University of Essex

Seamless Optical and Electrical Routing -

the Key Enabler for High Speed Media Networks?

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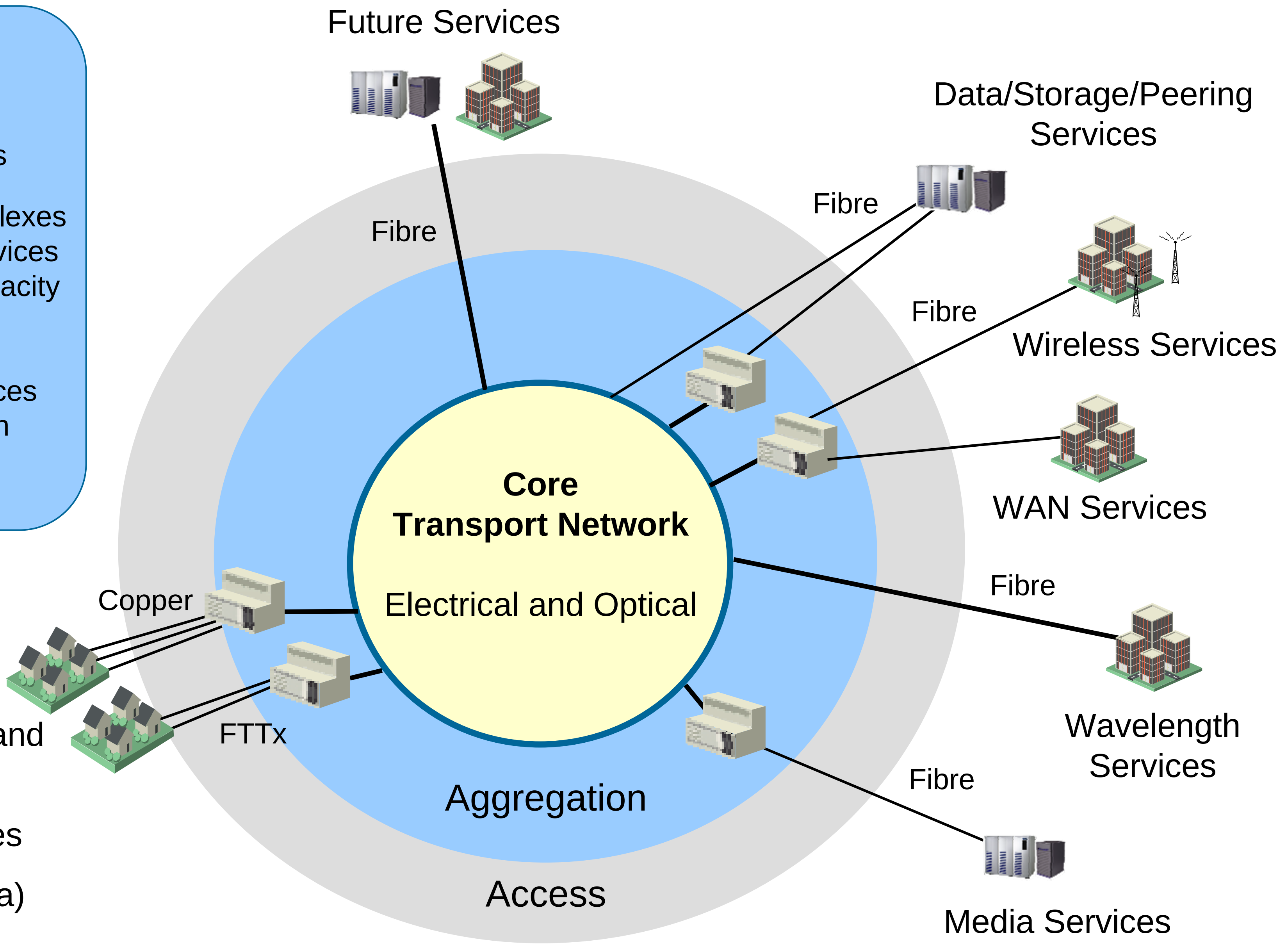
Outline

- The evolving role of the Optical Transport Network
- Opaque and Transparent Networks
- Multi-layer networking
- Dynamic bandwidth-on-demand
- Summary

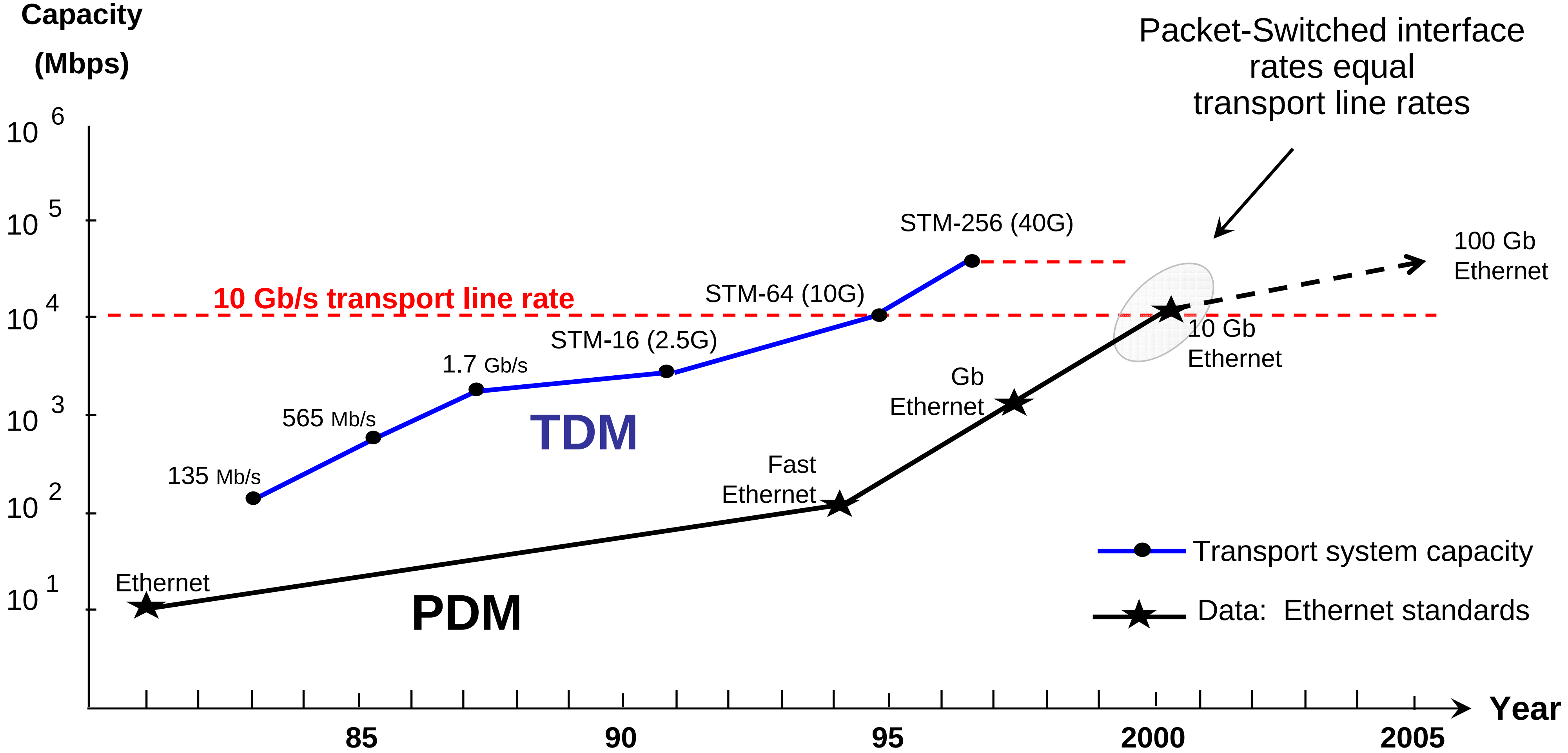
Generalised Network Architecture

Multi-Service Access/ Provisioning Platforms

Equipment that multiplexes multiple protocols/services onto a single high capacity service 'pipe".
Performs traffic engineering and reduces number of aggregation devices in network.

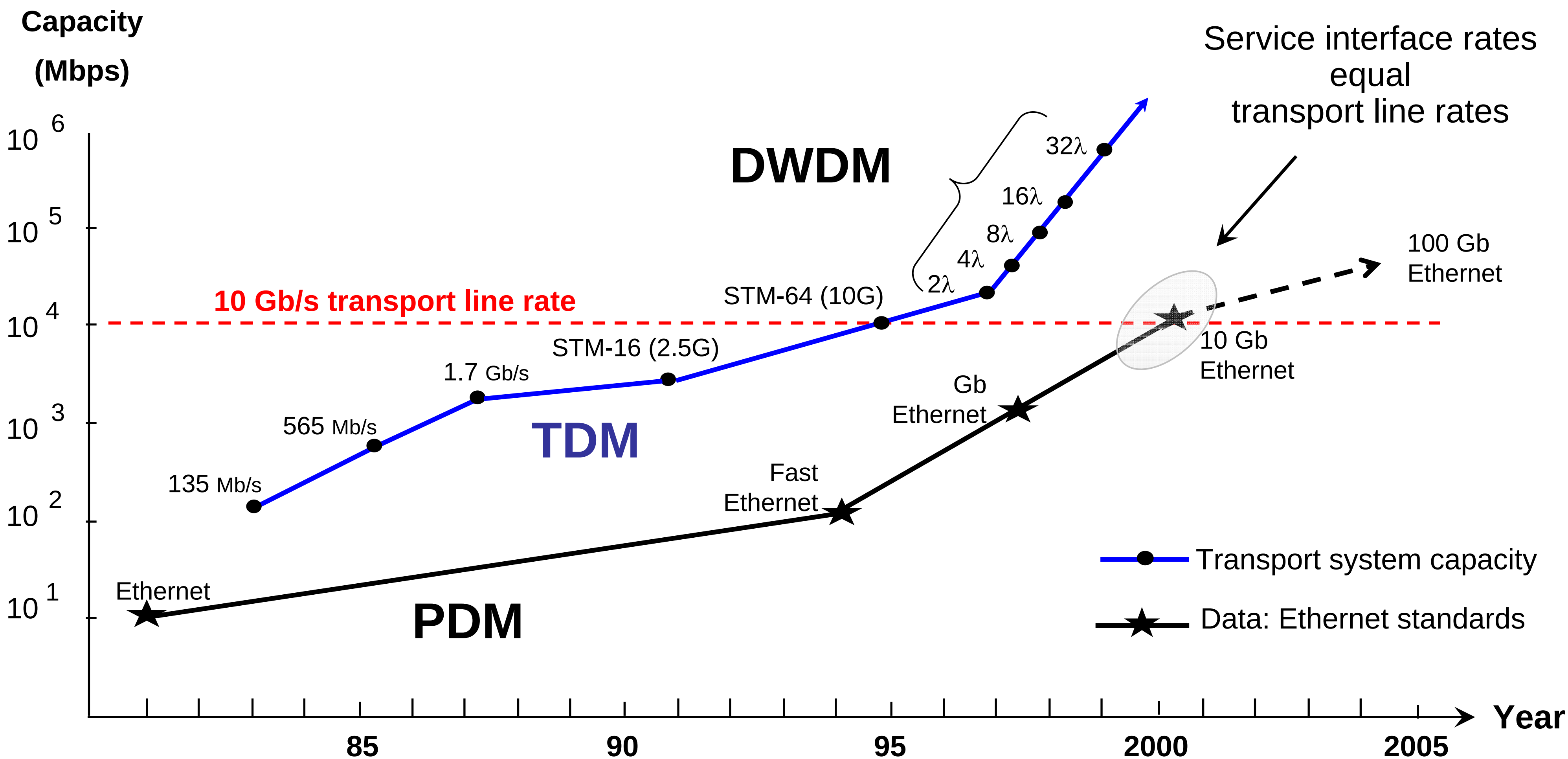


Evolving Role of the Optical Transport Network



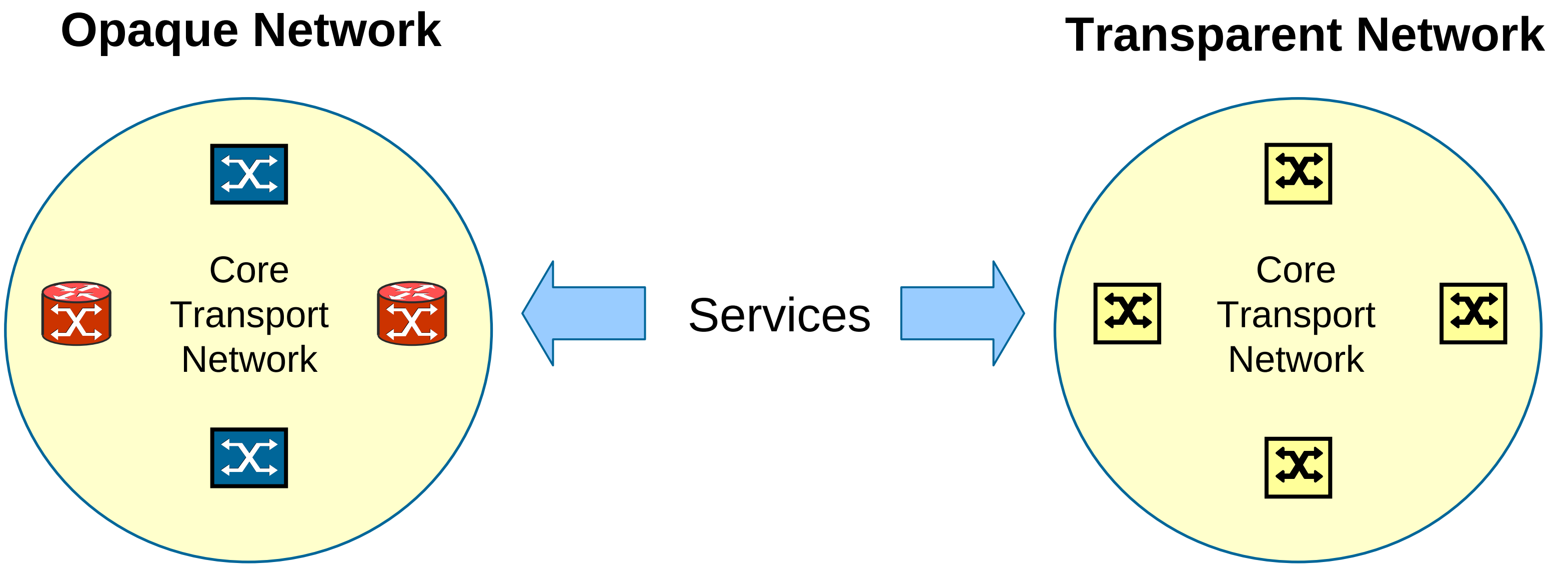
Interface rates on IP/MPLS routers and Multi-Service Platforms now have interfaces at the transport line rates of 2.5Gbps, 10Gbps and recently 40Gbps.

Evolving Role of the Optical Transport Network



Dense Wavelength Division Multiplexing (DWDM) allows the transport layer transport capacity to grow as service demands increase.

Opaque and Transparent Transport Networks

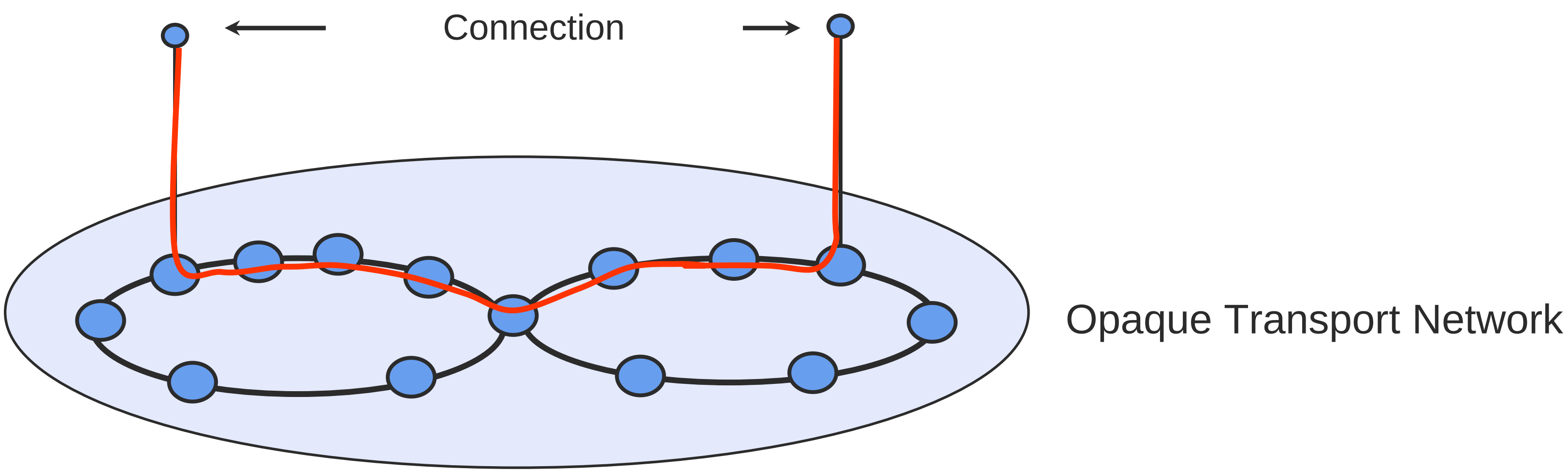


- Nodes are electrical switches/routers
  - Fixed bit-rate and limited protocol variation
  - Large size and high power
- Every wavelength per fibre is converted to electronics at each node
  - Many transponders for large network (largest % of network cost)

- Nodes are optical switches
  - Transparent to bit-rate protocol/modulation format
  - Low power and small footprint
- Signal is only converted to electronics if exiting the transport network
- WDM transponders required only when electrical processing required

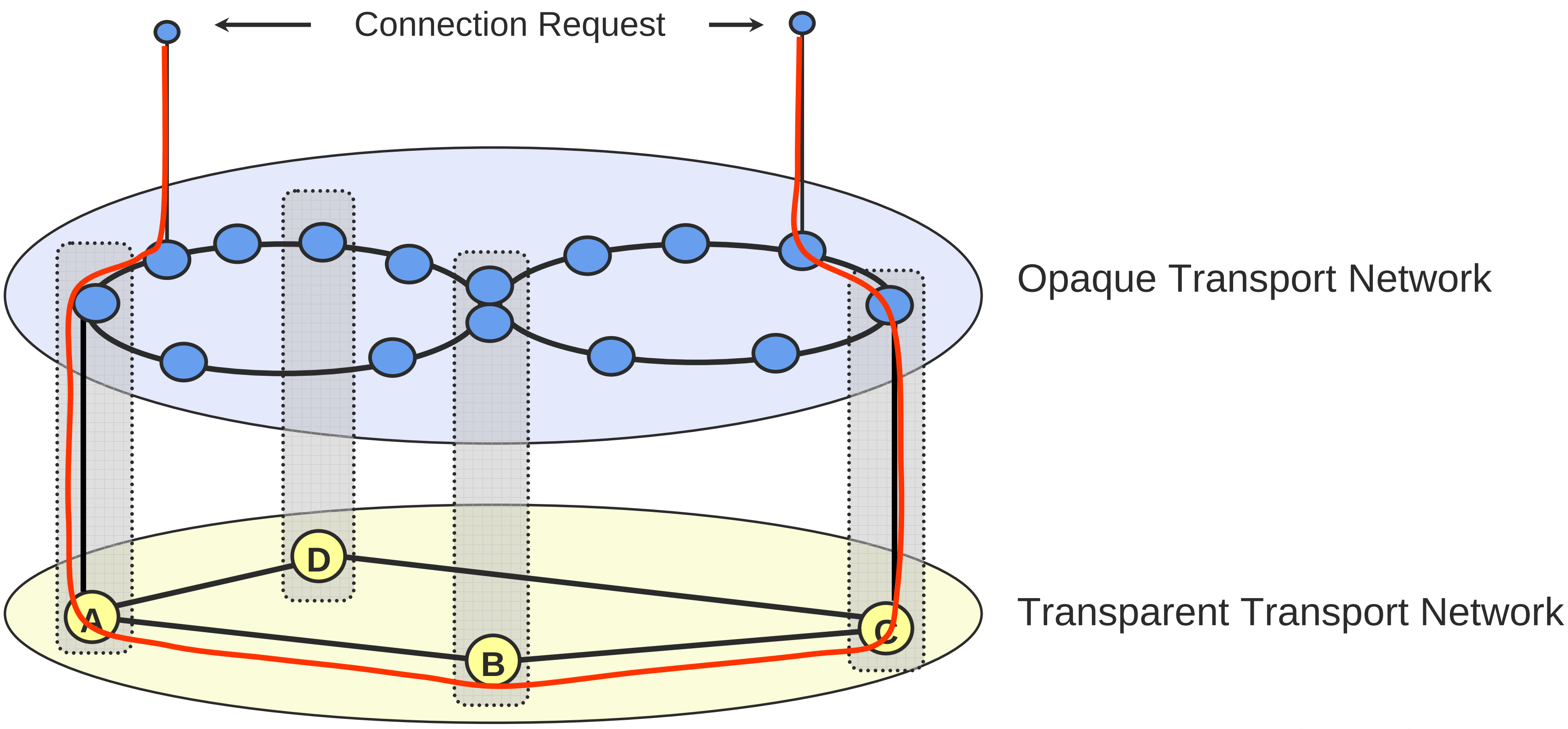
Opaque Transport Networks

- Opaque transport networks require many optical-to-electrical (OEO) conversions (ie many expensive transponders)
- Switching fabrics forwarding both add/drop and transit traffic is wasteful
- Inter-ring traffic (as in example below) consume large amount of intra-ring traffic



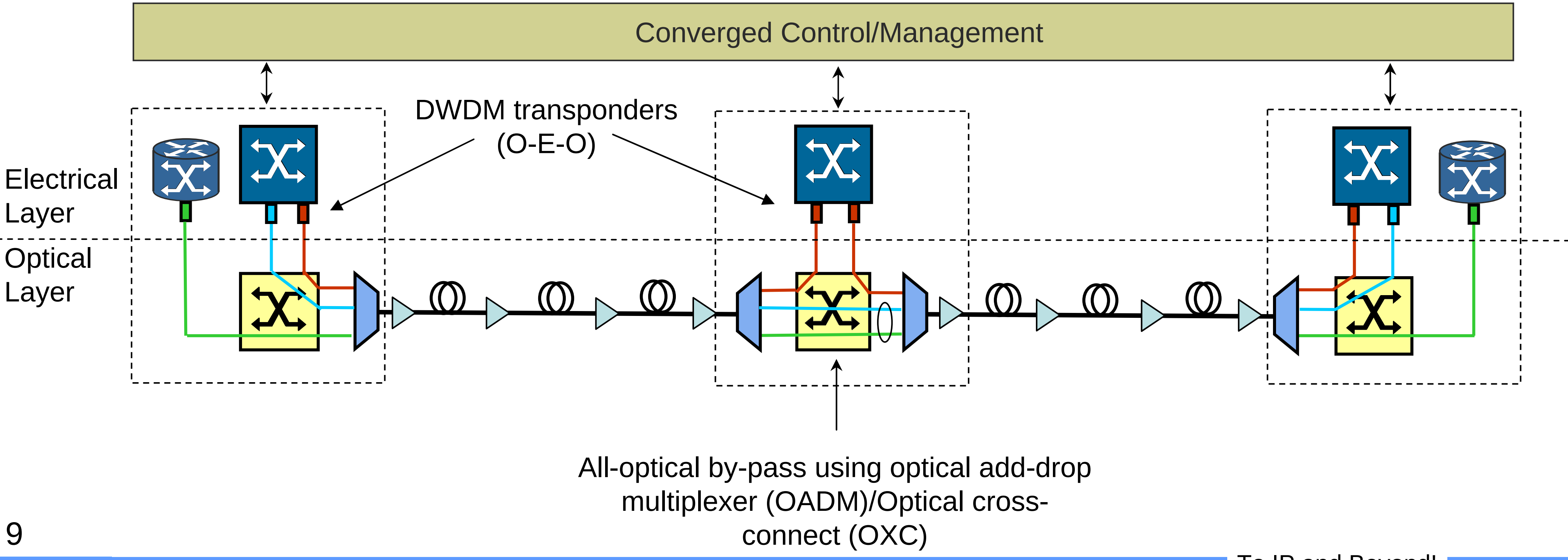
Transparent Optical Networks

- The Transparent Transport Network (or “optical overlay”) allows optical bypass of electrical switches/routers.
- Extends the lifetime of collector rings by offloading the inter-ring traffic
- Can potentially reduce the size of the switch fabrics
- Reduces the maximum number of router hops – lower delay variation for IP/MPLS



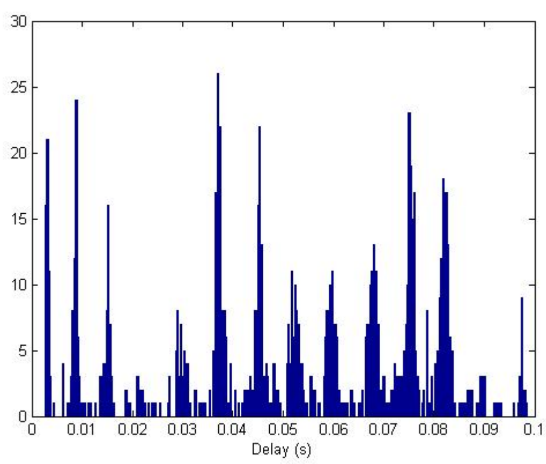
Multi-Layer Networking

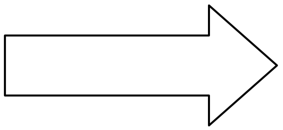
- Optical Layer is transparent to electrical transport technology (eg. NG-SDH, IP/MPLS, carrier class Ethernet, ATM etc..)
- Optical by-pass reduces the number of expensive DWDM transponders (biggest percentage of network cost), but can potentially result in low wavelength utilisation
- Integrated routing algorithm that has awareness of both the electrical and optical layers is essential for optimum use of network resources



- Media networks will contain mixtures of elastic services (eg. large file transfers) and inelastic services that require strict delay and delay variation requirements (eg video and audio)
- Unless properly engineered, large long-lived flows can adversely affect the performance of inelastic services. Also, TCP traffic is very greedy.
- Long-lived large flows between source-destination pairs should be identified
- Direct end-to-end connections (virtual circuit- or wavelength-switched) can be established for these flows such that the packet-switched layer is by-passed. This can significantly reduce the delay variation of real-time services (see below)

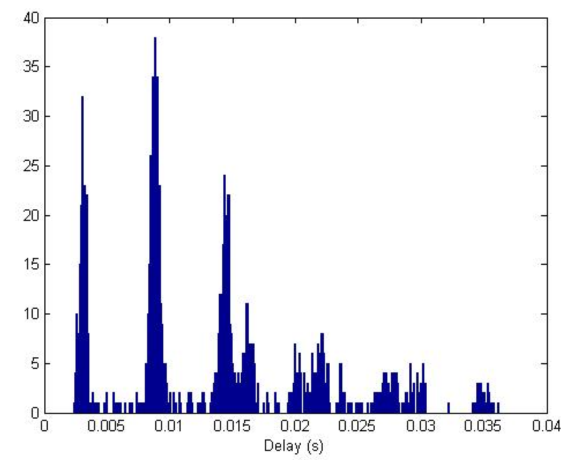
Video traffic delay variation with flows





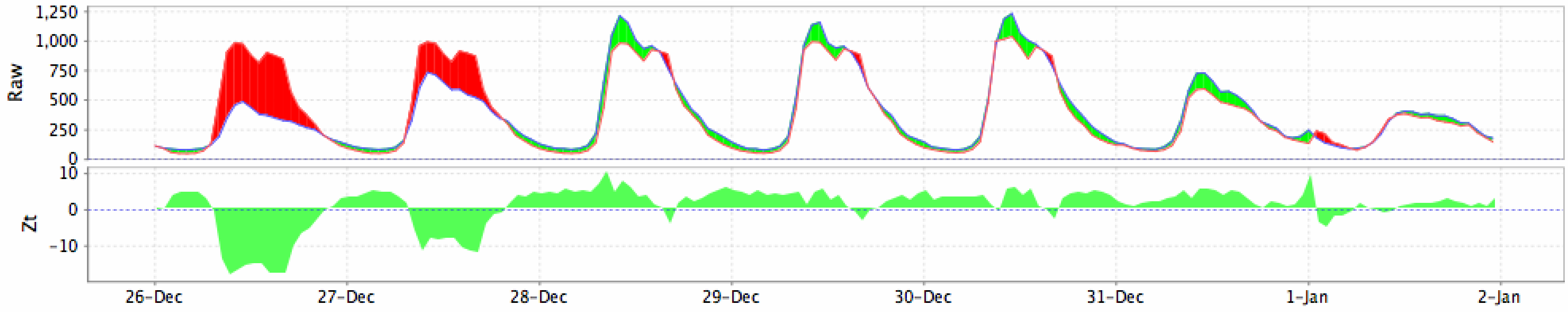
Circuit cut-through of large long-lived flows

Video traffic delay variation without flows

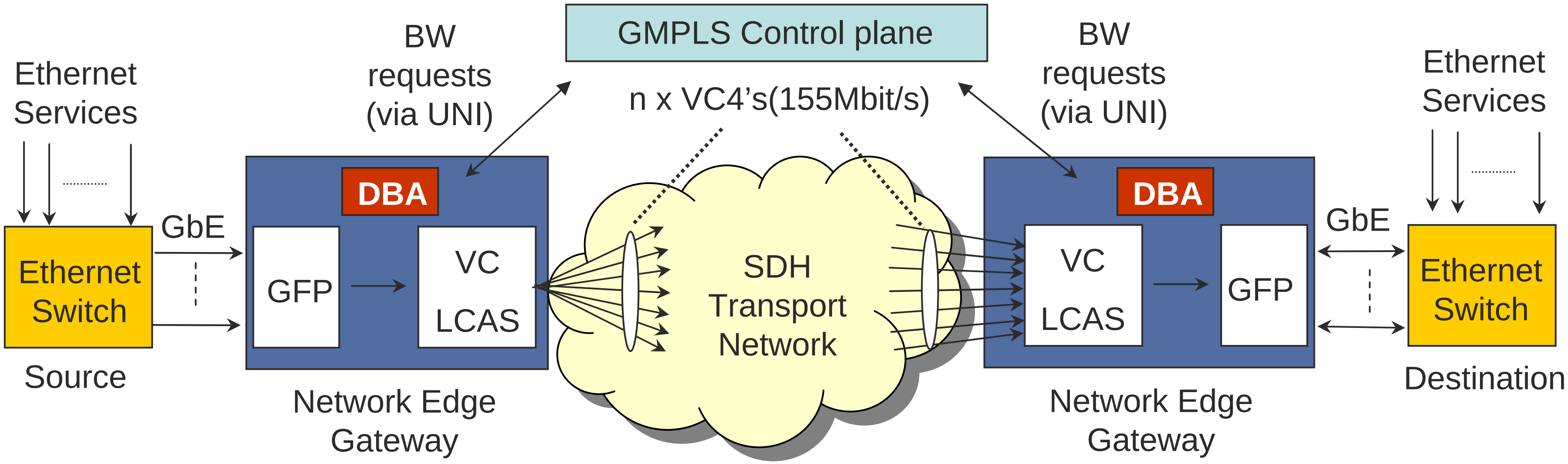


Source Destination Flow Analysis

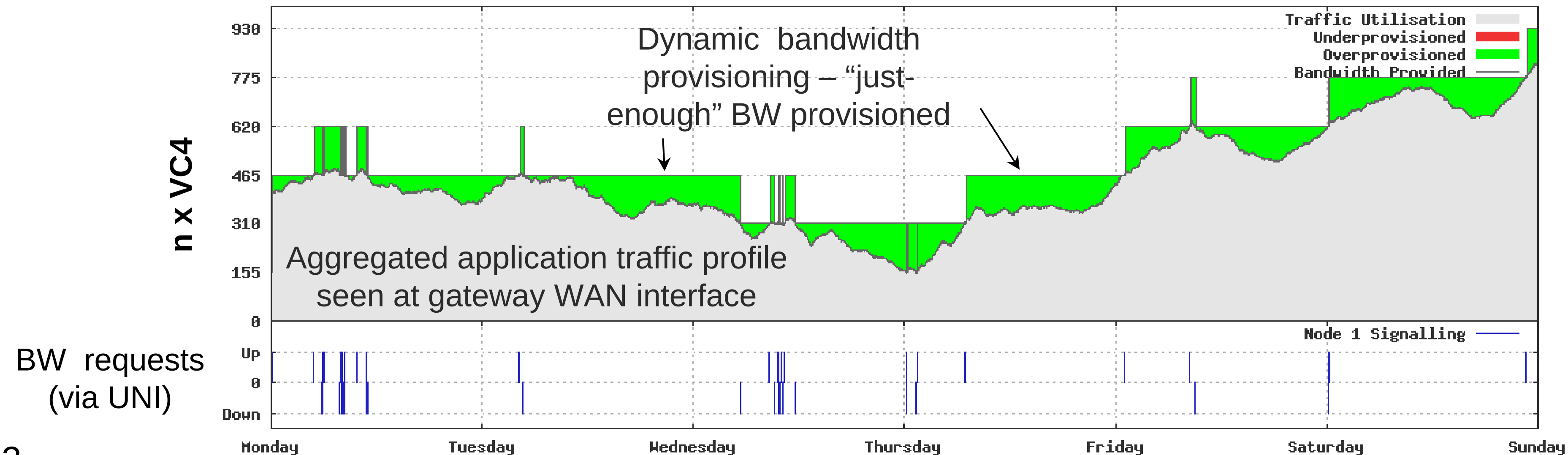
- Understanding the short- and long-term traffic trends is essential for network management and network planning
- Below is a processed traffic trace between two points in the network of a core network provider (red indicates that traffic is below the mean and green above)
- Understanding the content of this traffic (through deep packet inspection) allows more efficient use of network resources by attempting to provision “just-enough” bandwidth, instead of simply over-provisioning



Bandwidth on Demand (sub-wavelength)

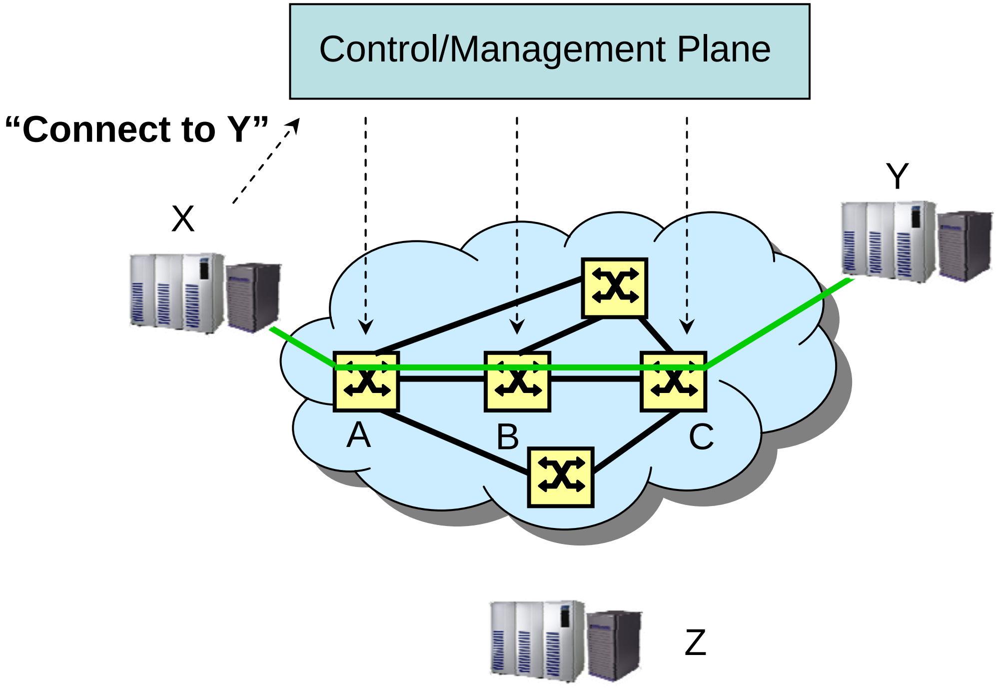


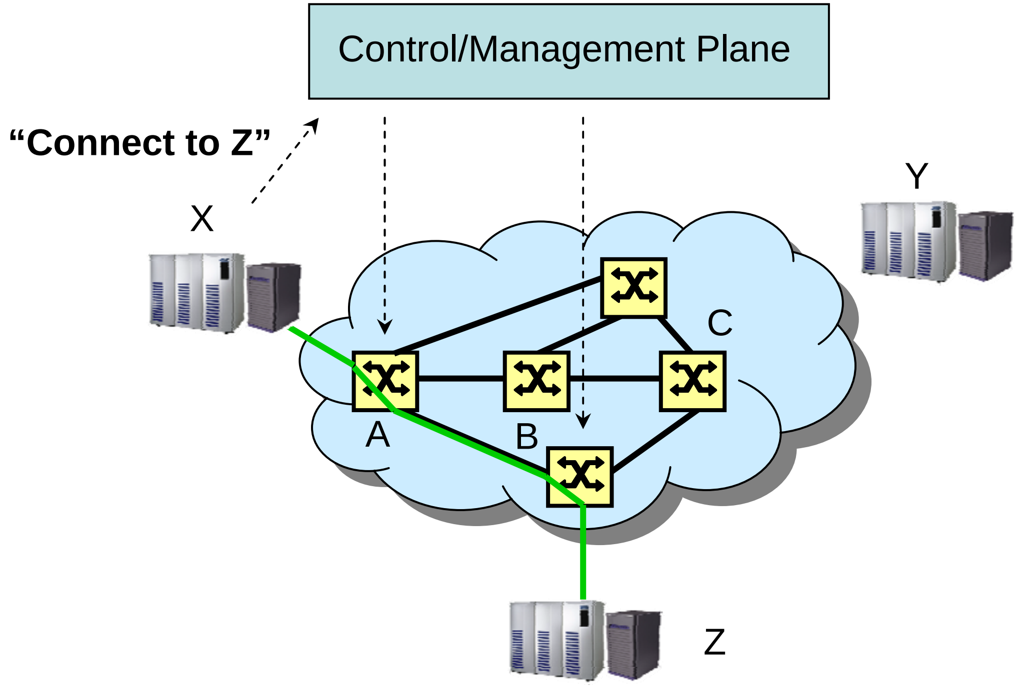
Similar principal for sizing label-switched paths in an IP/MPLS network



Bandwidth on Demand (wavelengths)

- Human or machine initiated bandwidth request via a user-network interface (UNI)
- A list of required parameters could also be included in the request. (eg. Required OSNR, residual dispersion, bit-error rate…)
- Physical transmission layer design is complicated in a transparent optical network





Opaque optical networks:

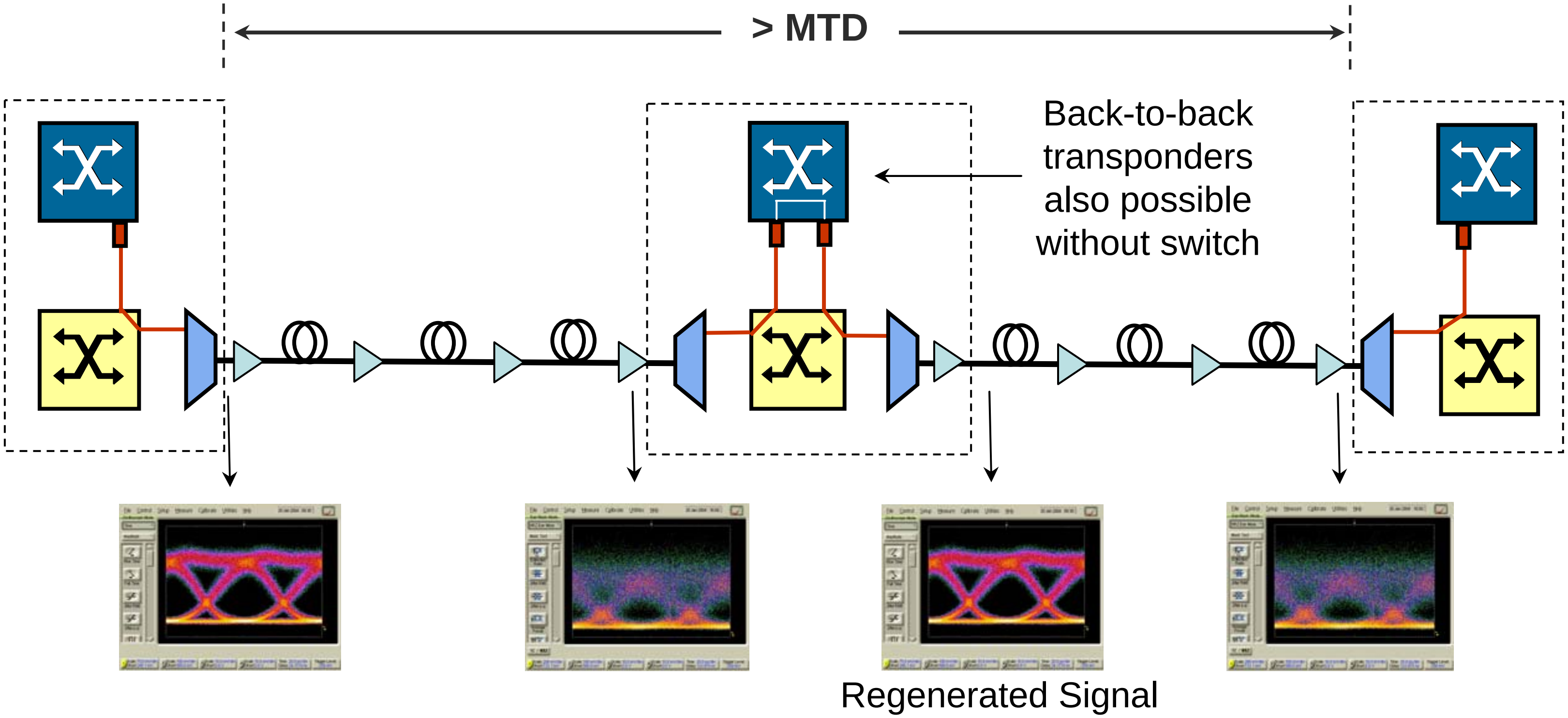
- Physical transmission layer is decoupled from higher network layers so routing algorithms are only bandwidth and physical connectivity constrained
- Link bandwidth between switching nodes is static (upgrading is a manual process)

Transparent optical networks:

- Signal quality is path-dependent and therefore impacts performance of higher network layers
  - Many impairments that affect the quality are: noise, chromatic dispersion, polarisation mode dispersion (PMD), non-linear effects, optical crosstalk…. Exact evaluation requires exhaustive simulations
  - Suitability of path depends on service requirements and service tolerance to impairments
- Flexible bandwidth management will be reflected as varying available bandwidth to higher network layers

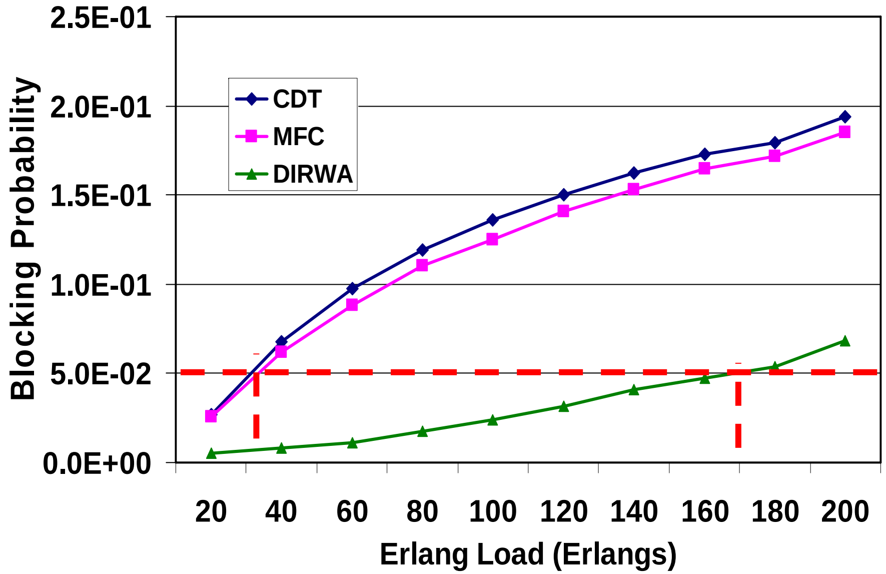
Quality of Service at the Optical Layer

- Optical service signal quality is highly dependent on the physical route taken through optical transport layer and many optical impairments affect the quality (eg. noise, dispersion, crosstalk…)
- The maximum transparency distance (MTD) is the distance an optical signal can propagate without undergoing regeneration. This is very dependent on the physical layer design and transponder tolerance to optical impairments.

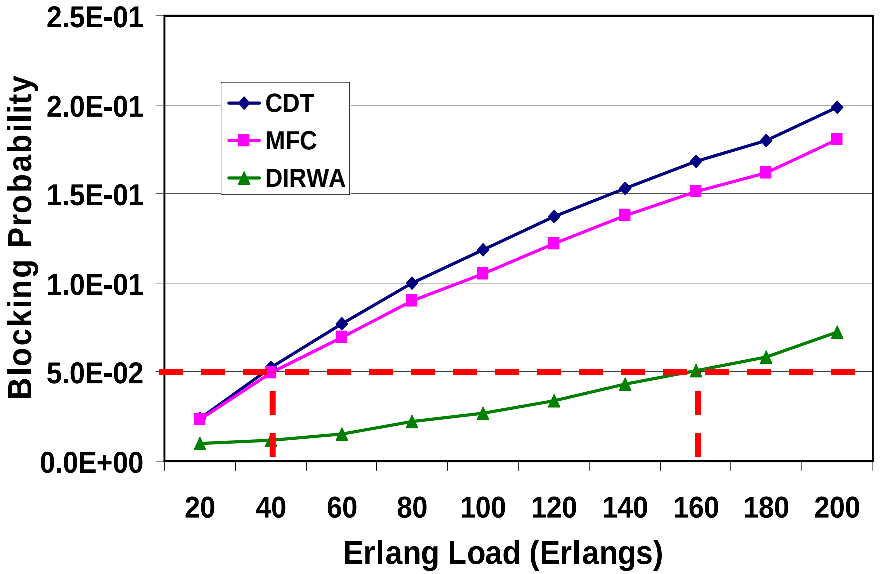


Optical Impairment-Aware Routing

- DIRWA is an impairment-aware routing and wavelength assignment algorithm that has been developed for heterogeneous 10/40Gbps wavelength services
- Allocates a path and wavelength that has just enough optical integrity (eg. noise, dispersion..) for the service requesting the wavelength.
- Increases the network transport capability by 300-400% when compared with a non impairment-aware routing algorithm (CDT and MFC), for the same blocking probability.



(A) 10/40 Gb/s Traffic demands (±1000 and ±63 ps/nm)



(B) Mixed 40 Gb/s Traffic demands (±63, ±150 and ±300 ps/nm)

Summary

- A transparent optical network enables the transportation of a wide variety of protocols, bit-rates and modulation formats
- Through a converged control/management plane, the optical transport network offers the ability to dynamically reconfigure the logical connectivity of the electrical layer (circuits or packets) in response to traffic conditions ie. allocate bandwidth to where it is really needed
- Source to destination flow analysis can be helpful in determining the trends within the network and be used to trigger network reconfigurations
- Multi-Layer Traffic Engineering at both the electrical and optical layers is necessary for efficient use of network resources and these algorithms should be included within a converged control /management plane

Thank you !

Any Questions?