Exam - questions

- Access Network
  - How upstream and downstream are managed in PONs
  - What is CSMA for in wireless systems and how it works
  - Describe the possible noise effects in a digital signal and how they are faced
  - Which are they key differences between the old use of copper wire to provide analog data and the digital one (optic fiber)
  - In the computation of the capacity that a channel can provide, both the effects of the bandwidth and of the SNR are present: discuss how these have an impact and how they can be managed to improve the channel capacity
  - Describe how the frequency band is used in the ADSL and how this is reflected in the ADSL architecture
  - Describe the functions that are performed in the different functional areas of a network and the main network topologies used in that areas
  - Describe how the modulation of the ADSL allows to use, in an efficient way, copper cables
  - Describe the architecture of access network for fiber optics
  - Describe 4G architecture
  - Similarity and differences between of 4G/5G with wired network
  - Water filling algorithm
  - VDSL architecture, advantages and disadvantages
  - OTN overhead
  - Difference and technologies of ADSL and VDSL
- Transport Network
  - Discuss the advantage of using wavelength conversion in optical network
  - Explain packet forwarding in MPLS with an example
  - Describe the field of IP routing table and how these are used to route a packet toward a destination with an example
  - With reference to fault management, explain the role of alarm management
  - Type of overhead in Optical domain, list all of them and how they work
  - Adaptation function dell ON 2nd generation
  - MPSL and why it is mroe efficient in faults, speak about difference of MPLS and IP
- My questions for do exercise
  - Access Network
    - Speak about wireless access protocols
    - Wireless LAN architecture

Access Network

How upstream and downstream are managed in PONs

- Downstream: OLT schedule traffic inside timeslot (TDMA) to send packets to ONUs.
- Upstream: ONUs share same cable but each of them have a slice of time assigned to transmitt, furthermore OLT communicate with ONU about required power to transmitt in a way packet arrive with the same power

completa la domanda

- onu scaratano pacchetti quando gli arrivano i paccchetti per vedere se loro sono i distanatari

What is CSMA for in wireless systems and how it works

CSMA stand for Carrier Sense Multiple acces and we can have Collision Avoidance (CA) or Collision Detected (CD). Given two mobile device sH1, H2, router R where H1 and H2 want to communicate with R.

Before transmission H1 and H2" send a Request To Send (RST) message after a DIFS. If a collision happend, H1 and H2 will recevice no response and will send another RTS after a certain time DIFS+backoff_time (H1 and H2 schedule their own backoff time). If no collision happend (e.g. R1 send succesfully an RST), R will send back a Clear To Send (CLS) message (in a broadcast way) to indicate at R1 the channel is free (and to others that is occupied).

After a couple of times that R1 doesn't receive an message (SIFTS time), it send an ACK to indicate that transmission in terminated.

probabilità di collisione nel csma/ca sono con rts-cts minori rispetto csma senza rts-cts.

Describe the possible noise effects in a digital signal and how they are faced

next fext echo cancellation, upstream adn downstream suddivision, shielding cavi e binder group (limite 12 coppie copper wire)

In ADSL the communication is done on copper wire cable but, due on their nature, they can interferece (cross-talk) eachother (e.g. cause by eletromagnetic interferences) affecting the transmission.

We have essentially two type of noise:

- NEXT (Near-End cross Talk): it the type of intereference that happend in the same side of cable when signal of RX is disturbed by a TX signal reducing the quality of signal. To mitigate this problem we have using frequency division techniques which is the reason of separate the band of UP and DOWNSTREAM in ADSL
- FEXT (Far-End Cross Talk): it is the intereference that happend in different side of the cable and it travel the entire lenght of the channel and since ADSL

is “short” length cable, signal are not strongly attenuated creating interferences. To mitigate this problem are not used more than 12 twistep pairs of cable

To be more explicit, this is a drawing of a a binder group where we can see out a cable is made. One of it contain more the one copper cable and wires sharing the same cable cause these intereferences.

Furthremo we have crhomatic dispersion and etc...

Which are they key differences between the old use of copper wire to provide analog data and the digital one (optic fiber)

- copper wire: less efficient and subject to interefences, cross-talks (NEXT e FEXT mitigated respectively using frequency division techniques and using not more than 12 twisted pairs of cable in the same binder group), performance depend on the distance between devices (it affect also the speed), signal degradade faster. It is compatible with lot of existing infrastructures. This is mainly used in ADSL which use the POTS line to provide its services. To measure the QoS one metric is the BER (which is done at electrical level)
- Optical fiber: high cost of installation (around 30-70 $/m but the cable cost around 5$), high data rate, signal can travel lots of km witouth degradating so much. It is not subject to magnetic intereferences. In optical domain we have different type of problem like cromatic dispersion (caused by different frequency components travelling at different speed and solved passing from MLM to SLM) and to measure the QoS one metric is the SNR.

In the computation of the capacity that a channel can provide, both the effects of the bandwidth and of the SNR are present: discuss how these have an impact and how they can be managed to improve the channel capacity

According to Shannon formula

$$C = B * \log_2(1 + SNR)$$

Where:

- C is the channel capacity (we can improve its using using modulation techniques)
- B represent the bandwidth, so a range of frequences (we can improve its using using modulation techniques)
- SNR it the signal to noise ratio (e.g. it can be improved using filtering techniques, increasing power, data rate)

SNR mitigated with MLM e SLM, SLM vedi beni se narrow o cosa. SLM perfette usare single fiber quindi 1 filametne per ogni connessione quidni maggior rimbalzi e minor collisioni , domanda sopra

Describe how the frequency band is used in the ADSL and how this is reflected in the ADSL architecture

ADSL (Asymmetric Digital Subscriber Line) have the following frequency division

- 0 - 4 kHz: dedicated to POTS
- 26-138 kHz: dedicate for upstream (communication from customer to CO)
- 138-1104 kHz: dedicated for downstream (communication to CO to costumers)ù

Downstream have higher frequency because CO can provided service list streaming and downloading (so a need a fast communication), while the communicaiton user to CO is less frequent so it is allocated a band centered in a minor frequency

The communication is done of copper wire cable (the one of POTS) and communication can suffer of cross talk (NEXT and FEXT, solved with freqeuncy division and mxium 12 twiste coppers pair

per co è che si aggiunge dslam which has N atu-c atu-r

Describe the functions that are performed in the different functional areas of a network and the main network topologies used in that areas

Functional areas are mainly threee

- Access Network: part of the communication network which connect subscribers to their intermediate service provider (we have copper-based DSL, fiber-based, wifi bases like wifi and 4G), the infrastrucure of AN is different based of the type .e.g. for cellulare communication we have infrastructure like MME, BS, S-GW, P-GW which are nto present for wired AN
- Core Network: is the backbone of the network, it provide any-to-any connection among devices of the newtork and usually have a mesh topology. It consist of multiple router or switches.
- Edge Network: area where network and user exist. In this part of the network are performed some intelligente functions like the path selection and authentication

Some topology are

- Ring topology: Metropolitan Area Network, TV distribution system
- Mesh topology: Wireless Mesh Network (e.g., municipal Wi-Fi), telecommunications backbone networks (e.g., internet backbones)
- Tree topology: Enterprise telecommunication networks, data distribution infrastructures with redundant trunk (e.g., SCADA networks)
- Bus topology: Legacy Ethernet networks, Controller Area Network (CAN) in vehicles
- cascaded splitters
- daisy chain

Describe how the modulation of the ADSL allows to use, in an efficient way, copper cables

- Discrete Multitone Carried (DMT): divide the bandwidth in small subchannels where discrete carriers (tones) are use in the center of each subchannels. In that way each subchannel can be indipendenlty manipulated/modulated, furthermore DMT adapt the data rate based on line condition (so considering interferences)
    - Advantages: maximizing frequecy spectrum usage with subchannel division, robust against interference, adaptability (if a subchannel suffer of interference it may not be used in favore of the other channes
    - Disadvantages: cross-talks (?)
- Carrierless Amplitude Phase (CAP): it is a version of QAM in which incoming data are modulated on a single carrier then transmitted down to telephone line. Before transmission the carrier is suppressed because it contain no information about data and it can be reconstructed by the recevier

The singal of each subcarrier is determinate as the depth of a liquid pol (speak about water filling algorithm)

Describe the architecture of access network for fiber optics

in AN for fiber optic we have

- OLT: Optical Line Terminal are used used in point-to-point link to multiplex and demultiplex wavelengths and is is composed by
    - transpoders: a device with perform OEO conversion adapting the incoming signals, add OTN overhead and monitor BER. It sign the end of OSC
    - wavelength multiplexers
    - optical amplifiers
    - In PON it can behave a like a CO e.g. for compute TDM and required power
- ONU: Optical Network Unit which is the end-point located at user side and it is also equipped with a transponder
- Passive splitter: use in PON to distribute signal but they have a loss of 3db*log_2(#ONUs) ant they can be used in cascade. They are they alternative to the curb switch in the optical domain

Those are the main element of an optical network and in general we can have differnt configuration of the fiber cable as:

- Fiber to the CO (it has a DSLAM)
- Fiber to the cabinet (DSLAM is replaces with a switch/router and DLAM moved to the first cabinet)
- Fiber to the curb (DSLAM is moved to the curb, second cabinet)
- Fiber to the builing (DSLAM into house)

This depend also on economic availablity becasue the installation of the fiber cost a lot

altre architetture

- Direct: costa un botto
- PON: costa meno ma ne servono parecchi (splitter in ring, tree, bus)
  - EPON: standard 802.3h
  - WDM-PON: suddivision lunghezze

Describe 4G architecture

- Base Station: a fixed station that facilitates wireless communication with mobile devices, it has a coverage area called cell
- Mobile Device: the user’s device that communication with base station
- Server and gateways: router and server of the network. We can distinguish two speacial router
  - Serving Gateway: it route data between base station to P-gw (so acting as access network, work like edge router) and other nodes of the network, furthermore support mobility of devices managing the handover.
  - PDN gateway: comunication between S-GW and managemetn units, NAT service (core router)

- Mobility Management Entity: a server dedicated to manage user mobility keeping their connection alive without interruption. It setup a path from mobile to P-GW, collabor with HSS with authentication
- Home Subscriber Service: handle authentication procedure (collaborating with MME), manage traffic billing, user contracts, etc ...

More information just to write:

- The purpose of cellular networks is to cover large areas while optimizing the use of frequency bands. Cellular networks can reuse the same frequency in different cells without interference because the cells are physically separated. This allows for efficient frequency reuse.
- Digital Identity: In cellular networks, mobile devices are identified by the SIM card, which is a novel concept compared to other types of networks. Unlike a PC, which doesn't have a fixed digital identity, a mobile phone can be uniquely identified by its SIM card, allowing for user authentication.

Similarity and differences between of 4G/5G with wired network

- Similarities: both of them have a distinction between edge and core network, it use protocols like HTTPS, DNS, TCP, UDP, IP, NAT and there is a sepation of data and control plane. Furthermore is interconnected with wired internet.
- Differences: it is projected for mobility as main service, different link wireless link layer, users are provided with a SIM and each of them subscribe to a business model

This type of AN differ from the wired, it has lots of different infrastructure as MME, HSS, BS, S-GE e P-GW

Water filling algorithm

It is an algorithm used to measure the power of each subcarrier. Given a frequency-(S/N)^-1 graphics, the liquid contained in the pool (based on depth of each subchannels) formed by the line represent average power of transmission. DMT will optimize the transmission based on noise information

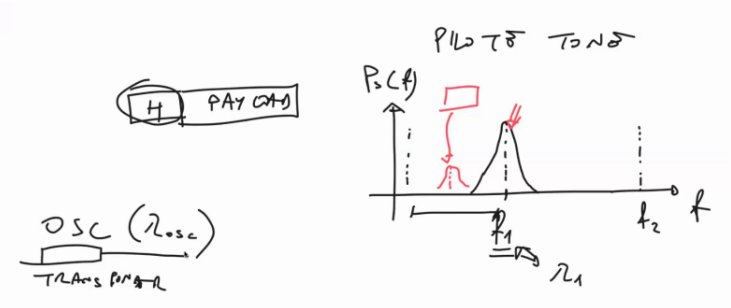
VDSL architecture, advantages and disadvantages

- Advantages: VDSL offer an higher transmission speed respect to DSL technologies (up to 24 twisted copper pair) which make it good for application which required higher bandwidth as streaming or online games. Key concept of VDSL is to maintain the lenght of copper wire as short as possibile, infact is is more efficient to provide high performance to user near to main buildings. Furthemore it can have more number of carrier respect to ADSL
- Disadvantages: transmission speed decrease with the increase of lenght and it can suffer of cross-talks decreasing the quality of service (this is mitigated with VDSL vectoring)

VDSL vectoring is a technique for cancelling cross-talks and it work analizing the interferences and injecting into the line an anti-signal to cancell it (so it requires a cross-talk estimation mechanism and anti-signal computation). This type of interfence can happen when wires share the same cable (binder group) and to face them NEXt with frequency division, FEXT non more then 12 twispet pairs of cables

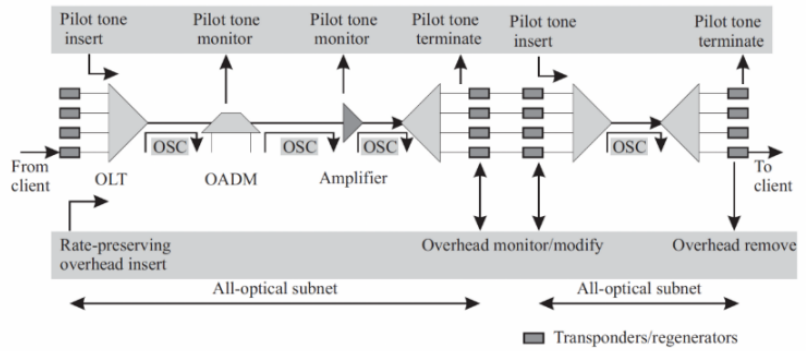
OTN overhead

Protocols and functions in the optical network, such as BER, path trace, and defect indicators, require special overhead. Two methods are used to achieve this:



Pilot Tone:

- Any wavelength is centered at a certain frequency, with gaps between signals for distinction.
- The **Pilot Tone** is placed in one of these gaps, utilizing low power and data rate.
- Messages, encoded in binary, are modulated and converted into optical signals sent via the Pilot Tone band.
- The Pilot Tone is added as overhead to the **Optical Channel Layer (OCh)** by the transponder and is terminated at the end of the OCh.
- It reflects faults or errors in the associated client signal.



- The **OSC** uses a reserved wavelength for control-monitoring purposes, independent of client signals.
- It has a single-fiber lifespan and monitors fiber health.
- Unlike the Pilot Tone, the OSC is not client-signal-specific and can be applied anywhere in the network.

Difference and technologies of ADSL and VDSL

Transport Network

Discuss the advantage of using wavelength conversion in optical network

Wavelength it is an important functionality in optical network that allow the wavelength of a signal to be changed as it traverse the netwotk. This capability provide significant advantages.

In WDM wavelength are treated as resources that must be allocated to differentiate data flow. Without that many path might remain undeutilized due to the constraints of wavelength continuity which require a signal to use the same wavelength across all links.

By enabling signal so switch wavelengths that restriction it's eliminated allowing a more efficient routing traffic. This lead to better utilization of the network withouth routing requiring additional physical infrastructure.

Moreover in the event of a failure, wavelength conversion facilitate the re-routing of traffic to alternative path so it offer protection because due to the reconfiguration proprerty is possible to look for an alternative path, mantainity service continuity.

The optical line terminal plays a crucial role for wavelength conversion. It is one of the two end-point in a point-to-point link and is composed by 3 main parte: transpoders, wavelength multiplexer and optical amplifiers.

The transponder (OEO) conver the signal into a wavelength which is suited for use inside the optical network (from 1.33 micro mmm to 1.55 micro mm)

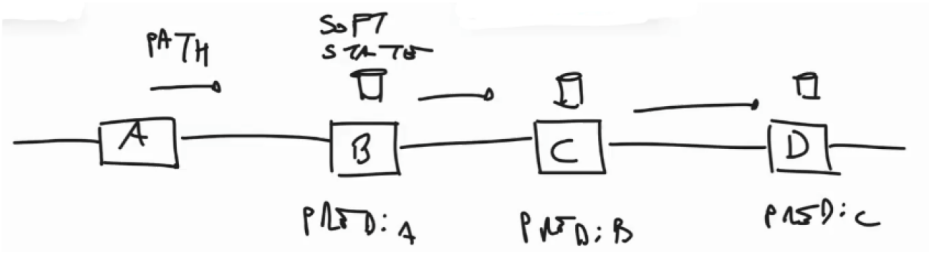
Explain packet forwarding in MPLS with an example

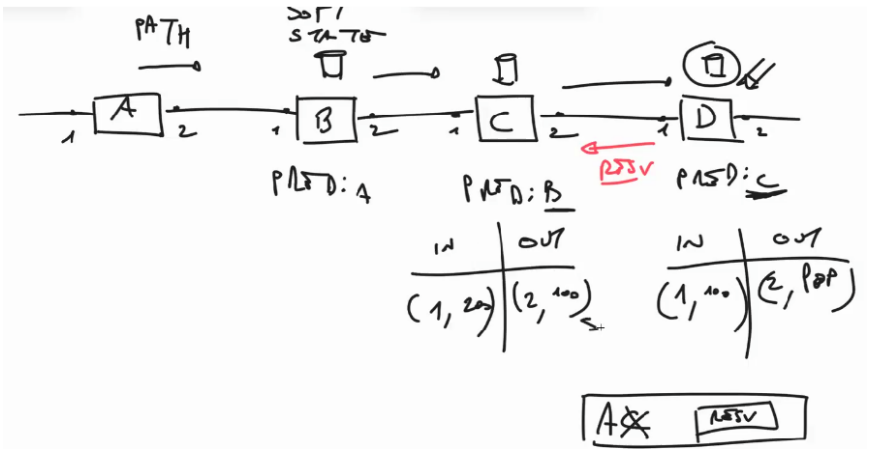
An MPLS packet follow the LSP and it is continually forwarded by router according to the routing table created during the LSP setup.

LSP path creation work in that way: given a source node A and a destination node D

1. Node A send a "packet path message" (into an IP packet) which will be delivered to node D
2. When a node receive a "packet path message" it internally create a "soft state" which can be though as a variable where is stored the ID of "packet path message" , previous hop and other useful information

3. Once the “packet path message arrive at destination”, node D will send back a RESV message (wrapped in an IP packet) specifying label and interface at which the receiver should send MPLS message (here is the moment where MPLS routing table are populated)
4. When RESV message arrive at source node A, LSP is create





Note that:

- Node A will perform action PUSH
- Node D will perform action POP
- Intermediate node will perform action SWAP

Describe the field of IP routing table and how these are used to route a packet toward a destination with an example

An IP routing table have the following information:

- destination IP address: at who the packet must be delivered

- output interface (next hop): at which interface must be send out the arrived packet

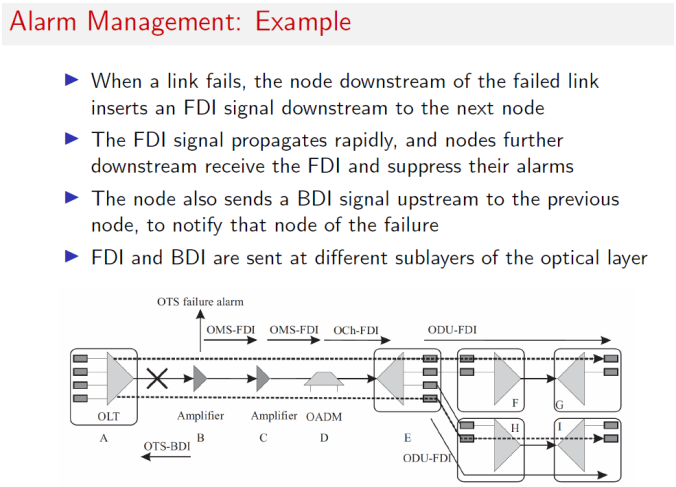
These four information are enough for a router to understand at what interface they should send out the packet

With reference to fault management, explain the role of alarm management

When a link fail, every device that detect an error (so basically everyone on tha path) start to send an allarm creating redundant allarm (e.g. if there are 32 lightpath passing for 4 device, we will have 128 alarm + 1 of the transponder).

The idea is that the node that detected the failuter to send a Defect Indicator (FDI and BDI, both direction) and if a node receive a DI, it stop sending alarm (FDI and BDI are sent on different layer of the optical network).

FDI in upstream e BDI in downstream. furthermore they are sent in differental layer og optical network.



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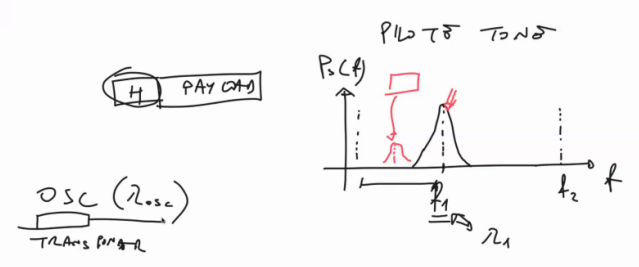

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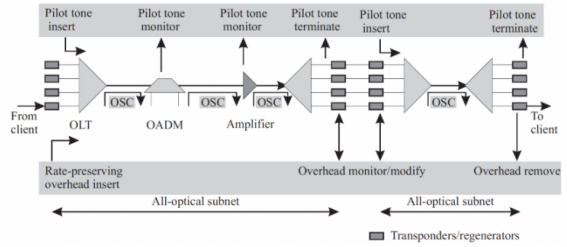

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Type of overhead in Optical domain, list all of them and how they work

Speak mainly of Pilot Tone and DI, futhermore list other type of overhead

Adaptation function dell ON 2nd generation

MPSL and why it is mroe efficient in faults, speak about difference of MPLS and IP

My questions for do exercise

Access Network

Speak about wireless access protocols

- TDMA: ...
- FDMA: ...
- CDMA: (Code Division Multiple Access) works differently. Here, users can transmit at the same frequency and time but every of them has its own chipping sequence (a code) to encode data (original_data*chipping_.sequence) and decode (encoded_data*chipping_sequence). The code is a specific bit sequence known to both the sender and the receiver. Encoding and decoding add complexity. If the code has more bits than the original message, this requires the network to transmit at a higher speed, which demands more bandwidth. Since we're transmitting M bits, we must transmit M times faster, which increases the bandwidth usage.The advantage of CDMA becomes clear when multiple users share the same frequency and time, but can still distinguish their communications thanks to the unique codes (this is known as spread spectrum communication): thanks to that code the receiver is able to filter the right signal.

Wireless LAN architecture

- Access Point (AP): A device that provides a wireless network connection to terminals (users) within a specific coverage area.
- Terminals: Users or devices connected to the AP.
- Basic Service Set (BSS): Also referred to as a "cell." It is the fundamental building block of a Wi-Fi network, representing the coverage area of one AP. It is composed by a wireless hsot, access point (a bases station), ad hoc mode (host only)

When connecting to Wi-Fi, a terminal must associate itself with a specific AP within a BSS. The process includes detecting whether an AP is present and capable of establishing a connection. There are two scanning methods for this:

- passive scanning: the AP continuously sends out a beacon, which is a message containing its information. When a user device captures this beacon, it sends an association request frame to the selected AP. The AP then responds with an association response frame, completing the connection.
- active scanning: the process is initiated by the wireless host (the user device). The host sends out a probe request frame to check if there are any APs in a certain area. The APs that are present respond with probe response frames. After receiving these responses, the host selects an AP, sends an association request frame, and the AP replies with an association response frame to establish the connection.
    - When we turn on wifi, we automatically connect to AP because the system already already know the device (quick association), instead with Sapienza wifi we have to do the whole association procedure
    - We can have some disatvantages with active scanning (minuto 50, riascolta)

What are the implications of chromatic dispersion in PON optical networks and how is it mitigated?

Chromatic dispersion is the phenomenon for that a light pulse broad which can cause overlapping between signal (i.e. cause interferences).

To overcome this problem we can apply two methods:

- narrow the core of the fiber: in that way lights will bounce with more frequency reducing cromatic dispersion

During the years we saw an evolution of the optical network; the first generation of optical networks rely on heavy electronic processing and TDM for multiplexing, furthermore the swtich was performed entirely in electrical domain requirest a costant conversion between optical and electrical domain having an impact also on costs.

Some improvement that have been done between first and second generation is the less use of electronics to keep staying in optical domain, in particual I want to given an overview on the evolution of transmitted that impacted the chromatic dispersion:

1. LED (Light Emitting Diode): it was the first transmitter but was inefficient for long distances
2. MLM (Multi-Laser Mode): it improved precision of the laser but still suffering of chromatic dispersion
3. SLM (Multi-Laser Mode): reduce the chromatic dispersion which is cause by different frequency travelling at different speed

Describe the handover process in 4G and 5G cellular networks and how it supports user mobility

Handover is the process in which a mobile device change it point of attachment to another base station and it work on that way:

1. current (source BS) select target Bs sending and Handover Request Message
2. Target BS pre-allocate radio time slots and responde with HR ACK with information for mobile device
3. source BS inform the device what will be new Bs at which it must communication, here the handover is completed for mobile device
4. Now the source BS will send datagram to the new BS instead to the mobile device
5. Target BS inform Mobility Management Entity (MME) which will instruct the S-GW to change end-point of the target BS
6. Target BS ACK the source BS which can release resource, handover completed
7. Now datagram flow into new tunnel from target BS to S-GW

Transport Network

Describe the network architecture of fiber optics

- OXC: Optical Cross Connect work similary to a router performing switching and routing operation. it is a multiport device with a large number of port,

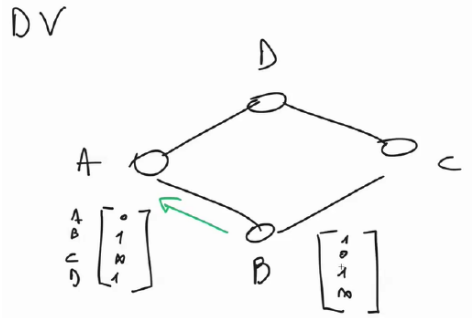
making it suitable for handling extensive network connection, furthermore they are dynamic meaning that can reconfigure to redirect correctly lightpaths based also on traffic changes. They can detect failure of links, switch signal with arbitrary bit rate, change wavelenght. Reconfiguration is done changing the orientation of a prisma

- OADM: they are similare to OXC but they are static devices handling the passthrough traffic passively
- OLT: Optical Line Terminal are used used in point-to-point link to multiplex and demultiplex wavelengths and is is composed by
    - transpoders: a device with perform OEO conversion adapting the incoming signals, add OTN overhead and monitor BER. It sign the end of OSC (used for maintenance purposes including remote site alarm reporting, communication necessary for fault location, and order wire). Also it converts the signal into a wavelength that is suited for use inside the optical network (from 1.3 µm to 1.55 µm)
    - wavelength multiplexers
    - optical amplifiers
- At the edge of network we find IP routers and SONET devices

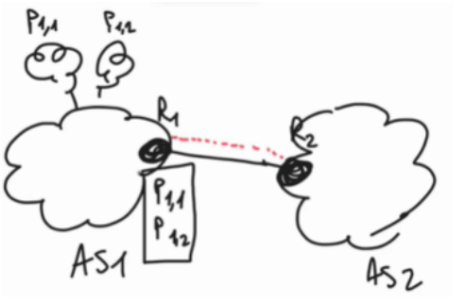
What is BGP protocol and what are its charateristics

Border Gateway Protocol (BGP) it is a policy bases protocol and appartain to Exterior Gateway Protocol (EGP) family which are the ones that route packets between different Autonoumous Systems (AS).

This protocol use the concept of Distance Vector (more precisely use Path Vector) where (spiega esempio)



To be more precise, in BGP they exchange information about subnetworks in a way other routers know how reach those subnetworks



We have four type of messages:

- Open: establishing a peer connection
- Keep alive: handshake at regular interval
- Notification: shut down a peering session
- Update: announcing new routes

In general every AS has its own client and they compete with other AS and minimizing “hop count” can violate commercial relationships that constrain inter-domain routing.

Speak about first and second generation of optical network

- first generation: optics essentially used for transmission and simply provide capacity, switchign and other intelligent function are handled in electronics domain having a constatn OEO switchin
- second generation: routing switchin and intelligence in he optical layer

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What is and how and OLT work in optical domain

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mesh topology

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  - optical amplifiers
- At the edge of newrok we find IP routers and SONET devices

What is the difference between data control and management plane and what are their functionalities

- Control plane: it is responsible for routing building up the routing table, it is where protocol are locate. For example a in wifi AN MME and HSS compose control-plane state performing authentication of devices, carte about mobility, security
- Data plane: it is know as forwarding plane and it is responsible for data exchange (using the routing table). This plane perform the whole packet processing pipeline so adding headers, moving packets
- Management plane: it is the part of the network responsible for configuration task like assign IP, monitoring the network behavior to ensure healty

Some advantage of control and data plane separation are:

- more availability: if the control plane has some kind of interruption, data plane can continue to work
- scaling: because both planes are indipendent, it is possible to allocate different resource for them (in general data plane handle much more data than the control plane) and they can be update separately

Drawback insteads are the incrementation of complexity, may be

Difference between connection-less and connection-oriented network in mpls domain and what are advantages and

disadvantages

Connection-oriented network is a network where a connection is established, meaning that exist like a virtual tunnel connecting two clients. In MPLS this is achieved with routing table of tipe |eht-label|eth-label| for input and output packet. Packet route along an established route ensuring low latency QoS established during the connetcion phase can be guaranted. In a connection-oriented enviroment managing connection in a large-scale network can be complex

Regard connectionless newtork each packet is trated indipendenlty and routed separaly to its destinetion (doesn't exist a pre-difined path) and router adapt dinamically (IP network are a connectionless network). In that way we can optimize resource utilization and it is suited for large scale network where dynamic routing can handle lots of user.

Some application for connection oriented are: online banking, real-time communication, file transfer (usually here is used TCP protocoll, it guarantee reliability, integrity) while for connectionless are the web browsing, IoT (UDP is a connection less protocoll, it is faster and lighted), streaming

How a vpn is created in mpls domain

A vpn in MLPS domain is created on that way

1. Achieving any-to-any connectivity amonge Provider Equipment (PE): in this step all PE in the same Autonomous System (AS) must be able to route packet i.e. we need to solve an internal routing problem using protocol like OSPF (Open Short Path First) or Dijkstra. At each PE is assign a loopback interface (a virtual interafce with an unique IP address) that remain active evei if a physical interface fail (intstead of assign an IP to every interface)
2. Use BGP to distribute customer prefixes: we can use MP-BGP (Multi-Protocol BGP) in which the reachability message include prefixes and identifier of the message, customer and its subnetwork in a way it is possible to uniquely identify a customer and look for a VPN identifier which is requires for create the VPN.

3. Use MPLS encapsulation among PEs: in this step we encapsulte packet into MPLS packet using different labels (e.g. one internal label which indicate the target PE and an external one to identify the next hop). In case we have a scenario where a customer have different prefixes because it is locate in different spatial position. To overcome problem of overlapping ip the router create virtual routing table associated with a specific interface, ensuring that packets are processed correctly

What is traffic engineering in MPLS domain

Traffic engineering in MPLS it is a function that allow network operator to better balance traffict in its own infrastructure also to meet a certain Serveil level agreemetn with custome (e.g. bandwtih, latency)

it focuses on optimizing the utilization of network resources and managing traffic flows effectively. Traditional IP networks face challenges such as congestion on certain links and underutilization of others due to shortest-path routing logic.

In mpls we can enforce optimal path we must create an lsp (a tunnel) for each of flow will be, ech of them will be classifer by classifier and associated to a FEC (Forward Equivalent Class) which is a set of IP packets that are forward in the same way and receive the same treatment

What is protection in MPLs

Protection refers to the ability to restore a link quickly in the event of a failure.

In IP networks, routers detect a failure and send crash information to other routers, triggering path recomputation using Dijkstra's algorithm. However, this process takes hundreds of milliseconds, which can disrupt traffic flow.

With MPLS, recovery can be achieved much faster because traffic can be rerouted proactively in two ways: link bypass and path protection

To protect the network from link failures, we preconfigure a backup path. Under normal conditions, traffic follows the primary path (e.g., the green path). In case of

a failure, traffic is rerouted to the backup path (e.g., the red path) by encapsulating it for the new route.

The key advantage of MPLS protection is that the failure is localized. Only the nodes directly involved in the failure (e.g., Node B) need to be aware of it. Unlike IP networks, there is no need to notify all routers in the network, which significantly reduces recovery time and improves network resilience.

Path protection instead guarantees a better end-to-end path with improved performance. However, this comes at a higher cost due to the need for preconfigured backup paths and additional network resources.