153.3	0.006
11_34	931268	0.002	990132.5	0.003	923434	0.004	943793	0.006	999696	0.002	1059917.6	0.004
11_35	615066	0.004	728527	0.007	613869	0.005	630082.8	0.007	615066	0.005	681476.1	0.008
11_36	818665	0.003	931882	0.005	805299	0.003	896960.8	0.007	855216	0.002	982367.5	0.004
11_37	735714	0.003	844722.6	0.005	735359	0.004	796110.8	0.007	724956	0.003	836467.2	0.005
11_38	787806	0.002	849459.5	0.003	783780	0.002	836768.8	0.005	784104	0.002	890022	0.003
11_39	1016776	0.001	1108677.5	0.003	985485	0.004	1010472.9	0.006	986887	0.002	1093576.3	0.003
11_40	816767	0.002	869492.5	0.004	777223	0.003	812693.2	0.005	808893	0.002	897145.5	0.003
11_41	950520	0.003	1035664	0.005	935560	0.004	959581	0.007	950960	0.003	1008002.7	0.005
11_42	888372	0.003	926333.9	0.004	875315	0.005	893866.3	0.008	889312	0.003	946601.2	0.005
11_43	800174	0.004	815126.1	0.005	771394	0.004	771394	0.007	783732	0.005	845392.5	0.007
11_44	879032	0.002	915946.4	0.003	872871	0.003	915131.8	0.005	893302	0.002	984986.8	0.005
11_45	876293	0.002	889384.5	0.004	855215	0.004	855215	0.006	879138	0.003	943403.8	0.005
11_46	695857	0.002	750022.9	0.004	690887	0.003	725545.9	0.007	695857	0.002	750431.6	0.006
11_47	676455	0.005	714158.3	0.006	654949	0.004	678791.4	0.005	654949	0.002	672669.2	0.008
11_48	811329	0.002	903008.3	0.005	819595	0.004	842713.8	0.007	886239	0.002	948175.5	0.003
11_49	989781	0.003	1086862.9	0.003	989781	0.004	1038937.1	0.005	1014885	0.003	1068443.9	0.004

Table 41: Instances with 11 nodes and Eccentric Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
11_0	912352	0.002	990540.1	0.003	891275	0.003	899795	0.004	950399	0.003	1075614.2	0.004
11_1	1080564	0.001	1158416.7	0.003	1043006	0.002	1180038.3	0.004	1080564	0.002	1115869.2	0.003
11_2	1033704	0.001	1067296	0.004	986065	0.002	1069531.6	0.004	1039843	0.002	1092588.2	0.004
11_3	926160	0.002	1015977.9	0.004	880214	0.004	936826.8	0.007	880214	0.004	974225.8	0.005
11_4	915973	0.002	976677.2	0.006	847585	0.003	867216.3	0.007	870637	0.002	905910.1	0.007
11_5	999450	0.003	1038567.2	0.004	996058	0.004	1035708.8	0.005	999356	0.002	1077603.4	0.004
11_6	1020268	0.005	1056469.2	0.007	998474	0.006	1017067.1	0.007	1020612	0.005	1059349.4	0.008
11_7	771174	0.002	798895.3	0.003	772991	0.004	782965.6	0.005	776225	0.002	841159.9	0.004
11_8	1147968	0.002	1221949	0.003	1147968	0.003	1220164.3	0.005	1147968	0.002	1216358.2	0.003
11_9	964331	0.003	1017282.8	0.004	963336	0.004	963336	0.005	970505	0.003	1062973.8	0.005
11_10	893188	0.005	916061.4	0.007	881224	0.004	948904.1	0.006	914460	0.003	1000355.2	0.006
11_11	1056939	0.001	1155767.5	0.004	1020182	0.003	1092766.7	0.006	1020182	0.003	1114332.1	0.005
11_12	898238	0.003	928405.2	0.004	887007	0.004	916061.9	0.005	917987	0.003	968069.2	0.005
11_13	1004329	0.003	1026613.2	0.004	1004324	0.002	1045484.5	0.005	1024930	0.003	1079399.7	0.004
11_14	956779	0.002	995454.1	0.003	920383	0.005	944668.9	0.006	956779	0.002	1033372	0.005
11_15	875233	0.002	932327.3	0.004	867507	0.003	915645.5	0.005	875211	0.002	955538.2	0.004
11_16	922731	0.003	1019714.2	0.005	920046	0.004	940821.3	0.005	925688	0.003	988741.8	0.005
11_17	779368	0.002	842010.8	0.004	749253	0.003	786074.4	0.006	791696	0.003	855644	0.004
11_18	1057330	0.002	1112543.1	0.002	1044749	0.002	1109943.2	0.003	1064853	0.001	1129480.4	0.003
11_19	898724	0.003	994489.1	0.006	849438	0.004	913438.1	0.006	850762	0.002	916216.1	0.007
11_20	1016182	0.001	1074454.8	0.002	1011095	0.003	1087878.9	0.006	1029587	0.002	1122968.3	0.004
11_21	1174836	0.002	1318598.9	0.004	1140192	0.004	1221328.4	0.006	1204673	0.003	1277747	0.005
11_22	1152249	0.002	1191261.4	0.004	984920	0.003	1079842.4	0.005	996709	0.003	1151905.3	0.004
11_23	879065	0.002	983307.5	0.004	857981	0.004	891976.5	0.005	908299	0.004	941237.5	0.005
11_24	1001758	0.002	1109275.2	0.004	1001590	0.004	1064822.9	0.006	1038114	0.002	1140904.5	0.005
11_25	893660	0.003	1017741.7	0.004	906440	0.003	951847.3	0.005	917335	0.003	987371.5	0.006
11_26	804673	0.002	941635.2	0.003	787202	0.003	819075.5	0.006	795230	0.003	860764.5	0.006
11_27	1032179	0.004	1114033.3	0.007	1010356	0.003	1026480.7	0.006	1011947	0.003	1047461.1	0.006
11_28	923835	0.002	976898.1	0.003	923615	0.003	958518.8	0.004	923615	0.002	985931.2	0.004
11_29	971168	0.003	1062596.3	0.005	963729	0.004	1004348.4	0.007	971168	0.003	1011649.3	0.006
11_30	779159	0.002	862558.2	0.004	750317	0.004	769379.4	0.006	821572	0.002	884032.9	0.004
11_31	936648	0.001	1063009.6	0.003	861302	0.003	1000036.9	0.005	911492	0.002	1041545.5	0.004
11_32	879328	0.003	928599.6	0.004	878941	0.004	926320	0.006	880804	0.003	973034.5	0.005
11_33	772240	0.005	811900.8	0.006	773958	0.004	783800.6	0.008	776108	0.004	832479.6	0.006
11_34	1094338	0.002	1178911	0.004	1075631	0.004	1138504.4	0.005	1117298	0.002	1190843.2	0.005
11_35	866084	0.003	973900.1	0.005	856880	0.005	927083.2	0.007	866803	0.003	935284.4	0.006
11_36	993708	0.003	1057100.4	0.005	980342	0.002	1094453.2	0.005	1000945	0.002	1060627.7	0.005
11_37	830510	0.003	894106.6	0.006	830187	0.004	864543.5	0.009	830626	0.003	891187.5	0.006
11_38	899322	0.002	989139	0.003	903433	0.003	974933.2	0.004	937454	0.003	1000274.8	0.005
11_39	1032983	0.001	1068982.3	0.003	1005524	0.002	1036847.1	0.005	1035414	0.001	1120636.1	0.002
11_40	833979	0.003	850458.2	0.004	813135	0.004	882920	0.006	822948	0.002	892855	0.004
11_41	925683	0.003	963055.6	0.005	924153	0.004	924582.6	0.006	924153	0.003	964478.5	0.004
11_42	925123	0.002	960548.8	0.004	925123	0.003	959850	0.005	925123	0.003	969420.6	0.005
11_43	861952	0.002	913420.7	0.004	861952	0.004	861952	0.006	877200	0.005	895958.6	0.007
11_44	899102	0.002	923305	0.004	897542	0.004	939904.1	0.006	897568	0.002	966404.1	0.003
11_45	1107162	0.003	1189718.4	0.004	1106538	0.004	1173202.1	0.006	1148732	0.002	1211517.1	0.004
11_46	818511	0.003	891032.1	0.005	813541	0.004	882943.8	0.006	818511	0.003	908489.1	0.005
11_47	774418	0.004	859575.9	0.006	774418	0.004	780950.8	0.006	774418	0.003	799172.1	0.007
11_48	924920	0.003	969726.9	0.004	924920	0.002	995597.6	0.005	924920	0.003	977686.9	0.004
11_49	1089286	0.001	1169635	0.004	1088296	0.003	1134395	0.006	1089286	0.002	1107374.6	0.006

Table 42: Instances with 11 nodes and Random Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
11_0	978955	0.001	1003687.7	0.003	958033	0.003	966799.3	0.005	981902	0.002	1057058.9	0.003
11_1	1045194	0.001	1098771.5	0.002	1032899	0.003	1109925.3	0.005	1045194	0.001	1100468.7	0.003
11_2	999483	0.002	1059665.3	0.005	931276	0.004	1044356.8	0.005	933844	0.003	1015533.2	0.005
11_3	848566	0.002	944655.8	0.003	839860	0.003	970979.1	0.005	848566	0.002	946141.4	0.003
11_4	650497	0.003	678478.2	0.005	621242	0.004	642608.8	0.007	623158	0.003	680450.9	0.005
11_5	986939	0.002	1037312	0.002	958366	0.003	1013959.8	0.004	997325	0.002	1049208.5	0.003
11_6	1012259	0.003	1076404.7	0.005	977771	0.005	997965	0.006	1008403	0.003	1082544.7	0.006
11_7	769794	0.002	796323.8	0.003	761995	0.004	816275.7	0.005	789724	0.002	862679.4	0.004
11_8	1094470	0.001	1144278.7	0.003	1094470	0.003	1195752.1	0.004	1094470	0.002	1231004.2	0.003
11_9	953885	0.001	1161299	0.003	942553	0.004	942553	0.007	953764	0.002	1072157.4	0.004
11_10	860136	0.002	957089.3	0.004	845383	0.004	943260.3	0.007	852528	0.005	954536.6	0.007
11_11	832467	0.002	915395	0.004	813639	0.005	855736.3	0.007	814534	0.002	893464.7	0.006
11_12	831969	0.003	917935.9	0.005	831139	0.003	831139	0.005	899687	0.003	931620.4	0.006
11_13	1059421	0.003	1115665.5	0.004	1059050	0.004	1095311.2	0.006	1036332	0.002	1116537	0.004
11_14	883879	0.003	974688.8	0.004	882065	0.005	883839.5	0.007	883879	0.003	917185.2	0.004
11_15	936157	0.002	1003561.2	0.004	924262	0.003	958496.6	0.006	928091	0.002	1001266.2	0.005
11_16	861196	0.002	912711.5	0.004	857908	0.003	861749	0.005	857908	0.003	950995	0.005
11_17	688523	0.002	763625.9	0.004	681433	0.004	750331.5	0.005	738828	0.002	802738.3	0.004
11_18	1168477	0.002	1283043	0.003	1160376	0.003	1227385.8	0.005	1168477	0.002	1266646.2	0.004
11_19	719384	0.003	829540.4	0.007	719382	0.006	735178.8	0.008	729518	0.004	772957.1	0.007
11_20	1002280	0.002	1133275.5	0.003	983788	0.003	1028953.1	0.006	988875	0.002	1095081.8	0.003
11_21	1139055	0.001	1199259.5	0.004	1051129	0.004	1162364.3	0.005	1059028	0.003	1183046.6	0.005
11_22	745166	0.003	844542.4	0.004	745116	0.003	812664.9	0.005	745116	0.003	806547.6	0.003
11_23	843807	0.003	980519.3	0.005	793493	0.004	838058.6	0.007	793493	0.004	885117.7	0.007
11_24	834658	0.002	994115.5	0.003	824742	0.002	896318.6	0.004	846721	0.002	935450.7	0.004
11_25	874223	0.002	1017398.9	0.005	840374	0.004	893187.2	0.006	850124	0.004	923171.8	0.006
11_26	717558	0.003	800750.7	0.004	709530	0.003	725218.7	0.004	750323	0.002	805414.9	0.004
11_27	751228	0.003	794103.5	0.006	731641	0.004	733911.4	0.006	736372	0.005	769580	0.008
11_28	918167	0.002	1011122.3	0.004	905025	0.003	925715.2	0.005	913809	0.003	997866.7	0.004
11_29	834301	0.003	849070.7	0.004	821238	0.005	876998.9	0.006	828986	0.003	892407.2	0.006
11_30	871913	0.002	945346.5	0.005	831047	0.005	878196.3	0.006	885925	0.003	930857.1	0.006
11_31	837773	0.002	947085.3	0.003	802813	0.003	906956.7	0.005	855118	0.003	951533.8	0.004
11_32	669713	0.003	728002.5	0.005	619159	0.005	651865.7	0.007	680433	0.003	725193.5	0.005
11_33	745851	0.004	786093.1	0.006	735723	0.006	742013.3	0.008	737873	0.005	769610.5	0.007
11_34	895251	0.003	940947.1	0.003	893992	0.005	921391.2	0.006	920206	0.003	984596	0.005
11_35	668955	0.003	706471.2	0.006	667758	0.005	700701.8	0.007	670309	0.003	720656.4	0.006
11_36	840396	0.003	864569	0.004	787571	0.005	809674.3	0.006	844500	0.003	882977	0.004
11_37	735468	0.002	845846.5	0.003	742869	0.003	807153.7	0.005	724710	0.002	800984.4	0.004
11_38	841813	0.001	889019	0.002	837655	0.002	870744.8	0.003	899611	0.002	958324.1	0.002
11_39	1048814	0.001	1138241.5	0.003	1047120	0.003	1097165	0.005	1110201	0.002	1221268.6	0.003
11_40	721213	0.002	765556.6	0.003	721213	0.004	721213	0.005	741852	0.002	841916.2	0.004
11_41	924981	0.002	1009405	0.005	908234	0.005	908908	0.006	920078	0.003	983379.4	0.005
11_42	873017	0.003	957404.3	0.005	871205	0.005	894390.2	0.008	882554	0.003	939085.2	0.005
11_43	796689	0.002	813156.4	0.005	770268	0.005	783687	0.008	796282	0.004	827808.7	0.007
11_44	882031	0.002	942656.2	0.003	878431	0.004	893341.7	0.005	885564	0.002	950277.7	0.004
11_45	893661	0.003	1013449.4	0.004	872184	0.004	890236.2	0.006	879128	0.003	990223.8	0.004
11_46	762597	0.004	844994.9	0.006	757627	0.004	807252.5	0.006	757627	0.002	878772.3	0.005
11_47	618335	0.005	656817	0.006	620218	0.003	622643.8	0.005	617694	0.005	631450.5	0.007
11_48	933826	0.002	1048679	0.004	933794	0.004	989571.4	0.006	962282	0.003	985558.1	0.005
11_49	995895	0.002	1016547.6	0.003	959587	0.003	967257.6	0.005	1002150	0.002	1043769.1	0.004

Table 43: Instances with 16 nodes and Central Base Station position

	Swap – First Improvement				**Shift – First Improvement**				**Swap21 – First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
16_0	1079076	0.009	1200558.7	0.015	1064036	0.015	1126705.7	0.023	1091694	0.009	1170962.1	0.017
16_1	1143598	0.022	1210133	0.035	1043050	0.022	1080691.8	0.035	1080614	0.022	1193690.9	0.032
16_2	1080460	0.016	1199624.9	0.021	1039727	0.017	1073748.9	0.023	1076182	0.016	1170525.2	0.024
16_3	1029156	0.015	1189808.2	0.020	995386	0.013	1115806	0.022	1046713	0.014	1186366.9	0.020
16_4	1059938	0.010	1156283	0.015	1008063	0.016	1100596	0.019	1028087	0.008	1176147.3	0.015
16_5	1177623	0.008	1319447.9	0.013	1148891	0.013	1213715.2	0.019	1189287	0.011	1300892.8	0.018
16_6	1092522	0.012	1216312	0.020	1099342	0.008	1184190	0.020	1117600	0.012	1200590.4	0.017
16_7	889272	0.014	956722	0.021	885427	0.012	983168.6	0.023	917057	0.012	996543.3	0.019
16_8	1091678	0.009	1243772.3	0.014	1023035	0.016	1121467.4	0.021	1101237	0.011	1210302	0.019
16_9	948394	0.014	1086016.6	0.022	940622	0.017	1001173.9	0.021	903782	0.014	987475.7	0.020
16_10	1097235	0.015	1263543.3	0.023	1075901	0.017	1171954.4	0.024	1101894	0.016	1194359.6	0.026
16_11	1203781	0.012	1276923.3	0.016	1167026	0.014	1228364.8	0.020	1226346	0.010	1315137	0.015
16_12	1104845	0.011	1229475.3	0.014	1043450	0.012	1089793.1	0.017	1053915	0.008	1175067.5	0.014
16_13	634462	0.017	772615.4	0.026	604965	0.015	681460.4	0.022	642408	0.014	720596.8	0.022
16_14	1021626	0.012	1195216.2	0.019	1047212	0.015	1157893.4	0.022	1080176	0.011	1182207.4	0.019
16_15	864835	0.011	938376.3	0.019	820988	0.011	898697.3	0.020	864763	0.012	952312.8	0.021
16_16	1179637	0.006	1341596.9	0.014	1229788	0.018	1307870.6	0.022	1232413	0.008	1351957.2	0.016
16_17	1067862	0.013	1136363.3	0.019	1052642	0.014	1151979.8	0.020	1029969	0.010	1189567.1	0.020
16_18	941216	0.015	1076036.3	0.021	918428	0.012	946778.9	0.020	950631	0.013	1010743.7	0.020
16_19	1260986	0.008	1347852.3	0.018	1206650	0.014	1276372.7	0.022	1204487	0.014	1307641.9	0.019
16_20	870430	0.014	992008.5	0.020	860629	0.015	960862.8	0.021	916726	0.015	1005052.9	0.023
16_21	1057205	0.009	1180540.8	0.014	1054978	0.011	1161636.4	0.016	1092101	0.009	1201879	0.016
16_22	1009039	0.010	1116255.6	0.016	984602	0.011	1076353.6	0.020	1057417	0.008	1126387.6	0.017
16_23	927599	0.008	1060280.5	0.015	850694	0.015	945067.7	0.019	916817	0.008	1032708	0.018
16_24	1125471	0.009	1221499	0.014	1041237	0.013	1121406.3	0.021	1059208	0.007	1153178.6	0.014
16_25	948888	0.008	1150978.9	0.015	1022558	0.013	1107368.7	0.017	1008802	0.011	1092430.2	0.017
16_26	1031232	0.010	1111080.7	0.019	975157	0.013	1034226.3	0.020	967850	0.013	1061430.5	0.019
16_27	1040733	0.015	1138341.8	0.020	946986	0.010	1062299.7	0.020	977239	0.015	1167536.7	0.020
16_28	1100136	0.012	1215440.8	0.017	1018955	0.013	1057459.8	0.022	1050263	0.010	1161355.2	0.021
16_29	1143301	0.007	1222607.1	0.017	1125777	0.014	1200206.7	0.018	1187079	0.010	1243274.1	0.017
16_30	977816	0.010	1088685.9	0.016	854455	0.012	886068.6	0.021	845006	0.010	995308.8	0.017
16_31	887717	0.009	1035659.2	0.018	846875	0.011	935094.1	0.023	877959	0.010	1000709	0.022
16_32	1164969	0.015	1242340.1	0.020	1062946	0.015	1154544.2	0.027	1115639	0.019	1187603.9	0.030
16_33	962558	0.011	1101808.3	0.017	960927	0.015	999740.7	0.020	997897	0.013	1050282.8	0.019
16_34	1292853	0.009	1407775.7	0.014	1294230	0.016	1389180.1	0.020	1318487	0.009	1426100.3	0.018
16_35	839083	0.012	952983.2	0.026	839054	0.016	975788.8	0.022	926508	0.010	1009355.1	0.019
16_36	1022113	0.014	1140357.5	0.021	1015087	0.012	1095582.6	0.023	1075898	0.013	1192151.2	0.021
16_37	1004869	0.014	1174168.3	0.019	1000438	0.015	1123478.8	0.021	990102	0.013	1117942.8	0.020
16_38	1101455	0.010	1311832.5	0.018	1058724	0.011	1103755.1	0.018	1074958	0.015	1182461.7	0.022
16_39	915493	0.010	1015437.1	0.019	881557	0.013	1035941	0.018	933883	0.007	1095815.5	0.016
16_40	1176961	0.011	1272115.8	0.020	1082878	0.016	1185955.6	0.021	1146560	0.015	1202190.7	0.022
16_41	1248585	0.007	1341132.5	0.010	1220535	0.014	1308061.1	0.017	1287535	0.009	1366786.5	0.013
16_42	929165	0.011	1040772.4	0.016	913454	0.015	974979.3	0.020	979904	0.007	1074124.7	0.016
16_43	1057158	0.009	1198362	0.015	1058158	0.015	1127395.1	0.020	1103199	0.008	1181162	0.017
16_44	1083427	0.012	1195907.7	0.018	1072013	0.014	1163635.4	0.022	1101216	0.010	1212485.4	0.019
16_45	900110	0.010	1020586.6	0.017	866208	0.012	920751.8	0.019	896532	0.013	1025955.8	0.021
16_46	1093687	0.008	1196830.2	0.016	891514	0.011	999449.5	0.016	970798	0.010	1065530.6	0.015
16_47	1022102	0.020	1150269	0.024	1005237	0.014	1070526	0.024	1018794	0.014	1085389	0.028
16_48	906328	0.009	1082551.1	0.014	938889	0.014	1026688.1	0.019	937947	0.011	1070366.4	0.018
16_49	1174310	0.007	1325056.6	0.015	1101336	0.013	1167020.1	0.020	1139520	0.012	1218543.1	0.018

Table 44: Instances with 16 nodes and Eccentric Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
16_0	1114108	0.008	1267860.9	0.013	1114108	0.015	1226126.7	0.022	1152262	0.011	1219773.2	0.018
16_1	1196003	0.017	1349962.6	0.029	1144630	0.013	1178018	0.025	1218715	0.013	1357854.2	0.027
16_2	1315084	0.012	1472623.8	0.019	1194988	0.012	1281023.4	0.018	1196148	0.013	1320481.1	0.021
16_3	1157322	0.012	1337335	0.021	1003142	0.013	1168519.6	0.021	1069207	0.014	1184940.1	0.022
16_4	1050053	0.009	1289132.8	0.016	1114789	0.010	1203980.6	0.015	1080644	0.009	1252743.3	0.017
16_5	1170296	0.008	1391506.9	0.014	1143048	0.013	1270316.5	0.018	1248535	0.012	1371883.2	0.016
16_6	1108261	0.013	1285699.6	0.019	1073974	0.014	1217750.3	0.020	1111641	0.015	1227721.6	0.019
16_7	1209392	0.014	1326233.3	0.022	1147845	0.016	1216161.8	0.021	1170723	0.016	1336280.8	0.022
16_8	1223977	0.007	1365453.9	0.014	1082035	0.015	1162009.3	0.019	1118792	0.013	1273683.9	0.017
16_9	1083482	0.017	1193999	0.024	1061696	0.010	1160929	0.017	1055931	0.009	1082381.2	0.018
16_10	1101175	0.014	1308745.6	0.023	1087983	0.013	1230010.7	0.024	1109436	0.011	1270575.9	0.021
16_11	1236866	0.010	1339498.9	0.015	1188106	0.016	1259179.9	0.020	1252225	0.010	1338191.7	0.017
16_12	1162969	0.010	1316251.1	0.014	1150120	0.011	1287730.3	0.014	1181812	0.009	1265638.5	0.017
16_13	932264	0.017	1066973.3	0.022	884689	0.018	890707.6	0.022	903372	0.026	963600.7	0.033
16_14	1147918	0.014	1282011.3	0.018	1074012	0.010	1235038.2	0.016	1074230	0.012	1306112.1	0.019
16_15	1095581	0.013	1181896.2	0.019	1051395	0.014	1101264.5	0.018	1124560	0.018	1228983.6	0.022
16_16	1239313	0.013	1389503.5	0.019	1204669	0.014	1375223.3	0.020	1258584	0.013	1353764.2	0.022
16_17	1089417	0.010	1185444.7	0.020	1038437	0.018	1161614.7	0.026	1109327	0.014	1197824.6	0.021
16_18	1050042	0.010	1151568.5	0.022	1021693	0.013	1054682.7	0.020	1038851	0.010	1108703.9	0.021
16_19	1221599	0.009	1359032.7	0.020	1190173	0.012	1310687.4	0.020	1262238	0.016	1326453.6	0.023
16_20	1049010	0.010	1156972.9	0.019	965449	0.016	999420.8	0.021	1006922	0.010	1175859.8	0.020
16_21	1187729	0.008	1403660.7	0.013	1261225	0.011	1403364.8	0.014	1225678	0.009	1407066.7	0.015
16_22	1086683	0.012	1324245.3	0.019	1074942	0.015	1204134	0.021	1091849	0.013	1273669.7	0.023
16_23	1022736	0.007	1218734.5	0.014	1067592	0.010	1187049.9	0.018	1007243	0.015	1114684.7	0.019
16_24	1117323	0.006	1239452	0.014	1051925	0.010	1204239.4	0.015	1127061	0.010	1240706.7	0.016
16_25	1039716	0.011	1242464.9	0.017	1026777	0.015	1216505.5	0.019	1054323	0.012	1153430.5	0.020
16_26	990784	0.012	1136137.9	0.023	989464	0.016	1072612.7	0.023	993383	0.018	1110231.5	0.029
16_27	948646	0.011	1276247.1	0.023	941190	0.014	1006968.7	0.019	981353	0.015	1131111	0.024
16_28	1103054	0.012	1199008.8	0.017	1075463	0.014	1171281.5	0.022	1135035	0.017	1190591.2	0.025
16_29	1054988	0.011	1160647	0.019	1038710	0.012	1228114.7	0.020	1063692	0.009	1190770.2	0.018
16_30	1083062	0.008	1241715	0.018	1064455	0.009	1162676	0.018	1051917	0.010	1157311.9	0.019
16_31	1175333	0.014	1290180.6	0.018	1018895	0.016	1132237.2	0.027	1113533	0.014	1209443.2	0.023
16_32	1209989	0.017	1328453.4	0.022	1058612	0.012	1131483.5	0.022	1058612	0.009	1178069	0.024
16_33	967552	0.011	1078758.1	0.018	1010336	0.010	1095439.8	0.017	1032393	0.011	1114119.7	0.015
16_34	1312660	0.009	1471651.9	0.015	1399547	0.014	1535873.7	0.020	1284081	0.010	1401704.4	0.018
16_35	1052091	0.014	1189934.5	0.022	1022334	0.013	1126410.8	0.018	949412	0.012	1056990.4	0.021
16_36	1226088	0.009	1322026	0.019	1118624	0.014	1222401.4	0.019	1205473	0.017	1260802.7	0.022
16_37	1062498	0.011	1248766.6	0.019	1069339	0.010	1163863.5	0.016	1093804	0.013	1208064	0.018
16_38	1139133	0.011	1255587.1	0.015	1079521	0.012	1226673.5	0.017	1116407	0.009	1222878.5	0.019
16_39	1168604	0.012	1245499	0.017	1178112	0.010	1233777.8	0.021	1068984	0.013	1219116.7	0.017
16_40	1225266	0.010	1287756.4	0.014	1114630	0.018	1214801.4	0.023	1088753	0.012	1232706.8	0.020
16_41	1283845	0.012	1395999.7	0.014	1225502	0.010	1305175.2	0.015	1226232	0.009	1320777.9	0.014
16_42	1131424	0.012	1231558.6	0.019	1096529	0.012	1180754	0.019	1119888	0.009	1214064	0.021
16_43	1260219	0.008	1370029.3	0.012	1190349	0.011	1309015.3	0.017	1233666	0.009	1321597.7	0.017
16_44	1045162	0.012	1257040.6	0.020	1040989	0.013	1068729.5	0.019	1116078	0.009	1282574.2	0.022
16_45	1128942	0.008	1287532.7	0.020	1044945	0.015	1157218.2	0.018	1065217	0.009	1227534.7	0.021
16_46	1308699	0.006	1361528.1	0.013	1095361	0.014	1214112.4	0.018	1121877	0.011	1298020.6	0.017
16_47	1050080	0.009	1225772.1	0.025	1045801	0.011	1096786.8	0.019	1064938	0.012	1170471.7	0.026
16_48	1129833	0.010	1331524.4	0.017	1063278	0.013	1229529.3	0.017	1053160	0.012	1203619	0.022
16_49	1254014	0.007	1336724.9	0.014	1179305	0.010	1263427	0.016	1194577	0.008	1278845.6	0.016

Table 45: Instances with 16 nodes and Random Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
16_0	1048213	0.011	1167246.2	0.016	1048213	0.013	1133309.5	0.024	1048213	0.012	1141166.6	0.020
16_1	1213227	0.014	1341529.2	0.025	1049729	0.017	1128806.2	0.039	1090370	0.020	1242147.1	0.031
16_2	1098041	0.013	1189183.9	0.019	981365	0.021	1061891.3	0.028	1011549	0.013	1215723	0.020
16_3	991718	0.012	1224836.1	0.018	969186	0.019	1149104.6	0.024	1142828	0.016	1205240.8	0.021
16_4	1132188	0.009	1365734.8	0.014	949898	0.011	1054818.7	0.019	1144626	0.010	1306816.1	0.016
16_5	1097347	0.009	1265308.2	0.014	1076950	0.017	1174564	0.020	1097900	0.008	1258349.7	0.013
16_6	1047887	0.012	1161569.1	0.018	1001465	0.014	1162110.5	0.019	1069762	0.011	1168716.1	0.017
16_7	927242	0.008	1081731.2	0.014	885746	0.021	953453	0.026	902215	0.017	1000722	0.021
16_8	1041070	0.011	1195130.3	0.017	1004588	0.017	1078005.7	0.020	1117234	0.009	1203792.3	0.016
16_9	1000108	0.015	1072697.2	0.022	966407	0.014	1095299.5	0.019	966728	0.016	1058242	0.027
16_10	1160228	0.007	1253740.3	0.018	1048948	0.016	1225224.3	0.021	1176468	0.011	1257490.2	0.024
16_11	1227259	0.013	1334454.6	0.016	1237397	0.015	1301665.1	0.019	1197816	0.016	1292857.4	0.021
16_12	1043541	0.008	1275210.9	0.014	1027170	0.013	1201733.2	0.016	1076511	0.009	1166272.9	0.017
16_13	601512	0.013	798306	0.021	608925	0.016	657390.1	0.022	604145	0.017	679054.4	0.028
16_14	1147327	0.008	1272426.6	0.015	1002144	0.010	1105046.8	0.019	1017451	0.014	1200603.3	0.019
16_15	857206	0.015	974173.5	0.024	864408	0.014	951523.1	0.020	873591	0.012	996022.5	0.019
16_16	1220747	0.007	1338273.5	0.012	1238915	0.011	1353167.7	0.016	1233409	0.016	1324732.6	0.019
16_17	1033599	0.016	1185524.1	0.022	985809	0.012	1113932.5	0.024	1031652	0.015	1112055.5	0.025
16_18	949137	0.013	1108170.9	0.024	935293	0.015	997574.8	0.020	989763	0.017	1066845.1	0.024
16_19	1258742	0.015	1361970.8	0.021	1227792	0.017	1276985.7	0.023	1188834	0.015	1319920.2	0.025
16_20	1071531	0.014	1157081.2	0.020	902959	0.015	1063762.9	0.021	984390	0.012	1144395	0.024
16_21	1153954	0.008	1332074.7	0.013	1127378	0.012	1243451.4	0.019	1150119	0.010	1274517.9	0.018
16_22	1041001	0.012	1116710.8	0.020	992726	0.015	1050480.8	0.018	1069242	0.013	1134409.9	0.023
16_23	899172	0.010	966722.4	0.018	811863	0.016	891459.4	0.019	906728	0.010	990944.8	0.021
16_24	1068986	0.009	1236958.8	0.014	1017075	0.015	1071246.5	0.018	1068986	0.014	1142403.9	0.021
16_25	983947	0.010	1122747.6	0.014	922093	0.013	1028034.6	0.020	939331	0.010	1112025.5	0.015
16_26	979750	0.017	1153833.7	0.024	942745	0.021	1029107.4	0.026	1002326	0.019	1119858	0.032
16_27	1202503	0.018	1324881.4	0.022	924920	0.014	1045747.6	0.018	951317	0.013	1151473.6	0.021
16_28	1048494	0.012	1148300.8	0.018	991968	0.013	1050845.1	0.023	1051482	0.018	1115374.3	0.024
16_29	1074616	0.012	1209654.9	0.018	1058138	0.011	1180657.7	0.016	1077450	0.011	1165832.5	0.018
16_30	912251	0.013	1116286.8	0.018	860685	0.016	1065227.8	0.019	888851	0.014	967867.7	0.019
16_31	894474	0.013	1020690	0.020	897350	0.016	978961.9	0.024	880811	0.013	961237.4	0.019
16_32	1127464	0.013	1213496.8	0.020	1067718	0.017	1111954.6	0.025	1047240	0.020	1152464.6	0.028
16_33	938771	0.013	1121788	0.017	935358	0.011	1030306.9	0.018	952369	0.015	1073691.5	0.020
16_34	1200086	0.010	1443867.2	0.015	1244627	0.012	1299516.5	0.019	1202847	0.012	1394982	0.018
16_35	887064	0.011	1011656.8	0.019	871426	0.016	991349.9	0.022	922494	0.010	1066016.2	0.021
16_36	1072080	0.007	1264657	0.017	1008284	0.014	1174800.5	0.020	1094483	0.011	1227348.2	0.018
16_37	1108480	0.013	1227816.7	0.017	1035249	0.017	1098104.6	0.021	1029182	0.014	1128011.1	0.020
16_38	1039254	0.012	1188182.3	0.019	979200	0.015	1077834.6	0.019	958042	0.015	1041518.3	0.023
16_39	943807	0.008	1079031.1	0.018	889127	0.015	1040770.9	0.022	897096	0.011	1035808.4	0.018
16_40	1163481	0.011	1301688.2	0.021	1026171	0.014	1113506.4	0.020	1051509	0.017	1232637.6	0.024
16_41	1156357	0.006	1338704.9	0.012	1115894	0.010	1264822	0.017	1236185	0.008	1324304.2	0.013
16_42	1032248	0.009	1101546.7	0.014	944646	0.010	1032412.8	0.017	944233	0.009	1069960.9	0.015
16_43	1093496	0.010	1211711.1	0.013	1069247	0.009	1147327.1	0.019	1113197	0.011	1154049.3	0.016
16_44	1041923	0.014	1267077.7	0.018	964791	0.014	1075046.4	0.019	1112425	0.008	1216683.8	0.017
16_45	1051466	0.013	1123389.1	0.019	924675	0.010	1060350.7	0.018	956318	0.015	1048520.3	0.023
16_46	977016	0.011	1102156.3	0.017	903920	0.011	1049623.4	0.016	863435	0.008	989687.1	0.013
16_47	1078269	0.018	1213223.4	0.027	1005485	0.017	1074717.3	0.023	978891	0.018	1163579.7	0.025
16_48	1065122	0.010	1198331.2	0.017	1054633	0.010	1139414.2	0.018	1086902	0.011	1185307.7	0.020
16_49	1210226	0.008	1313200.7	0.014	1099320	0.007	1213393.4	0.018	1139599	0.014	1238305.2	0.019

Table 46: Instances with 21 nodes and Central Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
21_0	1183351	0.036	1356132.2	0.047	1074140	0.030	1205645.6	0.053	1123240	0.048	1251406.2	0.075
21_1	1241783	0.025	1406876.3	0.073	1141241	0.044	1326881.5	0.071	1258993	0.057	1376052	0.077
21_2	1245136	0.029	1429264.7	0.063	1116652	0.032	1271722.3	0.059	1161786	0.032	1319275.9	0.058
21_3	1170155	0.029	1290612.3	0.043	1155228	0.030	1249416.3	0.051	1179816	0.025	1240078.3	0.047
21_4	1227227	0.052	1418715.3	0.066	1174774	0.037	1301720.5	0.060	1250706	0.043	1394304.3	0.062
21_5	1019770	0.042	1162265.9	0.063	1001527	0.045	1111063.4	0.058	1013560	0.038	1101841	0.066
21_6	1061798	0.029	1160391.1	0.070	955689	0.068	1045779.6	0.094	1012337	0.078	1085360.5	0.108
21_7	1149839	0.034	1310466.2	0.052	1107193	0.046	1218131.3	0.065	1107514	0.032	1247742.7	0.050
21_8	1190045	0.025	1425134.3	0.039	1207268	0.025	1405971.7	0.041	1357209	0.034	1438535.9	0.046
21_9	1166765	0.034	1392409.8	0.045	1095634	0.030	1227699.4	0.055	1123127	0.034	1309066.7	0.051
21_10	1202281	0.030	1421654.1	0.076	1090035	0.033	1196431.5	0.056	1202866	0.045	1322904.1	0.078
21_11	1150758	0.023	1323587.2	0.050	1146825	0.037	1237142.6	0.058	1194986	0.039	1320937.9	0.058
21_12	1331657	0.028	1561854.2	0.053	1337935	0.031	1400436.2	0.061	1273511	0.031	1393198.5	0.058
21_13	1073982	0.031	1329843.7	0.065	1049081	0.032	1121352.7	0.064	1109716	0.040	1183806.3	0.070
21_14	1117914	0.030	1232069.7	0.066	985355	0.032	1099247.1	0.059	1062763	0.035	1196956.5	0.056
21_15	1061449	0.025	1259496	0.045	1050498	0.033	1190422.3	0.046	1065808	0.026	1212001.6	0.046
21_16	1289645	0.024	1446858	0.056	1161153	0.039	1317070.5	0.078	1334592	0.037	1410280.5	0.051
21_17	1248673	0.028	1441230.6	0.064	1239455	0.037	1335161	0.061	1220749	0.052	1350801	0.073
21_18	1142499	0.028	1317663.1	0.051	1002525	0.035	1107706.5	0.052	1123080	0.022	1231656.8	0.050
21_19	1362497	0.037	1492877.3	0.055	1264248	0.043	1399635.2	0.063	1354288	0.039	1448172.5	0.057
21_20	1066685	0.038	1191159	0.058	936365	0.045	1045406.4	0.056	1005950	0.033	1093339.7	0.062
21_21	1235613	0.033	1388160.4	0.044	1199225	0.035	1264082.1	0.048	1217020	0.033	1359806.6	0.057
21_22	1245560	0.030	1410042.3	0.061	1115575	0.031	1239997.8	0.046	1165355	0.017	1396114	0.048
21_23	987365	0.042	1217272.2	0.061	1027218	0.021	1105729.6	0.037	1074238	0.038	1198362	0.060
21_24	1104410	0.028	1379910.3	0.048	1053396	0.033	1293674.9	0.047	1201647	0.041	1335299.5	0.061
21_25	1112551	0.022	1361485.5	0.038	1052374	0.030	1293343.9	0.045	1117261	0.022	1268385.6	0.048
21_26	1149863	0.048	1253680.1	0.080	1056706	0.039	1138917.1	0.063	1051680	0.054	1164258.6	0.079
21_27	1325164	0.033	1476265	0.042	1154677	0.040	1268770.1	0.054	1365859	0.030	1439733.4	0.053
21_28	1169735	0.025	1288509.4	0.049	1126608	0.028	1181524.2	0.049	1127890	0.036	1242120.1	0.055
21_29	1385787	0.029	1538598.2	0.049	1190304	0.037	1298845.4	0.058	1270665	0.034	1387855.6	0.072
21_30	1215662	0.025	1408146.6	0.041	1300521	0.032	1377450.1	0.055	1194327	0.029	1369343.8	0.053
21_31	1150671	0.046	1336474.5	0.069	1058701	0.033	1143003.1	0.047	1032423	0.023	1162272.8	0.054
21_32	1264034	0.036	1444661.3	0.050	1247822	0.028	1392893.4	0.057	1275315	0.036	1338002.3	0.058
21_33	1224092	0.042	1384240.7	0.071	1074192	0.040	1206248.6	0.079	1167948	0.048	1289991.2	0.071
21_34	1090987	0.034	1334610.6	0.065	1059635	0.036	1216239.4	0.063	1051484	0.065	1209981.4	0.095
21_35	1209970	0.034	1363231.5	0.050	1168037	0.039	1320613.8	0.060	1212492	0.041	1364410.3	0.069
21_36	1224895	0.023	1480097.8	0.052	1140832	0.032	1365680	0.043	1267174	0.034	1410965.3	0.055
21_37	1288208	0.032	1455983.3	0.051	1248791	0.037	1356093.7	0.056	1360656	0.022	1465955	0.050
21_38	1327221	0.055	1422726.8	0.083	1178383	0.042	1253970.1	0.056	1226057	0.047	1331065.9	0.091
21_39	1226774	0.038	1361777.8	0.061	1065992	0.026	1251629.4	0.054	1195576	0.039	1360514.5	0.058
21_40	1166866	0.033	1424984.7	0.054	1115297	0.040	1275735.2	0.050	1197409	0.033	1333470.2	0.064
21_41	1264908	0.040	1453735	0.056	1221390	0.034	1316181	0.052	1235293	0.048	1320756.5	0.069
21_42	1205859	0.034	1507116.4	0.049	1235838	0.044	1382603	0.060	1293886	0.035	1429584.4	0.071
21_43	1254279	0.027	1467065.2	0.038	1272838	0.035	1447407	0.046	1366391	0.025	1480235.3	0.041
21_44	1144170	0.042	1243244	0.057	908388	0.041	1100902.7	0.055	1026722	0.029	1134542.3	0.049
21_45	1226087	0.023	1454325.9	0.051	1197707	0.038	1347671.9	0.056	1251211	0.020	1358073.5	0.056
21_46	1089708	0.034	1246681.1	0.062	1074992	0.043	1181297	0.060	1052486	0.026	1124867.5	0.062
21_47	1504918	0.044	1621739.6	0.074	1310197	0.035	1463551.5	0.063	1372916	0.041	1457006	0.077
21_48	1089283	0.031	1357490.1	0.049	1060904	0.034	1140066.7	0.047	1088519	0.030	1181319	0.059
21_49	1398242	0.027	1567912.6	0.045	1203654	0.026	1401407.4	0.050	1335041	0.029	1487771.4	0.052

Table 47: Instances with 21 nodes and Eccentric Base Station position

	Swap − First Improvement				**Shift − First Improvement**				**Swap21 − First Improvement**			
	Min		**Avg**		**Min**		**Avg**		**Min**		**Avg**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**
21_0	1247202	0.031	1421934	0.046	1127359	0.033	1291531.3	0.050	1196858	0.039	1310585.7	0.061
21_1	1403089	0.029	1503075.5	0.049	1416044	0.030	1543413.9	0.044	1342257	0.043	1466887.8	0.062
21_2	1371194	0.017	1503839.7	0.043	1295109	0.030	1404479.1	0.051	1193861	0.038	1294060.3	0.062
21_3	1346854	0.024	1483008.2	0.041	1113891	0.033	1300349.2	0.045	1163637	0.029	1317246.4	0.053
21_4	1141566	0.034	1502588.7	0.055	1089715	0.037	1266848.6	0.064	1192482	0.032	1394303.1	0.074
21_5	1223559	0.041	1412237.4	0.059	1091315	0.029	1220422.2	0.050	1088960	0.034	1239360.5	0.063
21_6	1110916	0.050	1232557.6	0.080	1045927	0.044	1147776.5	0.068	1139287	0.044	1209685.8	0.090
21_7	1281958	0.028	1475096.6	0.045	1231873	0.035	1301651.8	0.050	1281093	0.039	1350148.5	0.063
21_8	1224950	0.025	1611913.8	0.042	1277503	0.039	1492355.2	0.051	1276888	0.030	1432272	0.057
21_9	1250014	0.020	1426850.7	0.040	1173846	0.035	1353392.4	0.046	1215343	0.017	1333465.9	0.061
21_10	1235828	0.036	1434912.8	0.065	1151603	0.040	1241704.1	0.061	1226773	0.032	1391638.3	0.069
21_11	1206080	0.023	1424350.5	0.050	1255993	0.029	1396890.7	0.051	1244176	0.033	1353133	0.059
21_12	1333238	0.020	1505348	0.051	1261148	0.038	1416533.9	0.050	1237321	0.034	1433445.3	0.061
21_13	1220907	0.024	1440863.6	0.054	1096471	0.026	1345553.4	0.045	1123089	0.044	1292849.7	0.060
21_14	1167967	0.056	1372378	0.073	1083337	0.030	1284517.4	0.053	1183832	0.052	1348307.5	0.082
21_15	1200508	0.034	1363637	0.050	1110648	0.032	1249991.2	0.045	1174171	0.043	1307371.8	0.059
21_16	1349326	0.032	1505854	0.059	1252755	0.041	1366217.2	0.059	1306161	0.021	1491732.1	0.063
21_17	1398487	0.035	1569719.1	0.064	1286484	0.050	1431464.4	0.068	1319935	0.034	1437101.6	0.074
21_18	1170821	0.030	1382726.9	0.053	1159210	0.026	1274307	0.044	1225310	0.040	1327280.6	0.071
21_19	1549580	0.035	1706847.4	0.051	1458242	0.037	1580820.7	0.052	1420789	0.041	1554112.3	0.071
21_20	1205364	0.035	1397039.6	0.058	1057944	0.031	1219095.1	0.052	1137080	0.029	1280741.9	0.063
21_21	1546168	0.030	1671232.3	0.052	1375829	0.037	1515176.4	0.054	1430429	0.040	1491315.4	0.062
21_22	1374593	0.017	1564084	0.047	1272837	0.015	1410060.9	0.054	1203227	0.040	1455677.2	0.067
21_23	1144344	0.042	1296947.8	0.056	1091971	0.025	1188168.8	0.043	1131647	0.023	1182126.8	0.052
21_24	1193113	0.022	1595310.1	0.048	1126232	0.034	1385274.2	0.051	1204481	0.029	1435996.4	0.055
21_25	1250770	0.025	1493471.6	0.034	1070644	0.026	1272052.3	0.037	1116623	0.023	1349196.7	0.039
21_26	1276511	0.029	1394024.1	0.067	1137714	0.035	1228407.1	0.056	1157100	0.037	1256082.4	0.065
21_27	1397964	0.030	1584161.2	0.054	1327455	0.032	1349563.9	0.056	1362996	0.052	1490288.4	0.071
21_28	1270956	0.029	1477441.8	0.054	1247641	0.037	1355511.4	0.057	1259702	0.052	1346152.1	0.071
21_29	1313875	0.022	1532598	0.055	1139311	0.031	1358769.1	0.044	1236741	0.034	1434714.1	0.062
21_30	1219425	0.035	1508111.6	0.049	1313770	0.028	1433689.3	0.044	1313159	0.035	1523583.3	0.061
21_31	1143326	0.022	1339693.7	0.055	1077377	0.032	1281051.3	0.045	1133602	0.028	1284302.1	0.048
21_32	1412260	0.044	1523487.9	0.063	1217750	0.034	1396206.4	0.048	1305076	0.033	1442953.1	0.060
21_33	1397019	0.038	1631364.3	0.071	1284956	0.039	1385039	0.064	1362520	0.042	1507202.3	0.068
21_34	1178211	0.042	1489034.1	0.065	1081616	0.031	1342845	0.046	1181804	0.028	1456810.2	0.056
21_35	1359504	0.045	1454269.7	0.059	1201885	0.039	1421662.1	0.054	1298833	0.031	1445880	0.060
21_36	1276815	0.037	1505576.7	0.050	1291588	0.033	1495974.8	0.050	1282677	0.030	1485990.7	0.055
21_37	1327219	0.026	1550573.6	0.051	1192164	0.028	1279282.1	0.047	1191646	0.043	1393221.4	0.072
21_38	1244314	0.040	1398332.3	0.061	1182625	0.032	1289108.5	0.048	1194042	0.028	1298302.6	0.057
21_39	1257224	0.038	1552609.1	0.061	1193976	0.040	1397659.1	0.050	1296089	0.043	1449577.9	0.064
21_40	1540310	0.022	1662333.9	0.042	1369152	0.037	1526411.4	0.054	1337640	0.032	1559564.1	0.081
21_41	1356443	0.030	1598205.4	0.061	1348558	0.029	1487867.6	0.051	1355813	0.028	1472158.4	0.056
21_42	1306901	0.035	1462162.9	0.048	1208599	0.026	1424387.9	0.054	1259798	0.031	1387334.2	0.053
21_43	1369630	0.023	1610137.8	0.043	1385248	0.035	1529581.3	0.044	1435442	0.033	1630499.8	0.049
21_44	1339149	0.038	1506848.8	0.062	1193082	0.036	1334272	0.057	1170489	0.036	1258520.7	0.088
21_45	1172343	0.026	1472090.9	0.048	1117177	0.031	1338126.9	0.053	1199962	0.038	1344735.9	0.051
21_46	1192022	0.030	1346337.1	0.054	1118750	0.033	1273047.7	0.057	1158812	0.027	1218859.6	0.047
21_47	1305956	0.039	1584681.3	0.060	1376550	0.036	1514534	0.056	1308459	0.058	1454776.4	0.083
21_48	1255241	0.033	1524284.6	0.045	1095177	0.028	1303765.3	0.039	1118970	0.039	1359022.9	0.060
21_49	1424325	0.019	1608901.9	0.040	1336164	0.031	1450951.3	0.046	1364435	0.033	1503704.9	0.048

Table 48: Instances with 21 nodes and Random Base Station position

	Swap − First Improvement				Shift − First Improvement				Swap21 − First Improvement			
	Min		Avg		Min		Avg		Min		Avg	
Inst.	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)	Sol	T (s)
21_0	1153687	0.032	1330720.7	0.047	986526	0.036	1190801.4	0.048	1079192	0.024	1250570.8	0.053
21_1	1321900	0.031	1412233.2	0.050	1120748	0.042	1279168.6	0.061	1038123	0.042	1314733.1	0.071
21_2	1352751	0.027	1533707.9	0.042	1118408	0.029	1303633.3	0.048	1118559	0.040	1313521	0.067
21_3	1179114	0.029	1368537.1	0.049	1146937	0.032	1286417.2	0.057	1150535	0.030	1281192.6	0.043
21_4	1128628	0.041	1419763.3	0.063	1058495	0.040	1271578.2	0.066	1101890	0.068	1313373.2	0.084
21_5	1250524	0.036	1386646.2	0.057	1003763	0.034	1130283.8	0.047	1050397	0.054	1140922.9	0.071
21_6	1077516	0.039	1227570.5	0.057	933028	0.048	1054802.1	0.081	1034500	0.065	1120480	0.093
21_7	1081217	0.022	1313333.3	0.045	1131470	0.050	1260950	0.064	1189799	0.034	1274355.2	0.068
21_8	1332042	0.019	1504463.1	0.032	1102090	0.034	1335866.7	0.046	1207533	0.034	1441847.4	0.052
21_9	1229026	0.021	1404553.3	0.036	1125932	0.028	1268996	0.042	1200905	0.018	1319294.4	0.045
21_10	1166114	0.036	1338586.3	0.070	1085801	0.039	1152493.4	0.059	1115434	0.049	1199311.8	0.068
21_11	1247408	0.025	1406126.5	0.048	1180032	0.027	1266404.1	0.044	1299770	0.041	1378038.2	0.066
21_12	1307499	0.027	1462833.2	0.056	1203223	0.044	1373950.5	0.055	1320622	0.038	1431529.4	0.063
21_13	1121545	0.035	1227217.9	0.050	978286	0.033	1154734	0.049	981126	0.035	1238636.1	0.065
21_14	1101162	0.037	1329865.5	0.066	933465	0.032	1076146.8	0.050	1074234	0.031	1179174.3	0.067
21_15	1075073	0.036	1301626.7	0.055	1000925	0.040	1179575.6	0.062	1008004	0.027	1125805.4	0.050
21_16	1281356	0.030	1529957.3	0.057	1129608	0.051	1295427.3	0.069	1297364	0.034	1446775.5	0.059
21_17	1253395	0.046	1342488.9	0.062	1152774	0.031	1287621.3	0.063	1192269	0.033	1313257.5	0.066
21_18	1172434	0.030	1344518.3	0.051	1010052	0.024	1139063.6	0.049	1087327	0.042	1220910.3	0.060
21_19	1431599	0.034	1564416.7	0.059	1289715	0.037	1467939.8	0.052	1367948	0.048	1464776.8	0.063
21_20	1008812	0.035	1265437.8	0.063	968676	0.035	1127951.7	0.058	913533	0.042	1125338.9	0.072
21_21	1398159	0.034	1512584.5	0.054	1250897	0.034	1378305.5	0.064	1244304	0.033	1400611.8	0.077
21_22	1263929	0.035	1471365.6	0.055	1097368	0.024	1327987.8	0.044	1228951	0.042	1363255.3	0.068
21_23	1094341	0.045	1262479.6	0.066	1015180	0.025	1126877.7	0.049	1029864	0.031	1159811.1	0.057
21_24	1363193	0.020	1502096.3	0.037	1038512	0.028	1199832.8	0.050	1049544	0.038	1292903.3	0.059
21_25	1243456	0.017	1444972.3	0.040	1162881	0.019	1363525.2	0.033	1185974	0.017	1355839.7	0.040
21_26	1158530	0.024	1355108.1	0.074	1089645	0.037	1212825.7	0.062	1043339	0.043	1219906.5	0.076
21_27	1385722	0.030	1525937.2	0.046	1269308	0.033	1398027	0.057	1342155	0.032	1472572.3	0.060
21_28	1293507	0.031	1415743.6	0.057	1199280	0.042	1335468.3	0.051	1332900	0.038	1398023.8	0.060
21_29	1363426	0.033	1563487.7	0.050	1106082	0.030	1272980.1	0.048	1283614	0.038	1448404.9	0.061
21_30	1234428	0.028	1417775.8	0.042	1160624	0.034	1279942.3	0.047	1172085	0.026	1361264.1	0.040
21_31	1075153	0.037	1246316.9	0.050	1069520	0.019	1167890.5	0.041	1069155	0.024	1170049.4	0.041
21_32	1219011	0.040	1503405.1	0.063	1247083	0.030	1486707.9	0.042	1236651	0.032	1421119.1	0.059
21_33	1153838	0.028	1384336.9	0.065	1068588	0.038	1209462.2	0.049	1206402	0.033	1343870.4	0.067
21_34	1049493	0.040	1285127.1	0.060	1020569	0.037	1202223	0.056	995964	0.023	1218196.4	0.058
21_35	1188248	0.040	1339071.8	0.062	1113058	0.038	1270878.1	0.054	1112533	0.043	1267344.3	0.053
21_36	1162349	0.037	1441396.8	0.056	1146701	0.034	1404794.1	0.044	1176904	0.047	1365650.6	0.061
21_37	1202015	0.024	1366060.5	0.037	1090075	0.032	1307958.5	0.051	1118959	0.019	1436345.6	0.041
21_38	1161400	0.058	1332265.4	0.077	1135840	0.038	1252508.4	0.062	1159886	0.074	1273476.7	0.098
21_39	1254652	0.035	1434176.5	0.063	1134939	0.031	1253565.4	0.045	1158769	0.041	1269109.8	0.068
21_40	1153417	0.040	1517889.5	0.063	1146991	0.034	1319443.1	0.046	1140432	0.036	1360403.8	0.057
21_41	1235333	0.022	1530322.9	0.053	1154498	0.044	1274166.5	0.053	1286857	0.020	1385208.5	0.055
21_42	1347325	0.030	1560024.9	0.048	1206431	0.055	1399808.2	0.066	1284948	0.041	1426285.2	0.061
21_43	1390386	0.028	1525281.2	0.036	1334549	0.035	1466561.3	0.046	1286705	0.034	1431055.8	0.051
21_44	1227298	0.025	1327346.2	0.048	960902	0.040	1114660	0.047	1031753	0.028	1120887.3	0.059
21_45	1162540	0.024	1460258.4	0.045	1157833	0.033	1362722.4	0.044	1133807	0.033	1256767.7	0.063
21_46	1111881	0.056	1174809.2	0.071	1051364	0.033	1135678.3	0.055	1078864	0.038	1151304.7	0.058
21_47	1579236	0.030	1674234.1	0.060	1260413	0.050	1467425.3	0.072	1381999	0.037	1493398	0.076
21_48	1099223	0.032	1336039.9	0.045	1039552	0.036	1223833.3	0.044	1039552	0.026	1233807.2	0.048
21_49	1379395	0.034	1594818.6	0.044	1284721	0.032	1453550	0.047	1380735	0.031	1552979	0.049

.1.3 Average GAP's

The Tables 49–51 shows the minimum and the average gaps of the local searches *Swap*, *Shift* and *Swap21*, both for them using Best and First Improvement, compared to the mathematical formulation solutions. In this tables the column # **Sen.** show the result grouped by the number os sensors. The column **Base Station** identify the base station position. The columns **MIN** and **AVG** represents the minimum and the average gaps of the solutions, respectively. The columns **T (s)** shows the time spend in seconds by each local search tested. The GAP are calculated by the equation $GAP = \frac{(f_{LS} - f_{Exact})}{f_{Exact}}$, where f_{LS} represents the solution found by the tested local search method and f_{Exact} represents the solution found by the exact method.The methods were executed 10 times for each instance.

Table 49: Swap – Average GAPs

		Best Improvement				First Improvement			
# Sen.	**Base Station**	**MIN**	**T (s)**	**AVG**	**T (s)**	**MIN**	**T (s)**	**AVG**	**T (s)**
6	**central**	0.33%	0.000	1.98%	0.000	0.97%	0.000	2.76%	0.000
	eccentric	0.27%	0.000	0.82%	0.000	0.58%	0.000	1.26%	0.000
	random	0.34%	0.000	1.78%	0.000	0.71%	0.000	2.59%	0.000
7	**central**	0.48%	0.000	2.96%	0.001	0.71%	0.000	3.52%	0.001
	eccentric	0.26%	0.000	2.14%	0.001	0.86%	0.000	2.50%	0.001
	random	0.71%	0.000	3.49%	0.001	0.92%	0.000	4.59%	0.001
8	**central**	0.72%	0.001	4.72%	0.001	1.56%	0.001	5.86%	0.001
	eccentric	0.15%	0.001	3.80%	0.001	1.02%	0.001	4.55%	0.001
	random	0.66%	0.001	4.37%	0.001	1.54%	0.001	5.07%	0.001
9	**central**	0.84%	0.001	6.35%	0.002	1.83%	0.001	7.85%	0.002
	eccentric	0.40%	0.001	4.48%	0.002	0.77%	0.001	6.14%	0.002
	random	1.05%	0.001	6.00%	0.002	1.59%	0.001	7.05%	0.002
10	**central**	1.26%	0.002	7.45%	0.003	2.12%	0.001	9.04%	0.003
	eccentric	1.20%	0.002	7.16%	0.003	1.93%	0.002	8.91%	0.003
	random	1.63%	0.002	7.88%	0.003	2.14%	0.001	9.98%	0.002
11	**central**	1.54%	0.003	8.76%	0.005	2.45%	0.002	10.88%	0.004
	eccentric	1.25%	0.003	9.06%	0.005	2.17%	0.002	9.52%	0.004
	random	1.62%	0.003	8.52%	0.005	2.25%	0.002	11.16%	0.004
16	**central**	4.53%	0.014	16.36%	0.020	5.96%	0.011	18.58%	0.018
	eccentric	4.00%	0.014	17.21%	0.020	6.38%	0.011	20.11%	0.018
	random	6.19%	0.015	19.18%	0.020	7.66%	0.012	22.14%	0.018
21	**central**	7.92%	0.044	22.99%	0.062	9.28%	0.033	25.80%	0.056
	eccentric	7.67%	0.042	24.57%	0.062	10.55%	0.031	28.04%	0.054
	random	10.22%	0.044	26.59%	0.062	13.32%	0.032	30.64%	0.054
31	**central**	10.88%	0.182	25.48%	0.253	11.94%	0.142	27.54%	0.229
	eccentric	11.71%	0.187	27.91%	0.251	13.02%	0.117	29.17%	0.203
	random	10.76%	0.185	27.16%	0.252	13.58%	0.125	29.92%	0.209
41	**central**	13.20%	0.766	29.30%	1.028	16.73%	0.571	32.72%	0.914
	eccentric	14.60%	0.753	31.94%	1.004	19.40%	0.434	35.57%	0.767
	random	14.09%	0.743	31.39%	1.001	18.61%	0.492	35.11%	0.820
51	**central**	16.46%	2.276	32.52%	3.004	19.92%	1.691	35.30%	2.707
	eccentric	15.27%	2.306	34.80%	3.021	21.32%	1.354	38.13%	2.312
	random	18.32%	2.231	36.79%	2.911	22.66%	1.417	39.76%	2.321

Table 50: Shift – Average GAPs

		Best Improvement				First Improvement			
# Sen.	**Base Station**	**MIN**	**T (s)**	**AVG**	**T (s)**	**MIN**	**T (s)**	**AVG**	**T (s)**
6	**central**	0.21%	0.001	0.72%	0.001	0.18%	0.000	0.77%	0.001
	eccentric	0.03%	0.001	0.17%	0.001	0.00%	0.000	0.44%	0.001
	random	0.04%	0.001	0.45%	0.001	0.01%	0.000	0.50%	0.001
7	**central**	0.01%	0.001	0.87%	0.001	0.00%	0.001	1.13%	0.001
	eccentric	0.07%	0.001	1.08%	0.001	0.18%	0.001	1.27%	0.001
	random	0.00%	0.001	0.68%	0.001	0.05%	0.001	1.26%	0.001
8	**central**	0.00%	0.002	1.22%	0.003	0.21%	0.001	2.33%	0.002
	eccentric	0.00%	0.002	1.69%	0.003	0.13%	0.001	2.64%	0.002
	random	0.06%	0.002	1.34%	0.003	0.08%	0.001	2.17%	0.002
9	**central**	0.07%	0.003	2.69%	0.004	0.31%	0.002	3.22%	0.003
	eccentric	0.00%	0.003	1.59%	0.004	0.26%	0.002	3.17%	0.003
	random	0.10%	0.003	1.83%	0.004	0.50%	0.002	3.75%	0.003
10	**central**	0.11%	0.004	2.82%	0.006	0.30%	0.003	3.78%	0.004
	eccentric	0.12%	0.004	3.09%	0.006	0.08%	0.002	3.91%	0.004
	random	0.17%	0.004	2.28%	0.007	0.31%	0.003	4.06%	0.004
11	**central**	0.08%	0.007	3.26%	0.009	0.23%	0.004	4.04%	0.006
	eccentric	0.18%	0.006	3.42%	0.009	0.21%	0.004	5.42%	0.006
	random	0.30%	0.007	3.10%	0.010	0.25%	0.004	5.02%	0.006
16	**central**	1.00%	0.026	7.46%	0.036	2.35%	0.014	10.69%	0.021
	eccentric	0.56%	0.026	8.36%	0.038	2.36%	0.013	12.04%	0.019
	random	0.53%	0.026	8.50%	0.038	1.60%	0.014	12.30%	0.021
21	**central**	0.71%	0.087	10.80%	0.121	2.73%	0.036	14.46%	0.056
	eccentric	0.98%	0.084	12.30%	0.122	3.42%	0.033	16.76%	0.051
	random	1.17%	0.089	13.19%	0.122	2.95%	0.035	17.60%	0.053
31	**central**	1.36%	0.363	12.60%	0.498	5.28%	0.140	17.72%	0.219
	eccentric	1.31%	0.388	13.42%	0.499	5.66%	0.122	19.36%	0.195
	random	1.46%	0.382	13.13%	0.496	5.41%	0.134	19.01%	0.207
41	**central**	1.63%	1.398	13.80%	1.839	5.32%	0.451	18.70%	0.733
	eccentric	1.91%	1.455	13.87%	1.885	6.23%	0.400	20.13%	0.640
	random	1.36%	1.460	13.08%	1.865	5.68%	0.414	19.50%	0.683
51	**central**	2.41%	4.128	14.59%	5.358	6.27%	1.166	18.81%	1.817
	eccentric	2.81%	4.215	14.56%	5.417	7.15%	1.047	20.83%	1.642
	random	2.62%	4.180	16.03%	5.227	7.13%	1.062	21.37%	1.668

Table 51: Swap21 – Average GAPs

		Best Improvement				First Improvement			
# Sen.	**Base Station**	**MIN**	**T (s)**	**AVG**	**T (s)**	**MIN**	**T (s)**	**AVG**	**T (s)**
6	**central**	2.16%	0.000	4.10%	0.000	2.64%	0.000	5.39%	0.000
	eccentric	1.27%	0.000	2.62%	0.000	1.45%	0.000	3.73%	0.000
	random	1.25%	0.000	2.95%	0.000	1.41%	0.000	3.81%	0.000
7	**central**	0.62%	0.000	4.52%	0.001	1.41%	0.000	5.57%	0.001
	eccentric	0.30%	0.001	3.25%	0.001	0.42%	0.000	3.71%	0.001
	random	0.36%	0.000	4.76%	0.001	0.92%	0.000	5.68%	0.001
8	**central**	0.92%	0.001	5.80%	0.001	1.43%	0.001	6.99%	0.001
	eccentric	0.65%	0.001	4.93%	0.001	0.73%	0.001	5.10%	0.001
	random	0.81%	0.001	5.93%	0.001	1.04%	0.001	6.13%	0.001
9	**central**	1.36%	0.001	7.77%	0.002	2.53%	0.001	9.51%	0.002
	eccentric	1.06%	0.001	7.05%	0.002	0.90%	0.001	7.84%	0.002
	random	1.04%	0.001	8.11%	0.002	1.96%	0.001	9.52%	0.002
10	**central**	1.71%	0.002	8.48%	0.004	2.18%	0.002	10.25%	0.003
	eccentric	1.29%	0.002	7.72%	0.004	1.29%	0.002	8.07%	0.003
	random	1.40%	0.002	8.54%	0.004	2.45%	0.002	10.06%	0.003
11	**central**	2.58%	0.004	10.75%	0.006	3.43%	0.003	11.94%	0.005
	eccentric	1.41%	0.004	9.32%	0.006	2.28%	0.003	9.61%	0.005
	random	1.73%	0.004	9.77%	0.006	2.48%	0.003	10.78%	0.005
16	**central**	4.24%	0.016	14.08%	0.024	5.78%	0.012	16.32%	0.019
	eccentric	4.41%	0.018	14.19%	0.026	4.41%	0.012	15.49%	0.020
	random	4.96%	0.018	15.80%	0.026	5.40%	0.013	17.16%	0.021
21	**central**	5.85%	0.057	16.74%	0.085	8.06%	0.036	19.03%	0.062
	eccentric	5.49%	0.058	17.88%	0.085	6.39%	0.035	19.21%	0.063
	random	5.87%	0.060	18.50%	0.088	7.25%	0.037	21.29%	0.061
31	**central**	6.00%	0.248	17.49%	0.355	7.25%	0.136	18.41%	0.253
	eccentric	6.06%	0.255	18.12%	0.364	7.02%	0.144	19.71%	0.250
	random	6.84%	0.263	18.28%	0.366	6.22%	0.141	19.53%	0.258
41	**central**	5.94%	1.032	16.75%	1.468	6.61%	0.505	18.25%	0.949
	eccentric	5.23%	1.032	17.36%	1.466	7.68%	0.440	19.76%	0.921
	random	4.87%	1.038	16.75%	1.458	6.06%	0.469	18.74%	0.903
51	**central**	4.28%	3.302	15.37%	4.423	5.83%	1.258	17.09%	2.654
	eccentric	4.10%	3.114	15.70%	4.357	5.89%	1.073	18.21%	2.426
	random	4.92%	3.117	17.20%	4.274	6.95%	1.151	19.31%	2.469

.1.4 Average Improvements

The Tables 52–54 shows the average improvements to the initial solutions generated of the local searches *Swap*, *Shift* and *Swap21*, both for them using Best and First Improvement. In this tables the columns **MAX** and **AVG** represents the average maximum improvements and the average of average improvements of the solutions, respectively. The methods were executed 10 times for each instance.

Table 52: Swap – Average IMPs

		Best Improvement		First Improvement	
# Sensors	**Base Station**	**MAX**	**AVG**	**MAX**	**AVG**
6	**central**	16.76%	13.10%	16.31%	12.60%
	eccentric	19.55%	16.33%	19.05%	15.71%
	random	16.52%	13.63%	15.64%	12.62%
7	**central**	20.91%	13.56%	20.69%	13.52%
	eccentric	27.67%	16.72%	27.62%	16.47%
	random	25.97%	15.83%	22.39%	14.44%
8	**central**	27.59%	16.98%	27.90%	16.38%
	eccentric	30.65%	19.05%	28.51%	18.53%
	random	27.66%	18.10%	30.29%	17.46%
9	**central**	31.81%	21.41%	32.34%	20.96%
	eccentric	35.86%	24.08%	35.23%	23.48%
	random	36.54%	23.63%	32.41%	22.17%
10	**central**	36.82%	25.13%	36.58%	23.80%
	eccentric	40.65%	24.99%	41.29%	24.53%
	random	41.19%	27.24%	42.07%	26.61%
11	**central**	43.04%	29.13%	40.62%	28.01%
	eccentric	41.81%	28.42%	43.78%	29.36%
	random	42.59%	29.96%	41.70%	28.54%
16	**central**	53.43%	38.55%	47.92%	36.76%
	eccentric	55.90%	39.82%	52.17%	38.39%
	random	55.43%	41.26%	56.14%	40.01%
21	**central**	62.08%	47.51%	60.07%	46.34%
	eccentric	62.28%	46.90%	63.80%	45.93%
	random	65.35%	49.15%	59.71%	46.43%
31	**central**	61.87%	51.93%	62.08%	51.58%
	eccentric	64.35%	51.33%	61.34%	50.57%
	random	62.65%	51.70%	60.88%	50.62%
41	**central**	68.01%	58.60%	67.23%	57.38%
	eccentric	70.31%	58.09%	68.45%	57.37%
	random	67.95%	57.89%	64.56%	56.37%
51	**central**	72.71%	62.33%	71.40%	61.57%
	eccentric	73.29%	62.00%	73.87%	61.10%
	random	71.99%	61.56%	69.31%	60.35%

Table 53: Shift – Average IMPs

		Best Improvement		First Improvement	
# Sensors	**Base Station**	**MAX**	**AVG**	**MAX**	**AVG**
6	**central**	17.15%	14.56%	16.92%	14.14%
	eccentric	19.83%	16.62%	20.14%	16.51%
	random	17.05%	14.82%	16.92%	14.66%
7	**central**	22.17%	15.44%	22.62%	15.72%
	eccentric	26.58%	17.35%	28.09%	17.63%
	random	25.30%	17.70%	25.93%	17.51%
8	**central**	30.04%	20.48%	29.15%	19.48%
	eccentric	33.09%	21.00%	31.74%	21.02%
	random	32.71%	21.08%	30.13%	20.07%
9	**central**	35.25%	24.68%	34.69%	23.96%
	eccentric	36.95%	25.53%	35.37%	24.99%
	random	39.02%	26.49%	35.45%	24.56%
10	**central**	41.32%	28.55%	39.38%	27.23%
	eccentric	39.33%	27.13%	39.43%	26.97%
	random	43.75%	30.79%	41.40%	30.13%
11	**central**	42.83%	32.74%	41.48%	31.85%
	eccentric	45.99%	32.18%	41.69%	31.13%
	random	44.10%	32.97%	43.47%	32.59%
16	**central**	53.58%	42.88%	53.32%	41.28%
	eccentric	57.48%	45.15%	58.93%	42.88%
	random	57.97%	46.05%	56.45%	44.47%
21	**central**	62.56%	52.53%	65.39%	51.30%
	eccentric	66.37%	52.37%	64.85%	50.79%
	random	66.95%	53.57%	67.00%	51.97%
31	**central**	64.66%	56.86%	64.50%	55.13%
	eccentric	65.97%	56.13%	66.08%	54.52%
	random	65.81%	56.74%	64.57%	54.39%
41	**central**	71.73%	63.34%	68.46%	61.46%
	eccentric	68.89%	63.41%	69.62%	61.61%
	random	70.92%	63.78%	69.08%	61.49%
51	**central**	75.57%	67.62%	74.20%	66.28%
	eccentric	76.04%	67.13%	74.39%	65.46%
	random	77.70%	67.52%	75.74%	65.69%

Table 54: Swap21 – Average IMPs

		Best Improvement		First Improvement	
# Sensors	**Base Station**	**MAX**	**AVG**	**MAX**	**AVG**
6	**central**	14.85%	11.67%	14.44%	10.69%
	eccentric	18.47%	14.67%	17.91%	13.47%
	random	15.33%	12.60%	15.26%	11.78%
7	**central**	19.72%	12.33%	20.00%	11.65%
	eccentric	25.94%	15.87%	27.09%	15.26%
	random	23.46%	14.39%	22.76%	14.04%
8	**central**	27.58%	16.67%	26.05%	15.50%
	eccentric	27.66%	18.06%	29.03%	17.74%
	random	29.20%	16.48%	29.92%	16.49%
9	**central**	31.07%	19.73%	29.72%	19.18%
	eccentric	33.57%	21.84%	35.48%	22.19%
	random	35.56%	21.67%	32.17%	20.16%
10	**central**	36.74%	24.42%	34.81%	23.31%
	eccentric	41.36%	25.13%	39.72%	24.35%
	random	40.61%	26.45%	40.85%	25.84%
11	**central**	42.03%	27.93%	39.69%	26.84%
	eccentric	41.29%	28.43%	44.46%	28.49%
	random	42.07%	29.26%	44.65%	28.86%
16	**central**	50.34%	38.75%	50.91%	37.61%
	eccentric	54.47%	41.54%	54.38%	41.11%
	random	55.59%	43.23%	56.41%	42.16%
21	**central**	61.77%	50.07%	64.71%	49.93%
	eccentric	68.21%	50.31%	63.73%	48.83%
	random	66.18%	51.83%	64.78%	50.17%
31	**central**	66.64%	55.52%	64.11%	55.11%
	eccentric	65.73%	54.79%	65.28%	54.32%
	random	65.72%	55.51%	62.26%	54.35%
41	**central**	70.43%	62.56%	71.69%	62.10%
	eccentric	71.87%	62.69%	71.36%	61.76%
	random	71.89%	62.54%	71.76%	62.03%
51	**central**	75.56%	67.27%	77.97%	67.18%
	eccentric	78.86%	67.54%	74.72%	66.18%
	random	73.41%	66.68%	75.82%	66.24%

.2 Proposed heuristics tests

In this section the complete results of the tests with the two heuristics, GRVND and GVNS-RVND, compared with the mathematical formulation are presented in Tables 55–76. The mathematical formulation is executed with a time limit of 1 hour, and, if this time is exceded, the mathematical formulation was stoped and the solution found until the interupt was reported. In all tables, the two heuristcs are executed 10 times of each instance. In this tables, the first column identify the instance, the second and third columns presents the mathematical formulation solution and the time spend to find this solution, respectively. The columns **MIN**, **AVG** and **GAP** shows the best solution found by each heuristic, the average solution found in 10 executions and the GAP from the mathematical formulation solution. The columns **T (s)** shows the time, in seconds, spend in each method. The GAP is calculated using the equation $GAP = \frac{(f_{Heuristic} - f_{Exact})}{f_{Exact}}$, where $f_{Heuristic}$ represents the solution found by the tested heuristic, GRVND or GVNS-RVND, and f_{Exact} represents the solution found by the exact method.

Table 55: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 6 nodes and Central Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
6_0	546110	0.288	546114	0.111	546114	0.112	0.00%	0.00%	546114	0.091	546114	0.097	0.00%	0.00%
6_1	476890	0.289	476885	0.110	476885	0.111	0.00%	0.00%	476885	0.075	476885	0.081	0.00%	0.00%
6_2	819470	0.289	835637	0.067	835637	0.068	1.97%	1.97%	819466	0.080	819466	0.090	0.00%	0.00%
6_3	583500	0.569	583501	0.118	583501	0.129	0.00%	0.00%	583501	0.090	583501	0.096	0.00%	0.00%
6_4	393830	0.248	393830	0.099	393830	0.103	0.00%	0.00%	393830	0.085	393830	0.089	0.00%	0.00%
6_5	533550	0.228	533556	0.081	533556	0.085	0.00%	0.00%	533556	0.067	533556	0.072	0.00%	0.00%
6_6	621470	0.286	621491	0.069	621491	0.072	0.00%	0.00%	621491	0.066	621491	0.070	0.00%	0.00%
6_7	612360	0.269	612364	0.095	612364	0.098	0.00%	0.00%	612364	0.086	612364	0.091	0.00%	0.00%
6_8	520840	0.446	520829	0.090	520829	0.092	0.00%	0.00%	520829	0.095	520829	0.100	0.00%	0.00%
6_9	470070	0.232	470066	0.105	470066	0.115	0.00%	0.00%	470066	0.100	470066	0.104	0.00%	0.00%
6_10	639130	0.256	639134	0.068	639134	0.070	0.00%	0.00%	639134	0.068	639134	0.074	0.00%	0.00%
6_11	619900	0.284	619894	0.078	619894	0.079	0.00%	0.00%	619894	0.086	619894	0.092	0.00%	0.00%
6_12	522720	0.245	522721	0.121	522721	0.128	0.00%	0.00%	522721	0.105	522721	0.112	0.00%	0.00%
6_13	364160	0.282	364167	0.086	364167	0.087	0.00%	0.00%	364167	0.095	364167	0.099	0.00%	0.00%
6_14	611130	0.251	611143	0.077	611143	0.090	0.00%	0.00%	611143	0.073	611143	0.076	0.00%	0.00%
6_15	818870	0.246	818863	0.065	818863	0.067	0.00%	0.00%	818863	0.084	818863	0.087	0.00%	0.00%
6_16	821990	0.197	821989	0.089	821989	0.097	0.00%	0.00%	821989	0.078	821989	0.081	0.00%	0.00%
6_17	660660	0.507	660660	0.099	660660	0.100	0.00%	0.00%	660660	0.072	660660	0.077	0.00%	0.00%
6_18	840730	0.429	840727	0.072	840727	0.074	0.00%	0.00%	840727	0.066	840727	0.070	0.00%	0.00%
6_19	715990	0.205	715997	0.034	715997	0.034	0.00%	0.00%	715997	0.067	715997	0.069	0.00%	0.00%
6_20	549160	0.552	549152	0.115	549152	0.128	0.00%	0.00%	549152	0.099	549152	0.104	0.00%	0.00%
6_21	713940	0.172	713937	0.068	713937	0.069	0.00%	0.00%	713937	0.081	713937	0.085	0.00%	0.00%
6_22	591220	0.262	591211	0.035	591211	0.036	0.00%	0.00%	591211	0.082	591211	0.088	0.00%	0.00%
6_23	524510	0.296	524522	0.102	524522	0.110	0.00%	0.00%	524522	0.092	524522	0.095	0.00%	0.00%
6_24	866250	0.577	866253	0.078	866253	0.133	0.00%	0.00%	866253	0.101	866253	0.109	0.00%	0.00%
6_25	635590	0.366	635598	0.126	635598	0.132	0.00%	0.00%	635598	0.102	635598	0.107	0.00%	0.00%
6_26	538340	0.252	538351	0.119	538351	0.120	0.00%	0.00%	538351	0.098	538351	0.102	0.00%	0.00%
6_27	795020	0.205	795024	0.048	795024	0.069	0.00%	0.00%	795024	0.081	795024	0.089	0.00%	0.00%
6_28	638270	0.247	638259	0.077	638259	0.079	0.00%	0.00%	638259	0.069	638259	0.071	0.00%	0.00%
6_29	610590	0.247	610599	0.047	610599	0.048	0.00%	0.00%	610599	0.077	610599	0.083	0.00%	0.00%
6_30	465920	0.512	465915	0.077	465915	0.088	0.00%	0.00%	465915	0.072	465915	0.076	0.00%	0.00%
6_31	683710	0.400	683706	0.083	683706	0.085	0.00%	0.00%	683706	0.075	683706	0.080	0.00%	0.00%
6_32	537570	0.458	537562	0.121	537562	0.133	0.00%	0.00%	537562	0.098	537562	0.104	0.00%	0.00%
6_33	815380	0.212	815377	0.033	815377	0.034	0.00%	0.00%	815377	0.074	815377	0.078	0.00%	0.00%
6_34	732230	0.232	732237	0.081	764850.6	0.096	0.00%	4.45%	732237	0.064	732237	0.067	0.00%	0.00%
6_35	772550	0.270	772559	0.052	772559	0.053	0.00%	0.00%	772559	0.067	772559	0.072	0.00%	0.00%
6_36	510540	0.392	510537	0.119	510537	0.131	0.00%	0.00%	510537	0.088	510537	0.091	0.00%	0.00%
6_37	467340	0.269	467336	0.074	467336	0.076	0.00%	0.00%	467336	0.074	467336	0.078	0.00%	0.00%
6_38	421520	0.281	421521	0.105	421521	0.110	0.00%	0.00%	421521	0.081	421521	0.089	0.00%	0.00%
6_39	565620	0.253	565619	0.114	565619	0.129	0.00%	0.00%	565619	0.101	565619	0.107	0.00%	0.00%
6_40	534630	0.485	534631	0.066	534631	0.069	0.00%	0.00%	534631	0.079	534631	0.084	0.00%	0.00%
6_41	654680	0.539	654673	0.117	654673	0.126	0.00%	0.00%	654673	0.083	654673	0.088	0.00%	0.00%
6_42	761060	0.264	761059	0.074	761059	0.094	0.00%	0.00%	761059	0.057	761059	0.062	0.00%	0.00%
6_43	747820	0.232	747812	0.084	747812	0.086	0.00%	0.00%	747812	0.078	747812	0.082	0.00%	0.00%
6_44	491010	0.304	491016	0.092	491016	0.118	0.00%	0.00%	491016	0.084	491016	0.092	0.00%	0.00%
6_45	558570	0.432	584540	0.049	584540	0.050	4.65%	4.65%	558558	0.062	558558	0.066	0.00%	0.00%
6_46	491850	0.414	491839	0.123	491839	0.133	0.00%	0.00%	491839	0.104	491839	0.108	0.00%	0.00%
6_47	605060	0.258	605053	0.071	605053	0.074	0.00%	0.00%	605053	0.080	605053	0.087	0.00%	0.00%
6_48	505040	0.298	505033	0.069	505033	0.070	0.00%	0.00%	505033	0.079	505033	0.084	0.00%	0.00%
6_49	481590	0.333	481588	0.093	481588	0.104	0.00%	0.00%	481588	0.078	481588	0.083	0.00%	0.00%

Table 56: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 6 nodes and Eccentric Base Station position

	Mathematical		**GRVND**						**GVNSRVND**					
	Formulation		**MIN**		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
6_0	746540	0.483	746543	0.086	746543	0.121	0.00%	0.00%	746543	0.015	746543	0.016	0.00%	0.00%
6_1	791610	0.484	791604	0.095	791604	0.097	0.00%	0.00%	791604	0.012	791604	0.013	0.00%	0.00%
6_2	916750	0.385	916760	0.059	916760	0.060	0.00%	0.00%	916760	0.011	916760	0.011	0.00%	0.00%
6_3	741530	0.477	741533	0.073	741533	0.138	0.00%	0.00%	741533	0.016	741533	0.017	0.00%	0.00%
6_4	470350	0.460	470349	0.089	470349	0.098	0.00%	0.00%	470349	0.014	470349	0.015	0.00%	0.00%
6_5	631750	0.262	631759	0.074	631759	0.093	0.00%	0.00%	631759	0.012	631759	0.012	0.00%	0.00%
6_6	903110	0.354	903109	0.072	903109	0.072	0.00%	0.00%	903109	0.012	903109	0.013	0.00%	0.00%
6_7	705660	0.667	705643	0.054	705643	0.106	0.00%	0.00%	705643	0.011	705643	0.013	0.00%	0.00%
6_8	696170	0.223	696168	0.118	696168	0.120	0.00%	0.00%	696168	0.014	696168	0.015	0.00%	0.00%
6_9	567760	0.241	567748	0.123	567748	0.127	0.00%	0.00%	567748	0.017	567748	0.018	0.00%	0.00%
6_10	691490	0.301	691493	0.053	691493	0.075	0.00%	0.00%	691493	0.010	691493	0.012	0.00%	0.00%
6_11	904670	0.232	904670	0.084	904670	0.086	0.00%	0.00%	904670	0.014	904670	0.016	0.00%	0.00%
6_12	640840	0.761	640630	0.041	640630	0.114	-0.03%	-0.03%	640630	0.015	640630	0.016	-0.03%	-0.03%
6_13	535260	0.390	535258	0.082	535258	0.084	0.00%	0.00%	535258	0.013	535258	0.015	0.00%	0.00%
6_14	702460	0.421	702463	0.090	702463	0.091	0.00%	0.00%	702463	0.012	702463	0.013	0.00%	0.00%
6_15	952260	0.309	952253	0.061	952253	0.062	0.00%	0.00%	952253	0.013	952253	0.014	0.00%	0.00%
6_16	949830	0.228	949830	0.094	949830	0.095	0.00%	0.00%	949830	0.014	949830	0.015	0.00%	0.00%
6_17	899040	0.310	899054	0.082	899054	0.090	0.00%	0.00%	899054	0.010	899054	0.011	0.00%	0.00%
6_18	935330	0.361	935330	0.082	935330	0.084	0.00%	0.00%	935330	0.012	935330	0.013	0.00%	0.00%
6_19	844600	0.229	844611	0.070	844611	0.072	0.00%	0.00%	844611	0.011	844611	0.012	0.00%	0.00%
6_20	785540	0.327	785541	0.073	785541	0.075	0.00%	0.00%	785541	0.017	785541	0.018	0.00%	0.00%
6_21	841900	0.284	841903	0.056	841903	0.065	0.00%	0.00%	841903	0.010	841903	0.011	0.00%	0.00%
6_22	691130	0.400	691130	0.079	691130	0.085	0.00%	0.00%	691130	0.011	691130	0.012	0.00%	0.00%
6_23	645270	0.410	645265	0.120	645265	0.122	0.00%	0.00%	645265	0.016	645265	0.017	0.00%	0.00%
6_24	983990	0.391	983997	0.063	983997	0.070	0.00%	0.00%	983997	0.016	983997	0.017	0.00%	0.00%
6_25	800280	0.592	800280	0.069	812222.4	0.105	0.00%	1.49%	800280	0.014	800280	0.015	0.00%	0.00%
6_26	693300	0.529	693289	0.067	693289	0.068	0.00%	0.00%	693289	0.013	693289	0.015	0.00%	0.00%
6_27	808290	0.330	808294	0.051	808294	0.080	0.00%	0.00%	808294	0.010	808294	0.012	0.00%	0.00%
6_28	891390	0.195	891397	0.084	891397	0.085	0.00%	0.00%	891397	0.011	891397	0.012	0.00%	0.00%
6_29	734020	0.362	734012	0.070	734012	0.071	0.00%	0.00%	734012	0.012	734012	0.014	0.00%	0.00%
6_30	685770	0.405	685765	0.115	685765	0.118	0.00%	0.00%	685765	0.012	685765	0.013	0.00%	0.00%
6_31	732870	0.302	732864	0.085	732864	0.090	0.00%	0.00%	732864	0.012	732864	0.013	0.00%	0.00%
6_32	734570	0.947	734563	0.142	734563	0.145	0.00%	0.00%	734563	0.015	734563	0.017	0.00%	0.00%
6_33	842170	0.234	842181	0.066	842181	0.068	0.00%	0.00%	842181	0.010	842181	0.011	0.00%	0.00%
6_34	763120	0.302	763132	0.061	763132	0.073	0.00%	0.00%	763132	0.012	763132	0.012	0.00%	0.00%
6_35	833770	0.497	833773	0.073	833773	0.079	0.00%	0.00%	834247	0.012	834247	0.012	0.06%	0.06%
6_36	822350	0.449	822349	0.102	822349	0.116	0.00%	0.00%	822349	0.014	822349	0.015	0.00%	0.00%
6_37	754100	0.254	754106	0.077	754106	0.079	0.00%	0.00%	754106	0.011	754106	0.011	0.00%	0.00%
6_38	741230	0.340	741217	0.074	741217	0.107	0.00%	0.00%	741217	0.015	741217	0.016	0.00%	0.00%
6_39	756230	0.377	756234	0.095	756234	0.099	0.00%	0.00%	756234	0.014	756234	0.015	0.00%	0.00%
6_40	733220	0.422	733223	0.084	733223	0.086	0.00%	0.00%	733223	0.011	733223	0.012	0.00%	0.00%
6_41	815630	0.292	815641	0.109	815641	0.111	0.00%	0.00%	815641	0.014	815641	0.015	0.00%	0.00%
6_42	935730	0.286	935718	0.076	935718	0.078	0.00%	0.00%	935718	0.011	935718	0.012	0.00%	0.00%
6_43	870410	0.259	870408	0.050	870408	0.051	0.00%	0.00%	870408	0.012	870408	0.013	0.00%	0.00%
6_44	652830	0.231	652836	0.080	652836	0.092	0.00%	0.00%	652836	0.014	652836	0.015	0.00%	0.00%
6_45	668890	0.562	668894	0.077	668894	0.082	0.00%	0.00%	668894	0.010	668894	0.011	0.00%	0.00%
6_46	815090	0.383	815080	0.118	815080	0.135	0.00%	0.00%	815080	0.016	815080	0.017	0.00%	0.00%
6_47	637370	0.322	637378	0.086	637378	0.089	0.00%	0.00%	637378	0.012	637378	0.014	0.00%	0.00%
6_48	593180	0.301	593176	0.089	593176	0.093	0.00%	0.00%	593176	0.011	593176	0.013	0.00%	0.00%
6_49	815010	0.397	815000	0.086	815000	0.088	0.00%	0.00%	815000	0.012	815000	0.013	0.00%	0.00%

Table 57: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 6 nodes and Random Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
6_0	563040	0.474	563033	0.071	563033	0.089	0.00%	0.00%	563033	0.015	563033	0.016	0.00%	0.00%
6_1	498760	0.341	498775	0.071	498775	0.090	0.00%	0.00%	498775	0.013	498775	0.015	0.00%	0.00%
6_2	801100	0.327	801107	0.031	801107	0.059	0.00%	0.00%	801107	0.010	801107	0.011	0.00%	0.00%
6_3	708730	0.332	708729	0.064	708729	0.065	0.00%	0.00%	708729	0.015	708729	0.016	0.00%	0.00%
6_4	513500	0.342	513512	0.033	513512	0.042	0.00%	0.00%	513512	0.012	513512	0.013	0.00%	0.00%
6_5	567290	0.197	567295	0.075	567295	0.076	0.00%	0.00%	567295	0.011	567295	0.013	0.00%	0.00%
6_6	631190	0.262	631196	0.083	631196	0.084	0.00%	0.00%	631196	0.011	631196	0.012	0.00%	0.00%
6_7	759230	0.275	759234	0.108	759234	0.109	0.00%	0.00%	759234	0.013	759234	0.015	0.00%	0.00%
6_8	645810	0.391	645802	0.079	645802	0.110	0.00%	0.00%	645802	0.014	645802	0.015	0.00%	0.00%
6_9	656410	0.396	656406	0.113	656406	0.117	0.00%	0.00%	656406	0.015	656406	0.016	0.00%	0.00%
6_10	818120	0.372	818134	0.065	818134	0.066	0.00%	0.00%	818134	0.011	818134	0.013	0.00%	0.00%
6_11	682020	0.335	682015	0.096	682015	0.098	0.00%	0.00%	682015	0.013	682015	0.013	0.00%	0.00%
6_12	546880	0.464	546882	0.086	546882	0.111	0.00%	0.00%	546882	0.015	546882	0.016	0.00%	0.00%
6_13	379750	0.342	379749	0.114	379749	0.124	0.00%	0.00%	379749	0.014	379749	0.015	0.00%	0.00%
6_14	811170	0.315	811171	0.080	811171	0.084	0.00%	0.00%	811171	0.011	811171	0.012	0.00%	0.00%
6_15	786580	0.330	786583	0.071	786583	0.072	0.00%	0.00%	786583	0.011	786583	0.012	0.00%	0.00%
6_16	805170	0.206	805165	0.114	805165	0.118	0.00%	0.00%	805165	0.014	805165	0.015	0.00%	0.00%
6_17	665980	0.331	665984	0.086	665984	0.087	0.00%	0.00%	665984	0.011	665984	0.013	0.00%	0.00%
6_18	859520	0.442	859515	0.069	859515	0.071	0.00%	0.00%	859515	0.011	859515	0.012	0.00%	0.00%
6_19	736180	0.310	736186	0.070	736186	0.072	0.00%	0.00%	736186	0.010	736186	0.011	0.00%	0.00%
6_20	574910	0.473	574901	0.135	574901	0.137	0.00%	0.00%	574901	0.018	574901	0.019	0.00%	0.00%
6_21	689820	0.292	689819	0.034	689819	0.049	0.00%	0.00%	689819	0.011	689819	0.012	0.00%	0.00%
6_22	621060	0.322	621048	0.092	621048	0.100	0.00%	0.00%	621048	0.014	621048	0.015	0.00%	0.00%
6_23	586190	0.321	586199	0.075	586199	0.077	0.00%	0.00%	586199	0.014	586199	0.015	0.00%	0.00%
6_24	845620	0.349	845628	0.137	845628	0.143	0.00%	0.00%	845628	0.016	845628	0.018	0.00%	0.00%
6_25	640660	0.353	640665	0.100	640665	0.103	0.00%	0.00%	640665	0.016	640665	0.017	0.00%	0.00%
6_26	540750	0.322	540763	0.103	540763	0.119	0.00%	0.00%	540763	0.015	540763	0.017	0.00%	0.00%
6_27	753210	0.267	753218	0.082	753218	0.084	0.00%	0.00%	753218	0.013	753218	0.013	0.00%	0.00%
6_28	787940	0.237	787948	0.049	801720.4	0.058	0.00%	1.75%	787948	0.011	787948	0.012	0.00%	0.00%
6_29	694790	0.301	694788	0.073	694788	0.075	0.00%	0.00%	694788	0.011	694788	0.012	0.00%	0.00%
6_30	479480	0.279	479487	0.094	479487	0.095	0.00%	0.00%	479487	0.011	479487	0.012	0.00%	0.00%
6_31	713570	0.287	713564	0.105	713564	0.106	0.00%	0.00%	713564	0.011	713564	0.012	0.00%	0.00%
6_32	682890	0.412	682876	0.098	682876	0.103	0.00%	0.00%	682876	0.015	682876	0.016	0.00%	0.00%
6_33	769270	0.322	769271	0.057	769271	0.058	0.00%	0.00%	769271	0.011	769271	0.012	0.00%	0.00%
6_34	765690	0.299	853950	0.034	853950	0.035	11.53%	11.53%	765705	0.011	765705	0.012	0.00%	0.00%
6_35	834830	0.251	834834	0.084	834834	0.088	0.00%	0.00%	834834	0.010	834834	0.012	0.00%	0.00%
6_36	513640	0.357	513643	0.116	513643	0.117	0.00%	0.00%	513643	0.013	513643	0.015	0.00%	0.00%
6_37	580260	0.428	580264	0.082	580264	0.084	0.00%	0.00%	580264	0.010	580264	0.011	0.00%	0.00%
6_38	488000	0.459	487998	0.064	487998	0.098	0.00%	0.00%	487998	0.011	487998	0.012	0.00%	0.00%
6_39	596670	0.535	596675	0.069	596675	0.070	0.00%	0.00%	596675	0.015	596675	0.016	0.00%	0.00%
6_40	527070	0.502	527069	0.086	527069	0.094	0.00%	0.00%	527069	0.010	527069	0.011	0.00%	0.00%
6_41	643220	0.326	643222	0.096	643222	0.097	0.00%	0.00%	643222	0.013	643222	0.015	0.00%	0.00%
6_42	757350	0.290	757340	0.054	757340	0.055	0.00%	0.00%	757340	0.011	757340	0.012	0.00%	0.00%
6_43	743100	0.285	743108	0.034	743108	0.034	0.00%	0.00%	743108	0.011	743108	0.012	0.00%	0.00%
6_44	624860	0.308	624859	0.097	624859	0.099	0.00%	0.00%	624859	0.014	624859	0.014	0.00%	0.00%
6_45	527520	0.461	527529	0.076	527529	0.084	0.00%	0.00%	527529	0.011	527529	0.012	0.00%	0.00%
6_46	750890	0.618	750884	0.120	750884	0.139	0.00%	0.00%	750884	0.016	750884	0.016	0.00%	0.00%
6_47	598100	0.332	598092	0.068	598092	0.070	0.00%	0.00%	598092	0.011	598092	0.013	0.00%	0.00%
6_48	633310	0.336	633299	0.078	633299	0.082	0.00%	0.00%	633299	0.010	633299	0.011	0.00%	0.00%
6_49	560040	0.230	560037	0.096	560037	0.097	0.00%	0.00%	560037	0.011	560037	0.011	0.00%	0.00%

Table 58: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 7 nodes and Central Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
7_0	552990	1.518	552984	0.237	552984	0.257	0.00%	0.00%	552984	0.180	552984	0.192	0.00%	0.00%
7_1	506580	0.884	506579	0.212	506579	0.216	0.00%	0.00%	506579	0.187	506579	0.196	0.00%	0.00%
7_2	797100	0.647	797105	0.108	797105	0.189	0.00%	0.00%	797105	0.176	797105	0.190	0.00%	0.00%
7_3	798640	1.082	798622	0.166	798622	0.169	0.00%	0.00%	798622	0.159	798622	0.167	0.00%	0.00%
7_4	489310	0.767	489293	0.172	489293	0.219	0.00%	0.00%	489293	0.188	489293	0.198	0.00%	0.00%
7_5	411220	0.754	411217	0.228	411217	0.237	0.00%	0.00%	411217	0.191	411217	0.206	0.00%	0.00%
7_6	670390	0.991	670402	0.221	670402	0.223	0.00%	0.00%	670402	0.146	670402	0.161	0.00%	0.00%
7_7	715770	0.660	715776	0.171	715776	0.182	0.00%	0.00%	715776	0.169	715776	0.179	0.00%	0.00%
7_8	527640	0.901	527657	0.119	561912.2	0.138	0.00%	6.50%	527657	0.176	527657	0.190	0.00%	0.00%
7_9	657260	0.970	657259	0.142	657259	0.150	0.00%	0.00%	657259	0.127	657259	0.146	0.00%	0.00%
7_10	714780	0.968	714773	0.207	714773	0.230	0.00%	0.00%	714773	0.196	714773	0.208	0.00%	0.00%
7_11	796520	0.832	796508	0.093	796508	0.106	0.00%	0.00%	796508	0.132	796508	0.145	0.00%	0.00%
7_12	547930	0.749	547930	0.180	547930	0.197	0.00%	0.00%	547930	0.188	547930	0.196	0.00%	0.00%
7_13	637420	1.330	637412	0.214	637412	0.222	0.00%	0.00%	637412	0.172	637412	0.182	0.00%	0.00%
7_14	956260	0.837	959440	0.102	959440	0.105	0.33%	0.33%	956263	0.152	956263	0.164	0.00%	0.00%
7_15	343060	1.296	343071	0.130	343071	0.209	0.00%	0.00%	343071	0.197	343071	0.211	0.00%	0.00%
7_16	633830	1.544	633817	0.222	633817	0.250	0.00%	0.00%	633817	0.199	633817	0.211	0.00%	0.00%
7_17	959660	0.886	959654	0.129	959654	0.139	0.00%	0.00%	959654	0.150	959654	0.171	0.00%	0.00%
7_18	497980	1.249	497988	0.273	497988	0.293	0.00%	0.00%	497988	0.176	497988	0.190	0.00%	0.00%
7_19	730270	0.939	730268	0.169	730268	0.182	0.00%	0.00%	730268	0.160	730268	0.169	0.00%	0.00%
7_20	842000	0.826	841998	0.101	841998	0.107	0.00%	0.00%	841998	0.124	841998	0.130	0.00%	0.00%
7_21	719620	0.631	719618	0.134	719618	0.164	0.00%	0.00%	719618	0.131	719618	0.142	0.00%	0.00%
7_22	785370	0.412	785388	0.125	785388	0.133	0.00%	0.00%	785388	0.129	785388	0.136	0.00%	0.00%
7_23	764750	1.326	764756	0.115	764756	0.117	0.00%	0.00%	764756	0.155	764756	0.165	0.00%	0.00%
7_24	908940	0.681	908946	0.052	908946	0.052	0.00%	0.00%	908946	0.121	908946	0.128	0.00%	0.00%
7_25	714690	0.958	714706	0.098	714706	0.099	0.00%	0.00%	714706	0.155	714706	0.166	0.00%	0.00%
7_26	667950	1.292	667947	0.181	667947	0.200	0.00%	0.00%	667947	0.181	667947	0.195	0.00%	0.00%
7_27	577320	0.906	577316	0.115	581863.2	0.135	0.00%	0.79%	577316	0.145	577316	0.159	0.00%	0.00%
7_28	578060	1.485	578061	0.205	578061	0.222	0.00%	0.00%	578061	0.197	578061	0.209	0.00%	0.00%
7_29	603450	0.649	603449	0.046	603449	0.047	0.00%	0.00%	603449	0.135	603449	0.148	0.00%	0.00%
7_30	731110	1.122	731101	0.233	731101	0.241	0.00%	0.00%	731101	0.194	731101	0.210	0.00%	0.00%
7_31	710030	1.028	710037	0.183	710037	0.208	0.00%	0.00%	710037	0.157	710037	0.172	0.00%	0.00%
7_32	525430	0.699	525426	0.083	525426	0.096	0.00%	0.00%	525426	0.137	525426	0.148	0.00%	0.00%
7_33	749130	0.602	749125	0.127	749125	0.128	0.00%	0.00%	749125	0.134	749125	0.146	0.00%	0.00%
7_34	720540	1.320	720549	0.140	720549	0.169	0.00%	0.00%	720549	0.187	720549	0.204	0.00%	0.00%
7_35	873530	1.058	873530	0.176	873530	0.183	0.00%	0.00%	873530	0.128	873530	0.138	0.00%	0.00%
7_36	825410	0.750	825401	0.104	868887.4	0.120	0.00%	5.27%	825401	0.122	825401	0.132	0.00%	0.00%
7_37	666920	1.682	666921	0.186	666921	0.219	0.00%	0.00%	666921	0.186	666921	0.198	0.00%	0.00%
7_38	519500	0.611	519494	0.066	519494	0.107	0.00%	0.00%	519494	0.174	519494	0.184	0.00%	0.00%
7_39	641610	0.777	641626	0.169	643731.8	0.284	0.00%	0.33%	641626	0.176	641626	0.191	0.00%	0.00%
7_40	931190	0.719	931176	0.126	931176	0.127	0.00%	0.00%	931176	0.140	931176	0.145	0.00%	0.00%
7_41	670360	1.224	670362	0.139	670362	0.150	0.00%	0.00%	670362	0.144	670362	0.148	0.00%	0.00%
7_42	731540	1.205	731539	0.178	731539	0.219	0.00%	0.00%	731539	0.175	731539	0.180	0.00%	0.00%
7_43	753890	0.718	753888	0.170	753888	0.171	0.00%	0.00%	753888	0.158	753888	0.165	0.00%	0.00%
7_44	525660	0.891	525665	0.145	525665	0.148	0.00%	0.00%	525665	0.141	525665	0.152	0.00%	0.00%
7_45	827320	0.783	827318	0.130	827318	0.132	0.00%	0.00%	827318	0.172	827318	0.181	0.00%	0.00%
7_46	604950	1.016	604949	0.132	604949	0.174	0.00%	0.00%	604949	0.215	604949	0.227	0.00%	0.00%
7_47	689080	1.078	689082	0.220	689082	0.226	0.00%	0.00%	689082	0.147	689082	0.161	0.00%	0.00%
7_48	612820	0.757	612820	0.153	612820	0.156	0.00%	0.00%	612820	0.158	612820	0.166	0.00%	0.00%
7_49	652840	1.135	652825	0.095	652825	0.187	0.00%	0.00%	652825	0.165	652825	0.175	0.00%	0.00%

Table 59: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 7 nodes and Eccentric Base Station position

	Mathematical Formulation		**GRVND**						**GVNSRVND**					
			MIN		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
7_0	841090	1.530	841098	0.199	841098	0.223	0.00%	0.00%	841098	0.028	841098	0.030	0.00%	0.00%
7_1	682430	0.709	682429	0.119	682429	0.176	0.00%	0.00%	682429	0.024	682429	0.027	0.00%	0.00%
7_2	819610	1.007	819608	0.095	819608	0.104	0.00%	0.00%	819608	0.022	819608	0.024	0.00%	0.00%
7_3	910020	1.001	974974	0.100	974974	0.103	7.14%	7.14%	910034	0.023	910034	0.025	0.00%	0.00%
7_4	760200	1.170	760182	0.211	760182	0.226	0.00%	0.00%	760182	0.028	760182	0.031	0.00%	0.00%
7_5	744780	0.910	744768	0.201	744768	0.218	0.00%	0.00%	744768	0.027	744768	0.029	0.00%	0.00%
7_6	905230	1.000	905231	0.176	905231	0.198	0.00%	0.00%	905231	0.021	905231	0.022	0.00%	0.00%
7_7	942530	0.928	942536	0.126	942536	0.146	0.00%	0.00%	942536	0.024	942536	0.025	0.00%	0.00%
7_8	911100	1.237	911108	0.206	911108	0.226	0.00%	0.00%	911108	0.034	911108	0.035	0.00%	0.00%
7_9	796780	0.796	796780	0.139	796780	0.143	0.00%	0.00%	796780	0.018	796780	0.020	0.00%	0.00%
7_10	906520	1.035	906532	0.156	906532	0.158	0.00%	0.00%	906532	0.028	906532	0.030	0.00%	0.00%
7_11	832210	0.923	832198	0.103	832198	0.105	0.00%	0.00%	832198	0.016	832198	0.018	0.00%	0.00%
7_12	688730	0.614	688733	0.139	688733	0.149	0.00%	0.00%	688733	0.026	688733	0.028	0.00%	0.00%
7_13	739750	0.790	739740	0.173	739740	0.185	0.00%	0.00%	739740	0.023	739740	0.027	0.00%	0.00%
7_14	1069390	0.663	1069398	0.126	1069398	0.133	0.00%	0.00%	1069398	0.024	1069398	0.025	0.00%	0.00%
7_15	661360	1.389	661359	0.219	661359	0.239	0.00%	0.00%	661359	0.030	661359	0.032	0.00%	0.00%
7_16	826910	1.745	826900	0.224	826900	0.248	0.00%	0.00%	826900	0.031	826900	0.033	0.00%	0.00%
7_17	1000190	0.842	1000184	0.125	1000184	0.137	0.00%	0.00%	1000184	0.021	1000184	0.023	0.00%	0.00%
7_18	799070	1.169	799067	0.208	799067	0.219	0.00%	0.00%	799067	0.025	799067	0.028	0.00%	0.00%
7_19	843570	0.988	843569	0.130	872758.4	0.145	0.00%	3.46%	843569	0.025	843569	0.026	0.00%	0.00%
7_20	886670	0.968	886660	0.120	886660	0.135	0.00%	0.00%	886660	0.019	886660	0.020	0.00%	0.00%
7_21	803290	0.884	803270	0.117	803270	0.129	0.00%	0.00%	803270	0.018	803270	0.020	0.00%	0.00%
7_22	876860	0.832	876857	0.145	876857	0.158	0.00%	0.00%	876857	0.021	876857	0.022	0.00%	0.00%
7_23	836620	1.131	836621	0.122	836621	0.168	0.00%	0.00%	836621	0.023	836621	0.024	0.00%	0.00%
7_24	959910	0.605	959916	0.108	959916	0.110	0.00%	0.00%	959916	0.020	959916	0.021	0.00%	0.00%
7_25	833580	0.925	833577	0.113	847549.4	0.165	0.00%	1.68%	833577	0.024	833577	0.026	0.00%	0.00%
7_26	795250	1.345	795252	0.155	795252	0.173	0.00%	0.00%	795252	0.026	795252	0.027	0.00%	0.00%
7_27	807630	0.727	807620	0.088	807620	0.091	0.00%	0.00%	807620	0.024	807620	0.026	0.00%	0.00%
7_28	879640	1.045	879656	0.294	879656	0.306	0.00%	0.00%	879656	0.029	879656	0.033	0.00%	0.00%
7_29	865190	0.707	865189	0.142	865189	0.149	0.00%	0.00%	865189	0.022	865189	0.023	0.00%	0.00%
7_30	791330	1.297	791334	0.126	792174.2	0.181	0.00%	0.11%	791334	0.029	791334	0.030	0.00%	0.00%
7_31	977620	1.106	977635	0.181	977635	0.189	0.00%	0.00%	977635	0.024	977635	0.026	0.00%	0.00%
7_32	784640	0.937	784632	0.119	784632	0.122	0.00%	0.00%	784632	0.019	784632	0.021	0.00%	0.00%
7_33	847910	0.876	847917	0.126	847917	0.130	0.00%	0.00%	847917	0.022	847917	0.024	0.00%	0.00%
7_34	947200	1.381	947208	0.229	947208	0.232	0.00%	0.00%	947208	0.030	947208	0.033	0.00%	0.00%
7_35	871350	1.668	871357	0.183	871357	0.185	0.00%	0.00%	871357	0.023	871357	0.025	0.00%	0.00%
7_36	902230	1.254	902220	0.148	902220	0.155	0.00%	0.00%	902220	0.017	902220	0.019	0.00%	0.00%
7_37	753030	1.053	753039	0.178	753039	0.221	0.00%	0.00%	753039	0.029	753039	0.032	0.00%	0.00%
7_38	825320	0.886	825313	0.176	825313	0.182	0.00%	0.00%	825313	0.029	825313	0.031	0.00%	0.00%
7_39	776540	0.665	776551	0.171	776551	0.198	0.00%	0.00%	776551	0.029	776551	0.031	0.00%	0.00%
7_40	905730	0.928	905713	0.157	905713	0.158	0.00%	0.00%	905713	0.020	905713	0.022	0.00%	0.00%
7_41	742010	1.431	742008	0.137	742008	0.143	0.00%	0.00%	742008	0.019	742008	0.021	0.00%	0.00%
7_42	775600	1.333	775608	0.166	775608	0.171	0.00%	0.00%	775608	0.026	775608	0.028	0.00%	0.00%
7_43	952360	0.990	952347	0.146	952347	0.179	0.00%	0.00%	952347	0.026	952347	0.028	0.00%	0.00%
7_44	558830	1.009	558840	0.172	558840	0.179	0.00%	0.00%	558840	0.027	558840	0.029	0.00%	0.00%
7_45	972410	1.104	972401	0.153	972401	0.155	0.00%	0.00%	972401	0.025	972401	0.026	0.00%	0.00%
7_46	811390	1.213	811394	0.174	811394	0.212	0.00%	0.00%	811394	0.031	811394	0.035	0.00%	0.00%
7_47	757320	1.532	757313	0.177	757313	0.206	0.00%	0.00%	757313	0.023	757313	0.025	0.00%	0.00%
7_48	744860	1.069	744859	0.189	744859	0.193	0.00%	0.00%	744859	0.020	744859	0.022	0.00%	0.00%
7_49	827980	1.155	827960	0.207	827960	0.211	0.00%	0.00%	827960	0.022	827960	0.023	0.00%	0.00%

Table 60: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 7 nodes and Random Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
7_0	571150	1.354	571155	0.257	571155	0.285	0.00%	0.00%	571155	0.027	571155	0.029	0.00%	0.00%
7_1	521550	0.769	521552	0.222	521552	0.227	0.00%	0.00%	521552	0.027	521552	0.028	0.00%	0.00%
7_2	790860	1.215	790865	0.241	790865	0.246	0.00%	0.00%	790865	0.028	790865	0.030	0.00%	0.00%
7_3	828300	0.986	828313	0.174	847941.7	0.181	0.00%	2.37%	828313	0.021	828313	0.023	0.00%	0.00%
7_4	757690	0.816	757684	0.121	757684	0.181	0.00%	0.00%	757684	0.029	757684	0.032	0.00%	0.00%
7_5	403410	0.881	403402	0.217	403402	0.224	0.00%	0.00%	403402	0.029	403402	0.031	0.00%	0.00%
7_6	648820	1.140	648818	0.202	648818	0.206	0.00%	0.00%	648818	0.024	648818	0.025	0.00%	0.00%
7_7	710940	1.317	710948	0.176	710948	0.183	0.00%	0.00%	710948	0.022	710948	0.024	0.00%	0.00%
7_8	527380	1.148	527384	0.195	527384	0.235	0.00%	0.00%	527384	0.029	527384	0.031	0.00%	0.00%
7_9	625810	0.986	625810	0.147	625810	0.171	0.00%	0.00%	625810	0.023	625810	0.025	0.00%	0.00%
7_10	704420	1.343	704420	0.174	704420	0.191	0.00%	0.00%	704420	0.030	704420	0.032	0.00%	0.00%
7_11	952950	1.145	952954	0.102	952954	0.104	0.00%	0.00%	952954	0.019	952954	0.020	0.00%	0.00%
7_12	550930	0.776	550935	0.208	550935	0.214	0.00%	0.00%	550935	0.029	550935	0.030	0.00%	0.00%
7_13	719050	1.866	719069	0.151	719069	0.246	0.00%	0.00%	719069	0.028	719069	0.029	0.00%	0.00%
7_14	950460	0.919	950457	0.153	950457	0.160	0.00%	0.00%	950457	0.019	950457	0.020	0.00%	0.00%
7_15	358350	1.769	358357	0.235	358357	0.267	0.00%	0.00%	358357	0.032	358357	0.034	0.00%	0.00%
7_16	632540	1.972	632527	0.147	632527	0.181	0.00%	0.00%	632527	0.031	632527	0.034	0.00%	0.00%
7_17	961180	1.086	961175	0.057	961175	0.107	0.00%	0.00%	961175	0.023	961175	0.025	0.00%	0.00%
7_18	513470	1.831	513475	0.215	513475	0.226	0.00%	0.00%	513475	0.026	513475	0.027	0.00%	0.00%
7_19	793580	1.216	793571	0.197	793571	0.202	0.00%	0.00%	793571	0.023	793571	0.025	0.00%	0.00%
7_20	818130	0.804	818118	0.124	818118	0.130	0.00%	0.00%	818118	0.019	818118	0.021	0.00%	0.00%
7_21	712280	0.772	712292	0.133	712847	0.154	0.00%	0.08%	712292	0.021	712292	0.022	0.00%	0.00%
7_22	731980	0.515	731989	0.148	731989	0.151	0.00%	0.00%	731989	0.024	731989	0.025	0.00%	0.00%
7_23	778740	0.876	778746	0.145	778746	0.149	0.00%	0.00%	778746	0.021	778746	0.023	0.00%	0.00%
7_24	884400	0.443	884405	0.110	884405	0.111	0.00%	0.00%	884405	0.020	884405	0.021	0.00%	0.00%
7_25	709620	0.893	709621	0.096	709621	0.097	0.00%	0.00%	709621	0.023	709621	0.025	0.00%	0.00%
7_26	707780	1.413	707794	0.156	707794	0.203	0.00%	0.00%	707794	0.027	707794	0.029	0.00%	0.00%
7_27	548870	1.018	548868	0.136	548868	0.144	0.00%	0.00%	548868	0.026	548868	0.027	0.00%	0.00%
7_28	604090	0.957	604108	0.237	604108	0.240	0.00%	0.00%	604108	0.027	604108	0.029	0.00%	0.00%
7_29	609630	0.911	609603	0.079	609603	0.087	0.00%	0.00%	609603	0.022	609603	0.024	0.00%	0.00%
7_30	750420	1.209	750410	0.157	752226.4	0.184	0.00%	0.24%	750410	0.026	750410	0.028	0.00%	0.00%
7_31	718510	1.243	718517	0.093	718517	0.096	0.00%	0.00%	718517	0.027	718517	0.028	0.00%	0.00%
7_32	653950	0.777	653942	0.205	653942	0.207	0.00%	0.00%	653942	0.024	653942	0.026	0.00%	0.00%
7_33	827000	0.785	827013	0.125	827013	0.129	0.00%	0.00%	827013	0.021	827013	0.022	0.00%	0.00%
7_34	735210	1.646	735201	0.203	735201	0.231	0.00%	0.00%	735201	0.028	735201	0.031	0.00%	0.00%
7_35	856660	1.393	856669	0.118	856669	0.144	0.00%	0.00%	856669	0.022	856669	0.024	0.00%	0.00%
7_36	822960	0.845	822946	0.121	822946	0.125	0.00%	0.00%	822946	0.020	822946	0.021	0.00%	0.00%
7_37	704350	1.469	704358	0.172	704358	0.200	0.00%	0.00%	704358	0.028	704358	0.029	0.00%	0.00%
7_38	657580	0.676	657577	0.177	657577	0.212	0.00%	0.00%	657577	0.026	657577	0.028	0.00%	0.00%
7_39	630630	0.608	630646	0.255	630646	0.260	0.00%	0.00%	630646	0.029	630646	0.033	0.00%	0.00%
7_40	850520	1.089	850499	0.136	850499	0.151	0.00%	0.00%	850499	0.022	850499	0.023	0.00%	0.00%
7_41	696480	1.247	696470	0.174	696470	0.177	0.00%	0.00%	696470	0.024	696470	0.025	0.00%	0.00%
7_42	772790	1.066	772794	0.159	772794	0.219	0.00%	0.00%	772794	0.028	772794	0.030	0.00%	0.00%
7_43	731320	0.776	731317	0.190	731317	0.206	0.00%	0.00%	731317	0.027	731317	0.029	0.00%	0.00%
7_44	547190	1.429	547198	0.117	547198	0.136	0.00%	0.00%	547198	0.025	547198	0.026	0.00%	0.00%
7_45	798050	0.684	798048	0.102	798048	0.123	0.00%	0.00%	798048	0.023	798048	0.025	0.00%	0.00%
7_46	654810	1.266	654822	0.184	654822	0.191	0.00%	0.00%	654822	0.033	654822	0.036	0.00%	0.00%
7_47	700320	1.522	700321	0.117	700321	0.165	0.00%	0.00%	700321	0.020	700321	0.022	0.00%	0.00%
7_48	722670	0.757	722665	0.168	722665	0.189	0.00%	0.00%	722665	0.021	722665	0.022	0.00%	0.00%
7_49	655060	1.139	655045	0.171	655045	0.196	0.00%	0.00%	655045	0.019	655045	0.020	0.00%	0.00%

Table 61: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 8 nodes and Central Base Station position

	Mathematical Formulation		**GRVND**						**GVNSRVND**					
			MIN		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
8_0	590270	2.057	590280	0.301	590280	0.316	0.00%	0.00%	590280	0.326	590280	0.341	0.00%	0.00%
8_1	687340	2.349	687344	0.339	687344	0.347	0.00%	0.00%	687344	0.278	687344	0.306	0.00%	0.00%
8_2	707710	2.115	707704	0.168	710206.4	0.174	0.00%	0.35%	707704	0.249	707704	0.285	0.00%	0.00%
8_3	692910	3.104	692893	0.423	692893	0.444	0.00%	0.00%	692893	0.347	692893	0.411	0.00%	0.00%
8_4	768310	4.336	768310	0.286	768310	0.324	0.00%	0.00%	768310	0.313	768310	0.361	0.00%	0.00%
8_5	708580	2.851	708571	0.242	708571	0.269	0.00%	0.00%	708571	0.275	708571	0.294	0.00%	0.00%
8_6	820100	2.916	820088	0.272	820088	0.285	0.00%	0.00%	820088	0.258	820088	0.274	0.00%	0.00%
8_7	688080	2.940	688076	0.335	688076	0.348	0.00%	0.00%	688076	0.286	688076	0.302	0.00%	0.00%
8_8	725960	1.285	725973	0.245	725973	0.250	0.00%	0.00%	725973	0.250	725973	0.266	0.00%	0.00%
8_9	673870	0.958	673868	0.269	673868	0.279	0.00%	0.00%	673868	0.295	673868	0.311	0.00%	0.00%
8_10	944080	1.234	944077	0.206	944077	0.258	0.00%	0.00%	944077	0.237	944077	0.254	0.00%	0.00%
8_11	742430	4.951	742435	0.347	742435	0.355	0.00%	0.00%	742435	0.294	742435	0.334	0.00%	0.00%
8_12	691110	2.616	691124	0.275	691124	0.277	0.00%	0.00%	691124	0.272	691124	0.292	0.00%	0.00%
8_13	408710	5.449	408701	0.255	413539.4	0.339	0.00%	1.18%	408701	0.280	408701	0.306	0.00%	0.00%
8_14	866450	2.609	866449	0.137	866449	0.205	0.00%	0.00%	866449	0.232	866449	0.254	0.00%	0.00%
8_15	702800	1.368	702807	0.179	702807	0.238	0.00%	0.00%	702807	0.239	702807	0.248	0.00%	0.00%
8_16	822350	1.583	822327	0.248	822327	0.277	0.00%	0.00%	822327	0.268	822327	0.286	0.00%	0.00%
8_17	711420	2.480	711424	0.356	711424	0.362	0.00%	0.00%	711424	0.268	711424	0.290	0.00%	0.00%
8_18	733310	1.819	733302	0.301	733302	0.315	0.00%	0.00%	733302	0.246	733302	0.261	0.00%	0.00%
8_19	688790	1.699	688791	0.320	688791	0.332	0.00%	0.00%	688791	0.284	688791	0.314	0.00%	0.00%
8_20	700270	8.976	700291	0.187	700291	0.288	0.00%	0.00%	700291	0.292	700291	0.307	0.00%	0.00%
8_21	736760	2.292	736761	0.293	736761	0.392	0.00%	0.00%	736761	0.360	736761	0.381	0.00%	0.00%
8_22	711050	4.988	711051	0.306	711051	0.313	0.00%	0.00%	711051	0.297	711051	0.350	0.00%	0.00%
8_23	710240	6.077	710236	0.259	710236	0.286	0.00%	0.00%	710236	0.250	710236	0.281	0.00%	0.00%
8_24	664940	7.128	664936	0.386	664936	0.410	0.00%	0.00%	664936	0.354	664936	0.368	0.00%	0.00%
8_25	718400	8.329	718378	0.190	718378	0.304	0.00%	0.00%	718378	0.327	718378	0.349	0.00%	0.00%
8_26	713220	1.465	713245	0.333	713245	0.368	0.00%	0.00%	713245	0.348	713245	0.365	0.00%	0.00%
8_27	993330	1.518	993321	0.193	993321	0.197	0.00%	0.00%	993321	0.256	993321	0.268	0.00%	0.00%
8_28	807880	2.781	807868	0.362	807868	0.374	0.00%	0.00%	807868	0.315	807868	0.333	0.00%	0.00%
8_29	736510	1.166	736507	0.168	736507	0.186	0.00%	0.00%	736507	0.233	736507	0.252	0.00%	0.00%
8_30	819320	8.552	819322	0.285	838247.5	0.405	0.00%	2.31%	819322	0.310	819322	0.336	0.00%	0.00%
8_31	773270	2.209	773256	0.252	773256	0.341	0.00%	0.00%	773256	0.309	773256	0.329	0.00%	0.00%
8_32	703580	1.533	703568	0.194	712767.6	0.263	0.00%	1.31%	703568	0.366	703568	0.413	0.00%	0.00%
8_33	556780	4.496	556768	0.317	556768	0.395	0.00%	0.00%	556768	0.315	556768	0.337	0.00%	0.00%
8_34	833790	6.384	833784	0.229	833784	0.232	0.00%	0.00%	833784	0.267	833784	0.285	0.00%	0.00%
8_35	783100	2.885	783095	0.246	783095	0.294	0.00%	0.00%	783095	0.250	783095	0.274	0.00%	0.00%
8_36	859440	1.572	859443	0.217	872519.4	0.266	0.00%	1.52%	859443	0.246	859443	0.268	0.00%	0.00%
8_37	822370	1.796	822364	0.241	822364	0.303	0.00%	0.00%	822364	0.300	822364	0.328	0.00%	0.00%
8_38	808900	5.404	808889	0.218	808889	0.270	0.00%	0.00%	808889	0.268	808889	0.304	0.00%	0.00%
8_39	717900	4.194	717912	0.321	736813.6	0.370	0.00%	2.63%	717912	0.285	717912	0.312	0.00%	0.00%
8_40	595180	2.465	595167	0.303	595167	0.308	0.00%	0.00%	595167	0.265	595167	0.279	0.00%	0.00%
8_41	840170	2.488	840154	0.249	840154	0.289	0.00%	0.00%	840154	0.339	840154	0.360	0.00%	0.00%
8_42	569100	4.084	569095	0.164	569095	0.166	0.00%	0.00%	569095	0.310	569095	0.328	0.00%	0.00%
8_43	722350	0.946	722350	0.220	722350	0.224	0.00%	0.00%	722350	0.234	722350	0.257	0.00%	0.00%
8_44	685520	2.845	685529	0.337	685529	0.377	0.00%	0.00%	685529	0.330	685529	0.361	0.00%	0.00%
8_45	591020	4.914	591018	0.329	591018	0.338	0.00%	0.00%	591018	0.355	591018	0.379	0.00%	0.00%
8_46	668690	1.093	668687	0.278	668687	0.293	0.00%	0.00%	668687	0.292	668687	0.307	0.00%	0.00%
8_47	716800	8.737	716821	0.263	716821	0.321	0.00%	0.00%	716821	0.268	716821	0.299	0.00%	0.00%
8_48	766000	1.849	766014	0.228	766014	0.307	0.00%	0.00%	766014	0.245	766014	0.257	0.00%	0.00%
8_49	541110	4.136	541118	0.367	541118	0.412	0.00%	0.00%	541118	0.315	541118	0.334	0.00%	0.00%

Table 62: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 8 nodes and Eccentric Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
8_0	666220	3.499	666234	0.247	666234	0.359	0.00%	0.00%	666234	0.049	666234	0.053	0.00%	0.00%
8_1	847600	1.511	847597	0.168	877795.8	0.282	0.00%	3.56%	847597	0.040	847597	0.043	0.00%	0.00%
8_2	828820	3.643	828816	0.269	828816	0.288	0.00%	0.00%	828816	0.036	828816	0.038	0.00%	0.00%
8_3	930410	4.109	930397	0.451	930397	0.489	0.00%	0.00%	930397	0.062	930397	0.066	0.00%	0.00%
8_4	845660	3.277	845671	0.358	845671	0.439	0.00%	0.00%	845671	0.051	845671	0.056	0.00%	0.00%
8_5	901420	3.833	901411	0.152	901411	0.253	0.00%	0.00%	901411	0.037	901411	0.039	0.00%	0.00%
8_6	1010940	2.957	1010940	0.160	1010940	0.165	0.00%	0.00%	1010940	0.030	1010940	0.036	0.00%	0.00%
8_7	820080	2.930	820056	0.335	820056	0.376	0.00%	0.00%	820056	0.043	820056	0.045	0.00%	0.00%
8_8	756350	2.373	756355	0.268	756355	0.310	0.00%	0.00%	756355	0.036	756355	0.038	0.00%	0.00%
8_9	797790	3.991	797788	0.228	797788	0.279	0.00%	0.00%	797788	0.036	797788	0.040	0.00%	0.00%
8_10	1044720	1.580	1044721	0.239	1044721	0.276	0.00%	0.00%	1044721	0.036	1044721	0.037	0.00%	0.00%
8_11	908480	4.519	908475	0.386	908475	0.427	0.00%	0.00%	908475	0.045	908475	0.050	0.00%	0.00%
8_12	728990	2.575	728984	0.185	728984	0.272	0.00%	0.00%	728984	0.043	728984	0.044	0.00%	0.00%
8_13	655200	2.915	655193	0.324	655193	0.376	0.00%	0.00%	655193	0.050	655193	0.053	0.00%	0.00%
8_14	1076910	2.472	1076910	0.262	1076910	0.277	0.00%	0.00%	1076910	0.033	1076910	0.036	0.00%	0.00%
8_15	760420	2.005	760427	0.206	760427	0.210	0.00%	0.00%	760427	0.039	760427	0.043	0.00%	0.00%
8_16	1019190	2.123	1019179	0.239	1019179	0.300	0.00%	0.00%	1019179	0.037	1019179	0.040	0.00%	0.00%
8_17	794980	5.040	794978	0.372	794978	0.383	0.00%	0.00%	794978	0.037	794978	0.042	0.00%	0.00%
8_18	818370	2.984	818357	0.294	818357	0.317	0.00%	0.00%	818357	0.033	818357	0.036	0.00%	0.00%
8_19	776900	2.758	776896	0.200	776896	0.261	0.00%	0.00%	776896	0.043	776896	0.045	0.00%	0.00%
8_20	781240	14.507	781246	0.289	781246	0.397	0.00%	0.00%	781246	0.043	781246	0.046	0.00%	0.00%
8_21	808280	2.495	808264	0.379	808264	0.420	0.00%	0.00%	808264	0.051	808264	0.054	0.00%	0.00%
8_22	980080	3.915	980081	0.291	980081	0.355	0.00%	0.00%	980081	0.053	980081	0.058	0.00%	0.00%
8_23	958030	3.322	958051	0.306	958051	0.347	0.00%	0.00%	958051	0.037	958051	0.039	0.00%	0.00%
8_24	845540	4.039	845548	0.438	845548	0.493	0.00%	0.00%	845548	0.059	845548	0.063	0.00%	0.00%
8_25	919940	7.349	919924	0.341	919924	0.383	0.00%	0.00%	919924	0.052	919924	0.055	0.00%	0.00%
8_26	767820	6.432	767814	0.176	767814	0.180	0.00%	0.00%	767814	0.049	767814	0.053	0.00%	0.00%
8_27	1046100	1.213	1046091	0.127	1046091	0.151	0.00%	0.00%	1046091	0.034	1046091	0.036	0.00%	0.00%
8_28	930520	5.373	930531	0.344	937532.5	0.378	0.00%	0.75%	930531	0.048	930531	0.051	0.00%	0.00%
8_29	892510	2.168	892496	0.254	892496	0.271	0.00%	0.00%	892496	0.032	892496	0.037	0.00%	0.00%
8_30	951920	9.966	951920	0.338	951920	0.380	0.00%	0.00%	951920	0.062	951920	0.065	0.00%	0.00%
8_31	876870	2.512	876864	0.227	876864	0.236	0.00%	0.00%	876864	0.041	876864	0.048	0.00%	0.00%
8_32	813340	5.139	813344	0.186	819685.1	0.347	0.00%	0.78%	813344	0.044	813344	0.046	0.00%	0.00%
8_33	862900	14.144	862890	0.388	862890	0.427	0.00%	0.00%	862890	0.050	862890	0.051	0.00%	0.00%
8_34	970450	3.553	970444	0.230	975960	0.276	0.00%	0.57%	970444	0.041	970444	0.044	0.00%	0.00%
8_35	872810	2.407	872804	0.187	872804	0.227	0.00%	0.00%	872804	0.036	872804	0.038	0.00%	0.00%
8_36	839480	2.100	839482	0.316	839482	0.346	0.00%	0.00%	839482	0.036	839482	0.039	0.00%	0.00%
8_37	889780	1.098	889775	0.255	1009893.6	0.290	0.00%	13.50%	889775	0.045	889775	0.048	0.00%	0.00%
8_38	1008730	5.535	1008729	0.324	1008729	0.363	0.00%	0.00%	1008729	0.043	1008729	0.048	0.00%	0.00%
8_39	792710	3.667	792703	0.279	792703	0.353	0.00%	0.00%	792703	0.041	792703	0.045	0.00%	0.00%
8_40	912080	1.866	912065	0.207	912065	0.292	0.00%	0.00%	912065	0.038	912065	0.041	0.00%	0.00%
8_41	990370	4.315	990368	0.408	990368	0.417	0.00%	0.00%	990368	0.054	990368	0.057	0.00%	0.00%
8_42	785770	5.212	785772	0.149	785772	0.179	0.00%	0.00%	785772	0.038	785772	0.041	0.00%	0.00%
8_43	968960	1.004	968958	0.216	968958	0.219	0.00%	0.00%	968958	0.033	968958	0.035	0.00%	0.00%
8_44	761540	3.424	761545	0.340	761545	0.352	0.00%	0.00%	761545	0.057	761545	0.060	0.00%	0.00%
8_45	770280	2.848	770283	0.337	770283	0.461	0.00%	0.00%	770283	0.050	770283	0.055	0.00%	0.00%
8_46	843250	1.321	843248	0.218	843248	0.244	0.00%	0.00%	843248	0.037	843248	0.041	0.00%	0.00%
8_47	787050	6.935	787044	0.290	787044	0.342	0.00%	0.00%	787044	0.043	787044	0.045	0.00%	0.00%
8_48	908770	1.582	908778	0.287	908778	0.299	0.00%	0.00%	908778	0.041	908778	0.043	0.00%	0.00%
8_49	802900	3.727	802898	0.434	802898	0.459	0.00%	0.00%	802898	0.056	802898	0.059	0.00%	0.00%

Table 63: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 8 nodes and Random Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
8_0	636540	10.061	636554	0.492	636554	0.503	0.00%	0.00%	636554	0.050	636554	0.052	0.00%	0.00%
8_1	725980	2.318	725989	0.271	725989	0.280	0.00%	0.00%	725989	0.036	725989	0.040	0.00%	0.00%
8_2	833040	4.719	835609	0.132	922144	0.140	0.31%	10.70%	833036	0.044	833036	0.047	0.00%	0.00%
8_3	907170	5.093	907170	0.213	907170	0.267	0.00%	0.00%	907170	0.060	907170	0.066	0.00%	0.00%
8_4	783710	3.962	783711	0.344	783711	0.374	0.00%	0.00%	783711	0.058	783711	0.060	0.00%	0.00%
8_5	802860	2.298	802860	0.308	802860	0.310	0.00%	0.00%	802860	0.039	802860	0.041	0.00%	0.00%
8_6	832080	5.722	832065	0.291	832065	0.331	0.00%	0.00%	832065	0.039	832065	0.043	0.00%	0.00%
8_7	701320	3.090	701314	0.303	701314	0.349	0.00%	0.00%	701314	0.044	701314	0.046	0.00%	0.00%
8_8	729090	1.435	729089	0.229	729089	0.236	0.00%	0.00%	729089	0.035	729089	0.038	0.00%	0.00%
8_9	673660	1.673	673660	0.280	673660	0.297	0.00%	0.00%	673660	0.040	673660	0.043	0.00%	0.00%
8_10	941300	1.593	941305	0.239	941305	0.267	0.00%	0.00%	941305	0.036	941305	0.038	0.00%	0.00%
8_11	720070	3.921	720053	0.239	720053	0.316	0.00%	0.00%	720053	0.044	720053	0.049	0.00%	0.00%
8_12	690240	3.338	690241	0.348	690241	0.352	0.00%	0.00%	690241	0.043	690241	0.044	0.00%	0.00%
8_13	471890	3.388	471898	0.358	471898	0.431	0.00%	0.00%	471898	0.043	471898	0.047	0.00%	0.00%
8_14	914220	4.469	920858	0.298	921915.2	0.359	0.73%	0.84%	914222	0.035	914222	0.039	0.00%	0.00%
8_15	692890	1.567	692888	0.250	692888	0.286	0.00%	0.00%	692888	0.034	692888	0.035	0.00%	0.00%
8_16	804050	2.022	804057	0.304	804057	0.333	0.00%	0.00%	804057	0.040	804057	0.043	0.00%	0.00%
8_17	767010	3.668	767000	0.274	767000	0.322	0.00%	0.00%	767000	0.045	767000	0.047	0.00%	0.00%
8_18	726470	2.612	726454	0.212	726454	0.215	0.00%	0.00%	726454	0.040	726454	0.043	0.00%	0.00%
8_19	685650	1.693	685652	0.236	685652	0.270	0.00%	0.00%	685652	0.042	685652	0.044	0.00%	0.00%
8_20	742210	12.329	742238	0.097	742238	0.335	0.00%	0.00%	742238	0.043	742238	0.046	0.00%	0.00%
8_21	717650	3.328	717647	0.180	717647	0.290	0.00%	0.00%	717647	0.052	717647	0.053	0.00%	0.00%
8_22	705570	4.035	705567	0.257	705567	0.392	0.00%	0.00%	705567	0.062	705567	0.067	0.00%	0.00%
8_23	700650	3.997	700661	0.226	700661	0.262	0.00%	0.00%	700661	0.045	700661	0.047	0.00%	0.00%
8_24	695430	4.972	695449	0.315	695449	0.406	0.00%	0.00%	695449	0.059	695449	0.063	0.00%	0.00%
8_25	799310	8.402	799305	0.328	799305	0.370	0.00%	0.00%	799305	0.052	799305	0.056	0.00%	0.00%
8_26	716610	3.808	716624	0.188	716624	0.280	0.00%	0.00%	716624	0.054	716624	0.057	0.00%	0.00%
8_27	987560	1.062	987543	0.147	987543	0.153	0.00%	0.00%	987543	0.034	987543	0.035	0.00%	0.00%
8_28	841140	2.107	841134	0.370	841134	0.409	0.00%	0.00%	841134	0.052	841134	0.055	0.00%	0.00%
8_29	744730	1.924	744720	0.228	744720	0.231	0.00%	0.00%	744720	0.035	744720	0.037	0.00%	0.00%
8_30	783640	10.271	783634	0.377	783634	0.408	0.00%	0.00%	783634	0.047	783634	0.049	0.00%	0.00%
8_31	717290	0.845	717267	0.282	717267	0.284	0.00%	0.00%	717267	0.049	717267	0.052	0.00%	0.00%
8_32	706400	4.167	706391	0.220	706391	0.273	0.00%	0.00%	706391	0.042	706391	0.045	0.00%	0.00%
8_33	680500	4.524	680498	0.408	680498	0.441	0.00%	0.00%	680498	0.045	680498	0.051	0.00%	0.00%
8_34	870280	2.832	870273	0.257	870273	0.292	0.00%	0.00%	870273	0.038	870273	0.042	0.00%	0.00%
8_35	795950	3.935	795951	0.241	795951	0.292	0.00%	0.00%	795951	0.034	795951	0.037	0.00%	0.00%
8_36	874120	2.709	874127	0.267	874127	0.283	0.00%	0.00%	874127	0.038	874127	0.043	0.00%	0.00%
8_37	794020	2.263	794015	0.328	794015	0.340	0.00%	0.00%	794015	0.039	794015	0.045	0.00%	0.00%
8_38	789380	3.882	789386	0.390	789386	0.410	0.00%	0.00%	789386	0.042	789386	0.044	0.00%	0.00%
8_39	853410	3.865	853403	0.277	853403	0.317	0.00%	0.00%	853403	0.048	853403	0.053	0.00%	0.00%
8_40	795390	2.353	795391	0.216	838488.4	0.278	0.00%	5.42%	795391	0.036	795391	0.039	0.00%	0.00%
8_41	854800	3.268	854812	0.401	854812	0.411	0.00%	0.00%	854812	0.050	854812	0.051	0.00%	0.00%
8_42	594220	7.555	594210	0.397	594210	0.415	0.00%	0.00%	594210	0.047	594210	0.050	0.00%	0.00%
8_43	719950	0.811	719944	0.183	719944	0.185	0.00%	0.00%	719944	0.032	719944	0.036	0.00%	0.00%
8_44	685900	4.918	685895	0.325	685895	0.431	0.00%	0.00%	685895	0.050	685895	0.056	0.00%	0.00%
8_45	573460	4.106	573463	0.364	573463	0.434	0.00%	0.00%	573463	0.051	573463	0.055	0.00%	0.00%
8_46	624380	1.689	624371	0.230	624371	0.239	0.00%	0.00%	624371	0.042	624371	0.043	0.00%	0.00%
8_47	702750	7.201	702768	0.380	702768	0.395	0.00%	0.00%	702768	0.040	702768	0.043	0.00%	0.00%
8_48	767250	2.230	767250	0.322	767250	0.326	0.00%	0.00%	767250	0.040	767250	0.041	0.00%	0.00%
8_49	604260	7.548	604260	0.222	623030.5	0.361	0.00%	3.11%	604260	0.043	604260	0.046	0.00%	0.00%

Table 64: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 9 nodes and Central Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
9_0	614280	10.792	618196	0.352	618196	0.359	0.64%	0.64%	614266	0.419	614266	0.458	0.00%	0.00%
9_1	616960	9.431	616958	0.426	621270.2	0.510	0.00%	0.70%	616958	0.420	616958	0.435	0.00%	0.00%
9_2	868140	14.832	868155	0.442	868155	0.526	0.00%	0.00%	868155	0.477	868155	0.518	0.00%	0.00%
9_3	857790	9.415	861327	0.402	861327	0.442	0.41%	0.41%	857801	0.393	857801	0.452	0.00%	0.00%
9_4	902460	9.119	902448	0.278	902448	0.346	0.00%	0.00%	902448	0.339	902448	0.360	0.00%	0.00%
9_5	937350	10.739	937349	0.440	937349	0.461	0.00%	0.00%	937349	0.428	937349	0.458	0.00%	0.00%
9_6	671450	7.324	671444	0.430	671444	0.476	0.00%	0.00%	671444	0.471	671444	0.495	0.00%	0.00%
9_7	834120	4.748	834113	0.115	881818.5	0.226	0.00%	5.72%	834113	0.332	834113	0.370	0.00%	0.00%
9_8	766370	12.214	766381	0.367	766381	0.443	0.00%	0.00%	766381	0.409	766381	0.431	0.00%	0.00%
9_9	728910	6.799	728911	0.311	728911	0.333	0.00%	0.00%	728911	0.350	728911	0.396	0.00%	0.00%
9_10	520240	4.615	520251	0.589	520251	0.616	0.00%	0.00%	520251	0.486	520251	0.540	0.00%	0.00%
9_11	646890	13.582	646881	0.661	646881	0.849	0.00%	0.00%	646881	0.627	646881	0.667	0.00%	0.00%
9_12	883240	3.804	883236	0.322	883236	0.418	0.00%	0.00%	883236	0.477	883236	0.507	0.00%	0.00%
9_13	489940	13.235	489939	0.478	489939	0.624	0.00%	0.00%	489939	0.465	489939	0.514	0.00%	0.00%
9_14	711200	13.150	711205	0.432	711205	0.469	0.00%	0.00%	711205	0.518	711205	0.563	0.00%	0.00%
9_15	731940	13.365	731958	0.623	731958	0.696	0.00%	0.00%	731958	0.515	731958	0.565	0.00%	0.00%
9_16	763910	11.003	763903	0.566	773344.6	0.616	0.00%	1.24%	763903	0.466	763903	0.508	0.00%	0.00%
9_17	720470	5.811	720474	0.446	720474	0.516	0.00%	0.00%	720474	0.435	720474	0.458	0.00%	0.00%
9_18	935280	7.509	935266	0.543	935266	0.566	0.00%	0.00%	935266	0.450	935266	0.486	0.00%	0.00%
9_19	831350	11.333	831353	0.167	878242.1	0.172	0.00%	5.64%	831353	0.368	831353	0.410	0.00%	0.00%
9_20	675690	11.787	675685	0.418	676449.7	0.665	0.00%	0.11%	675685	0.530	675685	0.576	0.00%	0.00%
9_21	873370	6.924	873362	0.538	873362	0.548	0.00%	0.00%	873362	0.443	873362	0.466	0.00%	0.00%
9_22	757390	8.392	757371	0.506	757371	0.634	0.00%	0.00%	757371	0.468	757371	0.537	0.00%	0.00%
9_23	879350	10.782	879349	0.407	879349	0.412	0.00%	0.00%	879349	0.401	879349	0.448	0.00%	0.00%
9_24	717110	13.311	717108	0.578	717108	0.596	0.00%	0.00%	717108	0.493	717108	0.542	0.00%	0.00%
9_25	803010	5.850	802998	0.334	802998	0.376	0.00%	0.00%	802998	0.425	802998	0.459	0.00%	0.00%
9_26	825190	8.706	825197	0.127	825197	0.165	0.00%	0.00%	825197	0.406	825197	0.429	0.00%	0.00%
9_27	776950	12.862	776960	0.274	776960	0.343	0.00%	0.00%	776960	0.369	776960	0.399	0.00%	0.00%
9_28	693840	11.531	693839	0.422	693839	0.586	0.00%	0.00%	693839	0.453	693839	0.495	0.00%	0.00%
9_29	840660	15.275	840656	0.503	840656	0.549	0.00%	0.00%	840656	0.470	840656	0.524	0.00%	0.00%
9_30	523180	6.007	523174	0.431	523174	0.438	0.00%	0.00%	523174	0.387	523174	0.408	0.00%	0.00%
9_31	890870	5.534	890882	0.505	893631.4	0.577	0.00%	0.31%	890882	0.472	890882	0.499	0.00%	0.00%
9_32	869230	9.383	869228	0.236	883517.8	0.295	0.00%	1.64%	869228	0.370	869228	0.421	0.00%	0.00%
9_33	778090	12.202	778086	0.371	778086	0.451	0.00%	0.00%	778086	0.488	778086	0.525	0.00%	0.00%
9_34	619770	13.586	619774	0.457	619774	0.605	0.00%	0.00%	619774	0.466	619774	0.517	0.00%	0.00%
9_35	738490	9.906	738470	0.528	738470	0.641	0.00%	0.00%	738470	0.503	738470	0.540	0.00%	0.00%
9_36	873600	3.250	873604	0.348	889374.4	0.390	0.00%	1.81%	873604	0.362	873604	0.411	0.00%	0.00%
9_37	986780	10.163	986772	0.186	986772	0.321	0.00%	0.00%	986772	0.389	986772	0.421	0.00%	0.00%
9_38	845120	6.633	845112	0.372	845112	0.406	0.00%	0.00%	845112	0.380	845112	0.427	0.00%	0.00%
9_39	823450	14.774	823458	0.509	823458	0.685	0.00%	0.00%	823458	0.591	823458	0.633	0.00%	0.00%
9_40	608560	7.987	608580	0.384	618315	0.460	0.00%	1.60%	608580	0.433	608580	0.469	0.00%	0.00%
9_41	653000	5.190	653016	0.349	653016	0.485	0.00%	0.00%	653016	0.487	653016	0.538	0.00%	0.00%
9_42	817780	3.962	817780	0.452	817780	0.455	0.00%	0.00%	817780	0.411	817780	0.442	0.00%	0.00%
9_43	865850	11.400	865855	0.562	871562	0.663	0.00%	0.66%	865855	0.491	865855	0.536	0.00%	0.00%
9_44	935650	13.349	935627	0.212	935627	0.214	0.00%	0.00%	935627	0.439	935627	0.488	0.00%	0.00%
9_45	951290	12.111	951296	0.543	958579.5	0.604	0.00%	0.77%	951296	0.571	951296	0.614	0.00%	0.00%
9_46	630730	23.984	630721	0.491	630721	0.682	0.00%	0.00%	630721	0.493	630721	0.569	0.00%	0.00%
9_47	634590	9.266	634601	0.434	634601	0.546	0.00%	0.00%	634601	0.503	634601	0.520	0.00%	0.00%
9_48	840330	12.089	840329	0.439	840329	0.480	0.00%	0.00%	840329	0.424	840329	0.468	0.00%	0.00%
9_49	680170	14.704	680167	0.359	680167	0.370	0.00%	0.00%	680167	0.511	680167	0.558	0.00%	0.00%

Table 65: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 9 nodes and Eccentric Base Station position

	Mathematical Formulation		**GRVND**						**GVNSRVND**					
			MIN		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
9_0	0.488414	10.792	783925	0.404	783925	0.454	0.00%	0.00%	783925	0.057	783925	0.062	0.00%	0.00%
9_1	616960	9.431	746997	0.199	751558.8	0.268	0.00%	0.61%	746997	0.054	746997	0.058	0.00%	0.00%
9_2	868140	14.832	994252	0.632	994252	0.687	0.00%	0.00%	994252	0.066	994252	0.071	0.00%	0.00%
9_3	857790	9.415	935609	0.544	935609	0.550	0.00%	0.00%	935609	0.061	935609	0.064	0.00%	0.00%
9_4	902460	9.119	984256	0.343	988175.5	0.410	0.00%	0.40%	984256	0.046	984256	0.053	0.00%	0.00%
9_5	937350	10.739	1030525	0.428	1030525	0.491	0.00%	0.00%	1030525	0.064	1030525	0.068	0.00%	0.00%
9_6	671450	7.324	881429	0.485	881429	0.569	0.00%	0.00%	881429	0.068	881429	0.071	0.00%	0.00%
9_7	834120	4.748	917587	0.301	917587	0.347	0.00%	0.00%	917587	0.053	917587	0.056	0.00%	0.00%
9_8	766370	12.214	912593	0.303	912593	0.342	0.00%	0.00%	912593	0.058	912593	0.062	0.00%	0.00%
9_9	728910	6.799	760994	0.287	760994	0.317	0.00%	0.00%	760994	0.050	760994	0.053	0.00%	0.00%
9_10	520240	4.615	847636	0.385	847636	0.481	0.00%	0.00%	847636	0.067	847636	0.069	0.00%	0.00%
9_11	646890	13.582	941064	0.598	941064	0.740	0.00%	0.00%	941064	0.092	941064	0.096	0.00%	0.00%
9_12	883240	3.804	962773	0.435	962773	0.500	0.00%	0.00%	962773	0.071	962773	0.072	0.00%	0.00%
9_13	489940	13.235	869488	0.345	869488	0.547	0.00%	0.00%	869488	0.076	869488	0.080	0.00%	0.00%
9_14	711200	13.150	826909	0.551	826909	0.597	0.00%	0.00%	826909	0.084	826909	0.090	0.00%	0.00%
9_15	731940	13.365	902947	0.140	913171.8	0.505	0.00%	1.13%	902947	0.076	902947	0.080	0.00%	0.00%
9_16	763910	11.003	826186	0.530	826186	0.550	0.00%	0.00%	826186	0.077	826186	0.080	0.00%	0.00%
9_17	720470	5.811	911844	0.469	911844	0.495	0.00%	0.00%	911844	0.062	911844	0.065	0.00%	0.00%
9_18	935280	7.509	943129	0.286	943129	0.413	0.00%	0.00%	943129	0.068	943129	0.078	0.00%	0.00%
9_19	831350	11.333	903105	0.315	903105	0.348	0.00%	0.00%	903105	0.053	903105	0.056	0.00%	0.00%
9_20	675690	11.787	793622	0.444	793622	0.527	0.00%	0.00%	793622	0.064	793622	0.070	0.00%	0.00%
9_21	873370	6.924	993113	0.396	993113	0.500	0.00%	0.00%	993113	0.057	993113	0.061	0.00%	0.00%
9_22	757390	8.392	833819	0.472	833819	0.486	0.00%	0.00%	833819	0.060	833819	0.068	0.00%	0.00%
9_23	879350	10.782	966479	0.447	966479	0.482	0.00%	0.00%	966479	0.060	966479	0.066	0.00%	0.00%
9_24	717110	13.311	825224	0.319	825224	0.487	0.00%	0.00%	825224	0.067	825224	0.070	0.00%	0.00%
9_25	803010	5.850	864459	0.480	864459	0.493	0.00%	0.00%	864459	0.060	864459	0.064	0.00%	0.00%
9_26	825190	8.706	882448	0.342	882448	0.401	0.00%	0.00%	882448	0.054	882448	0.061	0.00%	0.00%
9_27	776950	12.862	960502	0.353	960502	0.355	0.00%	0.00%	960502	0.055	960502	0.058	0.00%	0.00%
9_28	693840	11.531	916966	0.542	916966	0.655	0.00%	0.00%	916966	0.084	916966	0.087	0.00%	0.00%
9_29	840660	15.275	937991	0.370	937991	0.375	7.34%	7.34%	873803	0.071	873803	0.077	0.00%	0.00%
9_30	523180	6.007	741853	0.171	741853	0.229	0.00%	0.00%	741853	0.053	741853	0.057	0.00%	0.00%
9_31	890870	5.534	888976	0.231	895991.5	0.424	0.00%	0.79%	888976	0.061	888976	0.071	0.00%	0.00%
9_32	869230	9.383	982125	0.328	1007663.8	0.388	0.00%	2.60%	982125	0.055	982125	0.060	0.00%	0.00%
9_33	778090	12.202	1007137	0.461	1007137	0.481	0.00%	0.00%	1007137	0.077	1007137	0.082	0.00%	0.00%
9_34	619770	13.586	718625	0.455	718625	0.600	0.00%	0.00%	718625	0.065	718625	0.070	0.00%	0.00%
9_35	738490	9.906	985162	0.462	985162	0.490	3.20%	3.20%	954565	0.072	954565	0.076	0.00%	0.00%
9_36	873600	3.250	914201	0.333	918980.3	0.412	0.00%	0.52%	914201	0.045	914201	0.050	0.00%	0.00%
9_37	986780	10.163	988714	0.416	988714	0.472	0.00%	0.00%	988714	0.059	988714	0.061	0.00%	0.00%
9_38	845120	6.633	1033208	0.371	1033208	0.442	0.00%	0.00%	1033208	0.056	1033208	0.060	0.00%	0.00%
9_39	823450	14.774	959387	0.575	959387	0.671	0.00%	0.00%	959387	0.081	959387	0.086	0.00%	0.00%
9_40	608560	7.987	855188	0.467	855188	0.512	0.00%	0.00%	855188	0.062	855188	0.065	0.00%	0.00%
9_41	653000	5.190	866869	0.286	869685	0.357	0.00%	0.33%	866869	0.074	866869	0.081	0.00%	0.00%
9_42	817780	3.962	962564	0.373	962564	0.399	0.00%	0.00%	962564	0.061	962564	0.065	0.00%	0.00%
9_43	865850	11.400	1104956	0.678	1104956	0.705	0.00%	0.00%	1104956	0.078	1104956	0.086	0.00%	0.00%
9_44	935650	13.349	988104	0.330	988104	0.401	0.00%	0.00%	988104	0.063	988104	0.068	0.00%	0.00%
9_45	951290	12.111	1117078	0.684	1117078	0.718	0.00%	0.00%	1117078	0.079	1117078	0.086	0.00%	0.00%
9_46	630730	23.984	827015	0.271	827015	0.318	0.00%	0.00%	827015	0.060	827015	0.062	0.00%	0.00%
9_47	634590	9.266	798625	0.478	798625	0.510	0.00%	0.00%	798625	0.071	798625	0.076	0.00%	0.00%
9_48	840330	12.089	960945	0.394	971516.4	0.504	0.00%	1.10%	960945	0.063	960945	0.068	0.00%	0.00%
9_49	680170	14.704	798112	0.563	798112	0.586	0.00%	0.00%	798112	0.071	798112	0.074	0.00%	0.00%

Table 66: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 9 nodes and Random Base Station position

	Mathematical		**GRVND**						**GVNSRVND**					
	Formulation		**MIN**		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
9_0	644740	8.045	644739	0.350	644739	0.400	0.00%	0.00%	644739	0.054	644739	0.061	0.00%	0.00%
9_1	603190	8.346	603190	0.336	603190	0.407	0.00%	0.00%	603190	0.060	603190	0.065	0.00%	0.00%
9_2	862080	8.806	862080	0.488	862080	0.529	0.00%	0.00%	862080	0.071	862080	0.076	0.00%	0.00%
9_3	878800	10.607	878815	0.489	878815	0.501	0.00%	0.00%	878815	0.057	878815	0.061	0.00%	0.00%
9_4	898820	3.999	898831	0.261	898831	0.359	0.00%	0.00%	898831	0.049	898831	0.052	0.00%	0.00%
9_5	929310	11.598	929312	0.428	929312	0.490	0.00%	0.00%	929312	0.061	929312	0.065	0.00%	0.00%
9_6	720110	9.756	720079	0.386	720079	0.490	0.00%	0.00%	720079	0.062	720079	0.065	0.00%	0.00%
9_7	982580	7.675	982583	0.276	990513.6	0.396	0.00%	0.81%	982583	0.055	982583	0.061	0.00%	0.00%
9_8	762840	8.890	762845	0.207	806973	0.253	0.00%	5.79%	762845	0.064	762845	0.068	0.00%	0.00%
9_9	813130	5.870	813131	0.229	813131	0.272	0.00%	0.00%	813131	0.053	813131	0.056	0.00%	0.00%
9_10	617200	4.540	617213	0.478	617213	0.517	0.00%	0.00%	617213	0.071	617213	0.077	0.00%	0.00%
9_11	689760	11.065	689749	0.581	689749	0.709	0.00%	0.00%	689749	0.104	689749	0.108	0.00%	0.00%
9_12	885830	3.744	885829	0.323	885829	0.429	0.00%	0.00%	885829	0.071	885829	0.076	0.00%	0.00%
9_13	437460	14.877	437449	0.518	437449	0.575	0.00%	0.00%	437449	0.072	437449	0.076	0.00%	0.00%
9_14	684490	12.485	684500	0.423	684500	0.446	0.00%	0.00%	684500	0.073	684500	0.082	0.00%	0.00%
9_15	750260	15.546	750274	0.506	750274	0.698	0.00%	0.00%	750274	0.082	750274	0.092	0.00%	0.00%
9_16	853810	8.416	853835	0.413	853835	0.478	0.00%	0.00%	853835	0.074	853835	0.078	0.00%	0.00%
9_17	720300	7.697	720303	0.409	720303	0.415	0.00%	0.00%	720303	0.066	720303	0.069	0.00%	0.00%
9_18	944040	5.047	944030	0.460	944030	0.642	0.00%	0.00%	944030	0.065	944030	0.071	0.00%	0.00%
9_19	840730	10.726	840734	0.422	840734	0.434	0.00%	0.00%	840734	0.056	840734	0.060	0.00%	0.00%
9_20	680760	10.250	680695	0.392	680695	0.540	-0.01%	-0.01%	680695	0.078	680695	0.080	-0.01%	-0.01%
9_21	882870	12.724	882864	0.476	882864	0.518	0.00%	0.00%	882864	0.058	882864	0.063	0.00%	0.00%
9_22	868410	12.638	868404	0.416	869101.2	0.513	0.00%	0.08%	868404	0.067	868404	0.074	0.00%	0.00%
9_23	854360	12.123	854354	0.401	854354	0.482	0.00%	0.00%	854354	0.064	854354	0.067	0.00%	0.00%
9_24	684290	8.858	684295	0.513	684295	0.603	0.00%	0.00%	684295	0.077	684295	0.080	0.00%	0.00%
9_25	767740	5.490	767737	0.493	767737	0.586	0.00%	0.00%	767737	0.065	767737	0.069	0.00%	0.00%
9_26	764210	3.584	764223	0.248	764223	0.284	0.00%	0.00%	764223	0.056	764223	0.061	0.00%	0.00%
9_27	814410	13.443	814398	0.429	814398	0.459	0.00%	0.00%	814398	0.057	814398	0.061	0.00%	0.00%
9_28	694590	12.970	694588	0.629	694588	0.700	0.00%	0.00%	694588	0.077	694588	0.080	0.00%	0.00%
9_29	855250	13.146	855246	0.552	855246	0.646	0.00%	0.00%	855246	0.078	855246	0.084	0.00%	0.00%
9_30	586870	5.321	586861	0.431	586861	0.453	0.00%	0.00%	586861	0.061	586861	0.063	0.00%	0.00%
9_31	895700	6.100	899442	0.486	899442	0.494	0.42%	0.42%	895712	0.074	895712	0.080	0.00%	0.00%
9_32	849040	6.648	849050	0.360	850942.2	0.409	0.00%	0.22%	849050	0.056	849050	0.060	0.00%	0.00%
9_33	772450	11.621	772452	0.437	772452	0.456	0.00%	0.00%	772452	0.069	772452	0.070	0.00%	0.00%
9_34	665310	14.014	665314	0.489	665314	0.584	0.00%	0.00%	665314	0.068	665314	0.071	0.00%	0.00%
9_35	748100	8.144	748090	0.502	748090	0.554	0.00%	0.00%	748090	0.076	748090	0.078	0.00%	0.00%
9_36	825670	5.349	825681	0.304	825681	0.335	0.00%	0.00%	825681	0.047	825681	0.052	0.00%	0.00%
9_37	973380	4.588	973375	0.437	973375	0.470	0.00%	0.00%	973375	0.064	973375	0.068	0.00%	0.00%
9_38	823470	3.554	823474	0.217	823474	0.325	0.00%	0.00%	823474	0.054	823474	0.058	0.00%	0.00%
9_39	814100	11.275	814113	0.526	814113	0.609	0.00%	0.00%	814113	0.095	814113	0.099	0.00%	0.00%
9_40	620480	6.840	620490	0.478	620490	0.499	0.00%	0.00%	620490	0.061	620490	0.065	0.00%	0.00%
9_41	666550	3.794	666571	0.604	666571	0.630	0.00%	0.00%	666571	0.079	666571	0.085	0.00%	0.00%
9_42	880290	3.704	880287	0.254	880287	0.321	0.00%	0.00%	880287	0.049	880287	0.053	0.00%	0.00%
9_43	869400	10.422	869391	0.420	869687.4	0.577	0.00%	0.03%	869391	0.078	869391	0.089	0.00%	0.00%
9_44	894490	6.055	894478	0.279	894478	0.354	0.00%	0.00%	894478	0.061	894478	0.066	0.00%	0.00%
9_45	963370	10.869	963389	0.578	963389	0.630	0.00%	0.00%	963389	0.072	963389	0.081	0.00%	0.00%
9_46	702330	20.489	702325	0.292	702325	0.542	0.00%	0.00%	702325	0.076	702325	0.083	0.00%	0.00%
9_47	839880	13.245	839884	0.471	839884	0.607	0.00%	0.00%	839884	0.060	839884	0.069	0.00%	0.00%
9_48	799300	12.738	799293	0.362	799293	0.435	0.00%	0.00%	799293	0.062	799293	0.065	0.00%	0.00%
9_49	656550	10.356	656559	0.299	656559	0.411	0.00%	0.00%	656559	0.080	656559	0.084	0.00%	0.00%

Table 67: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 10 nodes and Central Base Station position

	Mathematical		GRVND						GVNSRVND					
	Formulation		MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
10_0	828220	9.489	828229	0.730	828229	0.857	0.00%	0.00%	828229	0.761	828229	0.830	0.00%	0.00%
10_1	722460	10.268	722468	0.536	722468	0.575	0.00%	0.00%	722468	0.574	722468	0.619	0.00%	0.00%
10_2	719510	16.042	719509	0.675	719509	0.764	0.00%	0.00%	719509	0.593	719509	0.662	0.00%	0.00%
10_3	898400	17.003	898392	0.642	898392	0.822	0.00%	0.00%	898392	0.702	898392	0.756	0.00%	0.00%
10_4	698510	24.954	698499	0.956	698499	1.311	0.00%	0.00%	698499	0.838	698499	0.914	0.00%	0.00%
10_5	823380	13.337	823373	0.712	835369.4	0.990	0.00%	1.46%	823373	0.684	823373	0.734	0.00%	0.00%
10_6	706910	10.589	706920	0.434	706920	0.595	0.00%	0.00%	706920	0.730	706920	0.767	0.00%	0.00%
10_7	942490	19.092	942493	0.648	942493	0.854	0.00%	0.00%	942493	0.710	942493	0.782	0.00%	0.00%
10_8	854320	12.142	854315	0.587	860721	0.720	0.00%	0.75%	854315	0.575	854315	0.623	0.00%	0.00%
10_9	1007080	14.653	1007069	0.662	1007069	0.689	0.00%	0.00%	1007069	0.577	1007069	0.682	0.00%	0.00%
10_10	942880	13.051	942886	0.524	945677.1	0.558	0.00%	0.30%	942886	0.561	942886	0.609	0.00%	0.00%
10_11	793330	13.806	793339	0.517	794595.8	0.608	0.00%	0.16%	793339	0.586	793339	0.621	0.00%	0.00%
10_12	537910	28.436	537919	0.868	537919	0.986	0.00%	0.00%	537919	0.744	537919	0.809	0.00%	0.00%
10_13	610030	28.001	610006	0.860	610006	0.961	0.00%	0.00%	610006	0.865	610006	0.935	0.00%	0.00%
10_14	646550	16.205	646552	0.674	650574	0.728	0.00%	0.62%	646552	0.673	646552	0.716	0.00%	0.00%
10_15	796210	10.710	796231	0.744	796231	0.778	0.00%	0.00%	796231	0.666	796231	0.694	0.00%	0.00%
10_16	789980	9.961	789975	0.504	789975	0.557	0.00%	0.00%	789975	0.580	789975	0.636	0.00%	0.00%
10_17	1087320	5.952	1087310	0.327	1093028.6	0.476	0.00%	0.53%	1087310	0.530	1087310	0.566	0.00%	0.00%
10_18	776620	13.334	792656	0.451	794432.7	0.584	2.06%	2.29%	776608	0.625	776608	0.699	0.00%	0.00%
10_19	651670	24.510	651658	0.867	651658	0.886	0.00%	0.00%	651658	0.801	651658	0.844	0.00%	0.00%
10_20	975300	12.105	977782	0.632	977782	0.642	0.25%	0.25%	975320	0.676	975320	0.799	0.00%	0.00%
10_21	708350	32.478	708373	0.863	708373	0.936	0.00%	0.00%	708373	0.638	708373	0.691	0.00%	0.00%
10_22	612420	15.236	612424	0.799	612424	0.925	0.00%	0.00%	612424	0.680	612424	0.758	0.00%	0.00%
10_23	737710	18.240	737688	0.685	737688	0.723	0.00%	0.00%	737688	0.668	737688	0.722	0.00%	0.00%
10_24	518420	11.049	518419	0.518	518419	0.777	0.00%	0.00%	518419	0.643	518419	0.759	0.00%	0.00%
10_25	696860	19.392	696834	0.641	696834	0.729	0.00%	0.00%	696834	0.634	696834	0.700	0.00%	0.00%
10_26	658870	27.789	658875	0.739	658875	0.858	0.00%	0.00%	658875	1.005	658875	1.050	0.00%	0.00%
10_27	863250	10.761	863251	0.785	863251	0.878	0.00%	0.00%	863251	0.625	863251	0.669	0.00%	0.00%
10_28	996110	15.049	996114	0.554	1008180.6	0.629	0.00%	1.21%	996114	0.633	996114	0.698	0.00%	0.00%
10_29	630730	14.351	630719	0.710	630719	0.755	0.00%	0.00%	630719	0.675	630719	0.752	0.00%	0.00%
10_30	710670	13.415	710663	0.666	710663	0.712	0.00%	0.00%	710663	0.721	710663	0.750	0.00%	0.00%
10_31	866460	14.383	866449	0.794	866449	0.938	0.00%	0.00%	866449	0.862	866449	0.886	0.00%	0.00%
10_32	891430	16.116	891422	0.937	891422	0.955	0.00%	0.00%	891422	0.691	891422	0.769	0.00%	0.00%
10_33	923780	14.234	923800	0.736	923800	0.755	0.00%	0.00%	923800	0.746	923800	0.803	0.00%	0.00%
10_34	784250	14.707	784263	0.649	784263	0.737	0.00%	0.00%	784263	0.656	784263	0.718	0.00%	0.00%
10_35	828550	15.597	828550	0.796	828550	0.816	0.00%	0.00%	828550	0.102	828550	0.116	0.00%	0.00%
10_36	815150	13.617	815167	0.782	815167	0.961	0.00%	0.00%	815167	0.119	815167	0.131	0.00%	0.00%
10_37	545460	13.868	545452	0.863	545452	0.919	0.00%	0.00%	545452	0.106	545452	0.118	0.00%	0.00%
10_38	650150	16.462	650149	0.837	650149	0.867	0.00%	0.00%	650149	0.108	650149	0.118	0.00%	0.00%
10_39	836300	16.061	836311	0.907	836669.2	1.128	0.00%	0.04%	836311	0.101	836311	0.108	0.00%	0.00%
10_40	963160	13.181	963155	0.649	963155	0.683	0.00%	0.00%	963155	0.100	963155	0.107	0.00%	0.00%
10_41	918990	18.001	918988	0.867	918988	0.936	0.00%	0.00%	918988	0.127	918988	0.135	0.00%	0.00%
10_42	826910	10.340	826904	0.502	826904	0.548	0.00%	0.00%	826904	0.071	826904	0.082	0.00%	0.00%
10_43	876800	12.876	876788	0.638	876788	0.705	0.00%	0.00%	876788	0.089	876788	0.096	0.00%	0.00%
10_44	799910	16.867	799914	0.856	799914	1.078	0.00%	0.00%	799914	0.108	799914	0.125	0.00%	0.00%
10_45	1033310	12.203	1033311	0.659	1037483.5	0.786	0.00%	0.40%	1033311	0.103	1033311	0.113	0.00%	0.00%
10_46	798890	10.100	798872	0.678	798872	0.725	0.00%	0.00%	798872	0.088	798872	0.094	0.00%	0.00%
10_47	816730	18.396	816733	0.670	816733	0.962	0.00%	0.00%	816733	0.105	816733	0.118	0.00%	0.00%
10_48	654460	13.464	654464	0.737	654464	0.776	0.00%	0.00%	654464	0.111	654464	0.118	0.00%	0.00%
10_49	864030	11.398	864020	0.794	864020	0.830	0.00%	0.00%	864020	0.113	864020	0.120	0.00%	0.00%

Table 68: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 10 nodes and Eccentric Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
10_0	839990	12.532	839991	0.627	839991	0.721	0.00%	0.00%	839991	0.099	839991	0.105	0.00%	
10_1	874309.999929	9.284	874311	0.566	874311	0.595	0.00%	0.00%	874311	0.083	874311	0.087	0.00%	
10_2	834650	23.360	834660	0.745	834660	0.816	0.00%	0.00%	834660	0.098	834660	0.104	0.00%	
10_3	1060090	13.754	1060094	0.903	1060094	1.008	0.00%	0.00%	1060094	0.105	1060094	0.115	0.00%	
10_4	857210	35.219	857215	0.965	857215	1.003	0.00%	0.00%	857215	0.125	857215	0.133	0.00%	
10_5	950680	9.748	950671	0.707	950671	0.760	0.00%	0.00%	950671	0.092	950671	0.095	0.00%	
10_6	871950	16.626	871953	0.345	883513.8	0.584	0.00%	1.33%	871953	0.094	871953	0.111	0.00%	
10_7	1125470	13.034	1125485	0.638	1129558.2	0.843	0.00%	0.36%	1125485	0.110	1125485	0.130	0.00%	
10_8	969160	13.015	969140	0.605	969140	0.708	0.00%	0.00%	969140	0.084	969140	0.091	0.00%	
10_9	1030150	15.993	1030144	0.432	1035000.4	0.666	0.00%	0.47%	1030144	0.092	1030144	0.103	0.00%	
10_10	958220	13.379	958232	0.406	964981.4	0.548	0.00%	0.71%	958232	0.073	958232	0.079	0.00%	
10_11	877980	8.058	878007	0.700	878007	0.757	0.00%	0.00%	878007	0.092	878007	0.102	0.00%	
10_12	756070	26.929	756079	0.811	756079	1.057	0.00%	0.00%	756079	0.104	756079	0.115	0.00%	
10_13	747160	92.265	747152	1.209	747152	1.307	0.00%	0.00%	747152	0.134	747152	0.143	0.00%	
10_14	899100	14.817	899106	0.582	900041.2	0.786	0.00%	0.10%	899106	0.090	899106	0.099	0.00%	
10_15	870450	13.355	870479	0.581	870479	0.682	0.00%	0.00%	870479	0.082	870479	0.085	0.00%	
10_16	807990	12.913	808019	0.448	808019	0.453	0.00%	0.00%	808019	0.085	808019	0.089	0.00%	
10_17	1075030	10.457	1075013	0.486	1075013	0.531	0.00%	0.00%	1075013	0.068	1075013	0.073	0.00%	
10_18	927260	13.466	927281	0.522	927281	0.557	0.00%	0.00%	927281	0.096	927281	0.101	0.00%	
10_19	967440	14.749	967449	0.867	967449	1.134	0.00%	0.00%	967449	0.125	967449	0.135	0.00%	
10_20	1023080	10.613	1023091	0.728	1024330.6	0.754	0.00%	0.12%	1023091	0.096	1023091	0.103	0.00%	
10_21	837090	29.219	837100	0.804	837100	1.107	0.00%	0.00%	837100	0.101	837100	0.106	0.00%	
10_22	817230	18.122	817234	0.900	817234	1.011	0.00%	0.00%	817234	0.113	817234	0.117	0.00%	
10_23	941420	17.713	941423	0.878	941423	0.931	0.00%	0.00%	941423	0.114	941423	0.121	0.00%	
10_24	718420	10.611	718415	0.516	718415	0.716	0.00%	0.00%	718415	0.107	718415	0.111	0.00%	
10_25	981300	20.234	981300	0.592	982683.9	0.803	0.00%	0.14%	981300	0.081	981300	0.094	0.00%	
10_26	763820	16.057	763815	0.965	763815	1.024	0.00%	0.00%	763815	0.128	763815	0.144	0.00%	
10_27	868840	8.534	868855	0.619	868855	0.641	0.00%	0.00%	868855	0.094	868855	0.097	0.00%	
10_28	1012110	10.825	1012108	0.508	1012108	0.594	0.00%	0.00%	1012108	0.097	1012108	0.103	0.00%	
10_29	787530	12.653	787517	0.572	789270.9	0.683	0.00%	0.22%	787517	0.099	787517	0.109	0.00%	
10_30	1028660	14.021	1028667	0.562	1028667	0.598	0.00%	0.00%	1028667	0.101	1028667	0.117	0.00%	
10_31	896240	12.602	896235	0.589	896235	0.757	0.00%	0.00%	896235	0.101	896235	0.107	0.00%	
10_32	909550	16.733	909529	0.316	909529	0.572	0.00%	0.00%	909529	0.088	909529	0.093	0.00%	
10_33	1082740	14.635	1082746	1.060	1082746	1.067	0.00%	0.00%	1082746	0.106	1082746	0.115	0.00%	
10_34	985910	12.846	985926	0.679	989346.5	0.761	0.00%	0.35%	985926	0.097	985926	0.102	0.00%	
10_35	956560	11.470	956548	0.608	956548	0.823	0.00%	0.00%	956548	0.093	956548	0.098	0.00%	
10_36	971420	19.512	971414	0.906	971414	1.066	0.00%	0.00%	971414	0.110	971414	0.121	0.00%	
10_37	925390	12.921	925384	0.831	940948.1	0.934	0.00%	1.68%	925384	0.108	925384	0.112	0.00%	
10_38	766540	18.122	766544	0.778	766544	1.041	0.00%	0.00%	766544	0.108	766544	0.110	0.00%	
10_39	1050140	13.104	1050158	0.822	1050158	0.884	0.00%	0.00%	1050158	0.099	1050158	0.111	0.00%	
10_40	962840	13.129	962844	0.738	962844	0.799	0.00%	0.00%	962844	0.083	962844	0.098	0.00%	
10_41	951770	13.659	951783	0.997	951783	1.051	0.00%	0.00%	951783	0.107	951783	0.114	0.00%	
10_42	950610	11.082	950609	0.654	950609	0.736	0.00%	0.00%	950609	0.075	950609	0.080	0.00%	
10_43	967410	14.367	967400	0.704	967400	0.751	0.00%	0.00%	967400	0.095	967400	0.098	0.00%	
10_44	930000	16.317	929986	0.321	981273.6	0.679	0.00%	5.51%	929986	0.092	929986	0.100	0.00%	
10_45	1136690	13.590	1136682	0.778	1136682	0.839	0.00%	0.00%	1136682	0.099	1136682	0.108	0.00%	
10_46	919260	10.420	919244	0.652	919244	0.781	0.00%	0.00%	919244	0.088	919244	0.095	0.00%	
10_47	842940	22.555	842965	0.312	842965	0.524	0.00%	0.00%	842965	0.111	842965	0.116	0.00%	
10_48	771830	13.781	771828	0.774	771828	0.858	0.00%	0.00%	771828	0.105	771828	0.115	0.00%	
10_49	887660	13.404	887654	0.868	887654	0.887	0.00%	0.00%	887654	0.094	887654	0.100	0.00%	

Table 69: Computational experiments of mathematical formulation, GRVND and GVNSRVND – Instances with 10 nodes and Random Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
10_0	794820	9.157	794823	0.733	794823	0.794	0.00%	0.00%	794823	0.103	794823	0.107	0.00%	0.00%
10_1	680000	12.240	680010	0.651	680010	0.789	0.00%	0.00%	680010	0.108	680010	0.120	0.00%	0.00%
10_2	742600	22.168	742608	0.763	742608	0.823	0.00%	0.00%	742608	0.092	742608	0.102	0.00%	0.00%
10_3	881140	13.428	881128	0.754	881674.8	0.875	0.00%	0.06%	881128	0.098	881128	0.110	0.00%	0.00%
10_4	701980	34.910	701984	0.633	701984	0.764	0.00%	0.00%	701984	0.125	701984	0.140	0.00%	0.00%
10_5	803700	14.042	803685	0.671	803685	0.763	0.00%	0.00%	803685	0.102	803685	0.108	0.00%	0.00%
10_6	673210	11.822	673230	0.341	673230	0.724	0.00%	0.00%	673230	0.113	673230	0.119	0.00%	0.00%
10_7	918270	15.163	918282	0.878	918282	1.010	0.00%	0.00%	918282	0.116	918282	0.127	0.00%	0.00%
10_8	837310	13.361	837322	0.623	837322	0.728	0.00%	0.00%	837322	0.090	837322	0.097	0.00%	0.00%
10_9	1021500	15.040	1021504	0.658	1027674.4	0.773	0.00%	0.60%	1021504	0.093	1021504	0.105	0.00%	0.00%
10_10	933910	11.407	933915	0.472	933915	0.527	0.00%	0.00%	933915	0.076	933915	0.085	0.00%	0.00%
10_11	784370	12.985	784383	0.624	788670.6	0.693	0.00%	0.55%	784383	0.080	784383	0.087	0.00%	0.00%
10_12	538370	38.923	538366	0.877	538366	0.938	0.00%	0.00%	538366	0.113	538366	0.120	0.00%	0.00%
10_13	639340	22.851	639334	1.209	639334	1.256	0.00%	0.00%	639334	0.123	639334	0.138	0.00%	0.00%
10_14	774510	17.208	774520	0.772	774520	0.849	0.00%	0.00%	774520	0.089	774520	0.097	0.00%	0.00%
10_15	882250	8.996	882251	0.633	882251	0.676	0.00%	0.00%	882251	0.085	882251	0.091	0.00%	0.00%
10_16	922520	9.661	922521	0.629	922521	0.658	0.00%	0.00%	922521	0.091	922521	0.099	0.00%	0.00%
10_17	1034420	8.820	1034408	0.497	1034408	0.523	0.00%	0.00%	1034408	0.070	1034408	0.077	0.00%	0.00%
10_18	837060	11.974	837062	0.543	839346.1	0.634	0.00%	0.27%	837062	0.096	837062	0.113	0.00%	0.00%
10_19	903480	14.228	903482	0.905	903482	0.960	0.00%	0.00%	903482	0.124	903482	0.135	0.00%	0.00%
10_20	904700	8.065	904727	0.731	904727	0.843	0.00%	0.00%	904727	0.099	904727	0.112	0.00%	0.00%
10_21	715020	26.575	715031	0.528	715031	0.678	0.00%	0.00%	715031	0.093	715031	0.103	0.00%	0.00%
10_22	691370	12.680	691376	0.980	691376	1.024	0.00%	0.00%	691376	0.106	691376	0.114	0.00%	0.00%
10_23	771210	20.107	771191	0.831	771191	0.921	0.00%	0.00%	771191	0.107	771191	0.113	0.00%	0.00%
10_24	664470	11.714	664476	0.884	664476	0.980	0.00%	0.00%	664476	0.106	664476	0.115	0.00%	0.00%
10_25	719480	23.488	719458	0.708	719458	0.773	0.00%	0.00%	719458	0.088	719458	0.096	0.00%	0.00%
10_26	688020	26.873	688020	1.241	688020	1.456	0.00%	0.00%	688020	0.152	688020	0.168	0.00%	0.00%
10_27	886620	11.692	886632	0.659	886632	0.690	0.00%	0.00%	886632	0.092	886632	0.105	0.00%	0.00%
10_28	969860	9.719	969860	0.730	969860	0.767	0.00%	0.00%	969860	0.094	969860	0.099	0.00%	0.00%
10_29	681390	12.660	681387	0.816	681387	0.908	0.00%	0.00%	681387	0.096	681387	0.101	0.00%	0.00%
10_30	969950	11.742	969941	0.793	969941	0.828	0.00%	0.00%	969941	0.111	969941	0.116	0.00%	0.00%
10_31	812500	14.013	812507	0.883	812507	0.983	0.00%	0.00%	812507	0.131	812507	0.138	0.00%	0.00%
10_32	878010	10.334	877996	0.829	877996	0.922	0.00%	0.00%	877996	0.120	877996	0.130	0.00%	0.00%
10_33	917560	18.166	917577	0.932	917577	0.967	0.00%	0.00%	917577	0.118	917577	0.124	0.00%	0.00%
10_34	859310	13.438	859329	0.712	859329	0.780	0.00%	0.00%	859329	0.099	859329	0.106	0.00%	0.00%
10_35	832790	10.272	832788	0.712	832788	0.744	0.00%	0.00%	832788	0.090	832788	0.096	0.00%	0.00%
10_36	816890	19.399	816899	0.747	816899	0.871	0.00%	0.00%	816899	0.108	816899	0.114	0.00%	0.00%
10_37	611850	16.563	611860	0.584	637783	0.698	0.00%	4.24%	611860	0.111	611860	0.119	0.00%	0.00%
10_38	656680	17.410	656677	0.686	656677	0.696	0.00%	0.00%	656677	0.084	656677	0.092	0.00%	0.00%
10_39	836780	16.329	836797	0.926	836797	1.107	0.00%	0.00%	836797	0.109	836797	0.119	0.00%	0.00%
10_40	916910	11.454	916920	0.759	916920	0.898	0.00%	0.00%	916920	0.115	916920	0.119	0.00%	0.00%
10_41	902990	15.710	902995	1.027	902995	1.081	0.00%	0.00%	902995	0.132	902995	0.136	0.00%	0.00%
10_42	894370	15.547	894359	0.574	894359	0.720	0.00%	0.00%	894359	0.082	894359	0.090	0.00%	0.00%
10_43	866570	10.730	866551	0.635	866551	0.670	0.00%	0.00%	866551	0.086	866551	0.096	0.00%	0.00%
10_44	767100	15.469	767091	0.776	767091	0.833	0.00%	0.00%	767091	0.099	767091	0.108	0.00%	0.00%
10_45	983670	12.186	983672	0.673	983672	0.756	0.00%	0.00%	983672	0.094	983672	0.100	0.00%	0.00%
10_46	801440	9.527	807763	0.593	807763	0.663	0.79%	0.79%	801420	0.089	801420	0.097	0.00%	0.00%
10_47	991910	17.177	991891	0.683	993392	0.961	0.00%	0.15%	991891	0.126	991891	0.137	0.00%	0.00%
10_48	593640	13.494	593639	0.722	593639	0.839	0.00%	0.00%	593639	0.104	593639	0.111	0.00%	0.00%
10_49	830390	10.552	830381	0.707	830381	0.813	0.00%	0.00%	830381	0.103	830381	0.109	0.00%	0.00%

Table 70: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 11 nodes and Central Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
11_0	894920	13.361	894909	1.004	894909	1.074	0.00%	0.00%	894909	0.149	894909	0.164	0.00%	0.00%
11_1	895250	15.174	895268	0.837	919532.5	1.041	0.00%	2.71%	895268	0.128	895268	0.147	0.00%	0.00%
11_2	945370	18.280	945392	1.156	945392	1.278	0.00%	0.00%	945392	0.153	945392	0.178	0.00%	0.00%
11_3	832950	19.456	832957	1.026	832957	1.262	0.00%	0.00%	832957	0.160	832957	0.175	0.00%	0.00%
11_4	622730	19.325	622738	1.395	622738	1.626	0.00%	0.00%	622738	0.164	622738	0.173	0.00%	0.00%
11_5	944080	13.400	944070	0.747	944070	0.979	0.00%	0.00%	944070	0.128	944070	0.152	0.00%	0.00%
11_6	1001520	44.462	1001525	1.020	1009340	1.558	0.00%	0.78%	1001525	0.165	1001525	0.186	0.00%	0.00%
11_7	796820	29.158	796808	0.980	802133.9	1.499	0.00%	0.67%	796808	0.153	796808	0.161	0.00%	0.00%
11_8	1177080	12.920	1177088	0.440	1177088	0.779	0.00%	0.00%	1177088	0.105	1177088	0.122	0.00%	0.00%
11_9	935980	15.653	935997	0.974	945712.1	1.227	0.00%	1.04%	935997	0.145	935997	0.153	0.00%	0.00%
11_10	841630	26.821	841634	1.581	841634	1.767	0.00%	0.00%	841634	0.194	841634	0.219	0.00%	0.00%
11_11	815540	25.286	815549	1.128	815549	1.283	0.00%	0.00%	815549	0.163	815549	0.172	0.00%	0.00%
11_12	718590	33.628	718590	1.457	718590	1.576	0.00%	0.00%	718590	0.170	718590	0.179	0.00%	0.00%
11_13	967010	38.360	966999	0.733	967185	1.156	0.00%	0.02%	966999	0.129	966999	0.149	0.00%	0.00%
11_14	853150	19.115	853141	1.199	862949.8	1.553	0.00%	1.15%	853141	0.169	853141	0.180	0.00%	0.00%
11_15	774650	16.010	774656	0.963	774656	1.065	0.00%	0.00%	774656	0.147	774656	0.157	0.00%	0.00%
11_16	777490	23.307	777476	1.240	777476	1.348	0.00%	0.00%	777476	0.164	777476	0.175	0.00%	0.00%
11_17	596430	22.300	596445	1.092	596445	1.130	0.00%	0.00%	596445	0.143	596445	0.152	0.00%	0.00%
11_18	1041940	14.162	1041929	0.687	1043933.4	0.728	0.00%	0.19%	1041929	0.142	1041929	0.148	0.00%	0.00%
11_19	710820	25.946	710835	1.630	710835	1.722	0.00%	0.00%	710835	0.165	710835	0.180	0.00%	0.00%
11_20	954450	16.045	967516	0.933	967516	0.980	1.37%	1.37%	954445	0.133	954445	0.151	0.00%	0.00%
11_21	1084550	19.768	1084552	1.316	1084552	1.385	0.00%	0.00%	1084552	0.161	1084552	0.176	0.00%	0.00%
11_22	836410	17.077	836408	1.273	836408	1.412	0.00%	0.00%	836408	0.172	836408	0.189	0.00%	0.00%
11_23	786810	22.992	786811	1.125	786811	1.233	0.00%	0.00%	786811	0.146	786811	0.158	0.00%	0.00%
11_24	850400	16.802	850395	0.794	850395	0.885	0.00%	0.00%	850395	0.151	850395	0.161	0.00%	0.00%
11_25	795460	21.666	795461	0.977	799639.6	1.280	0.00%	0.53%	795461	0.169	795461	0.181	0.00%	0.00%
11_26	733640	19.511	733634	0.971	733634	1.353	0.00%	0.00%	733634	0.145	733634	0.155	0.00%	0.00%
11_27	731160	44.543	731156	0.663	731156	1.238	0.00%	0.00%	731156	0.163	731156	0.182	0.00%	0.00%
11_28	940560	27.557	940558	1.025	945855.2	1.649	0.00%	0.56%	940558	0.165	940558	0.185	0.00%	0.00%
11_29	886190	19.700	886187	1.532	886187	1.567	0.00%	0.00%	886187	0.178	886187	0.198	0.00%	0.00%
11_30	655380	15.351	655363	0.962	655363	1.422	0.00%	0.00%	655363	0.180	655363	0.190	0.00%	0.00%
11_31	710370	15.429	710364	0.748	710364	0.855	0.00%	0.00%	710364	0.141	710364	0.148	0.00%	0.00%
11_32	620860	27.167	620856	0.760	620856	1.141	0.00%	0.00%	620856	0.124	620856	0.146	0.00%	0.00%
11_33	668660	29.072	668646	1.084	668646	1.380	0.00%	0.00%	668646	0.186	668646	0.198	0.00%	0.00%
11_34	923430	19.102	923434	1.239	923434	1.310	0.00%	0.00%	923434	0.163	923434	0.186	0.00%	0.00%
11_35	613860	28.404	613869	1.796	613869	1.905	0.00%	0.00%	613869	0.167	613869	0.185	0.00%	0.00%
11_36	805300	15.577	805299	1.092	805299	1.162	0.00%	0.00%	805299	0.147	805299	0.151	0.00%	0.00%
11_37	724950	23.502	724956	0.719	724956	0.882	0.00%	0.00%	724956	0.146	724956	0.158	0.00%	0.00%
11_38	783780	18.811	783780	1.101	783780	1.249	0.00%	0.00%	783780	0.145	783780	0.161	0.00%	0.00%
11_39	985470	12.942	985485	0.732	1053315	0.831	0.00%	6.88%	985485	0.151	985485	0.162	0.00%	0.00%
11_40	777230	11.537	777223	0.988	777223	1.106	0.00%	0.00%	777223	0.144	777223	0.155	0.00%	0.00%
11_41	935560	24.445	935560	1.505	935560	1.616	0.00%	0.00%	935560	0.184	935560	0.193	0.00%	0.00%
11_42	875330	28.490	875315	1.128	876381.3	1.544	0.00%	0.12%	875315	0.178	875315	0.203	0.00%	0.00%
11_43	771380	52.391	771394	1.427	771394	1.661	0.00%	0.00%	771394	0.190	771394	0.210	0.00%	0.00%
11_44	872870	21.950	872871	1.101	872871	1.168	0.00%	0.00%	872871	0.156	872871	0.164	0.00%	0.00%
11_45	855220	19.849	855215	1.071	855215	1.215	0.00%	0.00%	855215	0.155	855215	0.168	0.00%	0.00%
11_46	690880	19.902	722834	1.181	722834	1.288	4.63%	4.63%	690887	0.174	690887	0.185	0.00%	0.00%
11_47	654960	33.329	654949	0.800	654949	1.122	0.00%	0.00%	654949	0.155	654949	0.165	0.00%	0.00%
11_48	811320	18.698	811329	0.959	811329	1.114	0.00%	0.00%	811329	0.119	811329	0.132	0.00%	0.00%
11_49	989790	15.990	1000568	1.098	1000568	1.199	1.09%	1.09%	989781	0.143	989781	0.152	0.00%	0.00%

Table 71: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 11 nodes and Eccentric Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
11_0	891260	16.515	891275	1.291	891275	1.329	0.00%	0.00%	891275	0.133	891275	0.141	0.00%	0.00%
11_1	1042980	15.391	1043006	0.877	1057208.4	1.261	0.00%	1.36%	1043006	0.145	1043006	0.159	0.00%	0.00%
11_2	986090	20.010	986065	1.100	986065	1.216	0.00%	0.00%	986065	0.131	986065	0.142	0.00%	0.00%
11_3	880220	19.606	880214	1.041	891386	1.789	0.00%	1.27%	880214	0.153	880214	0.167	0.00%	0.00%
11_4	847570	18.294	847585	1.357	847585	1.544	0.00%	0.00%	847585	0.165	847585	0.170	0.00%	0.00%
11_5	995740	14.164	995729	0.861	995794.8	1.038	0.00%	0.01%	995729	0.136	995729	0.163	0.00%	0.00%
11_6	998490	28.947	998474	0.951	998474	1.193	0.00%	0.00%	998474	0.169	998474	0.178	0.00%	0.00%
11_7	763490	27.781	763492	0.702	763492	1.046	0.00%	0.00%	763492	0.120	763492	0.133	0.00%	0.00%
11_8	1147960	9.061	1147968	0.569	1147968	0.643	0.00%	0.00%	1147968	0.126	1147968	0.136	0.00%	0.00%
11_9	963330	14.301	963336	0.782	963336	1.063	0.00%	0.00%	963336	0.140	963336	0.146	0.00%	0.00%
11_10	881220	33.535	882274	0.553	940549	1.483	0.12%	6.73%	881224	0.173	881224	0.185	0.00%	0.00%
11_11	1020180	22.967	1020182	1.292	1026581.4	1.540	0.00%	0.63%	1020182	0.179	1020182	0.204	0.00%	0.00%
11_12	885840	48.399	885846	0.889	896373.4	1.668	0.00%	1.19%	885846	0.166	885846	0.180	0.00%	0.00%
11_13	992710	41.824	992712	0.801	1002001.6	1.002	0.00%	0.94%	992712	0.163	992712	0.195	0.00%	0.00%
11_14	920400	16.378	920383	1.269	920383	1.340	0.00%	0.00%	920383	0.188	920383	0.198	0.00%	0.00%
11_15	867500	17.028	867507	1.089	867507	1.238	0.00%	0.00%	867507	0.168	867507	0.175	0.00%	0.00%
11_16	920040	21.335	920046	1.040	920046	1.439	0.00%	0.00%	920046	0.160	920046	0.173	0.00%	0.00%
11_17	749240	18.359	749253	0.608	751317.4	1.149	0.00%	0.28%	749253	0.154	749253	0.161	0.00%	0.00%
11_18	1044740	14.385	1044749	0.633	1051137.2	0.708	0.00%	0.61%	1044749	0.129	1044749	0.146	0.00%	0.00%
11_19	849430	25.798	849438	1.051	849438	1.427	0.00%	0.00%	849438	0.167	849438	0.181	0.00%	0.00%
11_20	1011100	15.065	1011095	1.015	1011095	1.139	0.00%	0.00%	1011095	0.129	1011095	0.142	0.00%	0.00%
11_21	1140180	14.626	1140192	1.101	1141736.2	1.482	0.00%	0.14%	1140192	0.151	1140192	0.175	0.00%	0.00%
11_22	984920	20.983	984920	1.398	998149.3	1.804	0.00%	1.34%	984920	0.177	984920	0.201	0.00%	0.00%
11_23	857990	19.063	857981	1.202	857981	1.324	0.00%	0.00%	857981	0.157	857981	0.170	0.00%	0.00%
11_24	989990	14.352	989993	1.372	989993	1.556	0.00%	0.00%	989993	0.156	989993	0.169	0.00%	0.00%
11_25	882780	25.524	882765	1.207	882765	1.478	0.00%	0.00%	882765	0.173	882765	0.184	0.00%	0.00%
11_26	787200	18.747	787202	0.930	787202	1.010	0.00%	0.00%	787202	0.126	787202	0.143	0.00%	0.00%
11_27	1010350	37.032	1010356	1.184	1010356	1.553	0.00%	0.00%	1010356	0.179	1010356	0.204	0.00%	0.00%
11_28	923600	20.558	923615	0.773	923615	0.920	0.00%	0.00%	923615	0.148	923615	0.158	0.00%	0.00%
11_29	963720	27.084	963729	1.110	963729	1.422	0.00%	0.00%	963729	0.169	963729	0.181	0.00%	0.00%
11_30	750320	12.529	750317	1.266	750317	1.366	0.00%	0.00%	750317	0.163	750317	0.175	0.00%	0.00%
11_31	861310	15.404	861302	0.837	861302	0.913	0.00%	0.00%	861302	0.141	861302	0.148	0.00%	0.00%
11_32	878950	25.456	878941	0.824	879872.5	1.352	0.00%	0.10%	878941	0.171	878941	0.201	0.00%	0.00%
11_33	772240	27.255	772240	1.060	772240	1.567	0.00%	0.00%	772240	0.172	772240	0.181	0.00%	0.00%
11_34	1075640	20.258	1075631	1.533	1075631	1.613	0.00%	0.00%	1075631	0.162	1075631	0.176	0.00%	0.00%
11_35	856870	27.830	856880	1.572	856880	1.726	0.00%	0.00%	856880	0.183	856880	0.201	0.00%	0.00%
11_36	977290	20.367	977286	1.141	978202.8	1.535	0.00%	0.09%	977286	0.152	977286	0.168	0.00%	0.00%
11_37	826700	28.816	826696	0.977	826696	1.128	0.00%	0.00%	826696	0.158	826696	0.164	0.00%	0.00%
11_38	888860	23.391	888872	0.957	888872	0.995	0.00%	0.00%	888872	0.146	888872	0.159	0.00%	0.00%
11_39	1005530	16.037	1005524	0.782	1005524	0.917	0.00%	0.00%	1005524	0.134	1005524	0.140	0.00%	0.00%
11_40	813120	10.708	813135	0.998	813135	1.054	0.00%	0.00%	813135	0.158	813135	0.170	0.00%	0.00%
11_41	924140	26.620	924153	0.877	924153	1.002	0.00%	0.00%	924153	0.176	924153	0.188	0.00%	0.00%
11_42	925130	43.464	925123	0.885	930084	1.049	0.00%	0.54%	925123	0.154	925123	0.171	0.00%	0.00%
11_43	861950	61.259	861952	1.023	861952	1.440	0.00%	0.00%	861952	0.178	861952	0.189	0.00%	0.00%
11_44	896430	26.848	896429	0.829	896429	1.098	0.00%	0.00%	896429	0.180	896429	0.187	0.00%	0.00%
11_45	1106550	18.242	1106538	1.154	1106538	1.336	0.00%	0.00%	1106538	0.150	1106538	0.173	0.00%	0.00%
11_46	813540	15.827	813541	1.060	813541	1.250	0.00%	0.00%	813541	0.164	813541	0.171	0.00%	0.00%
11_47	774410	30.604	774418	0.807	775124.5	1.768	0.00%	0.09%	774418	0.149	774418	0.167	0.00%	0.00%
11_48	924910	18.590	924920	0.881	924920	1.096	0.00%	0.00%	924920	0.129	924920	0.143	0.00%	0.00%
11_49	1074260	12.764	1074240	0.854	1075083.2	1.200	0.00%	0.08%	1074240	0.151	1074240	0.158	0.00%	0.00%

Table 72: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 11 nodes and Random Base Station position

	Mathematical Formulation		**GRVND**						**GVNSRVND**					
			MIN		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
11_0	958030	15.583	958033	0.765	958033	0.874	0.00%	0.00%	958033	0.130	958033	0.148	0.00%	0.00%
11_1	1019190	21.093	1032899	0.465	1044384.2	0.811	1.35%	2.47%	1019205	0.125	1024682.6	0.160	0.00%	0.54%
11_2	931290	22.044	931276	1.346	931276	1.445	0.00%	0.00%	931276	0.161	931276	0.172	0.00%	0.00%
11_3	839860	17.512	839860	1.086	839860	1.182	0.00%	0.00%	839860	0.165	839860	0.173	0.00%	0.00%
11_4	621230	19.761	621242	1.417	621242	1.502	0.00%	0.00%	621242	0.169	621242	0.181	0.00%	0.00%
11_5	958370	17.730	958366	0.797	963012.2	0.891	0.00%	0.48%	958366	0.131	958366	0.149	0.00%	0.00%
11_6	977780	35.379	977771	1.123	977771	1.321	0.00%	0.00%	977771	0.178	977771	0.187	0.00%	0.00%
11_7	761990	30.052	761995	0.957	762541.3	1.126	0.00%	0.07%	761995	0.139	761995	0.155	0.00%	0.00%
11_8	1094460	10.691	1094470	0.564	1094470	0.782	0.00%	0.00%	1094470	0.106	1094470	0.117	0.00%	0.00%
11_9	942540	10.601	942553	1.014	942553	1.081	0.00%	0.00%	942553	0.152	942553	0.160	0.00%	0.00%
11_10	845390	26.279	845383	1.442	846150.8	1.720	0.00%	0.09%	845383	0.199	845383	0.218	0.00%	0.00%
11_11	813650	20.402	813639	0.988	813639	1.232	0.00%	0.00%	813639	0.176	813639	0.186	0.00%	0.00%
11_12	831140	28.116	831139	1.102	831139	1.372	0.00%	0.00%	831139	0.147	831139	0.177	0.00%	0.00%
11_13	1024710	34.337	1024700	0.961	1027015.4	1.466	0.00%	0.22%	1024700	0.148	1024700	0.156	0.00%	0.00%
11_14	882050	16.874	882065	1.019	882065	1.129	0.00%	0.00%	882065	0.167	882065	0.175	0.00%	0.00%
11_15	924280	19.146	924262	1.250	924262	1.349	0.00%	0.00%	924262	0.143	924262	0.152	0.00%	0.00%
11_16	857900	23.192	857908	0.964	857908	1.170	0.00%	0.00%	857908	0.136	857908	0.145	0.00%	0.00%
11_17	681440	23.687	681433	1.108	681433	1.307	0.00%	0.00%	681433	0.148	681433	0.158	0.00%	0.00%
11_18	1143720	16.400	1143732	0.793	1143732	0.968	0.00%	0.00%	1143732	0.114	1143732	0.123	0.00%	0.00%
11_19	719130	27.805	719136	1.729	719136	1.968	0.00%	0.00%	719136	0.168	719136	0.188	0.00%	0.00%
11_20	983790	11.390	983788	1.029	983788	1.099	0.00%	0.00%	983788	0.142	983788	0.152	0.00%	0.00%
11_21	1040600	20.568	1040611	0.856	1050954.5	1.147	0.00%	1.00%	1040611	0.162	1040611	0.173	0.00%	0.00%
11_22	745130	19.917	745116	0.824	745116	0.984	0.00%	0.00%	745116	0.146	745116	0.156	0.00%	0.00%
11_23	793510	22.945	793493	1.370	793493	1.428	0.00%	0.00%	793493	0.160	793493	0.169	0.00%	0.00%
11_24	824740	12.663	824742	1.021	824742	1.247	0.00%	0.00%	824742	0.139	824742	0.160	0.00%	0.00%
11_25	840370	21.151	840374	1.225	840374	1.558	0.00%	0.00%	840374	0.158	840374	0.178	0.00%	0.00%
11_26	709520	20.238	709530	0.938	709530	1.097	0.00%	0.00%	709530	0.136	709530	0.151	0.00%	0.00%
11_27	731630	48.507	731641	1.855	731641	1.920	0.00%	0.00%	731641	0.179	731641	0.190	0.00%	0.00%
11_28	905020	22.525	905025	0.701	906899.8	0.879	0.00%	0.21%	905025	0.152	905025	0.164	0.00%	0.00%
11_29	816290	26.712	816291	0.791	816291	1.246	0.00%	0.00%	816291	0.168	816291	0.180	0.00%	0.00%
11_30	831050	17.104	831047	1.134	831047	1.297	0.00%	0.00%	831047	0.163	831047	0.177	0.00%	0.00%
11_31	802820	19.345	802813	1.031	802813	1.162	0.00%	0.00%	802813	0.132	802813	0.146	0.00%	0.00%
11_32	619160	24.394	619159	1.160	619159	1.347	0.00%	0.00%	619159	0.147	619159	0.156	0.00%	0.00%
11_33	734020	28.669	734005	1.163	734005	1.539	0.00%	0.00%	734005	0.189	734005	0.202	0.00%	0.00%
11_34	893990	20.573	893992	1.044	893992	1.223	0.00%	0.00%	893992	0.163	893992	0.173	0.00%	0.00%
11_35	667750	38.679	667758	1.216	667758	1.682	0.00%	0.00%	667758	0.193	667758	0.205	0.00%	0.00%
11_36	787560	19.450	787571	1.118	787571	1.173	0.00%	0.00%	787571	0.156	787571	0.164	0.00%	0.00%
11_37	724710	24.455	724710	1.029	724710	1.180	0.00%	0.00%	724710	0.141	724710	0.153	0.00%	0.00%
11_38	837660	20.187	837655	0.857	838217.8	1.103	0.00%	0.07%	837655	0.142	837655	0.160	0.00%	0.00%
11_39	1047110	10.894	1047120	0.932	1047120	1.033	0.00%	0.00%	1047120	0.147	1047120	0.156	0.00%	0.00%
11_40	721190	11.782	721213	0.545	721213	0.909	0.00%	0.00%	721213	0.139	721213	0.148	0.00%	0.00%
11_41	908220	28.093	908234	1.373	908234	1.452	0.00%	0.00%	908234	0.179	908234	0.189	0.00%	0.00%
11_42	871220	28.661	871205	1.284	880665.2	1.476	0.00%	1.08%	871205	0.176	871205	0.184	0.00%	0.00%
11_43	770270	40.664	770268	1.155	770268	1.483	0.00%	0.00%	770268	0.200	770268	0.213	0.00%	0.00%
11_44	878420	25.506	878431	0.850	878431	1.239	0.00%	0.00%	878431	0.154	878431	0.165	0.00%	0.00%
11_45	872190	19.565	872184	1.192	872184	1.265	0.00%	0.00%	872184	0.158	872184	0.168	0.00%	0.00%
11_46	757630	17.918	757627	1.362	757627	1.454	0.00%	0.00%	757627	0.168	757627	0.177	0.00%	0.00%
11_47	617700	41.820	617694	1.415	617694	1.505	0.00%	0.00%	617694	0.139	617694	0.159	0.00%	0.00%
11_48	918730	20.366	918733	1.194	918733	1.302	0.00%	0.00%	918733	0.127	918733	0.137	0.00%	0.00%
11_49	959600	12.778	959587	0.968	960851.8	1.184	0.00%	0.13%	959587	0.141	959587	0.156	0.00%	0.00%

Table 73: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 16 nodes and Central Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
16_0	1055180	201.604	1055213	4.464	1055213	5.760	0.00%	0.00%	1055213	0.576	1055213	0.719	0.00%	0.00%
16_1	1030820	3600.351	1039584	7.287	1039584	8.422	0.85%	0.85%	1030834	0.752	1038709	0.954	0.00%	0.77%
16_2	1016780	135.360	1016774	6.437	1016774	7.662	0.00%	0.00%	1016774	0.698	1016774	0.821	0.00%	0.00%
16_3	966680	105.727	966670	6.695	966670	7.132	0.00%	0.00%	966670	0.673	966670	0.722	0.00%	0.00%
16_4	995910	73.790	995894	5.031	995894	6.473	0.00%	0.00%	995894	0.643	995894	0.736	0.00%	0.00%
16_5	1101450	72.798	1101438	6.044	1101438	7.260	0.00%	0.00%	1101438	0.653	1101438	0.736	0.00%	0.00%
16_6	1080660	74.537	1080655	5.761	1092509.2	8.326	0.00%	1.10%	1080655	0.679	1080655	0.981	0.00%	0.00%
16_7	885420	415.223	885427	8.024	885427	8.534	0.00%	0.00%	885427	0.787	885427	0.893	0.00%	0.00%
16_8	1023040	94.136	1023035	6.195	1023035	6.399	0.00%	0.00%	1023035	0.741	1023035	0.784	0.00%	0.00%
16_9	891550	295.105	891532	7.349	891532	8.174	0.00%	0.00%	891532	0.849	891532	1.022	0.00%	0.00%
16_10	1075880	199.993	1075901	7.878	1075901	8.894	0.00%	0.00%	1075901	0.940	1075901	1.046	0.00%	0.00%
16_11	1167000	1656.137	1167026	3.859	1168245.8	5.962	0.00%	0.11%	1167026	0.725	1167026	0.964	0.00%	0.00%
16_12	1030810	63.872	1030827	4.822	1030827	5.775	0.00%	0.00%	1030827	0.634	1030827	0.744	0.00%	0.00%
16_13	589790	324.767	589803	8.193	589803	9.191	0.00%	0.00%	589803	0.735	589803	0.831	0.00%	0.00%
16_14	989030	64.550	989038	4.995	989038	5.715	0.00%	0.00%	989038	0.577	989038	0.665	0.00%	0.00%
16_15	814940	134.053	814948	7.149	814948	8.051	0.00%	0.00%	814948	0.800	814948	0.915	0.00%	0.00%
16_16	1169010	343.471	1168997	4.636	1168997	5.133	0.00%	0.00%	1168997	0.639	1168997	0.698	0.00%	0.00%
16_17	1014350	474.584	1014320	5.908	1014320	6.966	0.00%	0.00%	1014320	0.835	1014320	0.966	0.00%	0.00%
16_18	918440	97.061	918428	7.202	918428	7.716	0.00%	0.00%	918428	0.770	918428	0.840	0.00%	0.00%
16_19	1184580	291.497	1184576	7.539	1184576	8.472	0.00%	0.00%	1184576	0.812	1184576	0.914	0.00%	0.00%
16_20	849390	133.728	849413	7.285	849413	7.628	0.00%	0.00%	849413	0.703	849413	0.786	0.00%	0.00%
16_21	998450	43.574	998468	3.584	998468	4.646	0.00%	0.00%	998468	0.574	998468	0.702	0.00%	0.00%
16_22	963010	143.286	962992	6.267	962992	6.723	0.00%	0.00%	962992	0.722	962992	0.797	0.00%	0.00%
16_23	850690	106.731	850694	6.768	850694	7.208	0.00%	0.00%	850694	0.734	850694	0.861	0.00%	0.00%
16_24	1041230	63.319	1041237	4.795	1041237	5.390	0.00%	0.00%	1041237	0.596	1041237	0.706	0.00%	0.00%
16_25	910020	347.328	910015	4.255	926196.6	5.221	0.00%	1.78%	910015	0.621	910015	0.734	0.00%	0.00%
16_26	936140	1363.068	941509	5.977	954982.6	8.013	0.57%	2.01%	936104	0.870	936104	1.203	0.00%	0.00%
16_27	947000	108.901	946986	6.855	946986	7.745	0.00%	0.00%	946986	0.719	946986	0.790	0.00%	0.00%
16_28	1018960	658.235	1018955	6.473	1018955	6.894	0.00%	0.00%	1018955	0.795	1018955	0.842	0.00%	0.00%
16_29	1112730	110.213	1112742	4.822	1112742	5.769	0.00%	0.00%	1112742	0.644	1112742	0.829	0.00%	0.00%
16_30	798390	267.403	798416	5.468	798416	6.272	0.00%	0.00%	798416	0.741	798416	0.834	0.00%	0.00%
16_31	826560	143.772	826569	6.234	826569	7.543	0.00%	0.00%	826569	0.801	826569	0.878	0.00%	0.00%
16_32	1062960	893.632	1062946	7.385	1063128.3	8.914	0.00%	0.02%	1062946	0.928	1062946	1.053	0.00%	0.00%
16_33	943390	1089.454	943397	6.232	943397	6.730	0.00%	0.00%	943397	0.645	943397	0.698	0.00%	0.00%
16_34	1230180	93.757	1230203	5.739	1235690	7.107	0.00%	0.45%	1230203	0.679	1230203	0.959	0.00%	0.00%
16_35	839050	101.901	839054	7.069	839054	7.827	0.00%	0.00%	839054	0.712	839054	0.881	0.00%	0.00%
16_36	1015080	160.961	1015087	4.845	1015087	6.135	0.00%	0.00%	1015087	0.627	1015087	0.687	0.00%	0.00%
16_37	979590	105.637	979598	6.040	979598	6.390	0.00%	0.00%	979598	0.757	979598	0.852	0.00%	0.00%
16_38	970320	331.943	991506	6.819	991506	7.486	2.18%	2.18%	970332	0.721	973544.2	0.971	0.00%	0.33%
16_39	881560	299.302	881557	6.140	881557	7.350	0.00%	0.00%	881557	0.713	881557	0.896	0.00%	0.00%
16_40	1071500	1429.606	1071499	6.639	1071499	8.435	0.00%	0.00%	1071499	0.717	1071499	1.078	0.00%	0.00%
16_41	1110280	41.242	1110299	3.420	1145738.6	4.354	0.00%	3.19%	1110299	0.543	1110299	0.696	0.00%	0.00%
16_42	913380	86.035	913387	6.071	913387	7.254	0.00%	0.00%	913387	0.590	913387	0.691	0.00%	0.00%
16_43	1041660	115.877	1041656	5.089	1043306.2	7.249	0.00%	0.16%	1041656	0.662	1041656	0.787	0.00%	0.00%
16_44	1069460	2929.748	1069472	6.499	1069472	7.171	0.00%	0.00%	1069472	0.780	1069472	0.802	0.00%	0.00%
16_45	866210	98.081	866208	5.352	866208	5.728	0.00%	0.00%	866208	0.622	866208	0.707	0.00%	0.00%
16_46	891500	67.060	891514	6.105	891514	6.534	0.00%	0.00%	891514	0.618	891514	0.693	0.00%	0.00%
16_47	992920	525.142	992898	7.719	994131.9	9.521	0.00%	0.12%	992898	0.839	992898	0.957	0.00%	0.00%
16_48	901170	150.978	901169	6.144	901169	6.465	0.00%	0.00%	901169	0.740	901169	0.851	0.00%	0.00%
16_49	1066030	129.784	1066032	5.583	1066032	5.938	0.00%	0.00%	1066032	0.685	1066032	0.734	0.00%	0.00%

Table 74: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 16 nodes and Eccentric Base Station position

	Mathematical Formulation		GRVND						GVNSRVND					
			MIN		AVG		GAP		MIN		AVG		GAP	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
16_0	1112650	1448.070	1112665	3.831	1112665	4.384	0.00%	0.00%	1112665	0.634	1112665	0.776	0.00%	0.00%
16_1	1133550	3600.293	1133572	8.122	1133572	8.670	0.00%	0.00%	1133572	0.686	1133572	0.868	0.00%	0.00%
16_2	1195000	85.644	1194988	6.526	1194988	7.503	0.00%	0.00%	1194988	0.786	1194988	0.825	0.00%	0.00%
16_3	1002790	132.716	1002810	6.995	1002810	7.682	0.00%	0.00%	1002810	0.656	1002810	0.730	0.00%	0.00%
16_4	981710	64.765	981692	6.334	981692	6.526	0.00%	0.00%	981692	0.583	981692	0.641	0.00%	0.00%
16_5	1143050	62.071	1143048	5.090	1143048	5.724	0.00%	0.00%	1143048	0.671	1143048	0.744	0.00%	0.00%
16_6	1073970	82.921	1073974	6.021	1073974	6.185	0.00%	0.00%	1073974	0.613	1073974	0.691	0.00%	0.00%
16_7	1093060	201.379	1093044	8.119	1093044	8.546	0.00%	0.00%	1093044	0.892	1093044	1.020	0.00%	0.00%
16_8	1082040	221.000	1082035	6.496	1082035	6.801	0.00%	0.00%	1082035	0.755	1082035	0.803	0.00%	0.00%
16_9	1036230	1036.668	1036245	7.043	1036245	7.360	0.00%	0.00%	1036245	0.704	1036245	0.775	0.00%	0.00%
16_10	1087980	210.592	1087983	8.638	1087983	9.117	0.00%	0.00%	1087983	0.851	1087983	0.962	0.00%	0.00%
16_11	1185050	1150.227	1185053	4.854	1185053	5.747	0.00%	0.00%	1185053	0.670	1185053	0.860	0.00%	0.00%
16_12	1123310	75.480	1123328	4.976	1123406.7	7.923	0.00%	0.01%	1123328	0.583	1123485.4	0.738	0.00%	0.02%
16_13	884680	431.995	884689	8.823	884689	9.256	0.00%	0.00%	884689	0.749	884689	0.869	0.00%	0.00%
16_14	1074010	244.410	1074012	6.448	1074012	6.908	0.00%	0.00%	1074012	0.681	1074012	0.814	0.00%	0.00%
16_15	1048400	381.839	1048422	6.942	1048422	7.484	0.00%	0.00%	1048422	0.800	1048422	0.912	0.00%	0.00%
16_16	1204680	1973.803	1204669	5.083	1204669	5.623	0.00%	0.00%	1204669	0.626	1204669	0.689	0.00%	0.00%
16_17	1038420	326.428	1038437	6.088	1040995.7	8.219	0.00%	0.25%	1038437	0.704	1038437	0.838	0.00%	0.00%
16_18	1006890	245.592	1006873	7.624	1006873	8.074	0.00%	0.00%	1006873	0.721	1006873	0.839	0.00%	0.00%
16_19	1162740	480.297	1162726	7.298	1162726	8.222	0.00%	0.00%	1162726	0.722	1162726	0.875	0.00%	0.00%
16_20	959470	116.927	959478	6.647	959478	7.322	0.00%	0.00%	959478	0.696	959478	0.759	0.00%	0.00%
16_21	1152680	44.695	1152693	5.198	1152693	6.052	0.00%	0.00%	1152693	0.519	1152693	0.717	0.00%	0.00%
16_22	1074480	87.950	1074473	7.692	1074473	8.247	0.00%	0.00%	1074473	0.727	1074473	0.835	0.00%	0.00%
16_23	961990	85.816	961994	4.297	961994	5.441	0.00%	0.00%	961994	0.742	961994	0.797	0.00%	0.00%
16_24	1051920	83.284	1051925	5.721	1056124.2	8.030	0.00%	0.40%	1051925	0.605	1051925	0.888	0.00%	0.00%
16_25	1016010	297.784	1016020	4.867	1016020	5.177	0.00%	0.00%	1016020	0.610	1016020	0.676	0.00%	0.00%
16_26	983970	3600.280	989464	6.918	989464	7.239	0.56%	0.56%	983950	0.969	983950	1.202	0.00%	0.00%
16_27	941200	102.489	941190	6.527	941190	7.025	0.00%	0.00%	941190	0.568	941190	0.647	0.00%	0.00%
16_28	1073260	1921.570	1073226	5.741	1073226	6.599	0.00%	0.00%	1073226	0.739	1073226	0.818	0.00%	0.00%
16_29	1038700	85.905	1038710	5.249	1038710	5.703	0.00%	0.00%	1038710	0.628	1038710	0.684	0.00%	0.00%
16_30	1036080	1016.634	1036097	8.173	1039068.9	10.665	0.00%	0.29%	1036097	0.758	1036097	0.921	0.00%	0.00%
16_31	1018890	119.397	1018895	6.649	1018895	7.712	0.00%	0.00%	1018895	0.809	1018895	0.906	0.00%	0.00%
16_32	1058630	1088.716	1058612	8.876	1058612	9.546	0.00%	0.00%	1058612	0.829	1058612	0.934	0.00%	0.00%
16_33	959830	1171.176	959814	2.980	974074	5.534	0.00%	1.48%	959814	0.640	959814	0.686	0.00%	0.00%
16_34	1262860	95.222	1262879	5.246	1272435.4	8.386	0.00%	0.76%	1262879	0.745	1263844.2	0.930	0.00%	0.08%
16_35	933860	140.487	933857	6.559	933857	7.089	0.00%	0.00%	933857	0.707	933857	0.769	0.00%	0.00%
16_36	1110650	381.814	1110655	5.513	1110655	6.465	0.00%	0.00%	1110655	0.649	1110655	0.710	0.00%	0.00%
16_37	1052760	125.862	1052763	4.683	1052763	5.982	0.00%	0.00%	1052763	0.696	1052763	0.856	0.00%	0.00%
16_38	1063460	604.770	1070481	5.456	1077713	6.149	0.66%	1.34%	1063460	0.683	1064162.1	0.830	0.00%	0.07%
16_39	1059630	123.811	1059622	7.234	1059622	8.026	0.00%	0.00%	1059622	0.712	1059622	0.798	0.00%	0.00%
16_40	1088730	595.759	1088720	5.151	1088720	6.167	0.00%	0.00%	1088720	0.669	1088720	0.747	0.00%	0.00%
16_41	1157780	49.543	1157798	4.423	1157798	5.421	0.00%	0.00%	1157798	0.518	1157798	0.620	0.00%	0.00%
16_42	1095110	117.873	1095115	6.333	1095115	6.671	0.00%	0.00%	1095115	0.652	1095115	0.699	0.00%	0.00%
16_43	1190340	70.471	1190349	5.189	1196669.8	7.235	0.00%	0.53%	1190349	0.626	1190349	0.873	0.00%	0.00%
16_44	1037230	1506.996	1037247	7.265	1037247	7.555	0.00%	0.00%	1037247	0.718	1037247	0.791	0.00%	0.00%
16_45	1044940	182.084	1044945	5.620	1044945	6.639	0.00%	0.00%	1044945	0.679	1044945	0.758	0.00%	0.00%
16_46	1044860	92.052	1044867	5.130	1044867	6.605	0.00%	0.00%	1044867	0.638	1044867	0.729	0.00%	0.00%
16_47	1045820	949.475	1045801	6.749	1045801	7.504	0.00%	0.00%	1045801	0.677	1045801	0.772	0.00%	0.00%
16_48	1026180	154.978	1026188	7.091	1026188	7.466	0.00%	0.00%	1026188	0.706	1026188	0.816	0.00%	0.00%
16_49	1114910	186.670	1114926	5.872	1114926	6.334	0.00%	0.00%	1114926	0.622	1114926	0.708	0.00%	0.00%

Table 75: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 16 nodes and Random Base Station position

	Mathematical Formulation		**GRVND**						**GVNSRVND**					
			MIN		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
16_0	1048200	166.620	1048213	3.182	1048213	3.867	0.00%	0.00%	1048213	0.649	1048213	0.673	0.00%	0.00%
16_1	1046830	1688.788	1046842	8.076	1046842	11.672	0.00%	0.00%	1046842	0.864	1048390	1.056	0.00%	0.15%
16_2	981390	78.847	981365	3.881	986929.1	6.334	0.00%	0.56%	981365	0.713	981365	0.811	0.00%	0.00%
16_3	968850	216.874	968854	6.917	968854	8.953	0.00%	0.00%	968854	0.725	968854	0.809	0.00%	0.00%
16_4	936770	65.122	936773	7.081	936773	7.577	0.00%	0.00%	936773	0.820	936773	0.926	0.00%	0.00%
16_5	1054100	59.364	1054108	4.333	1065283	5.458	0.00%	1.06%	1054108	0.644	1054108	0.716	0.00%	0.00%
16_6	1001460	154.515	1001465	6.318	1001465	6.784	0.00%	0.00%	1001465	0.671	1001465	0.751	0.00%	0.00%
16_7	885730	501.827	885746	5.452	885746	6.380	0.00%	0.00%	885746	0.809	885746	0.916	0.00%	0.00%
16_8	1004610	97.915	1004588	5.065	1004588	5.382	0.00%	0.00%	1004588	0.671	1004588	0.730	0.00%	0.00%
16_9	949640	3600.314	949646	6.898	949926	9.611	0.00%	0.03%	949646	0.770	949646	0.904	0.00%	0.00%
16_10	1042430	112.208	1042436	6.851	1042436	7.582	0.00%	0.00%	1042436	0.978	1042436	1.065	0.00%	0.00%
16_11	1155490	287.279	1155498	4.801	1155498	5.851	0.00%	0.00%	1155498	0.668	1155498	0.773	0.00%	0.00%
16_12	1027170	88.312	1027170	5.290	1027170	5.695	0.00%	0.00%	1027170	0.592	1027170	0.637	0.00%	0.00%
16_13	597270	175.608	597269	8.280	597269	8.612	0.00%	0.00%	597269	0.793	597269	0.858	0.00%	0.00%
16_14	984870	153.908	984863	3.951	984863	5.952	0.00%	0.00%	984863	0.649	984863	0.720	0.00%	0.00%
16_15	846330	216.057	846339	6.919	846339	9.228	0.00%	0.00%	846339	0.739	846339	0.869	0.00%	0.00%
16_16	1181640	857.774	1181626	3.692	1182456.9	4.859	0.00%	0.07%	1181626	0.668	1181626	0.701	0.00%	0.00%
16_17	985820	390.590	985809	7.240	985809	7.812	0.00%	0.00%	985809	0.750	985809	0.855	0.00%	0.00%
16_18	935310	130.269	935293	7.758	935293	8.838	0.00%	0.00%	935293	0.834	935293	0.938	0.00%	0.00%
16_19	1167900	170.460	1167887	6.668	1167887	7.628	0.00%	0.00%	1167887	0.727	1167887	0.789	0.00%	0.00%
16_20	896970	77.714	896988	6.366	896988	7.185	0.00%	0.00%	896988	0.654	896988	0.761	0.00%	0.00%
16_21	1081450	44.702	1081463	5.374	1081463	5.589	0.00%	0.00%	1081463	0.583	1081463	0.650	0.00%	0.00%
16_22	992730	117.500	992726	6.574	992726	6.859	0.00%	0.00%	992726	0.733	992726	0.802	0.00%	0.00%
16_23	811860	76.339	811863	6.590	811863	7.776	0.00%	0.00%	811863	0.737	811863	0.785	0.00%	0.00%
16_24	1017080	168.113	1017075	5.516	1017075	5.839	0.00%	0.00%	1017075	0.652	1017075	0.690	0.00%	0.00%
16_25	922100	1110.901	922093	5.226	922093	5.908	0.00%	0.00%	922093	0.621	922093	0.667	0.00%	0.00%
16_26	942750	479.292	942745	8.019	942745	8.488	0.00%	0.00%	942745	0.787	942745	0.979	0.00%	0.00%
16_27	924930	91.064	924920	7.856	924920	8.502	0.00%	0.00%	924920	0.749	924920	0.856	0.00%	0.00%
16_28	989890	693.960	989868	7.237	989868	7.698	0.00%	0.00%	989868	0.758	989868	0.844	0.00%	0.00%
16_29	1047640	108.019	1047648	5.009	1047648	5.754	0.00%	0.00%	1047648	0.691	1047648	0.726	0.00%	0.00%
16_30	860690	2784.706	860685	6.468	860685	7.545	0.00%	0.00%	860685	0.691	860685	0.733	0.00%	0.00%
16_31	854490	644.797	854483	6.856	854754.6	8.934	0.00%	0.03%	854483	0.844	854550.9	0.965	0.00%	0.01%
16_32	1043700	1068.028	1043687	7.325	1043687	8.831	0.00%	0.00%	1043687	0.836	1043687	0.992	0.00%	0.00%
16_33	933630	1120.311	933626	5.479	933626	6.183	0.00%	0.00%	933626	0.639	933626	0.741	0.00%	0.00%
16_34	1181630	99.279	1182186	5.800	1182186	7.071	0.05%	0.05%	1181645	0.650	1181645	0.771	0.00%	0.00%
16_35	871420	136.431	871426	6.060	871426	6.495	0.00%	0.00%	871426	0.767	871426	0.838	0.00%	0.00%
16_36	1008260	122.994	1008284	5.479	1008284	6.228	0.00%	0.00%	1008284	0.663	1008284	0.786	0.00%	0.00%
16_37	1021410	107.714	1021428	6.820	1021428	7.718	0.00%	0.00%	1021428	0.759	1021428	0.851	0.00%	0.00%
16_38	925360	690.267	941428	5.910	941428	6.351	1.74%	1.74%	925367	0.726	926973.1	0.900	0.00%	0.17%
16_39	874270	69.799	874276	5.511	874276	6.580	0.00%	0.00%	874276	0.688	874276	0.793	0.00%	0.00%
16_40	1026160	99.199	1026171	7.156	1026171	7.839	0.00%	0.00%	1026171	0.642	1026171	0.712	0.00%	0.00%
16_41	1111850	51.754	1111868	4.667	1111868	6.196	0.00%	0.00%	1111868	0.585	1111868	0.770	0.00%	0.00%
16_42	917910	98.529	917917	4.837	917917	5.611	0.00%	0.00%	917917	0.611	917917	0.651	0.00%	0.00%
16_43	1043870	77.061	1043871	4.763	1043871	5.754	0.00%	0.00%	1043871	0.732	1043871	0.892	0.00%	0.00%
16_44	963060	120.315	963071	6.820	963071	7.215	0.00%	0.00%	963071	0.790	963071	0.828	0.00%	0.00%
16_45	924670	220.935	924675	6.683	924675	7.086	0.00%	0.00%	924675	0.655	924675	0.715	0.00%	0.00%
16_46	858360	123.157	858361	5.343	858361	5.552	0.00%	0.00%	858361	0.634	858361	0.667	0.00%	0.00%
16_47	978910	234.001	978891	6.692	978891	7.300	0.00%	0.00%	978891	0.700	978891	0.771	0.00%	0.00%
16_48	1019110	87.267	1019100	5.861	1019100	6.278	0.00%	0.00%	1019100	0.673	1019100	0.753	0.00%	0.00%
16_49	1043510	111.095	1043507	6.050	1052627.5	8.082	0.00%	0.87%	1043507	0.738	1043507	0.877	0.00%	0.00%

Table 76: Computational experiments of mathematical formulation, GRVND and GVNS-RVND – Instances with 21 nodes and Central Base Station position

	Mathematical Formulation		**GRVND**						**GVNSRVND**					
			MIN		**AVG**		**GAP**		**MIN**		**AVG**		**GAP**	
Inst.	**Sol**	**T (s)**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**	**Sol**	**T (s)**	**Sol**	**T (s)**	**MIN**	**AVG**
21_0	988190	238.883	988188	18.914	988188	19.642	0.00%	0.00%	988188	1.782	988188	1.968	0.00%	0.00%
21_1	1124920	2642.159	1124895	16.748	1140492.4	20.014	0.00%	1.38%	1124895	2.090	1125144.9	2.794	0.00%	0.02%
21_2	1162940	3600.277	1099242	21.077	1099242	23.171	-5.48%	-5.48%	1099242	1.813	1102223.1	2.717	-5.48%	-5.22%
21_3	1031710	1021.946	1031712	17.509	1031712	18.894	0.00%	0.00%	1031712	1.750	1031712	2.004	0.00%	0.00%
21_4	1083410	3600.311	1083411	25.725	1083411	26.522	0.00%	0.00%	1083411	2.171	1083411	2.805	0.00%	0.00%
21_5	982460	3604.384	981673	19.108	981887	25.937	-0.08%	-0.06%	974879	2.102	975558.4	2.461	-0.77%	-0.70%
21_6	900370	3613.324	880919	31.670	880919	32.996	-2.16%	-2.16%	880919	2.791	880919	3.844	-2.16%	-2.16%
21_7	1072170	3609.047	1072177	19.285	1072177	20.749	0.00%	0.00%	1072177	2.110	1077418.3	3.070	0.00%	0.49%
21_8	1171190	328.096	1171191	15.872	1171191	17.541	0.00%	0.00%	1171191	2.014	1171191	2.439	0.00%	0.00%
21_9	1064640	3601.956	1064636	22.440	1074605.6	31.168	0.00%	0.94%	1064636	2.369	1064636	2.700	0.00%	0.00%
21_10	1090040	3605.187	1090035	28.905	1090035	30.626	0.00%	0.00%	1090035	2.190	1090035	2.810	0.00%	0.00%
21_11	1111700	948.796	1111713	20.242	1111713	22.671	0.00%	0.00%	1111713	2.054	1111713	2.734	0.00%	0.00%
21_12	1170500	3602.343	1170496	27.667	1170496	30.999	0.00%	0.00%	1170496	2.191	1170496	3.128	0.00%	0.00%
21_13	954520	3603.942	954530	28.359	954530	29.186	0.00%	0.00%	954530	2.448	954530	2.826	0.00%	0.00%
21_14	1009110	3609.507	953605	23.341	953605	26.793	-5.50%	-5.50%	953605	1.903	953605	2.542	-5.50%	-5.50%
21_15	981790	3601.761	981797	19.003	981797	22.251	0.00%	0.00%	981797	2.078	981797	2.513	0.00%	0.00%
21_16	1102310	3603.240	1092580	24.250	1092580	25.788	-0.88%	-0.88%	1092580	2.099	1094418.7	3.023	-0.88%	-0.72%
21_17	1174240	3633.633	1169096	28.984	1169096	30.129	-0.44%	-0.44%	1169096	2.439	1169096	2.801	-0.44%	-0.44%
21_18	982100	3601.305	993787	18.955	993787	20.962	1.19%	1.19%	982117	2.025	984451	2.525	0.00%	0.24%
21_19	1262200	3621.698	1255279	21.196	1255279	24.869	-0.55%	-0.55%	1255279	2.284	1256665.2	3.600	-0.55%	-0.44%
21_20	1066240	3645.103	932429	31.067	932671.9	38.918	-12.55%	-12.53%	932429	2.479	932671.9	3.279	-12.55%	-12.53%
21_21	1176480	3624.382	1168601	23.339	1168601	24.521	-0.67%	-0.67%	1168601	2.297	1168601	3.312	-0.67%	-0.67%
21_22	1087710	3607.139	1087719	20.282	1088145.1	26.527	0.00%	0.04%	1087719	2.226	1087719	3.014	0.00%	0.00%
21_23	1022950	3631.000	984373	21.539	984373	22.335	-3.77%	-3.77%	984373	1.895	993420.1	2.703	-3.77%	-2.89%
21_24	1050900	436.280	1050895	19.920	1050895	20.528	0.00%	0.00%	1050895	1.882	1050895	2.086	0.00%	0.00%
21_25	1049790	1568.720	1049791	13.695	1049791	15.653	0.00%	0.00%	1049791	1.715	1049791	2.324	0.00%	0.00%
21_26	1078130	3616.112	1020350	31.689	1020350	33.020	-5.36%	-5.36%	1020350	2.484	1020350	3.569	-5.36%	-5.36%
21_27	1150470	1392.572	1150468	18.708	1150468	19.996	0.00%	0.00%	1150468	1.957	1150468	2.617	0.00%	0.00%
21_28	1057890	1346.693	1057907	20.758	1057907	24.445	0.00%	0.00%	1057907	1.854	1059047.9	2.947	0.00%	0.11%
21_29	1185260	3605.815	1185254	23.490	1186769	31.902	0.00%	0.13%	1185254	2.294	1185254	2.663	0.00%	0.00%
21_30	1154500	1842.588	1154502	18.825	1168373.7	27.457	0.00%	1.20%	1154502	1.730	1159125.9	2.364	0.00%	0.40%
21_31	988540	3629.428	988549	23.923	989248.8	28.424	0.00%	0.07%	988549	2.026	988549	2.743	0.00%	0.00%
21_32	1165960	1563.133	1165973	20.783	1167282.9	26.812	0.00%	0.11%	1165973	2.000	1168592.8	2.740	0.00%	0.23%
21_33	1040130	3726.238	1038504	27.205	1038504	28.948	-0.16%	-0.16%	1038504	2.215	1038504	2.552	-0.16%	-0.16%
21_34	1135190	3602.520	1000462	30.061	1000462	35.981	-11.87%	-11.87%	1000462	3.006	1000462	3.538	-11.87%	-11.87%
21_35	1101290	2204.284	1101298	17.709	1105668.5	27.597	0.00%	0.40%	1101298	2.047	1105668.5	2.547	0.00%	0.40%
21_36	1120580	2109.403	1120556	18.822	1120556	19.815	0.00%	0.00%	1120556	1.913	1120556	2.390	0.00%	0.00%
21_37	1158870	1823.964	1158887	19.603	1158887	20.141	0.00%	0.00%	1158887	2.064	1158887	2.444	0.00%	0.00%
21_38	1232780	3602.042	1161613	27.229	1161613	32.043	-5.77%	-5.77%	1161613	1.828	1161613	2.273	-5.77%	-5.77%
21_39	1057640	1686.590	1057616	23.666	1057616	26.416	0.00%	0.00%	1057616	1.911	1057616	2.580	0.00%	0.00%
21_40	1103280	1126.335	1103293	23.100	1103293	24.224	0.00%	0.00%	1103293	2.222	1103293	2.673	0.00%	0.00%
21_41	1167860	3610.106	1172692	19.070	1174235.7	25.333	0.41%	0.55%	1167841	2.118	1168811.2	3.256	0.00%	0.08%
21_42	1181570	3604.095	1181579	22.632	1181579	23.395	0.00%	0.00%	1181579	1.941	1181579	2.645	0.00%	0.00%
21_43	1185860	351.082	1185862	16.698	1185862	18.776	0.00%	0.00%	1185862	1.741	1197063.9	2.594	0.00%	0.94%
21_44	1010340	3603.534	907926	26.176	907926	27.439	-10.14%	-10.14%	907926	2.211	907926	2.559	-10.14%	-10.14%
21_45	1139910	3632.261	1120963	18.377	1120963	24.577	-1.66%	-1.66%	1120963	1.798	1124753.2	2.606	-1.66%	-1.33%
21_46	1068030	3613.738	996984	27.334	996984	29.125	-6.65%	-6.65%	996984	2.416	998406.2	2.862	-6.65%	-6.52%
21_47	1301900	3634.808	1266660	30.966	1266660	39.625	-2.71%	-2.71%	1266660	2.365	1269044.1	3.177	-2.71%	-2.52%
21_48	1062460	3601.832	1060904	18.044	1061370.8	22.463	-0.15%	-0.10%	1060904	1.726	1060904	2.169	-0.15%	-0.15%
21_49	1203650	925.529	1203654	17.255	1207372.1	23.761	0.00%	0.31%	1203654	1.799	1203654	2.340	0.00%	0.00%