Mesh Topology Viewer (MTV): an SVG-Based Interactive Mesh Network Topology Visualization Tool

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Abstract—**This paper discusses wireless mesh network topology visualization tools and their requirements. It presents an interactive tool for visualizing mesh network topologies. The proposed tool uses the SVG – Scalable Vector Graphics – web standard, which is based on XML, to build the network map. In a wireless mesh network, link quality varies quite often, therefore the visualization tool dynamically displays the quality metric of each link, in addition to presenting router configuration information and other network statistics. This work also introduces a configuration tool designed to adapt the topology view to different wireless mesh environments.**

Index Terms—**Link quality, mesh network management, network topology view, SVG, wireless mesh networks.**

I. INTRODUCTION

MESH networks have the advantage of being low-cost, easy-to-deploy and fault-tolerant. In those networks, wireless routers are usually fixed and communicate with each other in ad-hoc mode through multiple hops in order to deliver messages to their destinations. Final users can connect to the network using Ethernet (wired mode) or 802.11 (wireless mode) networks.

In order to provide multi-hop communication, mesh networks typically use ad-hoc routing protocols to compute the best available routes [1]. In a wireless network, link quality varies quite often, and therefore mesh routing protocols should use link quality metrics instead of hop-count to calculate the best paths [2].

In order to facilitate network management and maintenance in wireless environments, it is very useful to have a network visualization tool, which shows router configuration and, most of all, link quality and available routes. Moreover, in order to provide easy access to it, this network map should be developed as an interactive web document.

The ReMesh project [3, 11, 16, 17] provides wideband internet access to the university community, through a mesh network surrounding the campi. This project maintains two networks, one indoor, where new solutions for network performance improvements are tested before being applied to the outdoor network, which is used by the university community.

The main goal of this work is to describe the development of MTV – Mesh Topology Viewer – a mesh network topology visualization tool that shows the quality of each wireless link and exhibits the geographic position of each network node. The proposed tool was developed and has been used by the ReMesh project. Using a configuration tool, the interactive network topology map can be easily adapted to other networks. The usage of the proposed tool is crucial for network monitoring and makes maintenance procedures and the network problem solutions much easier.

One main concern about the development of a new network topology visualization tool is compatibility with current web standards. Thus, MTV was developed using the SVG [4] language – Scalable Vector Graphics – an XML-based markup language designed for building interactive graphics on the web.

The remainder of this paper is organized as follows. Section 2 discusses related work, showing the first visualization tool used in the ReMesh project and other tools used in other mesh projects. Section 3 presents some requirements that should be fulfilled by mesh topology viewers and describes the development of the proposed tool. Section 4 presents the configuration tool, used to adapt the visualization tool to a new mesh network environment. Section 5 discusses the integration of a mesh topology map and other mesh network management tools. Concluding remarks are given in Section 6.

II. RELATED WORK

There are several mesh network research and development projects around the world [3, 5, 6, 7, 8, 9, 12, 13, 14]. Some of them have developed their own topology visualization tools, such as Meraki [7], Roofnet [18], Google WiFi in Mountain View [8] and others.

Google's mesh visualization map only shows the network coverage area [8]. The Meraki solution utilizes a management tool developed by the NetEquality organization [9], called Dashboard, which it is only available for Meraki routers. Roofnet [18] has a real-time link map, which shows link quality among wireless routers, but does not provide user interactivity.

The ReMesh project [7] initially developed a network map using dotdraw, a plugin of the OLSR [10] routing protocol implementation. The tool was quite useful for live network monitoring but it was hard to visually understand the presented data (e.g. neighborhood, route to the Internet gateway and geographical localization of a node), as seen in Figure 1. This happened because the graph layout was built by an automatic graph drawing algorithm. In this solution, router geographical location was not considered and when the view was refreshed, network nodes changed their position, due to the automated graph drawing algorithm, making it difficult to understand the real network topology.
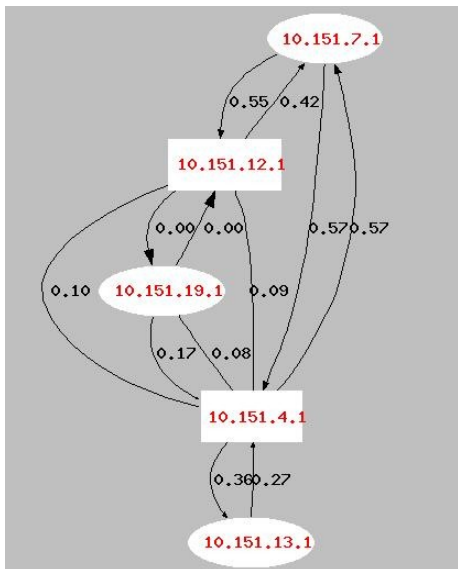
Fig 1. ReMesh´s initial visualization tool

III.SVG-Based Interactive Mesh Network Topology
Visualization Tool

In order to present the proposed mesh network topology visualization tool named MTV, which was developed as an interactive SVG document, this section addresses the most important requirements for a mesh network visualization tool, its architecture and some implementation details.

A. Visualization Tool Requirements

A mesh network visualization tool should draw the network graph presenting the link quality information over the network topology map, which means that fixed nodes should keep their geographical position.

In the ReMesh project, link quality is measured by the ML (minimum loss) metric [11, 16, 17]. ReMesh developed an extension of the OLSR routing protocol, called OLSR-ML [11, 17], where the best routes are the ones with the minimum packet loss rate. The ML metric is based on the ETX metric [12], but it uses a multiplicative approach for multi-hop paths, instead of the traditional additive approach.

In order to quickly assess the quality of a link, the topology visualization map should represent link quality metric values by a color scale. In the case of ReMesh, the color scale is defined according to the link ML value. To inform the map user about the correspondence between link quality and the color scale, a caption should be shown in the map.

The network topology visualization tool should provide more information about the network, such as router configuration or traffic information, for example. So, another requirement for the mesh topology visualization tool is to provide an interactive interface, where users click at a specific router and have access to more information about it.

Another important requirement is being available for web access, so the interactive tool should be developed using current web standards. SVG [4] – Scalable Vector Graphics – is an XML specification and file format for describing two-dimensional vector graphics, both static and animated. A

characteristic of a vector graphic is not to lose definition when resized. The difference of the SVG format from other vector image formats is that SVG is an open web standard. These reasons motivated the use of SVG for graphical programming in this work.

As the tool should be used to visualize different mesh networks, one last requirement is easy adaptation and configuration for new environments.

None of the related works presented in Section 2 fulfills the highlighted requirements, which motivated the development of a new mesh network topology visualization tool, as described in the next section.

B. Architecture and Implementation

The architecture of MTV, the mesh network visualization tool presented in this work, is shown in Figure 2. In short, a CGI program reads an XML configuration file, which brings information about router location and addresses, as will be detailed afterwards. The program also accesses the network gateway in order to find link quality information. Then the whole process outputs an SVG file to be presented by a web browser. As the graph is built as a dynamic web page, it is updated every time the page is refreshed.

As link quality frequently changes in a mesh network, the SVG map should be dynamically computed according to link quality parameters received periodically. In ReMesh network, all routers have a database that contains the ML metric value for each link. Hence, the visualization tool needs to access this database and collect this information before drawing the graphs. In fact, this database is a simple text file stored in each network router. In the implementation, we used the text file stored in the gateway node to get the quality metric information of all network links.
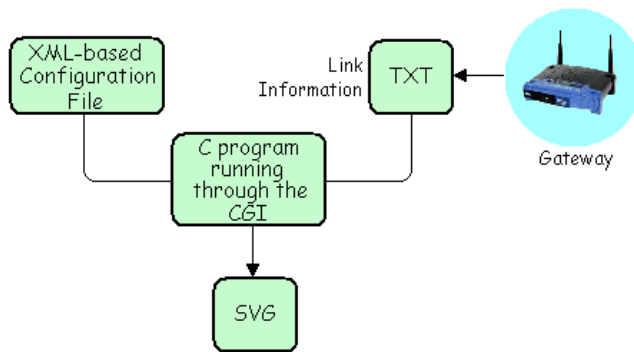

Fig 2. MTV architecture

Besides the network dynamic parameters, there are also static parameters, such as network configuration parameters (e.g. the gateway IP address, routers addresses and identification) and graph drawing parameters (e.g. the background image with geographic information, like a map or a satellite photo, its screen size and router locations on the map). These parameters are defined in an XML-based configuration file that is passed as an argument to the CGI program. This configuration file is used to adapt the proposed visualization tool to different mesh network topologies. A configuration file example is given in Figure 3. We also provide a configuration tool to build this XML-based configuration file using a graphical interface, which will be

detailed in Section 4.

Basically, the visualization tool is a C program that runs in a web server, through CGI, using an XML-based configuration file as an argument and generates a dynamic SVG code.

```
<topology    src="/images/topology_ext.jpg"    width="800"
height="500" gateway="200.20.15.238">
    <caption src="/images/caption.jpg" width="240" height="108"
x="560" y="392"/>
    <router    id="4"     x="280"    y="179"    ip="10.151.4.1"
href="http://mesh.ic.uff.br/mrtg/10.151.4.1_3.html"/>
    <router    id="13"    x="400"    y="240"    ip="10.151.13.1"
href="http://mesh.ic.uff.br/mrtg/10.151.13.1_3.html"/>
    <router    id="7"     x="180"    y="365"    ip="10.151.7.1"
href="http://mesh.ic.uff.br/mrtg/10.151.7.1_3.html"/>
    <router    id="12"    x="275"    y="355"    ip="10.151.12.1"
href="http://mesh.ic.uff.br/mrtg/10.151.12.1_3.html"/>
    <router    id="10"    x="140"    y="350"    ip="10.151.10.1"
href="http://mesh.ic.uff.br/mrtg/10.151.10.1_3.html"/>
    <router    id="19"    x="590"    y="110"    ip="10.151.19.1"
href="http://mesh.ic.uff.br/mrtg/10.151.19.1_3.html"/>
</topology>
```

Fig 3. XML-based topology configuration file

The XML-based topology configuration file allows customization of the network map according to specific mesh network information. It provides the background image URL, the gateway IP address and image screen size, the caption image URL, its size and position in the background image and identification (id), position and IP addresses for each fixed mesh router. Additionally, the topology configuration file permits specifying a URL for each router, which can indicate a customized web page giving direct access to router configuration or traffic information. In our implementation, it points to the MRTG [15] tool web page for each router. Figures 4 and 5 show the topology map of the ReMesh outdoor and indoor networks respectively (available at http://mesh.ic.uff.br/cgi-bin/topologia_ext   and   at http://mesh.ic.uff.br/cgi-bin/topologia_int). In the figures, captions are written in portuguese, because the ReMesh project has been developed in Brazil. Link quality metric values in OLSR-ML vary from 0 to 1. Greater values indicate better quality links. MTV uses a seven-color scale to present metric values in the map. This color scale is currently hardcoded in the CGI program, but it could be easily adapted if necessary.
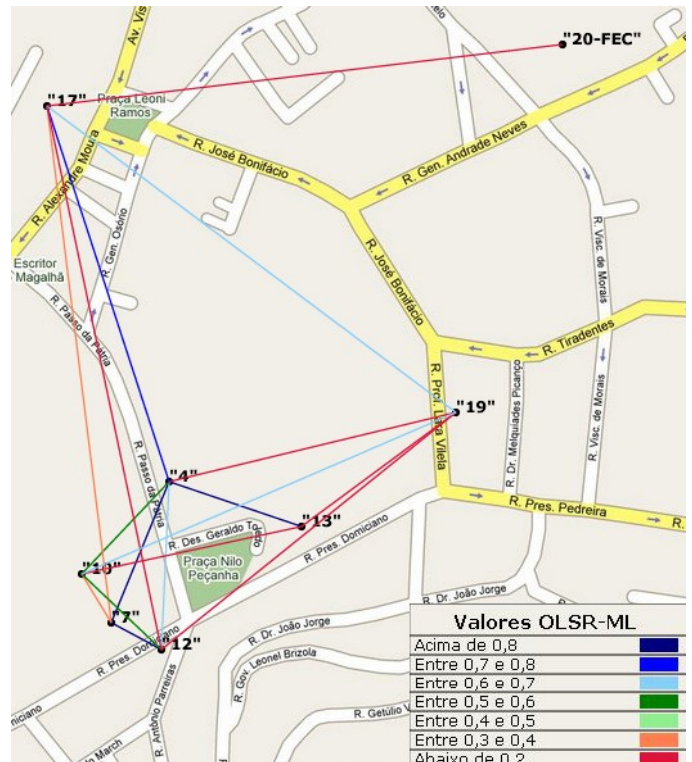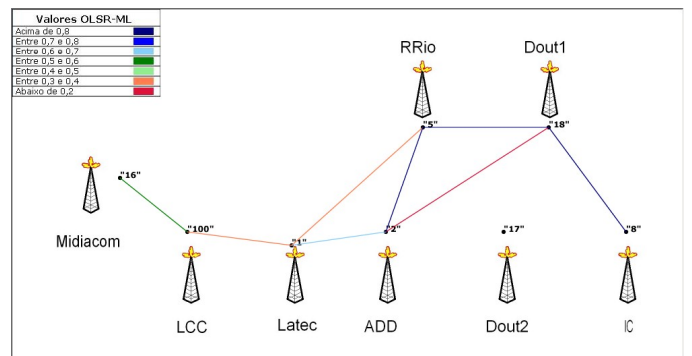

Fig 4. ReMesh outdoor network topology

Fig 5. ReMesh indoor network topology

IV. CONFIGURATION TOOL

In spite of the simplicity of the XML-based topology configuration file, one still needs to use a graphic editor to set router location coordinates, specify them in the configuration file and update the file in the web server, such that the new version of the topology map can be visualized. In order to facilitate the configuration file creation and edition, we provide a configuration tool with a graphic interface that allows updating the XML-based topology configuration file to different network parameters. With this configuration tool the user can set all parameters that are required by the configuration file graphically.

The user specifies all the configuration information needed using a graphical interface and the configuration tool generates a graphical view of the mesh network topology (without link information).

The configuration tool is a Java applet that can be accessed by any web client. It provides two windows, one for updating

configuration options and for displaying the XML configuration file code (menu frame) and another for visualizing the topology (topology frame).

In the menu frame, there are four tabs. They are responsible for adding or removing map components and setting mesh network parameters. The first tab is the topology tab, it contains the URL field, which specifies the background image URL, the width and height fields in order to specify the size of the picture on the screen and the gateway IP field, where the user should set the gateway IP address. After pressing the "Generate" button the image will appear on a new frame.

The next tab sets the caption on the map. It also has the URL, width and height fields. Additionally, it has the X and Y coordinate fields that will set the caption position on the frame. Once you press the "Generate" button, the caption will be placed on the frame.

The third tab is responsible for mesh router parameters and adding them to the topology map. The first field is the ID, where the user provides an identification for each router. There is also an IP address field. Finally, the URL field is optional, where the user may choose a web page that will be associated to each router. The idea is to provide additional information for each router in this customized web page. The position of the router can be set by a mouse click in the topology view frame. A black-filled circle will come up on the screen and its X and Y coordinates will be used to fill the X and Y fields accordingly. The router inclusion is concluded when the "Add" button is pressed and the black circle will be replaced by a picture of a router in the graphical interface.

The last tab removes routers, if necessary, by providing the router id and pressing the "Remove" button.

By pressing the button "Generate XML Code", the code will be printed in the text box placed in the menu frame. Figures 6 to 9 are snapshots of the four tabs with the XML Configuration Code Display.

After setting up all configuration parameters, the topology frame provides a preview of what will be seen in the map built by the visualization tool. We can see an example in Figure 10.
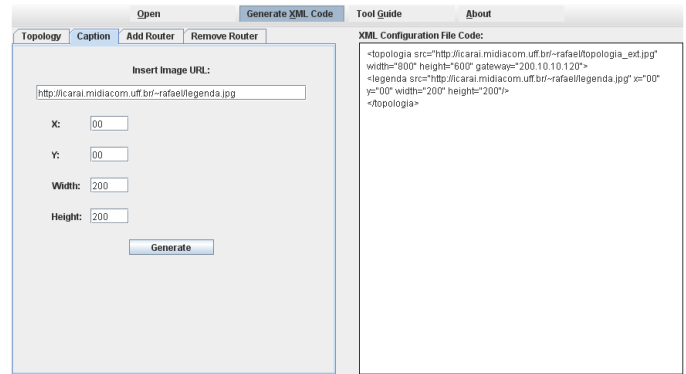

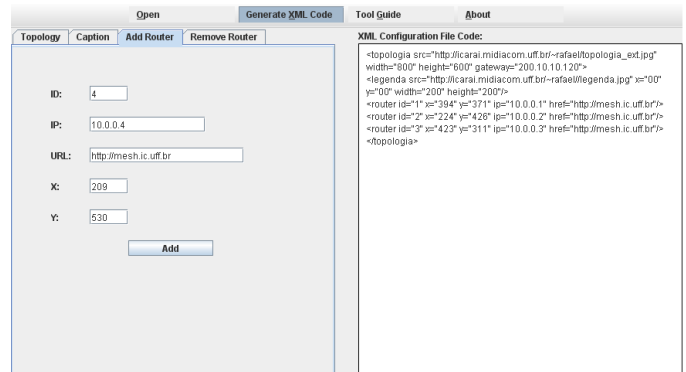Fig 7. Configuration tool Caption tab
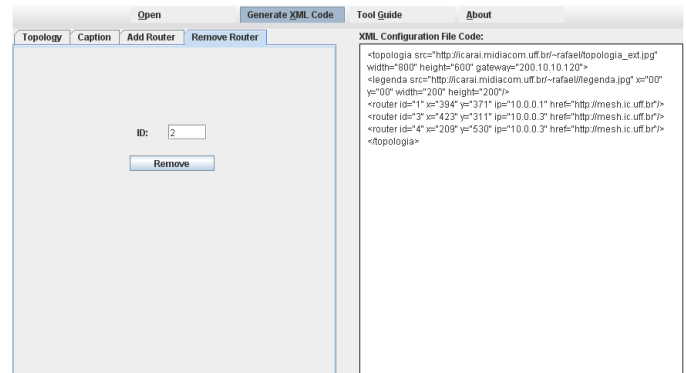

Fig 8. Configuration tool Add Router tab

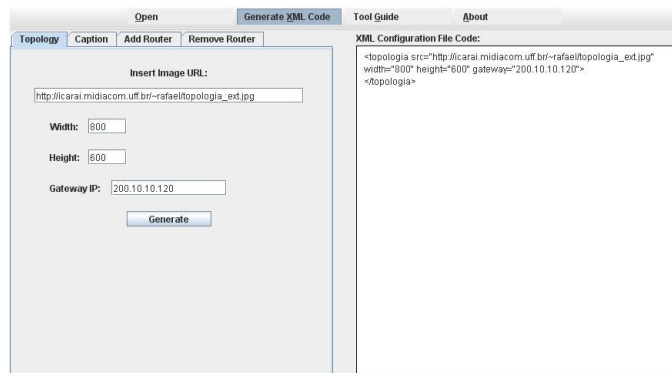Fig 9. Configuration tool Remove Router tab
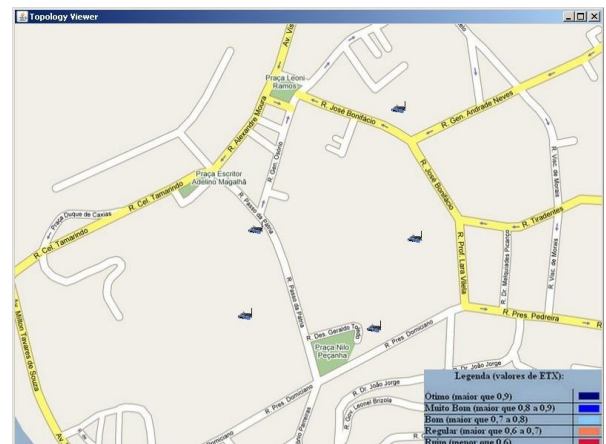

Fig 6. Configuration tool Topology tab

Fig 10. Topology view of the configuration tool

V. INTEGRATION OF MANAGEMENT TOOL

The ReMesh project has developed other management tools [3, 16] for mesh networks, mainly focusing on measuring network performance and on autonomic network configuration. As a future work, we intend to integrate all management tools into a single one, using the visualization tool as the graphical interface to access all network services. As partially provided in the NetEquality solution [9], the main idea is a complete management tool where all kinds of data stay on the same platform and the network administrator decides the type of information to display on the screen.

The topology visualization tool can be a good place to aggregate data of other tools as shown in Figure 11, because it is as naturally organized as the geographical displacement of nodes. Thus, the topology tool can combine information of the network to offer a richer map to a network manager, allowing it to quickly access all broader data about the network. For instance, the quality of all links or the number of authenticated users on each node, and with a simple request the manager could receive more detailed data on specific nodes, such as the names of authenticated users, performance metrics like memory consumption or recent activity history. The ultimate objective of integrating management tools is to pave a new way for a network manager to gather needed network information in a faster and easier way than before with a disperse set of tools.
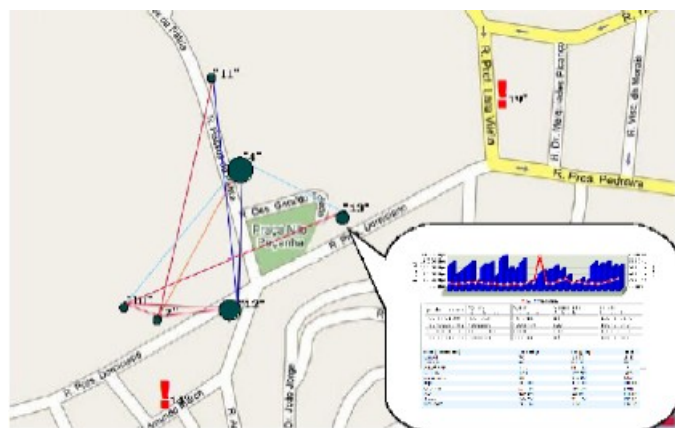

Fig 11. Visualization tool integrated with other management tools

VI. FINAL REMARKS

This work highlighted the main requirements for a mesh network topology visualization tool. In addition, it presented MTV, a graphic tool for visualizing mesh network topologies that fulfills all the identified requirements. MTV uses the SVG – Scalable Vector Graphics – web standard to build the network map. It shows routers in their geographic locations. In a wireless mesh network, link quality varies very often. Therefore MTV shows the quality metric of each link in the topology map, providing a color scale to present wireless link quality information. Moreover, when the user clicks in a mesh router, additional configuration and traffic information is available. Finally, the view can be easily adapted to different network environments using an XML-based configuration file.

Besides the visualization tool, we also provide a configuration tool to adapt the topology view to a specific wireless mesh network. The configuration tool has been used to configure network topology views for five different wireless mesh networks. It has been used by the ReMesh project in both outdoor and indoor mesh networks and by three other outdoor networks using the ReMesh solution. Those networks have been already installed in different Brazilian cities: Brasília, Belém and Curitiba. According to network administrators, the proposed visualization tool has been very useful for network monitoring and management in those different environments.

MTV can be used by any mesh network that uses the OLSR-ML routing protocol and can easily be adapted to the original OLSR protocol. As another advantage, the development has been done using web standards and free software and is freely available upon request.

As a future work, we intend to fully integrate MTV and other mesh network management tools that have been developed by the ReMesh Project. Also as future work, we intend to continue improving MTV facilities, for example, allowing the network administrator to configure the correspondence between link quality metric values and the color scale presented in the map, which is currently hardcoded in the CGI program. Another feature that can be included is configuring the router image that is displayed when a node is added in the map or when the user places the mouse over a specific router to indicate map interactivity.

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