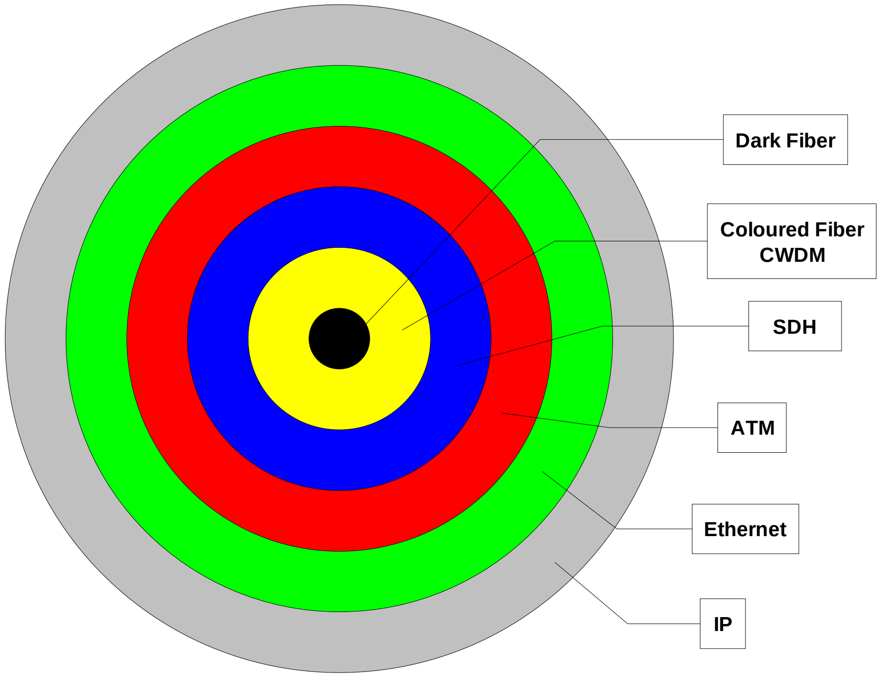
S-38.3191 Verkkopalvelujen tuotanto

S-38.3191 Network Service Provisioning

Lecture 2: Conventional L2 Network Technologies

L2 Technologies

- Link layer technologies are used to build a point-to-point connection for network layer protocols e.g. IP
  - Depends on
    - Span of the network
      - LAN/MAN/WAN
    - History of the network
      - Pure data network
      - Originally voice network
    - Age of the network



L2 Technologies

- Overall trend has been fluctuating from a low network stack to ones with very many protocols on top of each other to back one with very low stack
  - Low stack:
    - Efficient, coarse, rigid
  - High stack
    - Accurate, flexible

Transmission Systems

- LAN technologies scale for LANs and campuses
  - No transmission systems
    - Low controllability over resources
- For MANs and WANs you need transmission systems
  - Modern transmission systems use LAN interfaces for user side
  - Legacy transmission systems use IP and serial interfaces for user side

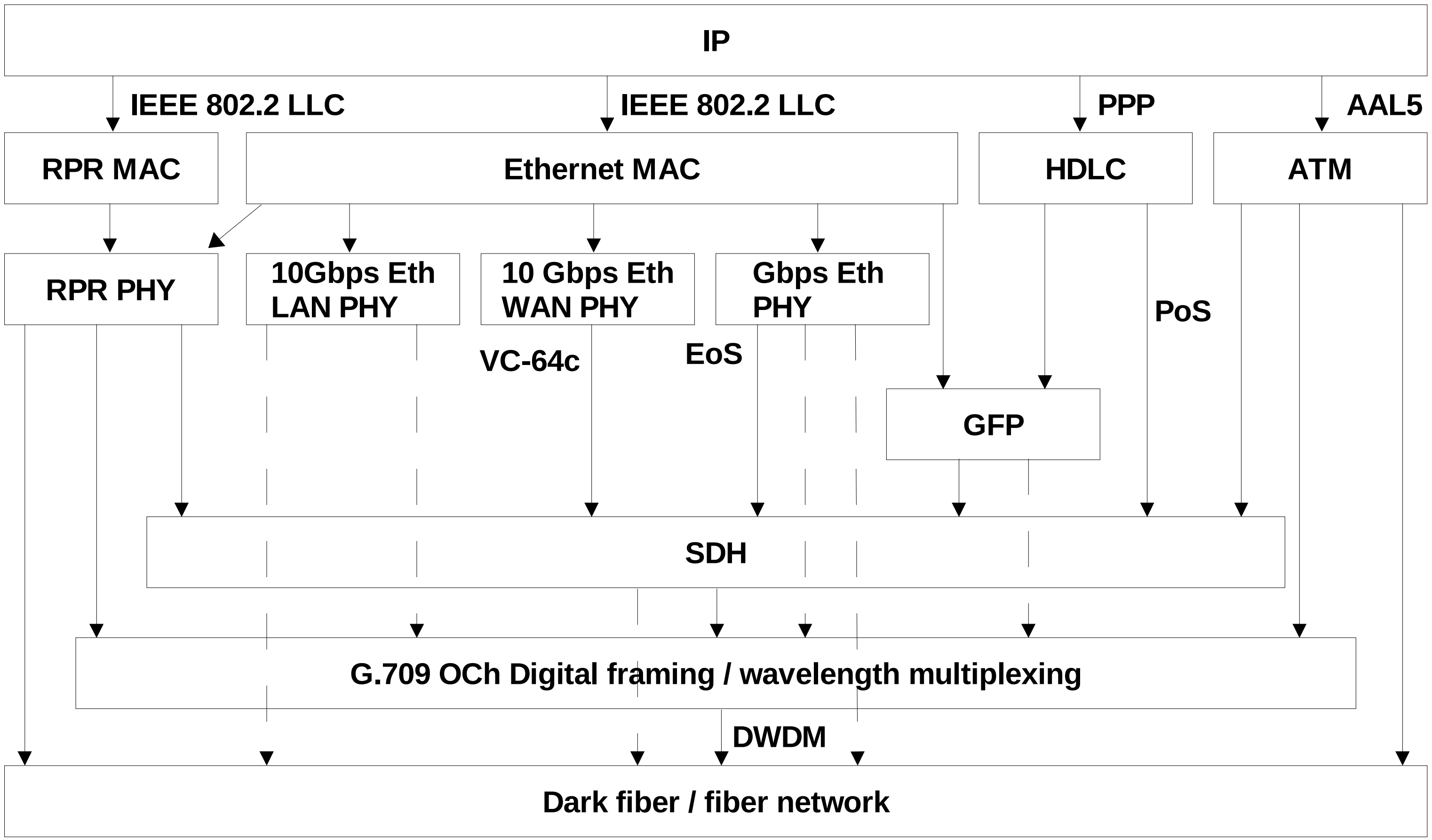
Speed vs Distance

- Transmission speed and distance without repeaters tend to be inversely proportional
    - 1Gbps Ethernet -> 80-150km in SM-fiber with ZX-transmitter
    - 10Gbps Ethernet -> 10-40km in SM-fiber with ZX-transmitter
- How to gain maximal throughput with a minimal cost
  - Balance between cost and sensitivity of transmitters and receivers
    - Adding repeaters lowers the sensitivity demand -> lowers the price -> adds device -> increases the price
  - TCO

Technologies

- **High bandwidth requirements**
- Transmission speeds are increasing with a constant rate
  – 1995: 155Mbps (SDH/ATM)
  – 2000: 2.4Gps (SDH)
  – 2004: 10 Gbps (SDH/Ethernet)
  – 2000-2004 wavelength technologies brought a new means to increase capacity
    - DWDM
    - CWDM

- **Frame based multiplexing**
  – Irrespective of low layer functionality
    - Fiber/Radio
  – Options today are
    - GMPLS
    - SDH
    - ATM
    - Ethernet
    - GFP
    - RPR

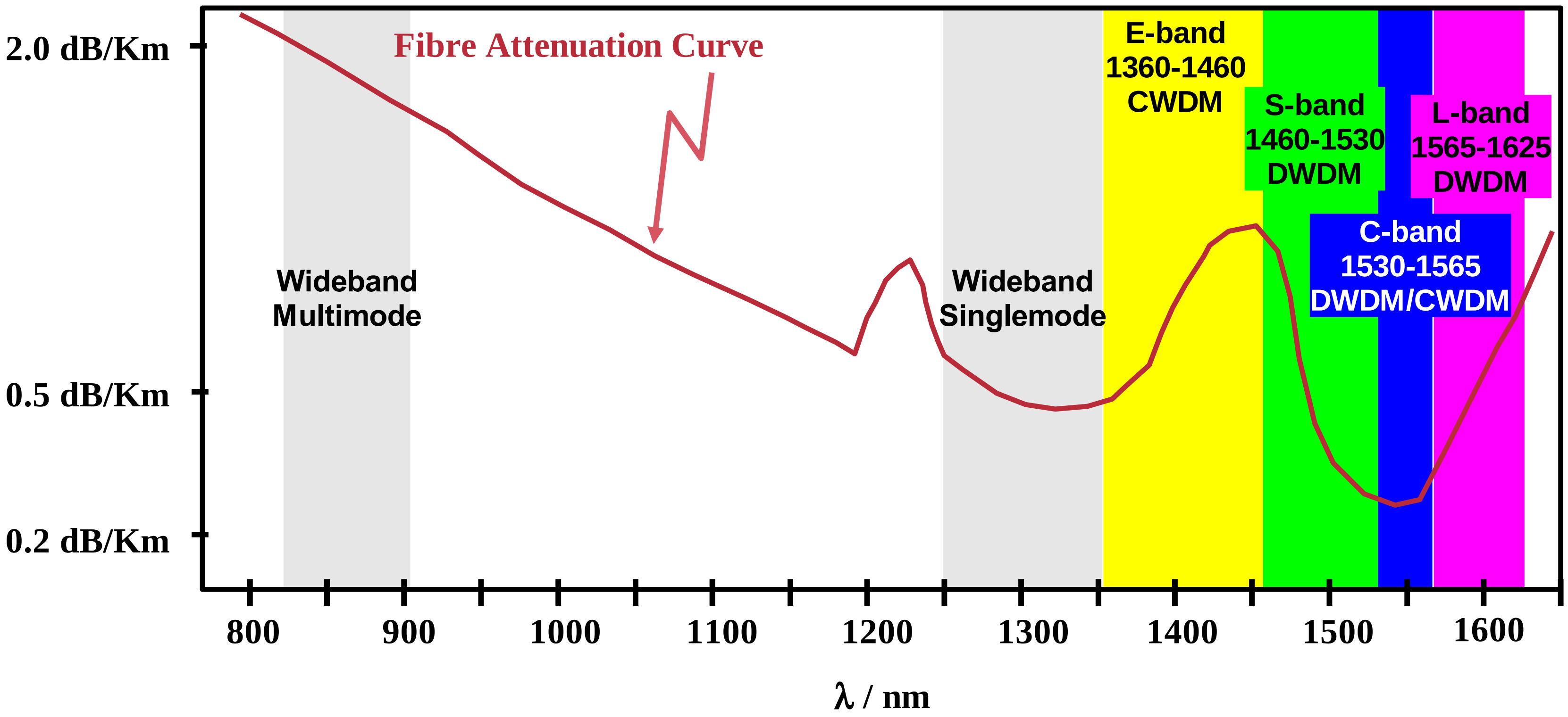


EoS Ethernet over SDH (Proprietary)
PoS Packet over SDH

RPR Resilient Packet Rings (IEEE 802.17)
GFP Generic Framing Procedure

Fiber communication

- Fiber optics offers wide spectrum of which only narrow part is used by conventional wideband fiber transmitters

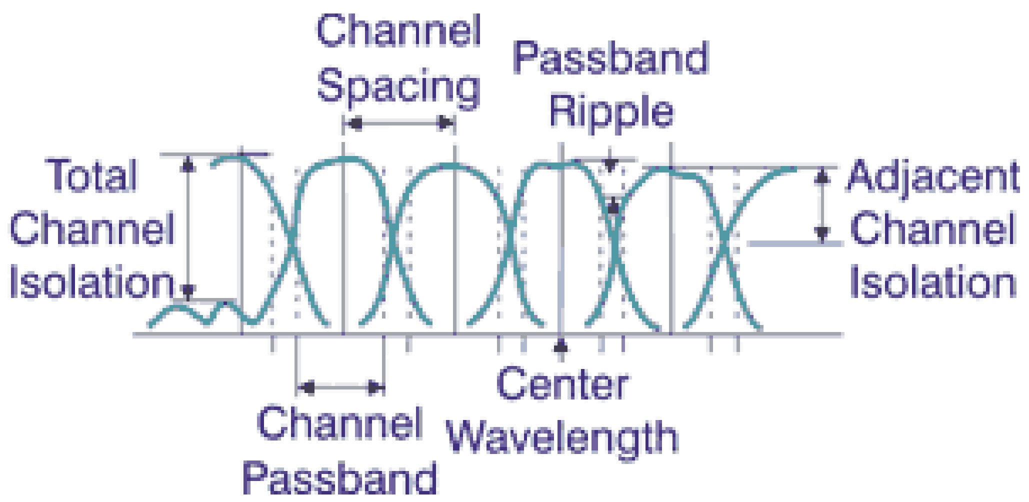


Modern fiber communication

- **The goal is to push the limits of wideband fiber communications**
  - Wideband transmitters are expensive and electrical part with high speed is error prone
    - **Multiple narrowband transmitters** achieve same performance on lower cost and lower error margin
  - To achieve longer transmission distances
    - Lower attenuation of lower frequencies serves this goal
      - Narrow transmission window in C-band
        - » Narrow spacing of transmission channels

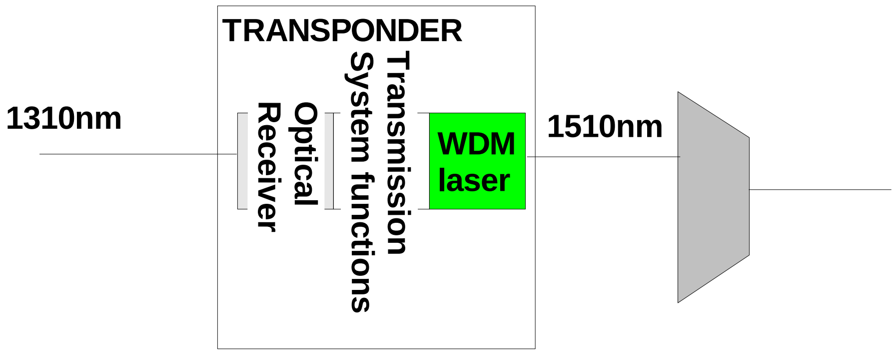
Modern fiber communication

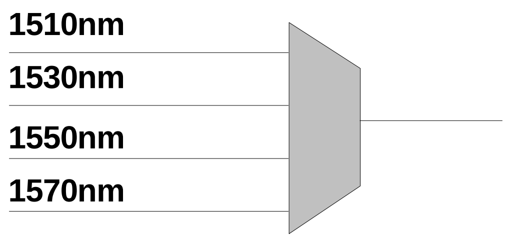
- Packing of several channels into a single media causes multiple problems related to interferences
  - Not just within fiber but also between channels
    - How to inject multiple closely spaced signals into a fiber
    - How to detect them in receiver
    - How to control their defects caused by
      - Dispersion
      - Attenuation



WDM

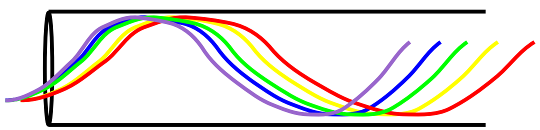
- Effectively N fold increase of transmission capacity from the same fiber infrastructure
  - Individual lambdas can be used independently
    - Usage depends on transponder unit





WDM

- Two operative versions
  - CWDM – Coarse Wavelength Division Multiplexing
    - Normally: 8 channels between (1470 - 1610nm / 20nm steps)
    - G.694.2: 18 channels between (1271 – 1611nm / 20nm steps)
  - DWDM – Dense Wavelength Division Multiplexing
    - ITU Grid (100 Ghz resolution around 193.1Thz/1552.52nm)
      - Sub grids with resolutions of 12.5/25/50GHz
      - Super grids with multiples of 100GHz
- https://www.ntt-review.jp/archive/ntttechnical.php?contents=ntr200709gls.pdf&mode=show_pdf

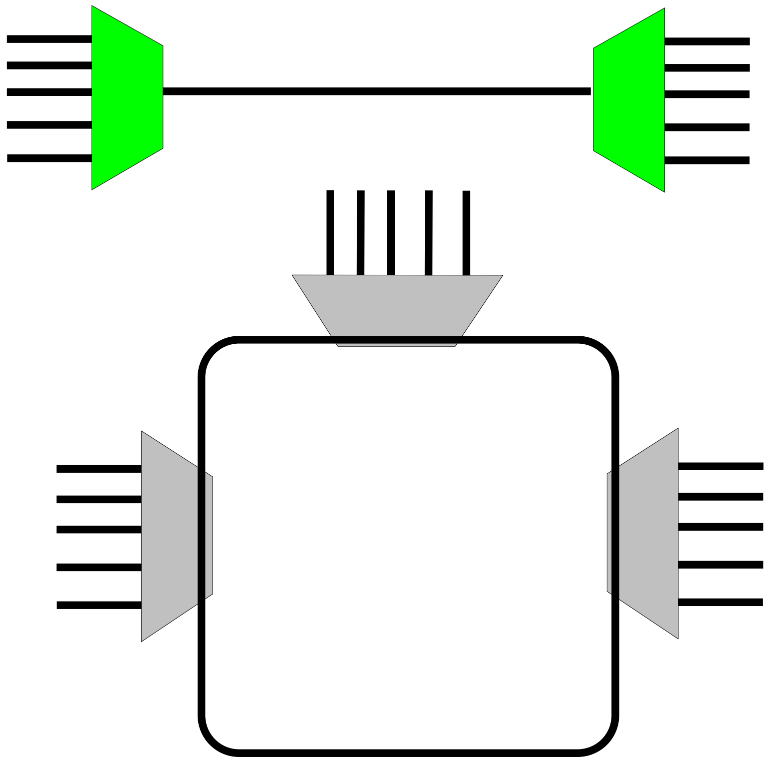


WDM

- **DWDM**
  - Narrow channel spacing
    - Components need to be compensated for temperature effects
      - Expensive
  - More channels to choose from
    - nonlinearities of fibers can be avoided by selecting proper wavelengths
- **CWDM**
  - Wide channel spacing
    - Component requirements are looser
      - Cheaper lasers and receivers
  - Less channels
    - Not suitable for long-haul networks
    - Suitable for MANs

WDM

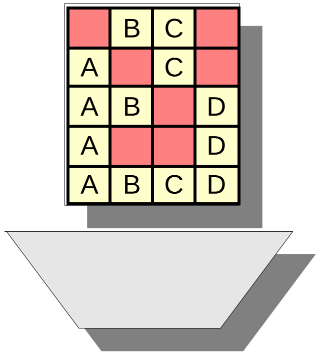
- Can be used as link or network technology
  - Link technology
    - Multiplexers at the ends of the links
  - Network technology
    - Optical switching components
      - Optical delay lines
      - Wavelength conversion
      - Photonic switching
    - Collision free routing
    - Crosstalk issues



WDM

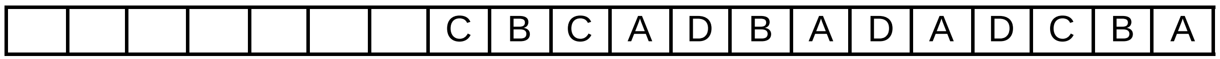
- **Pros:**
  - Protocol independent
  - Virtual fiber
  - Multiplexing different traffic through different wavelengths
- **Cons:**
  - Depending on system pay as you go may not be possible
    - The number of required channels need to be estimated for the lifetime of systems
      - Filters are designed for certain amount of wavelengths and spacing

Frame Multiplexing



Synchronous multiplexing
• Fixed usage of resources

Asynchronous multiplexing
• Free usage of resources



Frame Multiplexing

- Synchronous
  - Fixed usage of resources
  - Information does not need L2 addresses
  - Wastes resources if communication is not CBR
  - Easy to integrate
  - SDH
- Asynchronous
  - Free usage of resources
  - Information requires L2 addresses
  - Does not waste resources
  - Requires additional logics to control resource usage
  - ATM, Ethernet

SDH

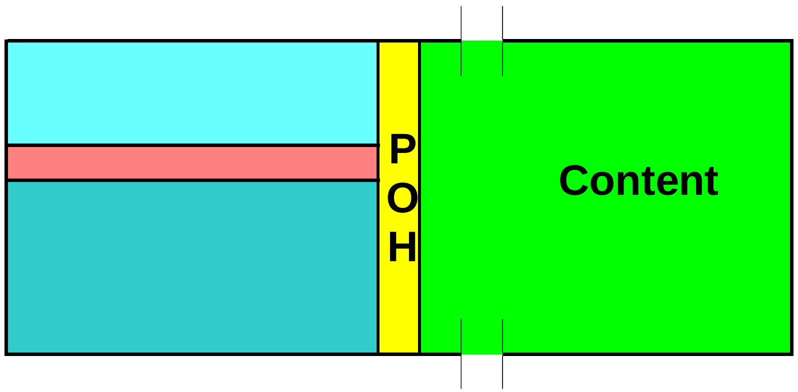
- **Synchronous frame based multiplexing** of transmitted signals
  - Link framing is done with 2430 byte frames
  - Generation interval is 125us -> reflects the original coding of speech with 8kHz sampling rate
    - Datarate = 155,52Mbps

1	2	3	4	5	6	7	8	9	10	11	?	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280	281	?	534	535	536	537	538	539	540
541	542										?						809	810
811	812										?						1079	1080
1081	1082										?						1349	1350
1351	1352										?						1619	1620
1621	1622										?						1889	1890
1891	1892										?						2159	2160
2161	2162										?						2429	2430

SOH (9-tavua) VC-4 (261-tavua)

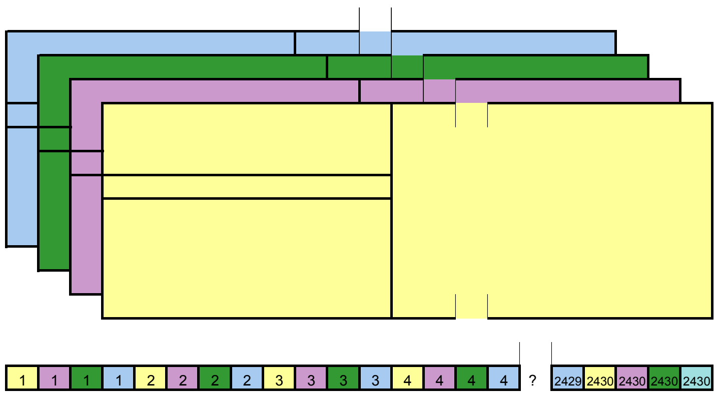
SDH

- Link frames contain virtual containers which carry the actual information
  - Header information (POH)
    - Flow and error control information between edge devices
  - Content
  - Virtual containers form point-to-point permanent connections through SDH network



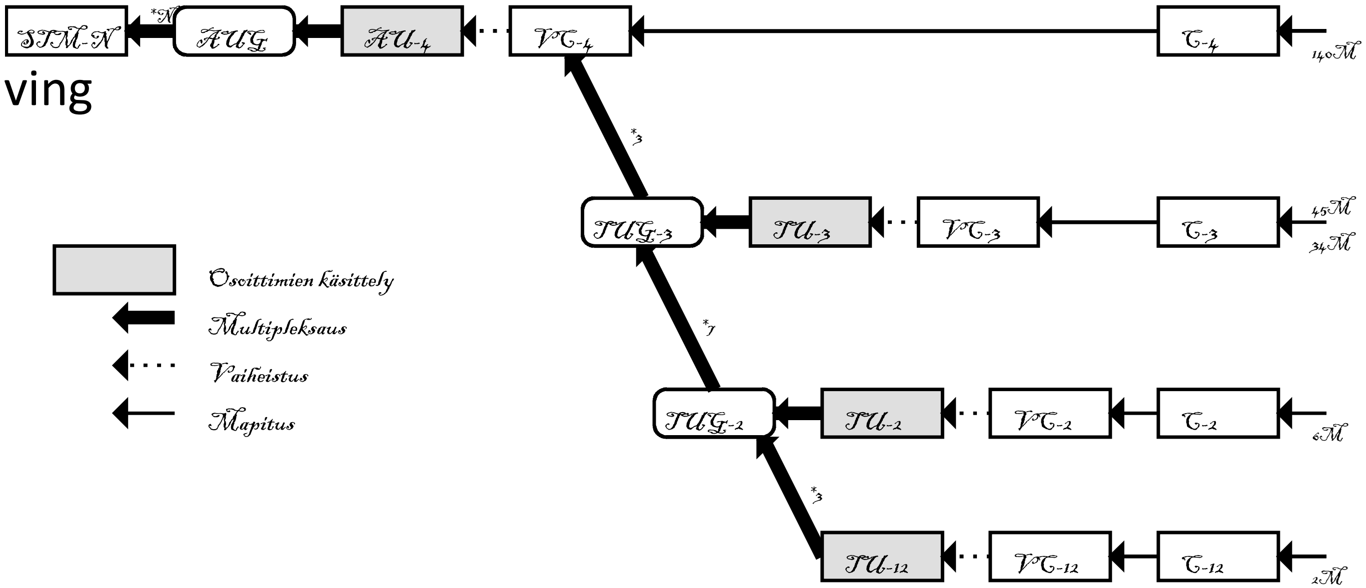
SDH

- **SDH hierarchy makes possible to use multiples and fractions of basic rate**
  - **Multiples** are generated by injecting multiple (factor of four) link frames within time-slot
    - STM-1: 155.52 Mbit/s (basic rate)
    - STM-4: 622.08 Mbit/s (first multiplex)
    - STM-16: 2488.32 Mbit/s (second multiplex)
    - STM-64: 9953.28 Mbit/s (third multiplex)
  - Operation is byte synchronous
    - Timing of individual bytes in multiplex is same than in basic rate frame



SDH

- **Fractions** are generated by multiplexing different streams of content into individual frame
  - Several virtual containers destined to same or different points in network
  - Multiplexing is do
    with byte interleaving

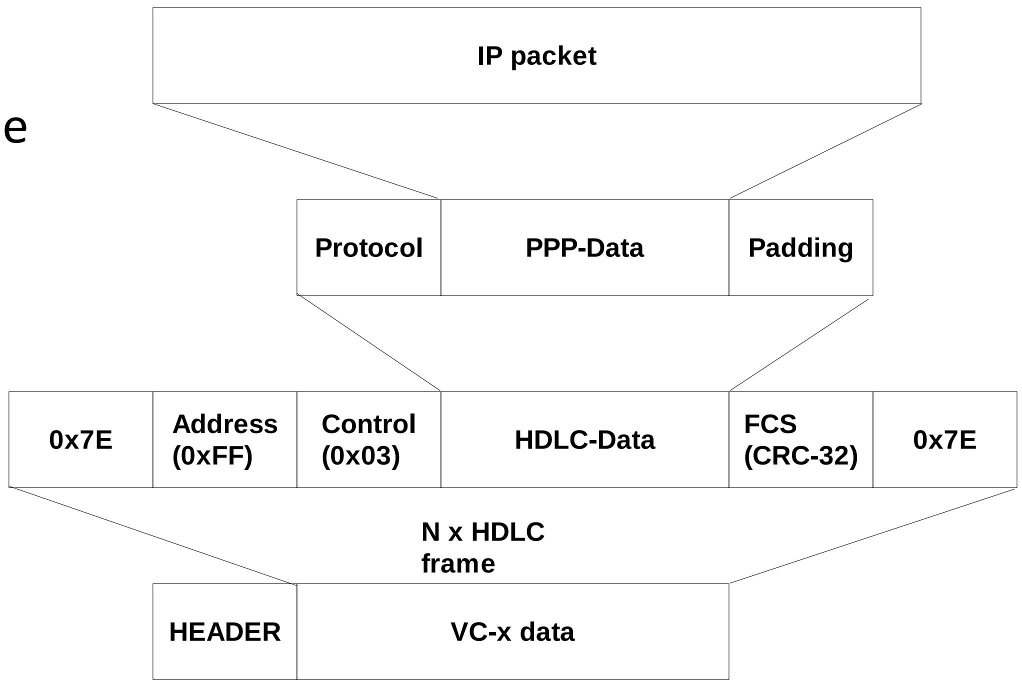


SDH

- SDH supports also **concatenation** of resources
  - **Old version – strict mode**
    - Clear channel operation (small 'c' after the virtual container type)
    - All VC:s in different frames form a single bit stream
    - Not feasible in SDH **networks**
    - Feasible if SDH is used as a point to point link technology
  - **New version – flexible mode**
    - Concatenation is used only in edge devices
      - Supports SDH networks
      - Concatenated VC:s need not be with same speeds
        - » Even over different fibers

SDH

- IP can not be used directly with SDH
  - Packet over Sonet (PoS) is method for delivering IP packets in SDH
    - Additional framing
      - IP packet into PPP-packet
      - PPP packet into HDLC frame
      - HDLC frame into SDH virtual container

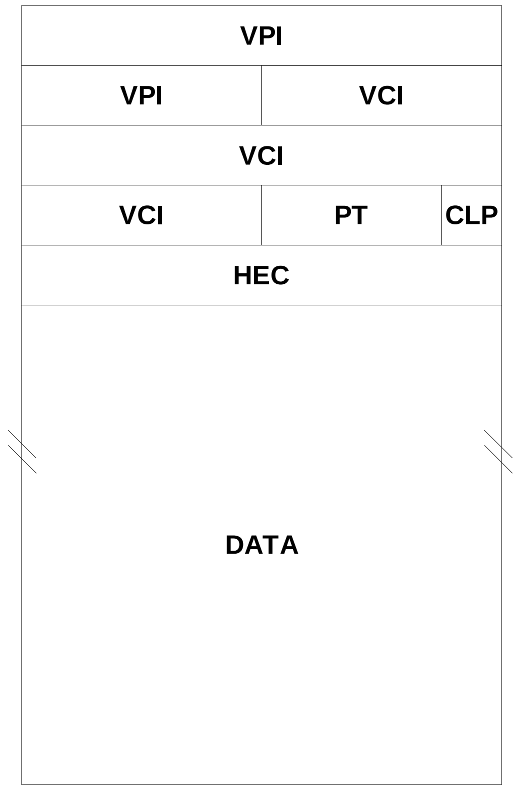


SDH

- **Pros:**
  - Optimized for TDM services (large income from leased line services)
  - Fully compatible with metro ring networks (SDH ADM rings)
  - Reliable and fast failure recovery (roughly 50ms with APS)
  - Price of SDH continuously coming down
- **Cons:**
  - Not cost effective for burst data traffic
    - Capacity in SDH network can only be allocated on multiples of 2Mbps
  - No multiple QoSs for different service charges
  - Expensive interfaces at routers

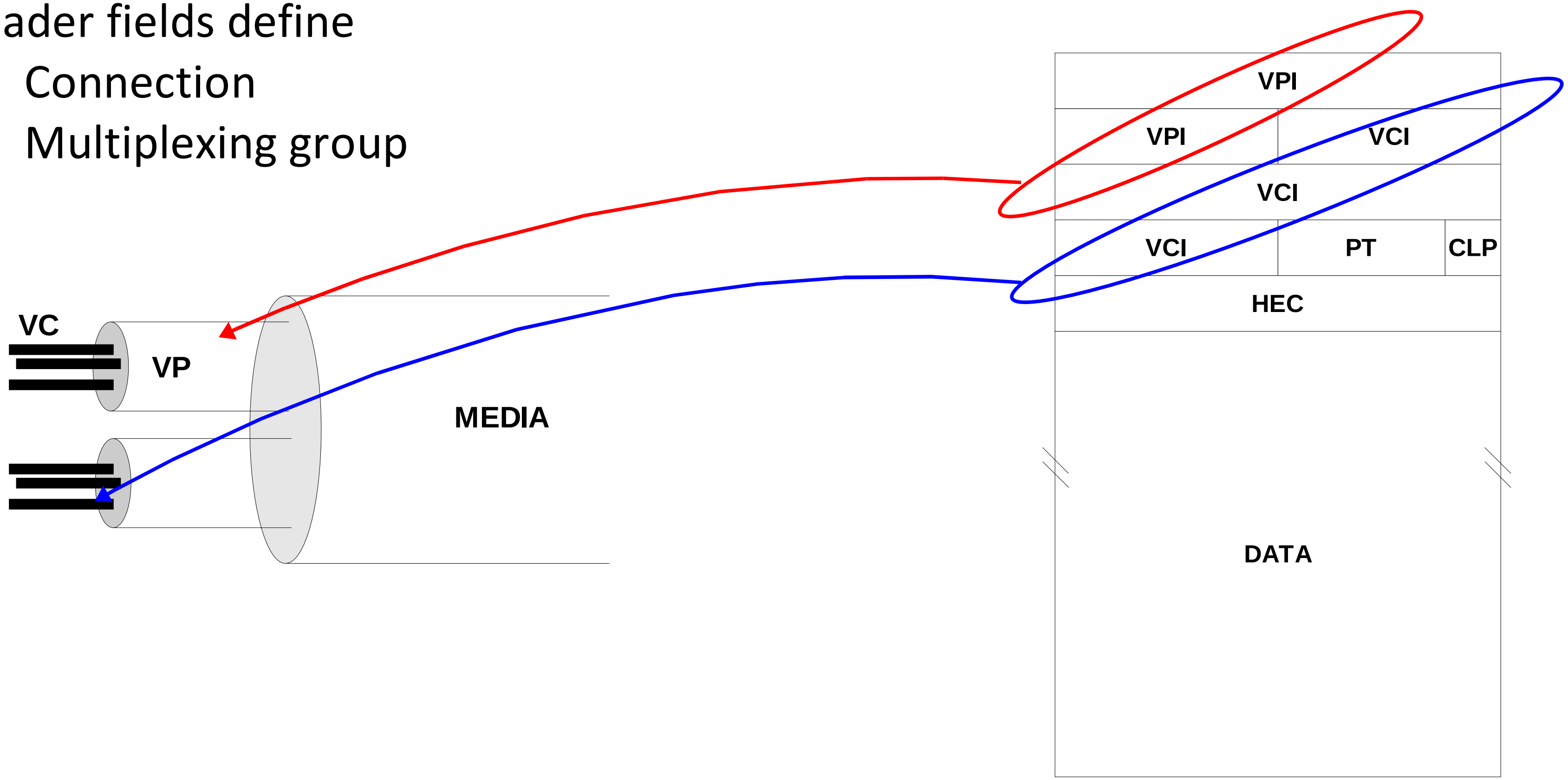
ATM

- **Asynchronous frame based multiplexing**
- Capabilities for dynamic switching
  - Not only PVP's or PVC's
- Connection oriented
- Fixed packet structure
  - 5 bytes of headers
    - Addresses (VPI, VCI)
    - Packet content type (PT)
    - Priority (CLP)
    - Checksum (HEC)
  - 48 bytes of data



ATM

- Header fields define
  - Connection
  - Multiplexing group

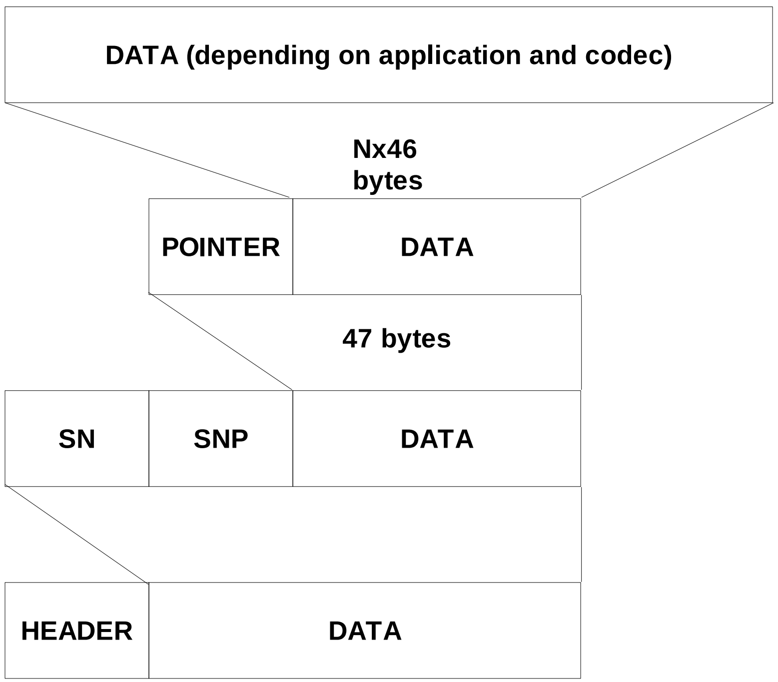


ATM

- Can be used
  - As is over the transmission media
    - Assumes low bit error ratio from the media
  - Over any other L2 protocol
    - Benefits from the error control of L2 media
- Why sensitivity to BER
  - Packet has not markers
    - Delineation is accomplished through state-machine which goes through packet bit by bit and looks header checksum matches
      - Sensitive to errors if high BER

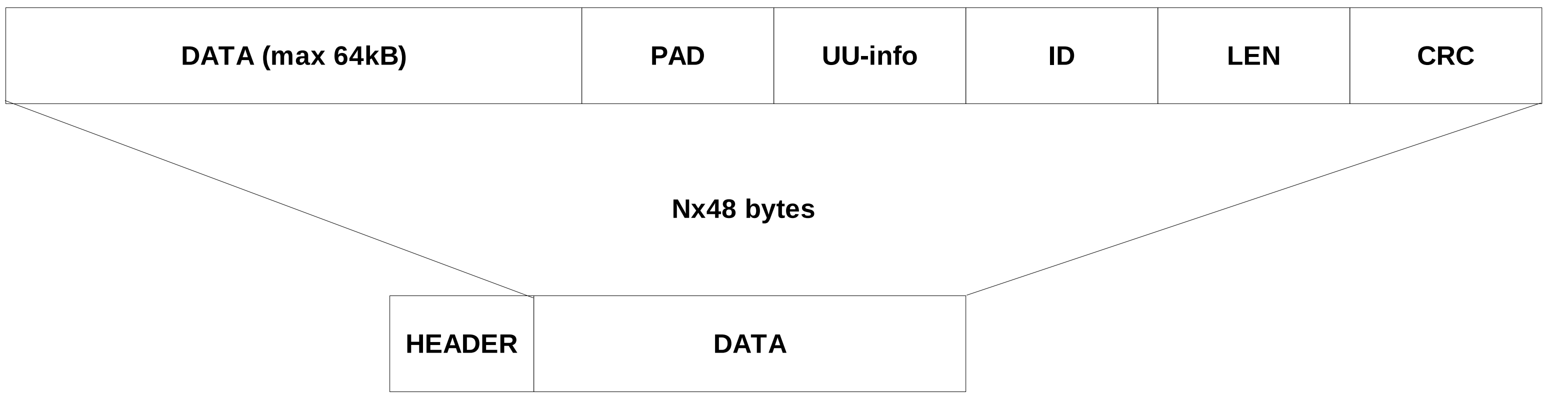
ATM

- 48 byte content field is too big for voice communications
  - Separate protocol layers to handle
    - Sub cell delineation
    - Timing
    - Sequencing
  - Clear channel communication for video applications



ATM

- 48 byte content field is too little for data networks
  - Fragmentation of data packets into multiple ATM cells
  - Separate protocol layer to handle the fragmentation and reassembly of protocol packets



ATM

- Framing options for IP traffic in ATM links:
  - RFC2684: Multiprotocol Encapsulation over ATM Adaptation Layer 5 (Classical IP)
    - Uses LLC/SNAP encapsulation of traffic within ATM adaption layer 5

Destination SAP =AA	AA-AA-03 -> SNAP
Source SAP =AA	
Frame Type =03	
OUI =00-00-00	00-00-00 -> Ethertype
Ethertype =08-00	08-00 -> IPv4
IP packet	
PAD (0-47 octect)	
~~**CPCS-UU (1 octect)**~~	**AAL5 -trailer**
CPI (1 octect) =0x00	
Length (2 octect)	
CRC (4 octect)	

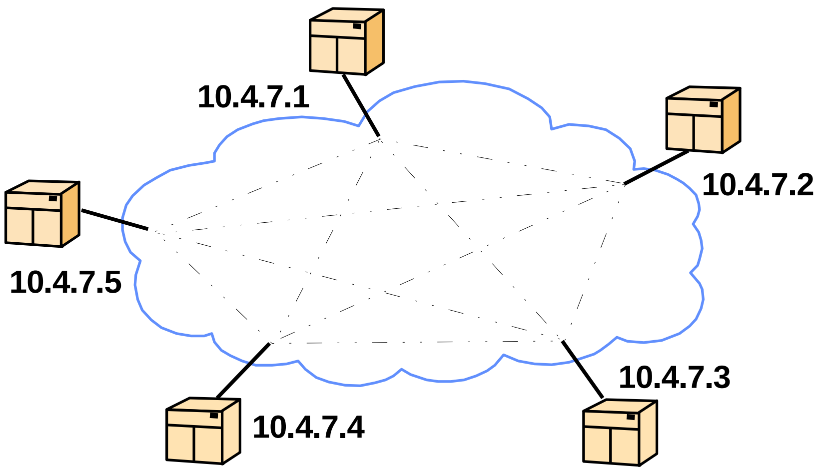
ATM

- Framing options for IP traffic in ATM links:
  - RFC2364: Point to Point Protocol over ATM
    - Uses in AAL5 frames either
      - raw PPP packets
      - PPP on LLC/NLPID packets

Destination SAP	LLC-otsikko
Source SAP	
Frame Type (UI)	
NLPID (PPP)	Network Layer Protocol ID
Protocol ID	PPP
PPP Information	
Padding	
PAD (0-47 octect)	AAL5 -trailer
CPCS-UU (1 octect)	
CPI (1 octect)	
Length (2 octect)	
CRC (4 octect)	

ATM

- **ATM network is from IP perspective**
  - **NBMA network**
    - Separate virtual connection between each and every router
      - Large number of connections and adjacencies in routing
    - Usually subinterface per connection



ATM

- **Pros:**
  - Easy capacity management
  - Virtual short-cuts without routing
  - MPLS ready
  - Fault tolerant if ATM-level dynamic routing is used
- **Cons:**
  - Additional layer of technology
    - Not good for framing itself
  - Expensive interfaces at routers
    - Subinterface structure in networked ATM

Ethernet

- **Technology has scaled to level where conventional core network technologies are**
  - STM-64 and 10GbE are the same
    - Even in optical interface level they are the same but ethernet is only 20% of the price
  - STM-256 will be the base for 40GbE ?
  - 1GbE is based on fiber channel but can be multiplexed in STM-16 networks by having two independent connections

Ethernet

- **10GbE**
  - IEEE 802.3ae
  - Full duplex
  - Adjustable MAC speed
    - 10Gb in LAN
    - 9.29Gb in WAN
  - Optical media
  - SDH WAN Phy
  - 10Gb LAN Phy
- **1GbE**
  - 802.3z
  - CSMA/CD + Full Duplex
  - Optical and copper media
  - Fiber channel Phy

Preamble (7 bytes)	Start (1 byte)	DST Add (6 bytes)	SRC Add (6 bytes)	Length (2 bytes)	Data	PAD	FCS (4 bytes)

Ethernet

- **Possibility to build transparent LAN services**
  - Majority of LAN networks are build with ethernet
  - Some applications benefit from the fact that ethernet headers are preserved
    - Possibility to have same IP subnet on both ends
    - WAN network is transparent for ethernet network
      - No PPP protocol in between SDH and Ethernet
  - Core network technologies are evolving
    - Metro VLAN separation
    - Core provider framing

Virtualisation of Ethernet

- **Virtual LAN is a network within the network**
  - It logically creates virtual networks on top of physical network
    - Virtuality is realized with additional fields in the frame
      - Tag Frame ID: 0x8100 for 802.1q
      - Priority: 802.1p priority
      - CFI: Canonical format indicator (MAC address can be or not)
      - VLAN ID: 4096 VLAN IDs
        - » Only few (read expensive) devices support simultaneously this number

Preamble (7 bytes)	Start (1 byte)	DST Add (6 bytes)	SRC Add (6 bytes)	(0x8100) (2 bytes)	Priority (3 bits)	CFI (1 bit)	VLAN ID (12 bits)	Length (2 bytes)	Data	PAD	FCS (4 bytes)

VLAN

- Separation of network resources to logical units is based on forwarding information databased (FID)
  - In **independent mode**, each VLAN has its own FID
    - Clients residing in different forwarding table are not able to communicate without external help
  - In **shared mode**, part of VLANs share a common FID
    - Clients residing (symmetrically) in same FID are able to communicate together
- Communication between VLANs is established with
  - ‘Misconfigured’ bridge that connects VLANs together
  - Router forwarding packets between VLANs

VLAN association

- Association of devices to VLANs is based on
  - Device tagging (end system is VLAN aware) – rarely
  - **Port based VLAN membership (switchports are assigned to particular VLAN) – commonly**
  - Protocol inspection (MAC address, ethertype, IP address, TCP/UDP port) – only in service switches

VLANs

- **PVID ~ Port VLAN identifier**
  - Each and every switchport is assigned to belong to particular VLAN
    - Incoming untagged traffic is forwarded by using this VLANs FID
      - Address learning is bound to that FID
    - Incoming tagged traffic is associated to VLAN based on VID or FID depending on ingress filtering rules

- **VID ~ VLAN identifier**
  - If frame is
    - Coming in from a trunk interface it contains 802.1q tag which carries VID
    - Going out to trunk link packet is coded to 802.1q tag mode
      - VID usually is PVID from the ingress port

Filtering rules

- **Ingress filtering rules:**
  - **Received frame is untagged**
    - Forward using PVID
    - Discard
  - **Received frame is tagged**
    - Forward using VID
      - VID = 0:
        - » Use only P-bits, forward using PVID
      - VID = 1
        - » Default tree, all interfaces
    - Forward using PVID
    - Discard

Filtering rules

- **Egress filtering rules**
  - **Interface is in untagged mode**
    - Forward untagged frame
      - Use configured priorities
  - **Interface is in tagged mode**
    - Set tag based on classification rules
      - Ingress VID
      - PVID
  - P-bits

Priority

- **802.1p is amendment in 802.1q**
  - Allow traffic prioritization within Ethernet networks
  - 3 bits -> 8 priorities
    - Number of queues dependent of HW
    - At minimum strict priority queuing between queues
  - Mapping traffic to queues is dependent on
    - Number of queues
    - Configured policy (egress filtering)
      - MAC address
      - Ethertype
      - DSCP
      - Address