

# Metro Core Networks

## Personal notes 2

Optical communication technology developed from the core towards the metro. Each fibre link aggregates data from several thousand to several hundred million users

	Access	Metro	Core
Aggregation factor	As low as 1:1 for CPE, 1:10K for CO	1:100K to 1:10M	1:1M to 1:100M+
Capacity	1 Mb/s to 1 Gb/s	10Gb/s to 100s Gb/s	100Gb/s to 10s Tb/s
Volume of expected sold units	Very high (even more than one per user)	Medium	Low (relatively few links)
Cost per unit	Must be very low	Medium	Can be high

The metro network can be referred to as aggregation as it aggregates data from the access networks.

The core network then *transports* the data across to the destination metro network.

Data that will remain local to the metro does not need to go through the core.

Content Delivery Networks will carry up to 71 percent of internet traffic by 2021

CDNs carry content closer to the user but presently the data is deposited on regional core networks, meaning the metro-delivered traffic is lower than the CDN traffic share. But metro delivered traffic is growing faster than core traffic

## Topology

Metro and Core networks are a mesh rather than point-to-point or tree structures (like access networks)

Metro topology often has rings, inherited from the previous transmission systems (SONET/SDH)

## Transport layers

The first three layers of the OSI scale

## First generation of optical networks

Optical transmission network was terminated by Electronic Cross Connects

IP topology is built on top of the E-XC links

## IP-over-WDM proposition

The idea is to remove the E-XC links and use the routers to terminate all traffic.

No need for two layer networks since IP is directly transmitting on top of WDM network

## Problems

- all traffic is terminated, every wavelength in the fibre needs to have a port in the router. This makes the routers very expensive.

## Second Generation Optical networks

Optics are truly a part of the network as the paths can be switched dynamically.

Optical Cross Connects is the optical element that provides the dynamic switching. This is called *Reconfigurable Optical Add Drop Multiplexer* or *ROADM*

The Degrees of a ROADM refer to the number of directions in which a packet can be dynamically switched. 2 degree ROADM is a bi-directional node, a 3-degree ROADM has three directions that the packet can go

## Advantages

Ability to route the entire optical channel at once.

1. No OEO conversion
2. Massive savings on expensive packet routing/switching resources.
3. Lower energy consumption

\* This only applies to the channels that don't need to operate add/dropping

## Optical Cross Connects

An optical Cross Connects is a device that switches packets without converting them a digital electronic signal. It does this by switching light

## Fibre Switch

Connects signal from entire fibres

Some examples would Beam Steering and MEMs

## **Wavelength Selective Service (WSS)**

Given an input fibre with multiple wavelengths, can select which wavelengths to send to different output fibres.

Examples of a WSS would be MEMs (fixed grid) and LCoS (flexible Grid)

### **Issues**

Analogue issues:

- If the new path is longer or goes through more nodes, and has a lower OSNR then it might not work
- Adding/Removing Wavelength channels create power excursion in the amplifier chains that generate errors in all other channels.
- It is difficult to predict the non-linear effects on the system after switching.

Topology issues:

- Now both optical and IP layers topology can change dynamically. If they both change independently then the changes can affect the layers mutually.

Complexity issues:

The operator now has the freedom to select routes on two layers, the IP (Network) and Optical (Physical) layers

- Called multi-layer optimisation
- Increases the complexity of the decision to be made.
- Optimising both layers together is computationally hard due to the number of variables in the model.

## **Network Planning**

Focusing on computationally reasonable solutions that may be sub-optimal but still acceptable.

- Fibre topology is planned over the long term.
- Wavelength path is dynamically switched.
- Data flows allow grooming of flows.

## **Sub-Wavelength switching**

The operator can change the weighting of the links to influence the distributed routing algorithms running on the network

Adjusting the weights in a distributed system can have unintended consequences.

## MPLS

transport protocol sitting at layer 2.5, can also be used to transport ethernet. Why? imagine another ethernet layer above MPLS as a service sold to a customer and it is separate to the ethernet of L2

Multi-Protocol Label Switching

- Transport protocol -> Can be used to transport different types of network protocols e.g IP, NDN, Ethernet?

Uses labels instead of addresses, the label identifies a virtual path and it only has local meaning (e.g between two adjacent MPLS switches)

The route flow is pre-determined.

A label distribution protocol (LPS) provides labels to each node for the pre-determined flows

Header:

- Label: bits 0..19 for packet switching
- Traffic Class: bits 20..22 class assignment for flow (QoS)
- Bottom of Stack: bit 23 indicates where the label sits in the stack. 1 for bottom of stack
- Time to Live (TTL): bits 24-31

The label replaced IP and is a local virtual path to be taken.

Use a label distribution algorithm that gives each switch a label for flow.

So when a packet arrives a MPLS switch reads the label, performs a table lookup, and finds the port it should send the label out of. performs pop and push of old and new label.

Ingress from IP: Forward equivalence class (FEC) performs mapping between IP and MPLS path

Egress to IP: opposite of ingress

Can have nested tunnels where a pop operation is not performed and another MPLS label is pushed on top of the previous one. Separate MPLS networks controlled by different entities.

MPLS is a centralised routing protocol: moving away from the distributed routing protocols of old

The Forwarding Equivalence Class (FEC) is the set of all IP addresses that get mapped into the same MPLS tunnel

A packet can be mapped to a particular FEC for the following:

- Destination IP address
- Source IP address

- TCP/UDP address
- In case of inter-AS MPLS, source-AS, Dest-AS
- Class of service
- Application used

FECs are manually initiated by the operator.

Advancements in ASIC and T-CAM have made IP switching at line rate possible and thus MPLS is obsolete.

The main application is for traffic engineering

- Choose most suitable route for different paths
- differentiate data paths by IP source, IP destination, or QoS metrics

## Personal Notes 1

Develop from the core as it is the point at which users data is aggregated

Metro network called aggregation as it aggregate the users data from the access networks.

Data from the metro does not need to reach the core: try to keep it local if possible.

CDN will carry more than 71 percent of user traffic by 2021.

Access networks are point to point but metro and core are mesh networks.

IP topology was built on top of E-XC

## IP over WDM

remove OXC and use routers to terminate all traffic.

Ip would transmit directly on top of WDM network

Considered when all information started to be transmitted over ip

Problem is that all traffic is terminated and each fibre needs a port in the router and routers are very expensive.

## Second gen optical networks

Dynamic switching of the paths taken at the optical layer of the network

Optical cross connects is the element that provides the switching

Entire optical switching element often referred to as ROADM

ROADM also used to connect L2 networks

- No need for optical electrical conversion
- big savings

- lower energy consumption

only applies to channels that don't need to operate add/dropping

### *Optical Cross connects*

Multiple means of implementation

- Fibre switch: connects signals from entire fibres (MEMs, eam steering)
  - Think about steering light through the use of mirrors or via beam steering
- Wavelength Selective Switching(WSS)

Problems:

- OSNR needs to be considered as since the paths are dynamic they can have different OSNRs and some of these may not work.
- Adding/dropping wavelength channels creates power excursion in the amplifier chains that generate errors in all other channels.
- It is difficult to predict how the non-linear effect will impact the system after switching.
- The separation of the layers can cause convergence issues in path calculation. For example if the IP layer calculates a new route but then the optical layer changes than the paths that are to be used differ and will take time to converge, creating instability.
- The operator has more freedom to decide the routes taken on multiple layers but the multiple layers increases the complexity of the determinations.

## **MPLS**

### **Ethernet**

Moving from LAN to Metro and Core networks

PRE	SFD	DA	SA	Length/ type	Payload	FCS
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- Preamble (PRE): 7-byte sequence for frame synchronization
- Start-of-frame delimiter (SFD): 1-byte, defines the end of the PRE
- Destination Address (DA): 6-byte Ethernet destination address of the frame
- Source Address (SA): 6-byte Ethernet source address of the frame
- Length/Type: 2-byte, indicates either the length of the data field (up to 1500 bytes value) or the frame type (if value higher than 1536)
- Payload: 46 to 1500 bytes, carries the data
- Frame Check Sequence (FCS): 4-byte cyclic redundancy check

Works off of a switching table with a star topology

Initially the table is empty, port A sends a message for C, the switch sees the source and destination of the message from As port. The table is empty so the switch sends the message to every port bar A.

The table is updated for A,

As messages come in from the other ports the table will be updated.

### **Virtual LAN (VLAN)**

Multiple independent sub-networks built on top of the same infrastructure defined in the 802.1Q standard

Adds a VLAN header to the ethernet frame

- 4-bytes in size
- first two bytes indicate it's a VLAN frame - 0x8100
- Next two bytes are the VLAN ID (12 bits), 1 bit flag and 3 bit priority
- 12 bits means 4096 separate VLANs

### **Carrier Ethernet**

802.1ad (Q-in-Q) adds a new tag to the ethernet header

The carrier has its own VLAN header as well as the customer VLAN header

The carrier will add their tag when the packet arrives from a customer network and remove it when it reaches the destination customer network. C-VID and S-VID

This can stack as a switch can operate over the first tag that it sees.

### **class notes**

Network terminated - Electronic core connects E-XC

IP topology built on top of E-XC links

The pre-existing infrastructure of the internet was the left over phone network.

Packet switching: bunch of transmission lines and send packets one after the other.

VOIP: voice over IP

### **IP over WDM**

Remove OXC and use routers to terminate all traffic

No need for L2 network as the IP transmits directly on top of WDM network.

Problem: All traffic is terminated in the router meaning it needs a dedicated port. Core Routers are very expensive though.

Also wasting switches cause we know where the packet is going

### **Second generation optical networks**

Dynamic switching of paths i.e routing at the optical level.

Optical cross connect is the optical element that provides switching.

Traffic leaving the network can be terminated at a router. The rest can be routed on at the optical layer with multiplexers.

Problem: Everything is fixed, the routes always go the same way. To add more capacity you need to physically adjust the multiplexer connections.

Fix: the ability to electronically reconfigure the device to decide where the connections go.

Degree denotes the direction i.e 2 degree is bi-directional. It goes two directions. 3 degrees means three directions etc.

Advantages: Route optical channel without multiplexing.

### **Optical cross connects**

Fibre switch: come in with a number of fibres and leave with a number of fibres. Simple device. micro mirrors tilt in various directions, this directing the signal.

Beam Steering: Lens on top of the beam and steer the beam.

These must be accurate

WSS: All the wavelengths come in to a reconfigurable device which can decide which port to export a wavelength at.

### **New issues**

Optical layer is analog

- new path could be longer and have a lower OSNR. dynamic switching
- Adding/Removing wavelength channels create power excursion in the amplifier chains that generate errors in all other channels.

Independent operating of layers can cause issues. Such as convergence issues

Fibre topology usually becomes the static topology. Have to dig up the ground to lay fibre.

Congestion can become an issue on a distributed network as one change causes change everywhere that's unpredictable



## **MPLS**

Centralised switching that works on a global network.

Header: focus on the label: used for packet switching.

the label identifies a virtual path and it only has a local meaning e.g between two adjacent MPLS switches.

Taking all the possible flows and deciding where they go.

Label distribution protocol: the exchange of labels and agreement on what should be used. Switching table has the incoming label and the port it comes in at and then replaces the label with an outgoing label and sends it out the correct port.

at the edge of the network you have to add and remove the MPLS label respectively. Thus converging from IP to MPLS and vice versa.

Label stacking: The idea of creating nested tunnels.

## **Forwarding Equivalence class(FEC)**

Putting in the first label of a packet, one coming from IP.

What is the mapping between fields in the IP header and the label that the packet receives.

There are many possible criteria for the mapping e.g Destination of IP address.

Problem: Advancements in ASIC and TCAM memories IP routing could be done fast (at line rate) so the speed advantage of MPLS became obsolete.

TCAM: special memories in your router. Look through an entire address space in one clock cycle.

## **Acronyms**

- E-XC: Electronic Cross connects
- ROADM: Reconfigurable optical Add Drop Multiplexer
- WSS: Wavelength Selective Switching
- OSNR: Optical Signal to Noise ratio
- MPLS: Multi-Protocol Label Switching
- TTL: Time To Live
- FEC: Forward Equivalence Class
- CPE: Customer Premises Equipment
- WDM: Wavelength Division Multiplexing
- LPS: Label Distribution Protocol