

Modelling packet insertion on a WSADM ring

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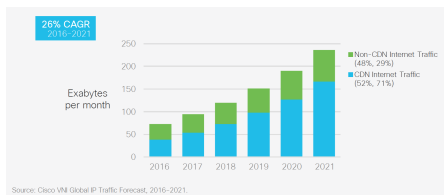
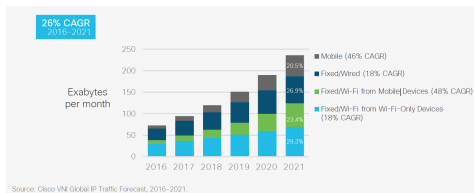
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Networking Context

Traffic Evolution



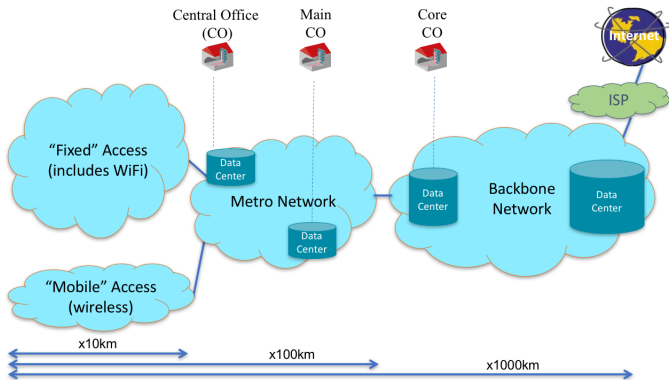
A majority of the traffic is destined to fixed access (including WiFi)!

A majority of the traffic corresponds to content distribution!

This impacts on how each network portion shall grow in the future

Networking Context

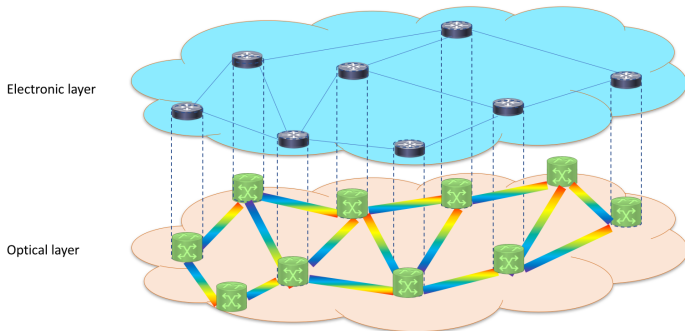
Network Architecture: segmenting the network and locating data centers



What architecture for the Metro Network?

Networking Context

Mapping traffic within an optical infrastructure



User traffic is generated within the electronic layer, and carried over optical fibres

Networking Context

WSADM as a Sub-Lambda Photonically Switched Optical Network

PROS

- Optical fibres can provide huge capacity transport
- Optical switching is potentially more energy efficient than electronic switching

CONS

- Light cannot be stored, i.e. lack of optical random access memory (RAM) to serve as "optical buffers"
- the optical granularity is rather coarse (wavelength, or grid based) in circuit switching
- Optical Packet Switching may still rely on custom optical components

A WDM slotted Add/Drop Multiplexer (WSADM) network :

- offers sub-lambda granularity
- relies on electronic contention resolution
- does not necessitate tunable lasers or specific/dedicated optical components
- necessitates WDM TRX that naturally support broadcast

WSADM operation

WSADM within OPS/OBS Network Classification

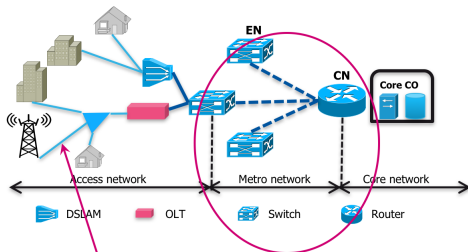
- Contention resolution within the Optical Network
 - Fibre Delay Lines
 - Wavelength conversion
 - Deflection (Hot Potato) routing
- No Contention resolution within the Optical Network
 - lossy optical network
 - **lossless optical network: contention resolution in edge nodes (implemented in electronics)**
- Packets
 - **"containers" filled by multiple electronic packets**
 - carried over a single or **multiple wavelengths**
- Topology: **Slotted Ring, Bus, Tree**
- Medium Access
 - **opportunistic insertion**
 - **scheduler based insertion**
 - static scheduler (TDMA compliant)
 - **dynamic scheduler**
 - token ring based

WSADM in a nutshell

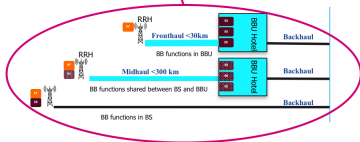
- lossless optical packet ring or bus
- carries containers over multiple wavelengths
- **opportunistic or reservation based MAC**

WSADM operation

Where can a WSADM network be useful?



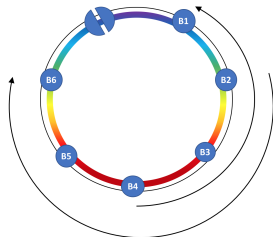
Xhaul



This presentation focuses on WSADM for metro/aggregation network

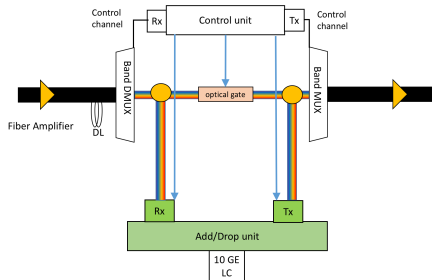
WSADM operation

Node architecture



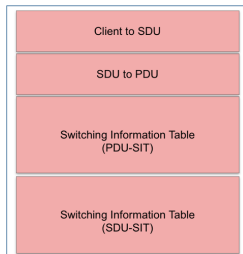
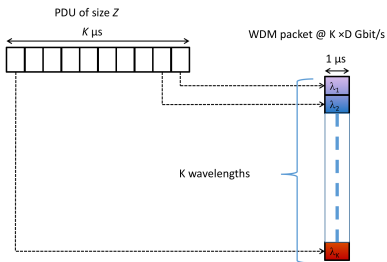
- unidirectional or bi-directional (for protection)
- slotted operation
- unicast and multicast support
- reservation based or opportunistic

- a single control channel and multiple data channels
- packet split over multiple channels (“colored” packets)



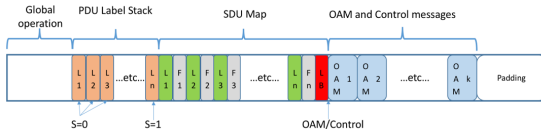
WSADM operation

Label Based Transfer Plane Operation and Control



Data container carried over K wavelengths (typically, $K = 10$, $D=10$ Gbit/s, $Z=100$ kbit)

Data plane control information within a WSADM node



Control PDU structure

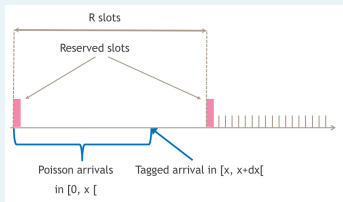
Modeling WSADM node behaviour

Derivation of insertion time distribution

- Assuming Poisson arrivals of packets (PDU): $\gamma_j(x) = e^{-\Lambda x} \frac{(\Lambda x)^j}{j!}$
- π is derived by solving $\pi P = \pi$
- Distribution of sojourn time before insertion on the ring
 - FIFO electronic queue
 - relies on memory-less property of the Poisson process

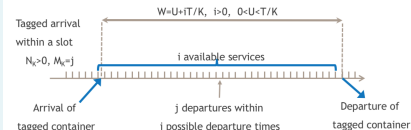
Reservation Based Mode

1 reserved every R slots



Opportunistic insertion

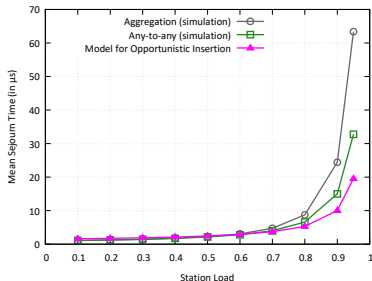
“Bernoulli” availability



Modeling WSADM node behaviour

Validity of Queueing Models

- Poisson arrivals of packets (PDU): OK for metro traffic
- nothing to check for reservation based mode !
- Bernoulli availability for opportunistic insertion: **to be checked**



Accuracy of Bernoulli availability

- OK as long as offered load is less than 0.8
- better for any-to-any than for aggregation

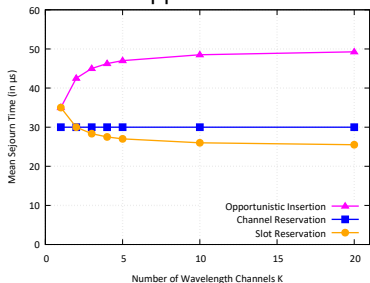
NS3 simulation versus queueing model

Modeling WSADM node behaviour

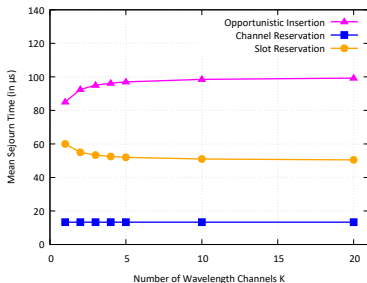
Comparing MAC for WSADM networks

Assess insertion times versus K , size of wavelength band

Benchmark of opportunistic and reservation versus channel reservation



$Z/D = 0.8$



$Z/D = 0.4$

Impact of K (data channel size)

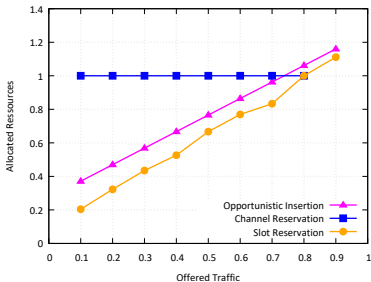
- very small K : large impact, $K > 5$, small impact, tends quickly to limit
- $\text{limit}(\text{opportunistic}) = 2 \times \text{limit}(\text{reservation})$ [similar to bus waiting paradox!]
- for small loads, better performance for benchmark [overdimensioning!]

Modeling WSADM node behaviour

Supporting Metro Networks

The Metro Ethernet Forum has set performance objectives for different network spans, including Metro (< 250km)

	Loss	Delay	Jitter
MEF 23.2	10^{-4}	10ms	3ms
WSADM PDU level	0	2.5ms (propagation) 0.25ms (insertion)	0.25ms insertion



WSADM dimensioning

- opportunistic insertion less efficient than reservation based mode
- both WSADM modes easily support MEF 23.2 performance objectives
- both WSADM modes are more efficient than channel reservation

- **Analytic models** for PDU insertion performance under PDU Poisson arrivals
 - models for opportunistic, slot reservation, channel reservation insertion policies
 - perspective: models for “elephants” (inter data-centers traffic)
- Sub-lambda granularity allows to efficiently allocate resources
 - **opportunistic and slot reservation are compatible with MEF performance for metro tier**
 - better performance with slot reservation
 - opportunistic and slot reservation can be used simultaneously
- Configuration and re-configuration can be SDN enabled
 - **K (size of wavelength band) can be chosen according to offered load, almost independently of performance**
 - opportunistic mode is more easily re-configured