The potential of subwavelength switching to reduce power consumption of metro and core networks

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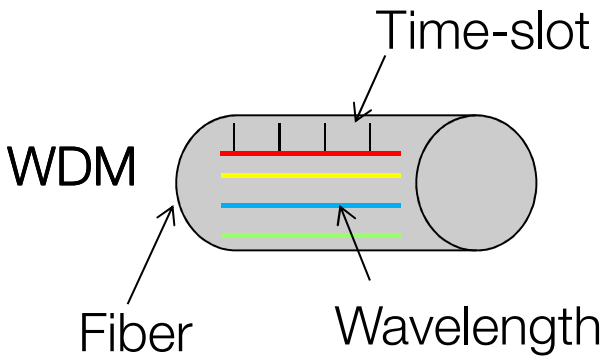
TREND plenary meeting
Gent, 14 Feb 2012

Subwavelength switching?



- Optical networks…are green(er)
- Subwavelength switching
  - Divide the wavelength capacity in time
- Metro networks

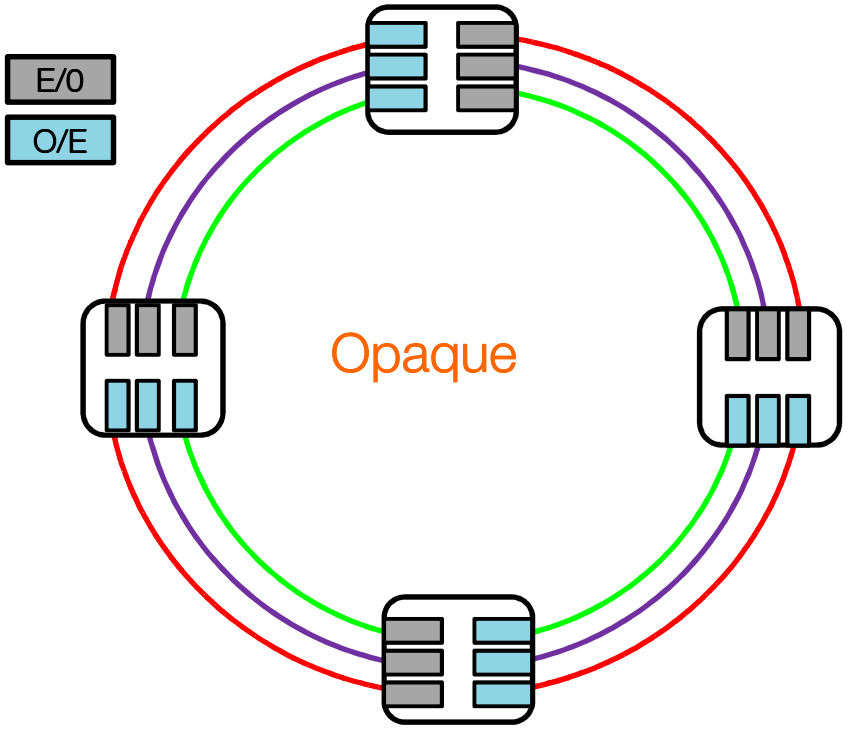
  Cost, power and performance evaluation of MAN architectures
  - TREND collaborative work between PoliTo and FT
  - Joint work with A. Bianco, T. Bonald, D. Cuda and E. Le Rouzic
- Core networks

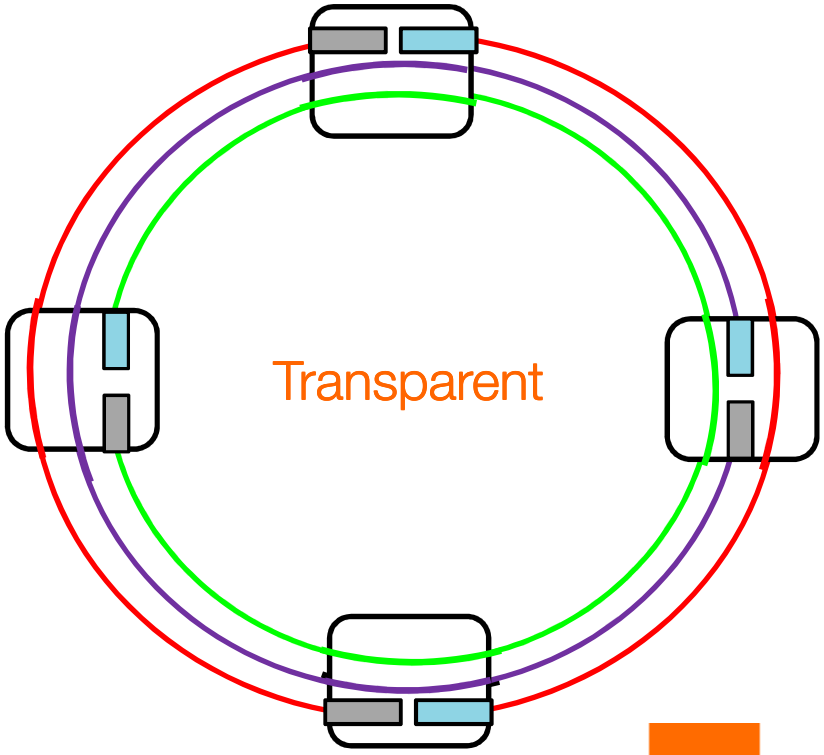
  Getting routers out of the core: building an all-optical WAN using multipaths
  - Joint work with D. Cuda, E. Le Rouzic, J. Roberts

Cost, power consumption and performance evaluation of MAN architectures

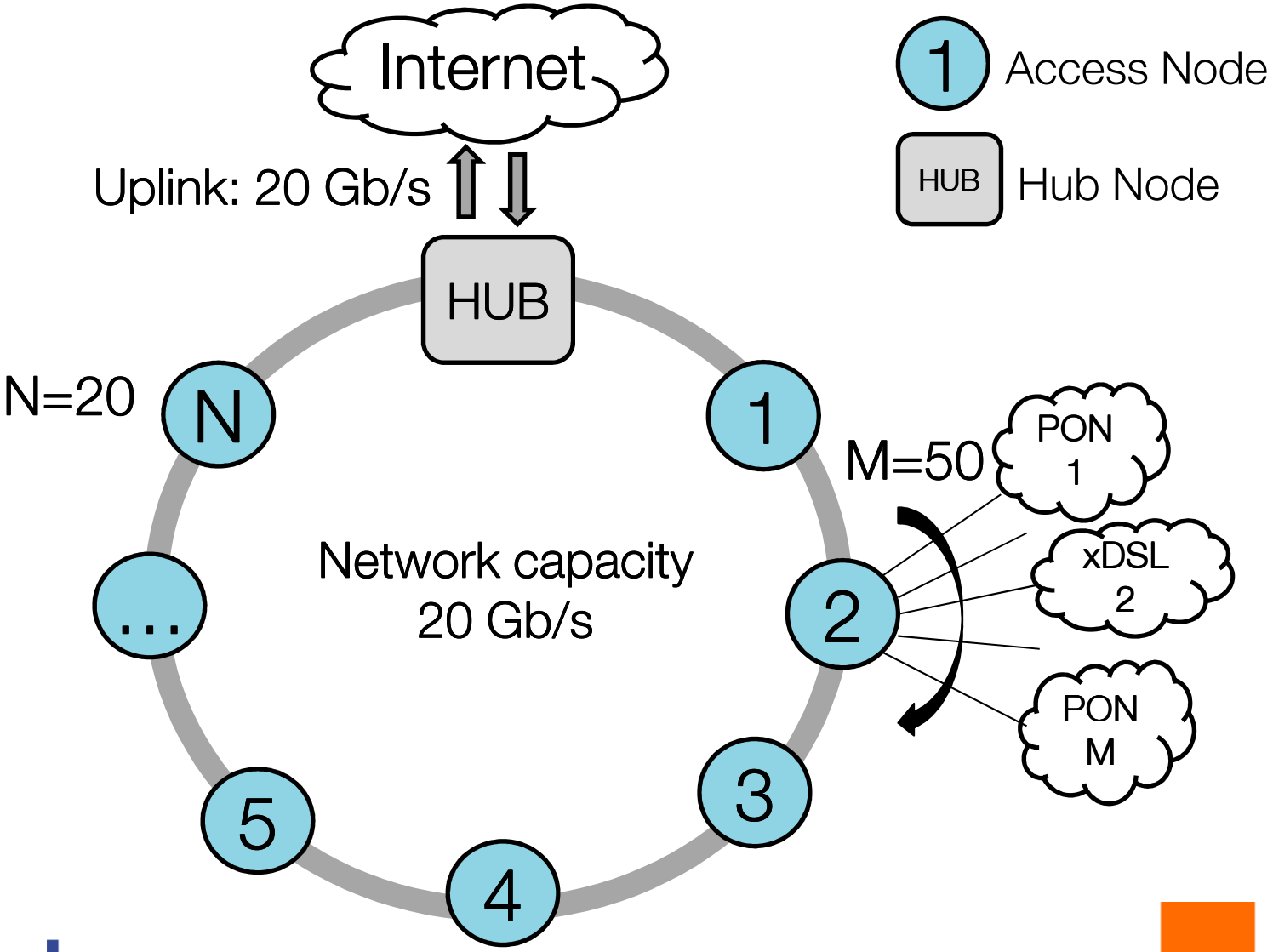
Overview

- Two opaque architectures
  - SONET/SDH and Ethernet
- Two transparent architectures
  - Hub-based and Slotted WDM

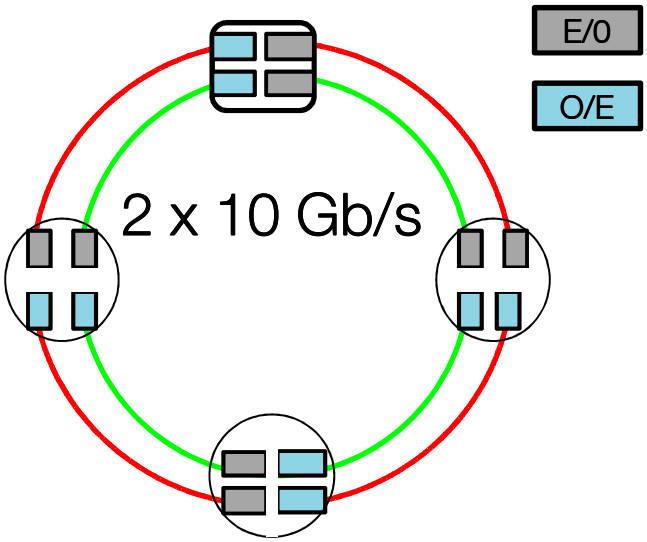




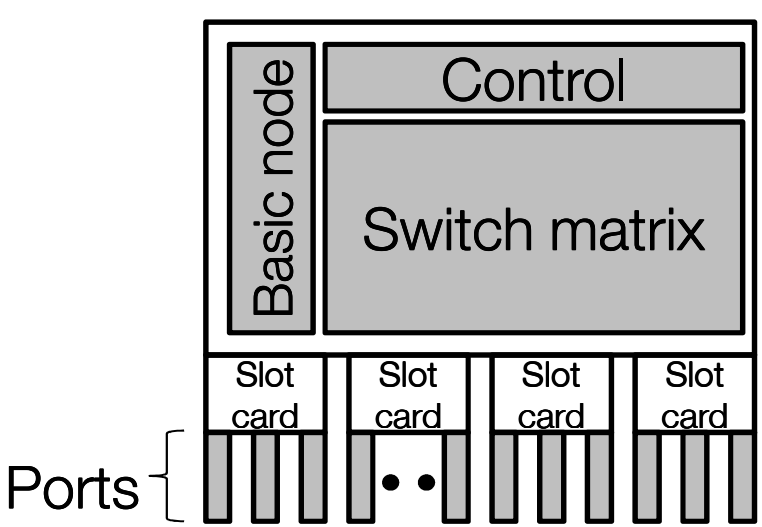
Common parameters

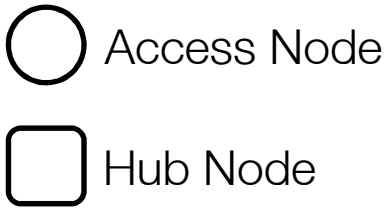


SONET/SDH



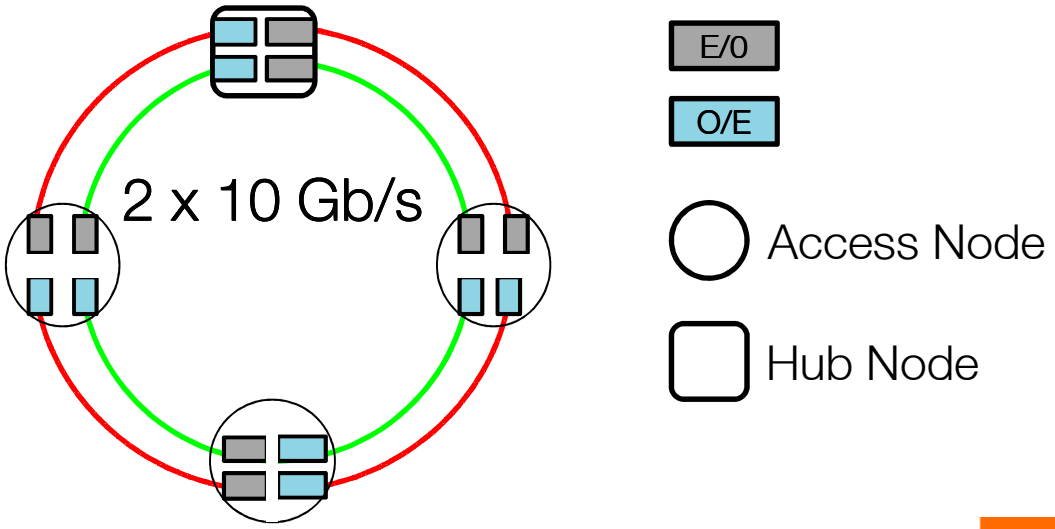
- Most popular architecture in the metro
- O/E/O conversion at every node
- Network architecture:
  - W=2 wavelengths @ 10 Gb/s
  - SONET/SDH nodes with W FTx and W FRx @ 10 Gb/s





Ethernet-based MAN

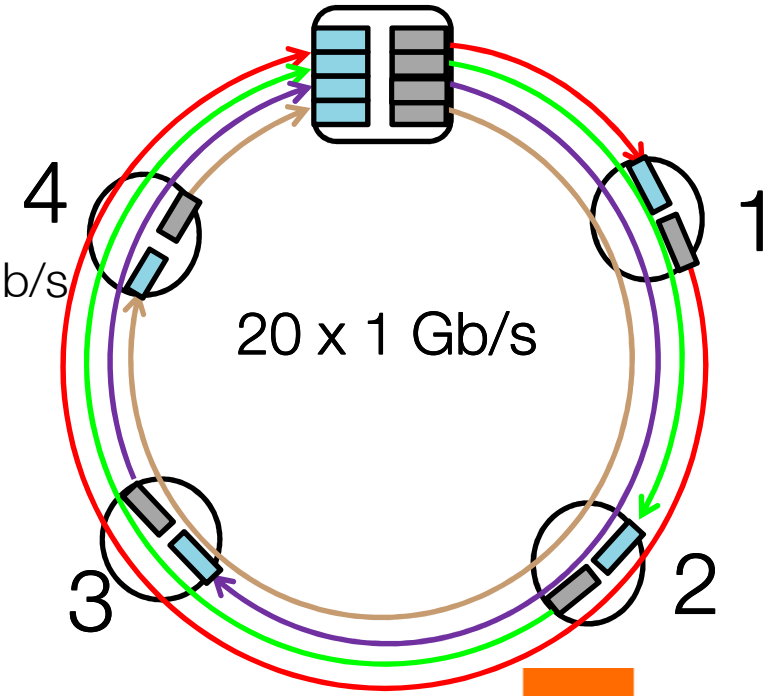
- SONET/SDH designed for constant-rate voice traffic
- Ethernet: a low-cost solution for the metro
- Network architecture
  - W=2 wavelengths @ 10 Gb/s
  - Ethernet switches: W fixed Tx and W fixed Rx @ 10 Gb/s



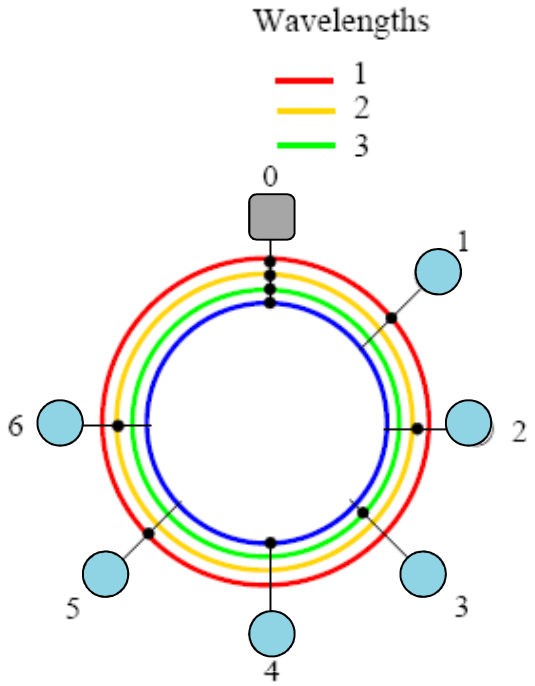
Hub-based

- Introduce transparency!
- Most traffic goes to Internet => to the Hub
- One lightpath between each access node and the Hub

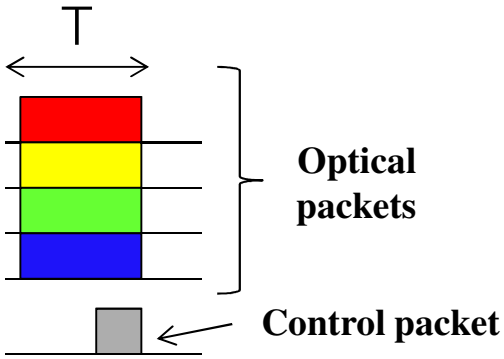
- Network architecture
  - W = N (20 wavelengths) @ 1 Gb/s
  - Access node: 1 FTx and 1 FRx @ 1 Gb/s
  - Hub node: N FTx & N FRx @ 1 Gb/s
- Scalability issues
  - Complexity of Hub grows with N
  - No sharing of wavelength channels



Slotted WDM



- Each wavelength shared by several SD pairs
- Wavelengths divided into fixed-size time-slots T
  - Nodes insert/extract traffic from the slots
  - Control packet -> associated to each slot
- Network architecture
  - W=2 wavelengths @ 10 Gb/s
  - Access nodes: 1 tunable Tx and 1 fixed Rx @ 10 Gb/s
  - Hub: W fixed Tx and W fixed Rx



Traffic Capacity (1/2)

- Maximum sustainable traffic such that the system is stable

1. Offered traffic < transmission capacity of each node i

$$\forall i, \quad \lambda_i < |t_i| C$$

Offered traffic by node i

Transmitter capacity @ i

No. of transmitters

2. Offered traffic < reception capacity of each node j

$$\forall j, \quad \sum_i \lambda_{ij} < |r_j| C$$

No. of receivers @ j

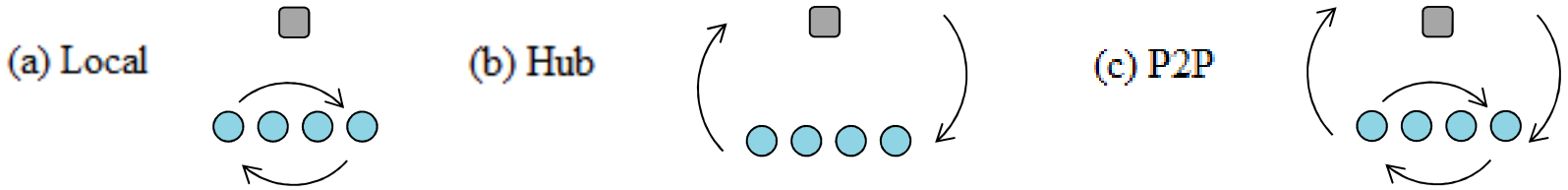
3. Offered traffic < capacity of each link ℓ

$$\forall l, \quad \sum_{i,j:l \in [i,j]} \lambda_{ij} < LC$$

No. of wavelengths

Traffic Capacity (2/2)

- Three traffic scenarios

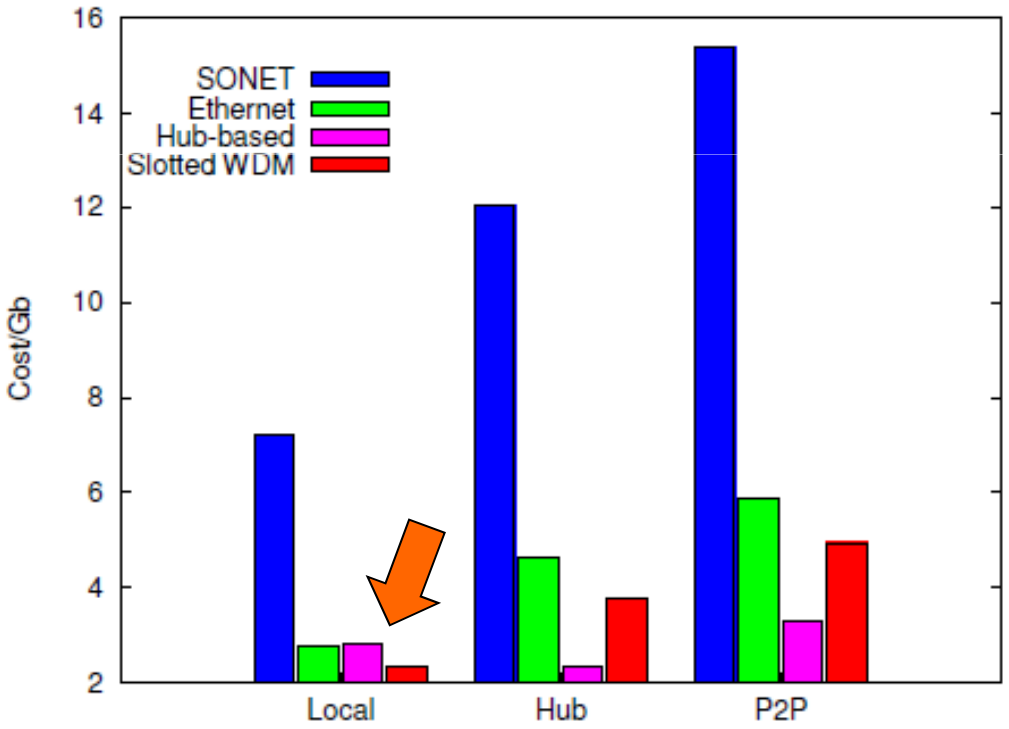


	Local (Gb/s)	Hub (Gb/s)	P2P (Gb/s)
Opaque	40.00	25.00	39.90
Hub-based	20.00	25.00	36.00
Slotted WDM	38.00	24.62	37.92

- Local scenario: traffic inserted in Hub-based half of Opaque & Slotted WDM
- Hub scenario favourable for the Hub-based architecture
- Slotted: WDM only 1 Tx & 1 Rx but the same traffic capacity as Opaque

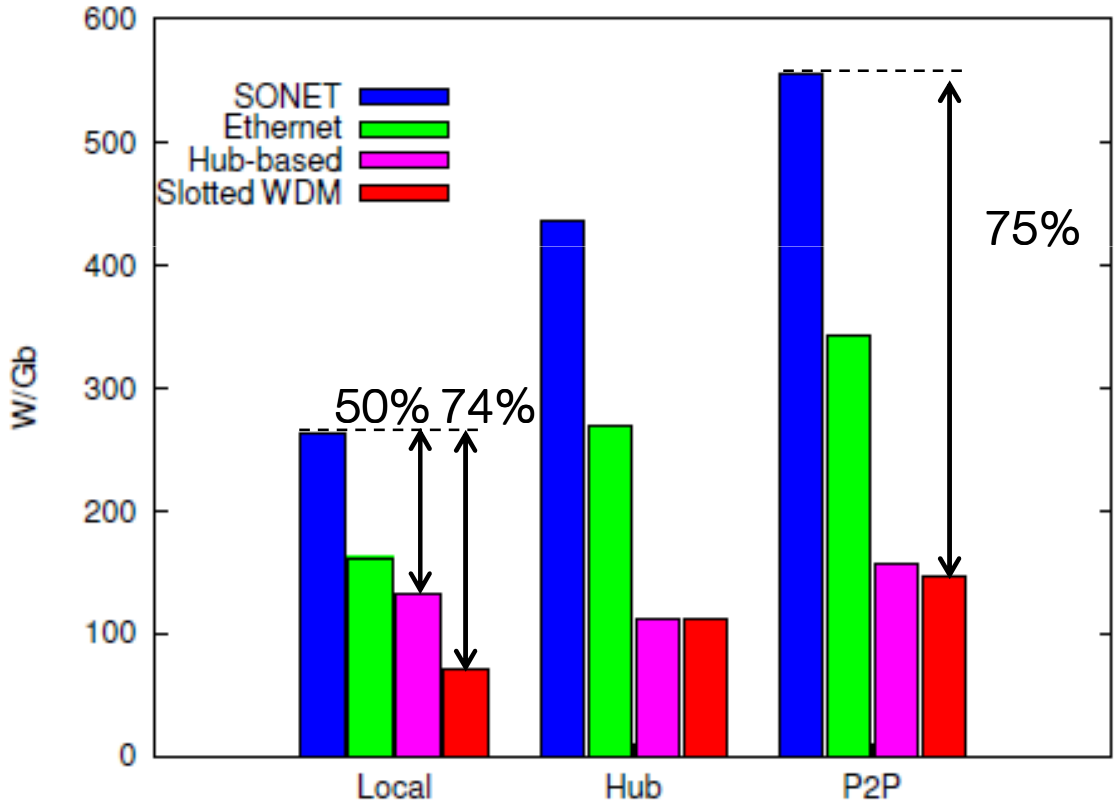
Cost per Gbit

- Costs are normalized to a 10 Gb/s transciever (40 km reach)
- Hub-based generally yields lowest cost pe Gbit
- Cost of Slotted WDM comparable to Ethernet & Hub-based



Power consumption per Gbit

- Transparent solution reduce power consumption by 75%
- Local scenario: Slotted WDM consumes less than Hub-based

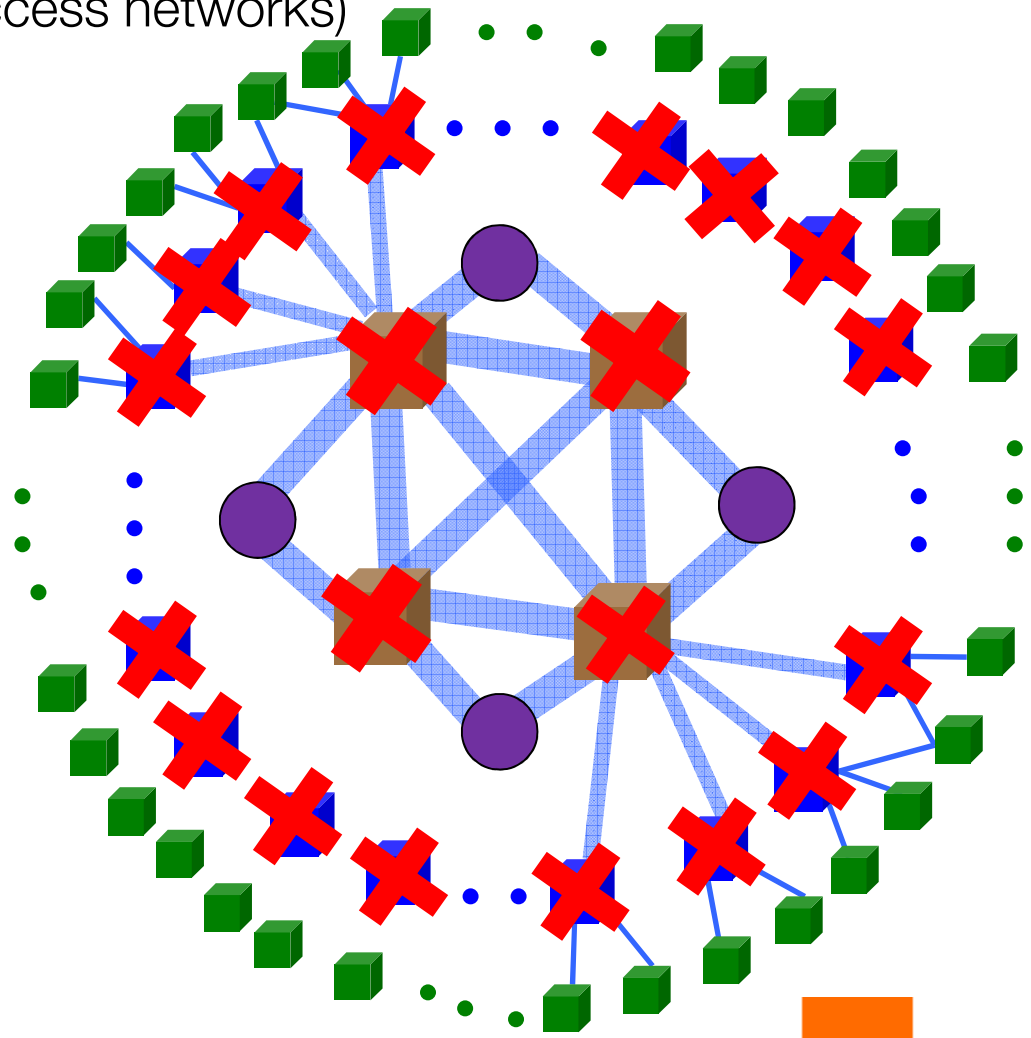


Getting routers out of the core: Building an all-optical WAN with *multipaths*

Today's networks

- Edge routers (aggregate access networks)
- Gateways
- 2-3 layers of transit routers

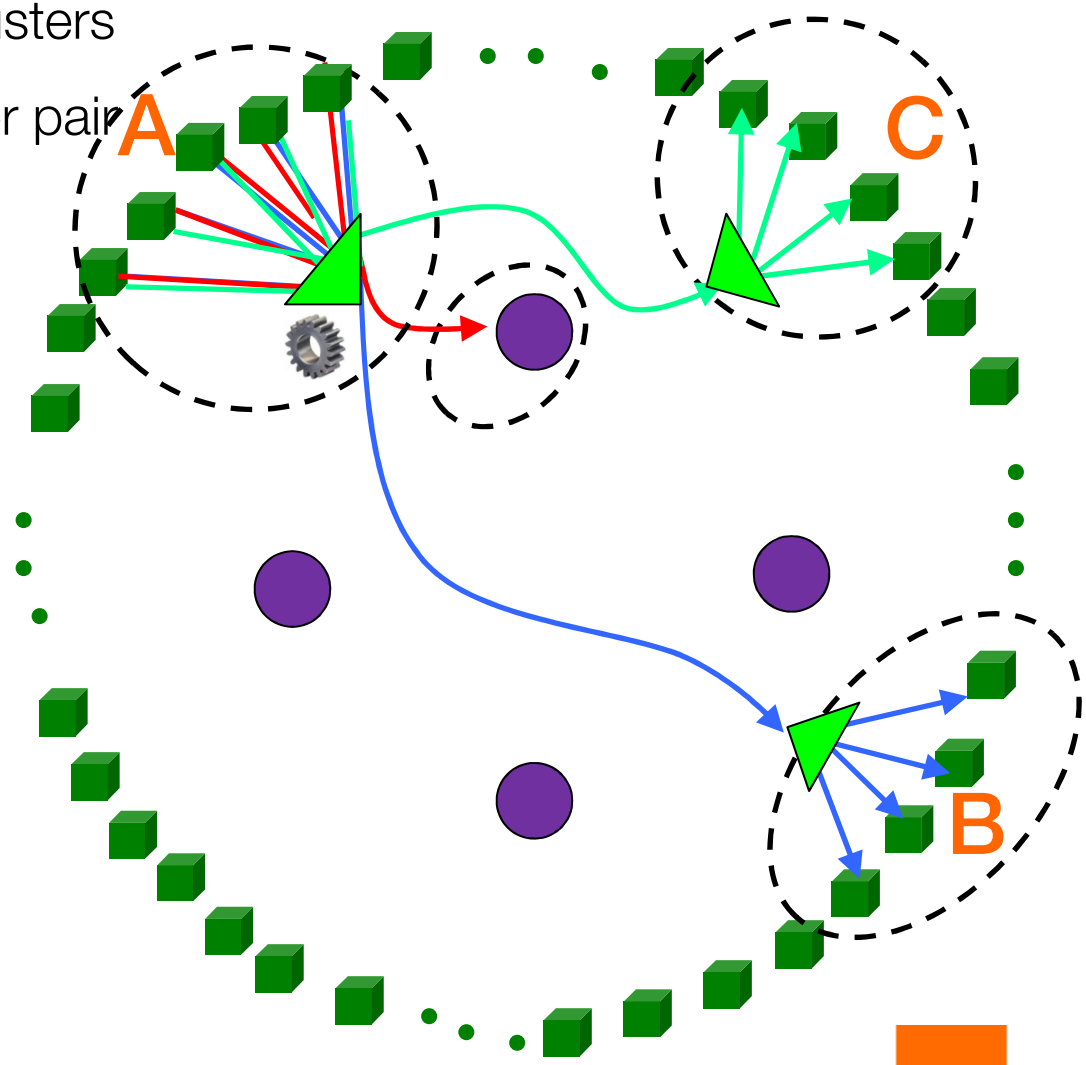
power-hungry



Multipath network

1. Group edge nodes into clusters
2. One wavelength per cluster pair
3. Controller grants access to shared wavelengths
4. Broadcast wavelengh in destination cluster

Multipath= multipoint to multipoint lighpath



Power consumption comparison

- Typical nation-wide ISP
  - 420 edge routers
  - 8 gateways to Internet and other ISPs

Router-based

- 3 hierarchical layers of routers
- 92 IP routers
- Total consumption: 6,5 MW
- Core consumption 1,7 MW

Multipaths

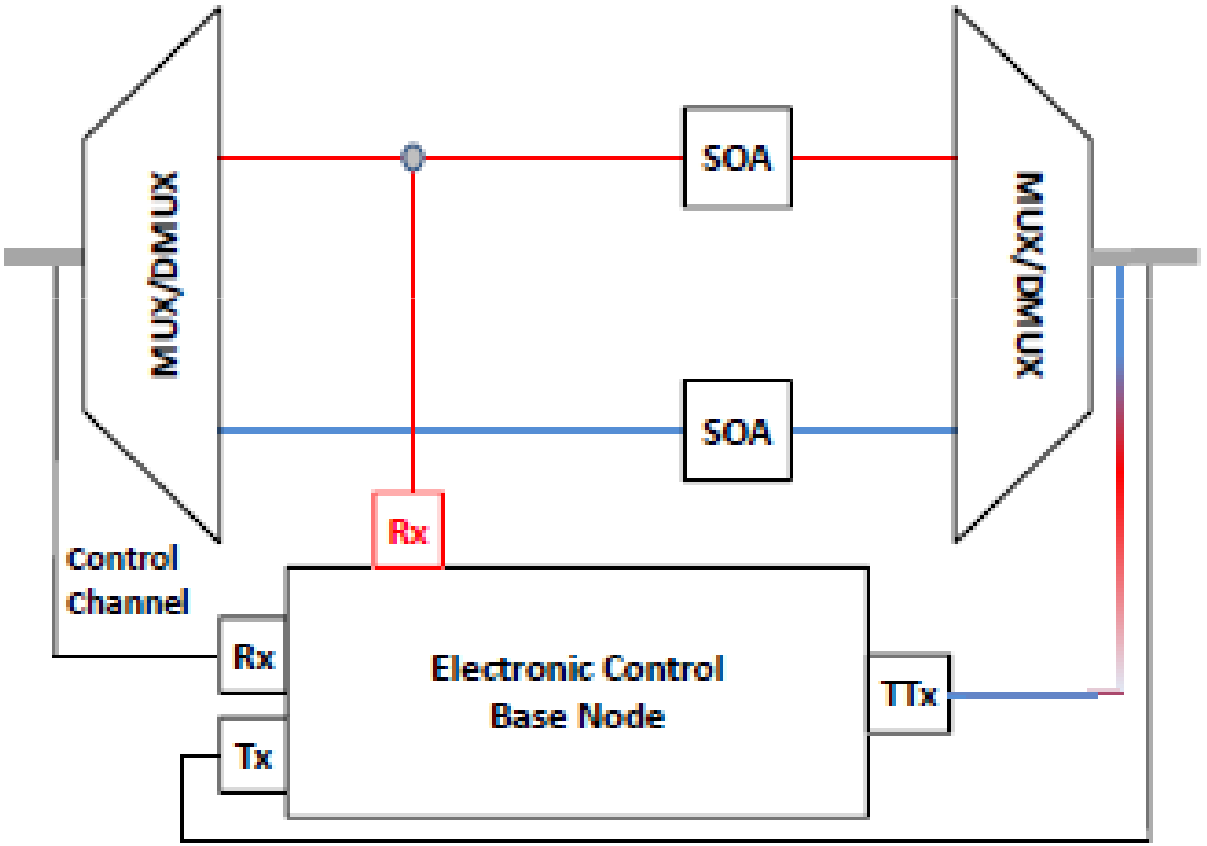
- 7 clusters of 60 nodes
- 7 controllers + receivers
- Total consumption: 4,8 MW
- Core consumption: 123 kW

- Total reduction: 25%
- Core consumption reduced more than 10 times!
- Conclusion? Get routers out of the core!

Thank you!

Any questions?

Optical Packet Add Drop Multiplexer



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ISP network power consumption

- ISP-like network:
  - Consumption of CRS-1 routers
  - Total consumption: 6.4 MW (1.7 MW transit routers)

Node	Power (kW)	Number	Total (kW)
Core	47	8	376
Regional	44	14	616
Metro	10	70	700
Edge	10	420	4200
Gateway	45	8	360
Peering point	38	4	152

Multipath network power consumption

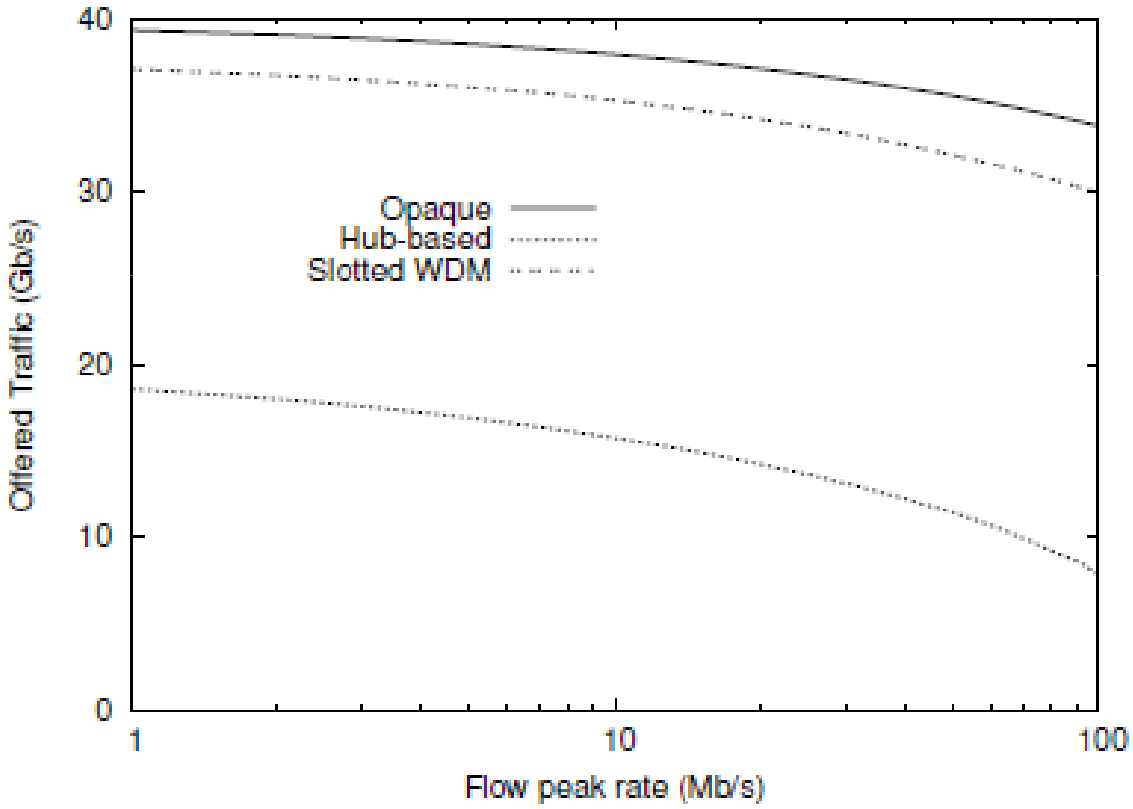
- Total power consumption: 123 kW

Equipment	Power (W)	Number	Total (kW)
Receivers	1.8	4200	7.56
Transmitters	1.2	840	1.01
Transponder Card	50	840	42
Controller	20	7	0.14
Optical cross connect	2500	7	17.50
Gateways increase (15%)	6750	8	54

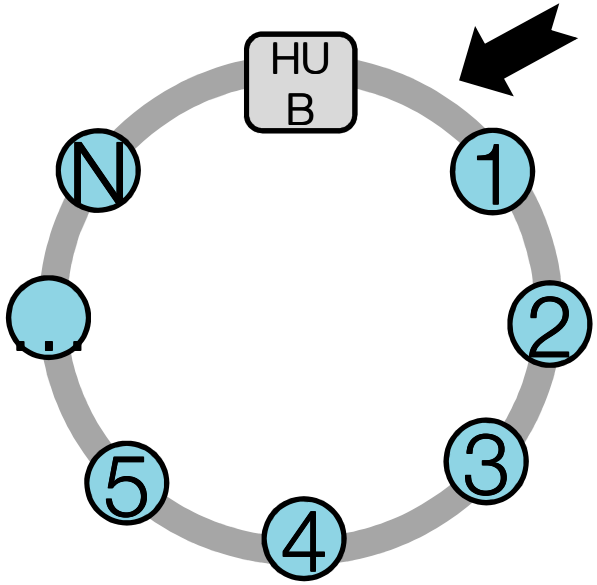
- Reduction of power 25%

Maximum sustainable traffic

- Congestion rate of 1%



Traffic capacity computation



- Opaque architectures
  - shared resource: link (20 Gb/s)

$$\sum_{i=2}^{N} \lambda_{i1} + \sum_{i=3}^{N} \lambda_{i2} + \ldots + \sum_{i=20}^{N} \lambda_{i19} < 20 \ \ \mathrm{Gb/s}.$$

- Slotted WDM
  - shared resource: wavelength (10 Gb/s)

$$\sum_{i=2}^{N} \lambda_{i1} + \sum_{i=4}^{N} \lambda_{i3} + \sum_{i=6}^{N} \lambda_{i5} + \ldots + \sum_{i=20}^{N} \lambda_{i19} < 10 \ \ \mathrm{Gb/s}.$$