Long –Term CAPEX Evolution for Slotted Optical Packet Switching

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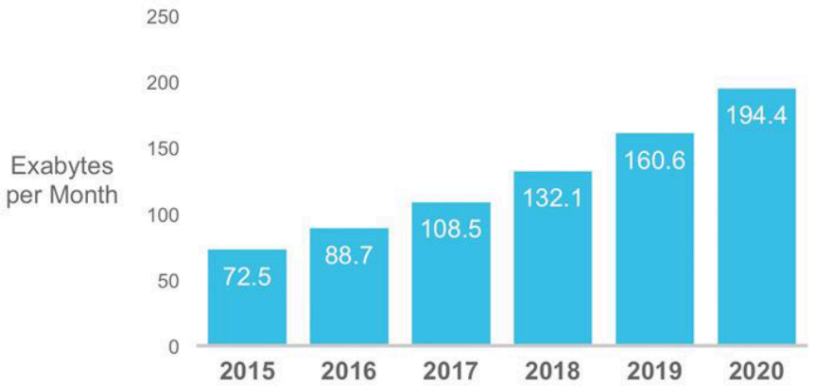
Ahmed Triki, Annie Gravey,
Philippe Gravey, Michel Morvan

Institut Mines Telecom – IMT Atlantique, Brest, France

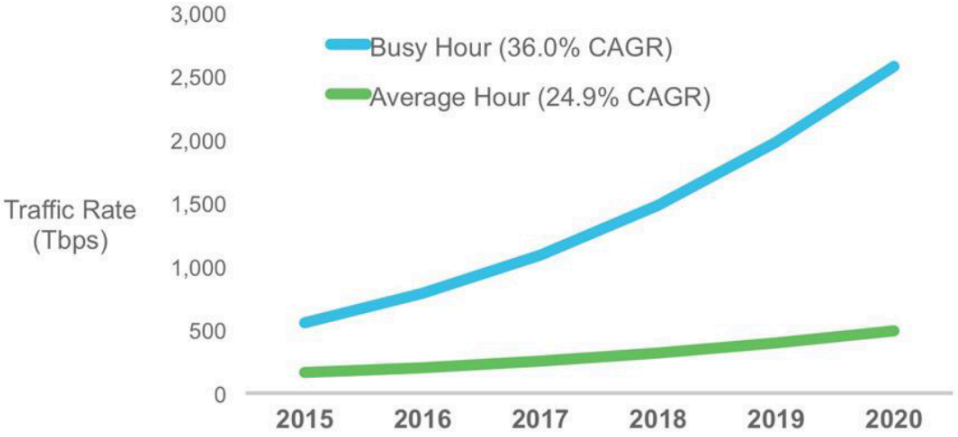
Outline

- Context
- Benchmarked technologies
- Network scenarios and cost models
- Results and Discussions
- Conclusion

IP traffic Growth



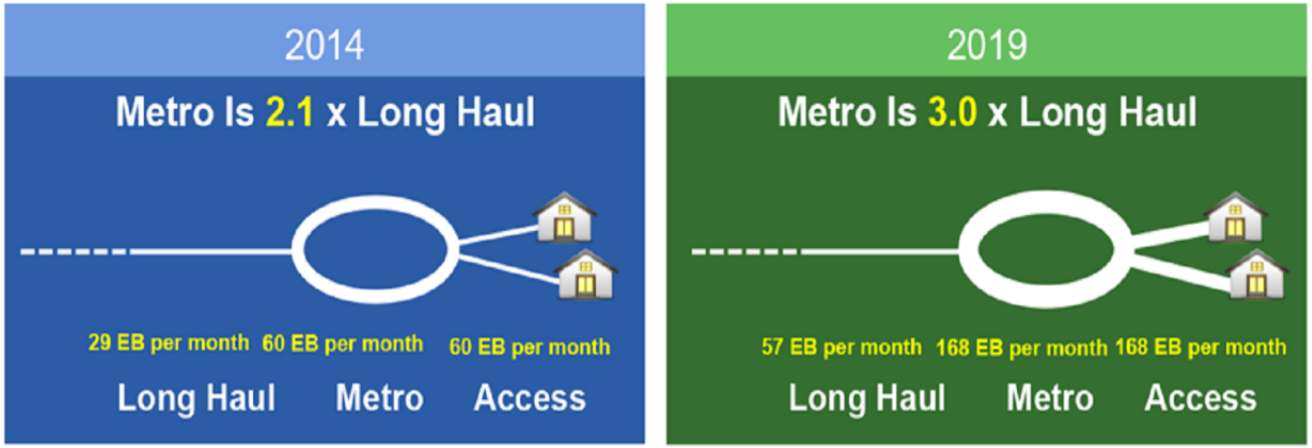
Source: Cisco VNI Global IP Traffic Forecast, 2015–2020



Source: Cisco VNI Global IP Traffic Forecast, 2015–2020

- The annual growth rate between 2015 and 2020 is roughly 25%.
- Fivefold increase of the busy hour IP traffic between 2015 and 2020.

Traffic Growth in the Metro Network



* Cisco, VNI, “The zettabyte era: Trends and analysis,” White Paper, 2015.

- Metro traffic increases even faster than Backbone (Long Haul) traffic
- The metro-backhaul networks will require
  - more bandwidth
  - flexible resource management

Slotted Optical Packet Switching

- **Slotted Optical Packet Switching architectures**
  - Designed to exploit the WDM dimension
  - Advanced control plane to avoid contention

- **Main characteristics**
  - More granular than Optical Circuit Switching architecture
  - More efficient than traditional Optical Burst Switching architectures (very low loss, even at high load)
  - Carrier-grade performance*
  - Cost and technological maturity?

* "*Carrier-grade performance evaluation in reliable metro networks based on optical packet switching",* A. Triki et al., Proc. of Int. Conf. on Computing, Networking and Communications, San Francisco, January 26-29 (2017)

Objectives

- **Cost assessment of three candidate slotted OPS technologies**
  - Time-domain Wavelength Interleaved Networking (TWIN)
  - Packet Optical Add/Drop Multiplexer (POADM)
  - Wavelength-Slotted Add/Drop Multiplexer (WSADM)

- **Method**
  - Use case: metro/aggregation network
  - Focus on CAPEX over 10 years
  - Benchmark: OTN/ROADM technology

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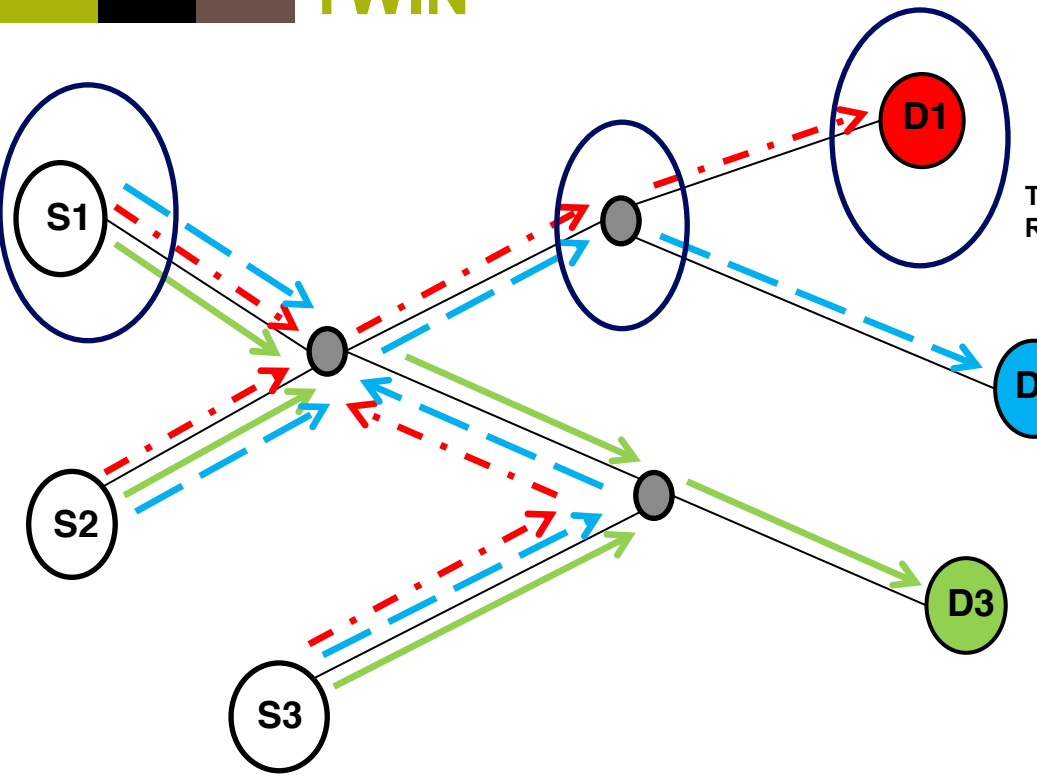
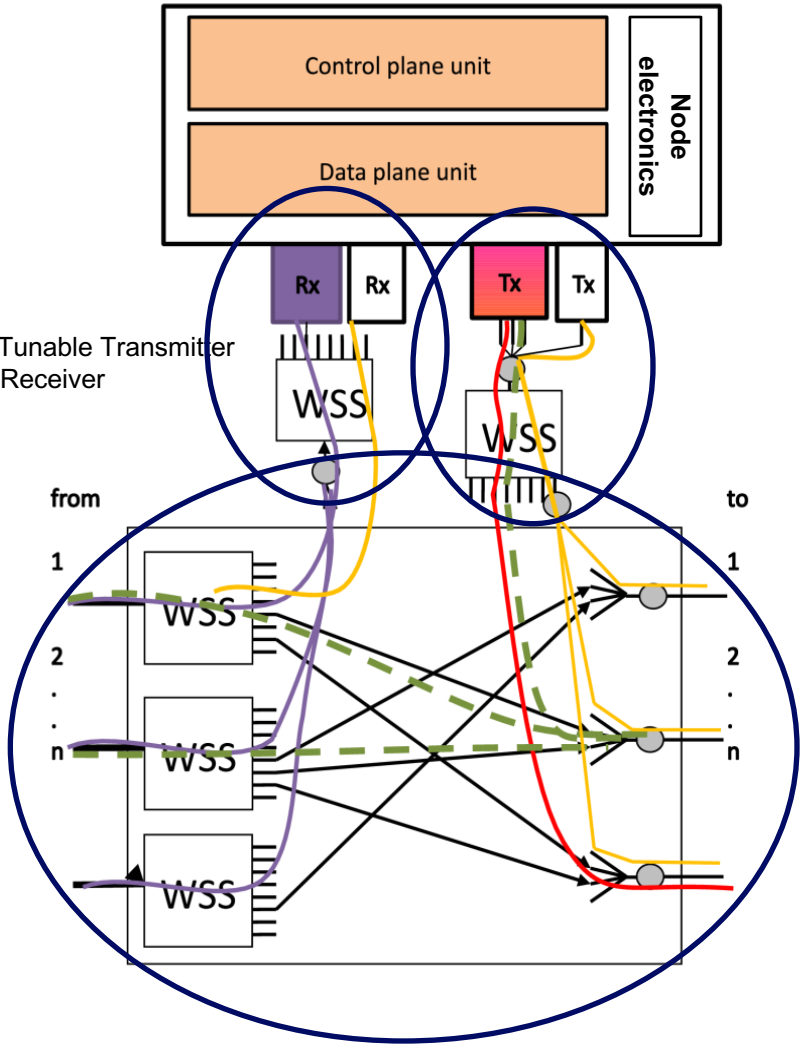
TWIN

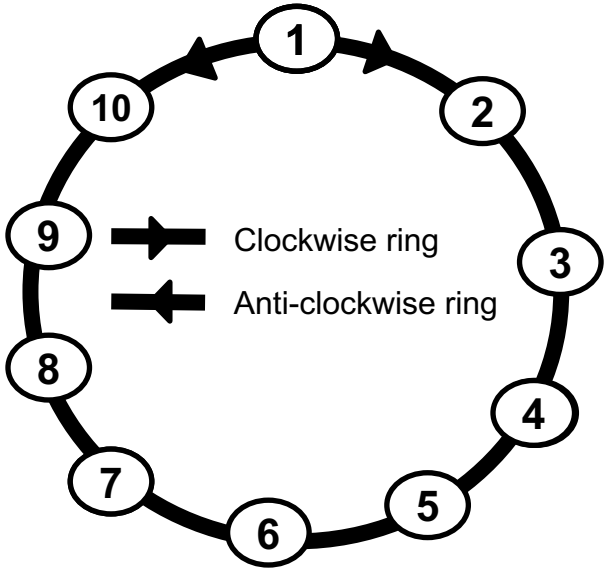


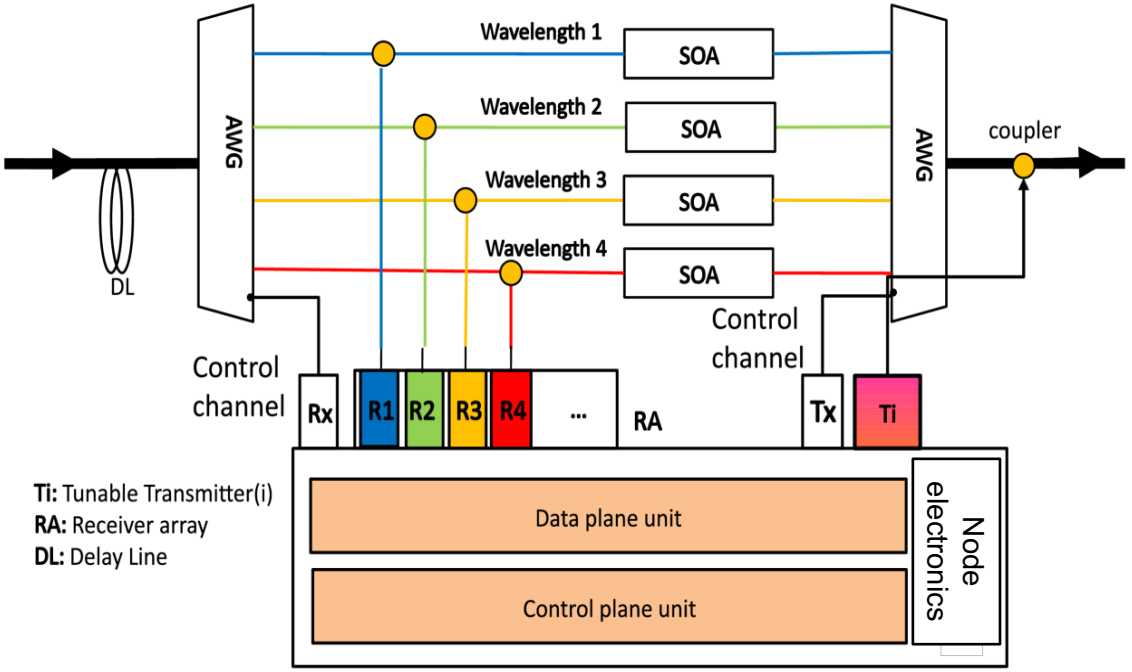


Tx: Tunable Transmitter
Rx: Receiver

- A wavelength per egress node: a TWIN network is a set of multipoint-to-point trees built on a **mesh network**
- Collisions are avoided by a **periodic schedule** applied at each source
- Intermediate nodes are passive (e.g. WSS-based ROADM)

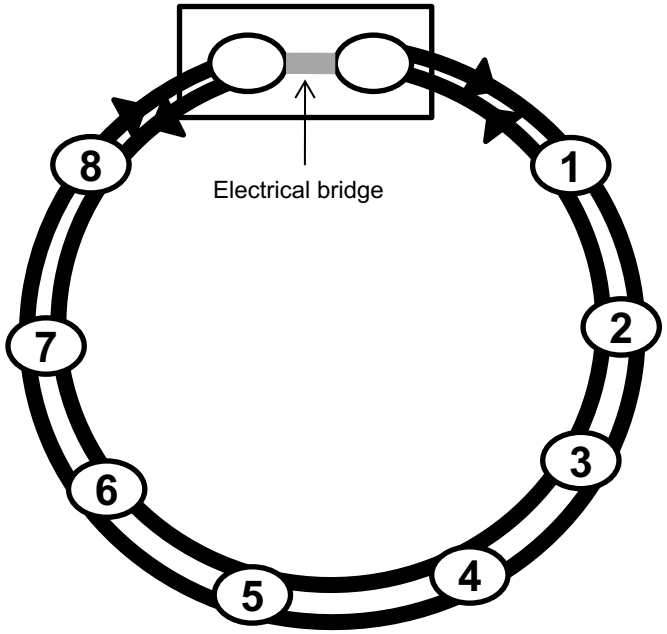
POADM

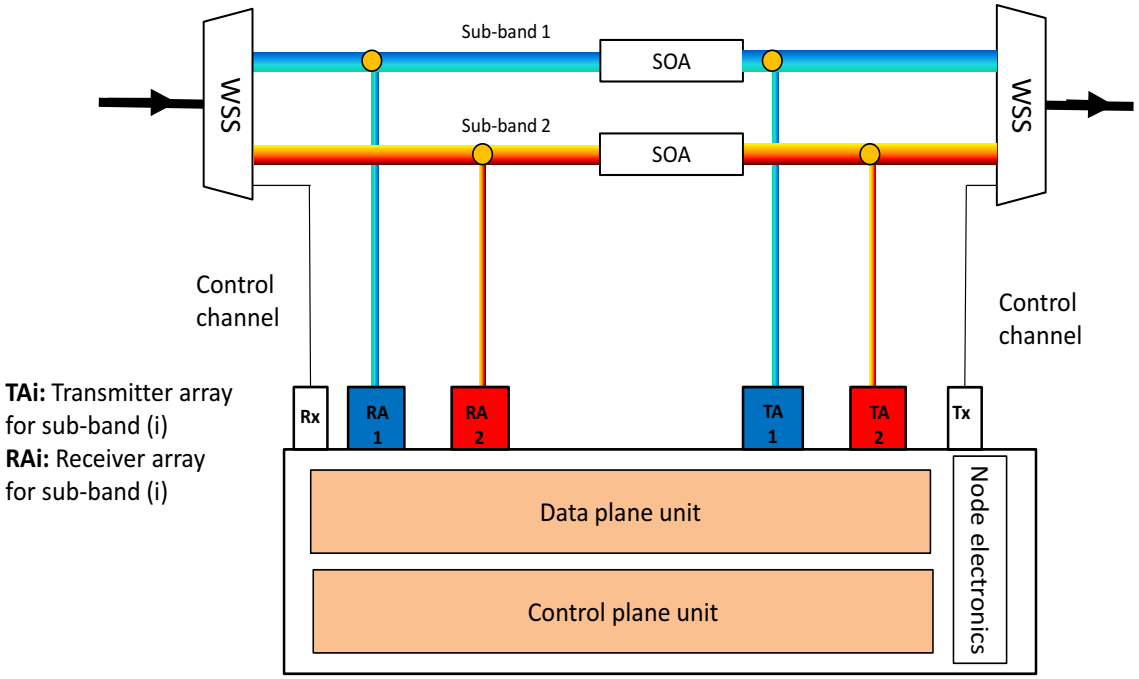




- **Synchronous** time-slotted access to the medium.
- Fixed-duration **time slot**
  - at most one optical packet per data channel,
  - one control packet carried over a control channel.
- Operation on a **bidirectional ring**
  - Each node selects the direction for sending optical packets based on the shortest path
  - In case of failure, traffic is rerouted in the opposite direction.
- **Opportunistic MAC and/or slot reservation**

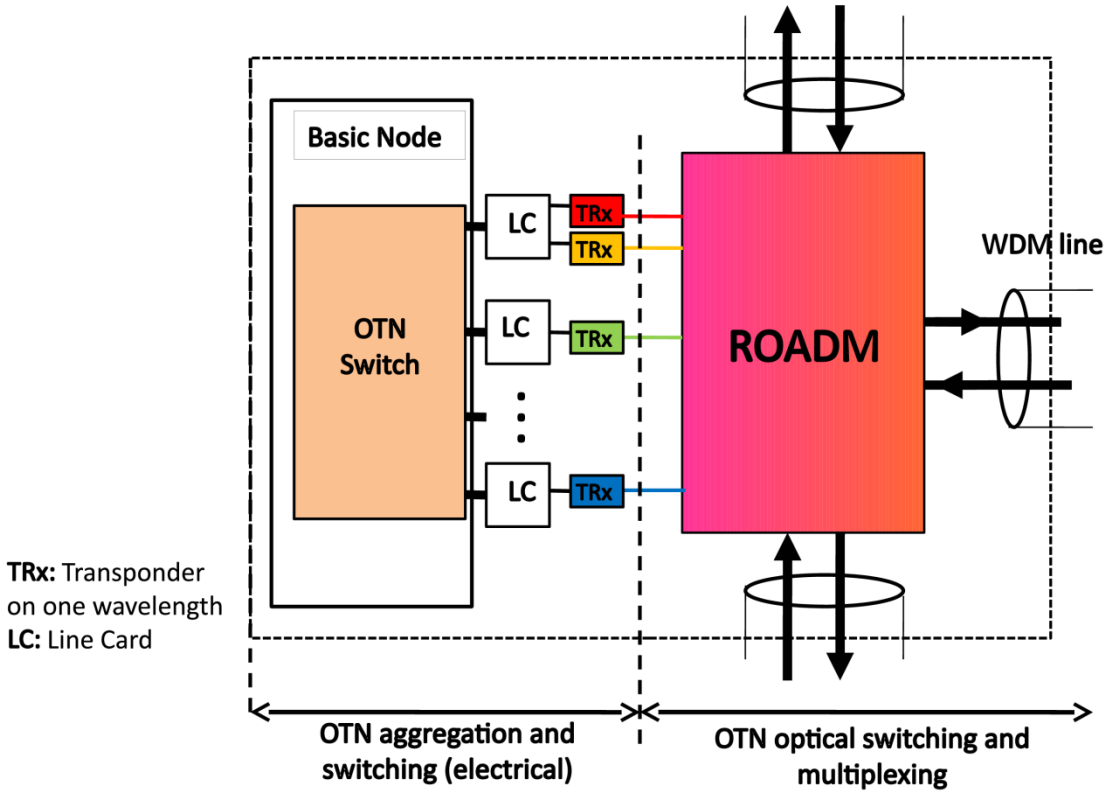
WSADM





- **Synchronous** and fixed-duration time-slots with a dedicated control channel
- **Multi-wavelength** packets
  - Arrays of fixed wavelength transmitters/receivers
- **Bidirectional ring**
  - **Opaque hub node**
  - Transparent route except in case of failure
- **Opportunistic MAC and/or slot reservation**

Benchmarking technology: OTN/WDM



- Sub-wavelength granularity with hybrid (OTN switch + ROADM) node

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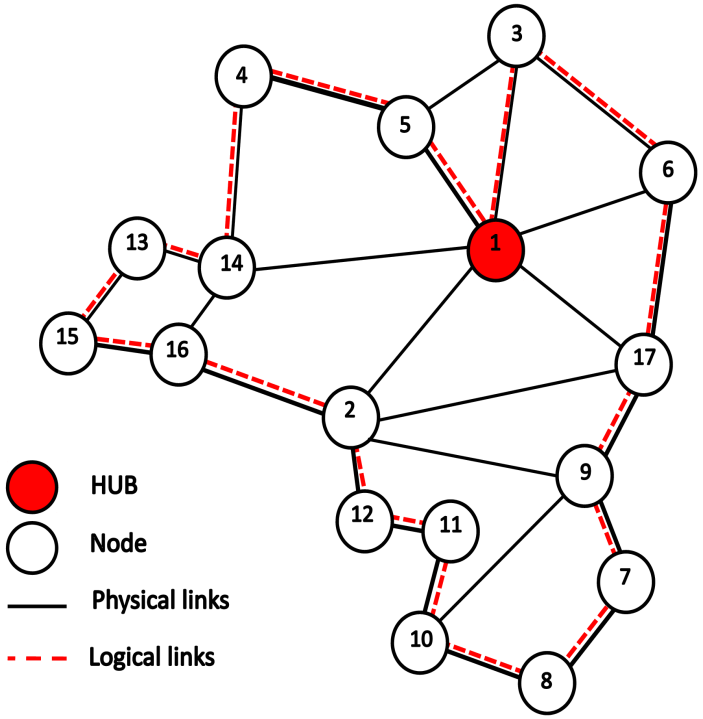
Network scenarios

- Network topology
  - Physical topology: 17 nodes and 26 links
  - WSADM/POADM logical topology: a single ring (~ 800 km)
  - TWIN logical topology: overlaid trees
  - Transparent or opaque OTN (shortest path)
- Hub-and-spoke (HAS) traffic scenarios
  - a “Hub” aggregates upstream traffic and distributes downstream traffic
  - the upstream traffic is the fourth of the downstream traffic
  - Homogeneous or heterogeneous traffic
- Realistic metropolitan traffic for 10 million users
  - 30% yearly growth over 10 years
- Dimensioning with heuristics
  - Less than 80% occupancy rule for wavelength (POADM & WSADM) or TRx (TWIN & OTN)



Cost model

Components	TWIN	POADM	WSADM
Node electronics	4	4	4
Array of 10 fixed TRx – 10G			5
Array of 10 fixed TRx – 100G			35
Tunable Tx – 100G	24	24	
Rx – 100G	6		
Array of 10 Rx – 100G		18	
SOA		0.4	0.4
WSS	4		4
AWG		0.9	
Fixed TRx – 10G (control plane)	1	1	1
Wavelength cost (/km.year)	0.004	0.004	0.004

Components	OTN &ROADM
OTN switch (8 slots)	5
OTN switch (16 slots)	7.3
OTN switch (32 slots)	12
OTN switch (64 slots)	30
OTN switch (128 slots)	75
Line card 1× 100G	12
Fixed wavelength TRx (100G)	8
N-degree colorless ROADM (N≤9)	N×16.8
N-degree colorless ROADM (9<N≤20)	N×20.8
Wavelength cost (/km.year)	0.004

F. Rambach et al., JOCN, Vol. 5 (2013)
M. Angelou et al., OFC 2012

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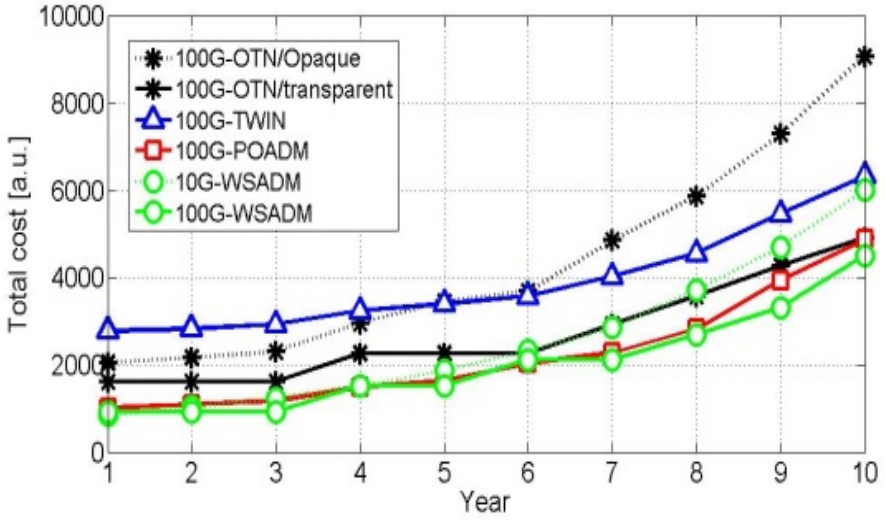
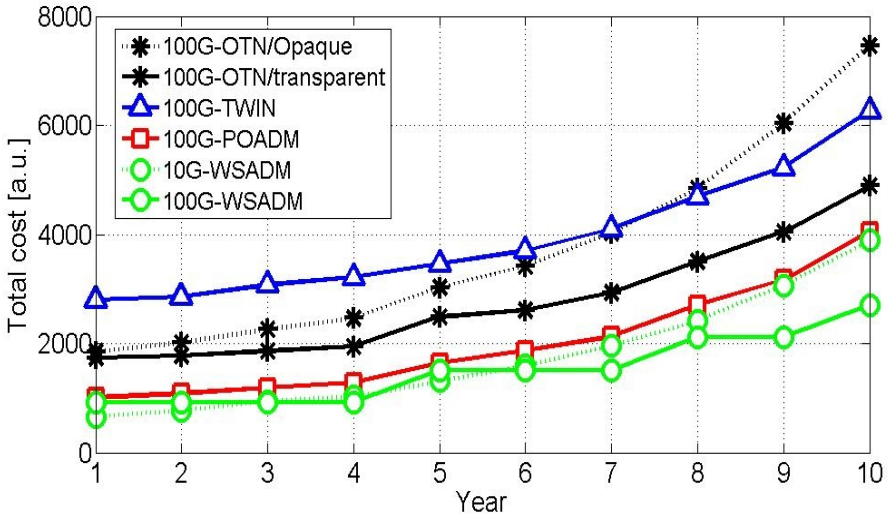
Total cost over 10 years

Homogeneous traffic



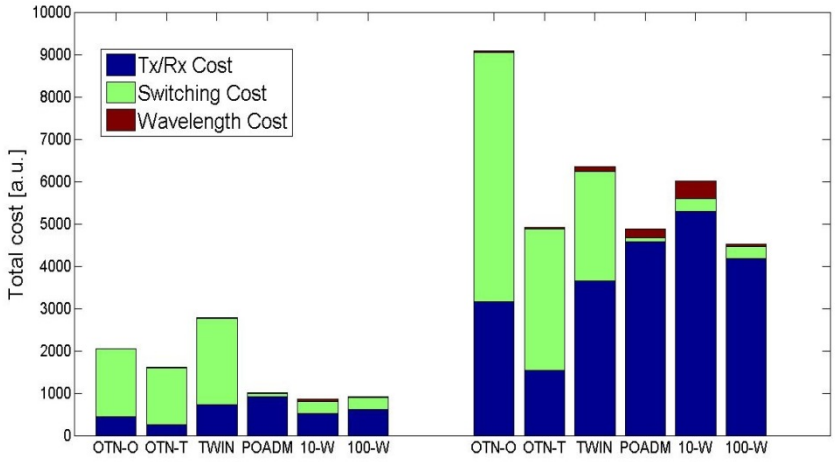
Heterogeneous traffic



- 100G-WSADM (with 100G / λ) provides the lower cost, especially for heterogeneous traffic
- TWIN is the most expensive OPS technology
- Transparent OTN scales better than opaque OTN
- POADM could compete with WSADM for homogeneous traffic

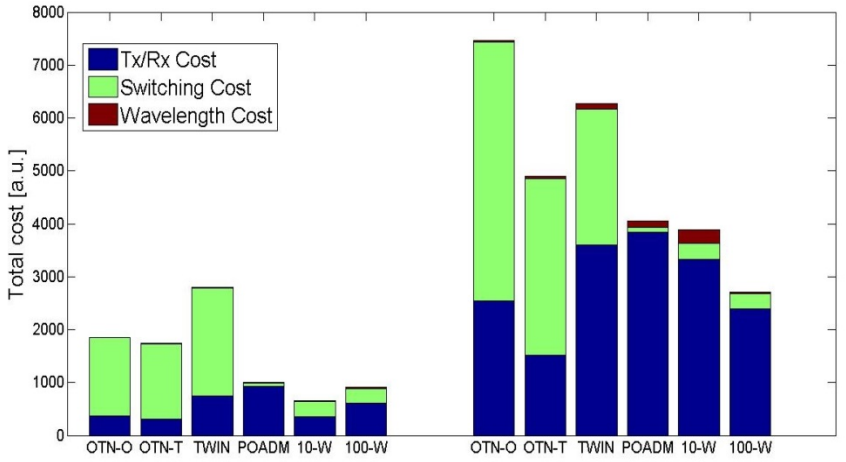
Cost decomposition

Homogeneous traffic



Year 1 Year 10

Heterogeneous traffic

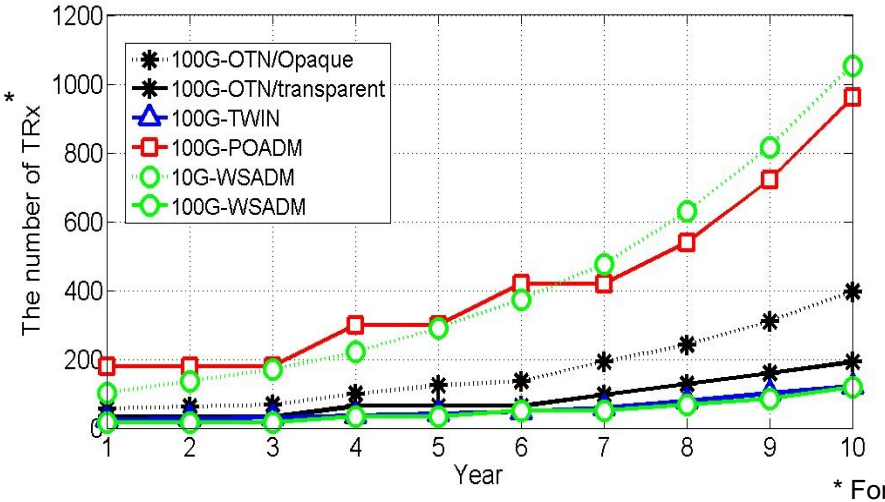


Year 1 Year 10

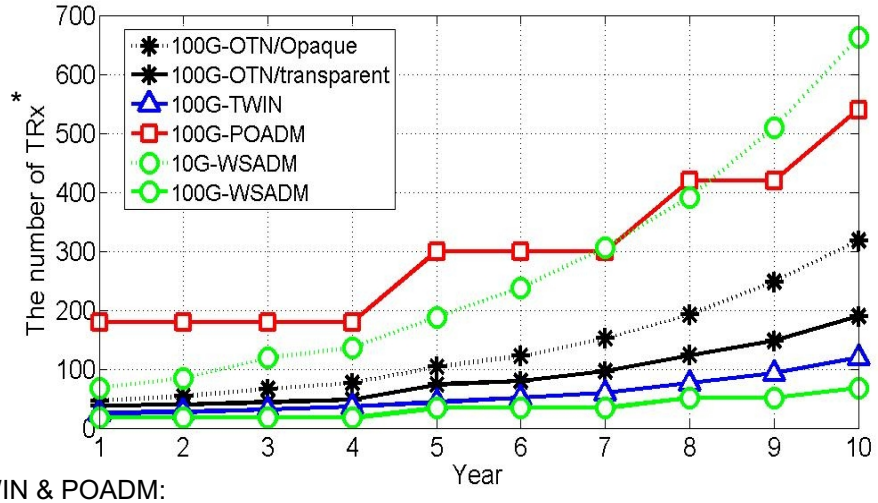
- Switching costs always dominate for OTN
- TWIN cost is impacted by the passive part of the node (multi-degree ROADM)
- The lower number of TRx in 100G-WSADM results in lower cost at the end of the considered period
- Wavelength cost remains low

Number of transponders

Homogeneous traffic



Heterogeneous traffic

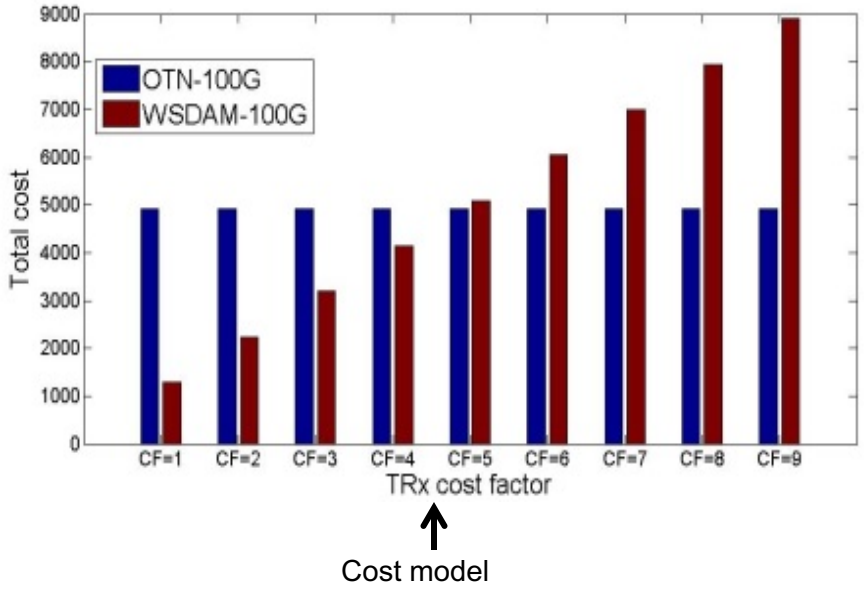


* For TWIN & POADM:
Max (Number of Tx, number of Rx)

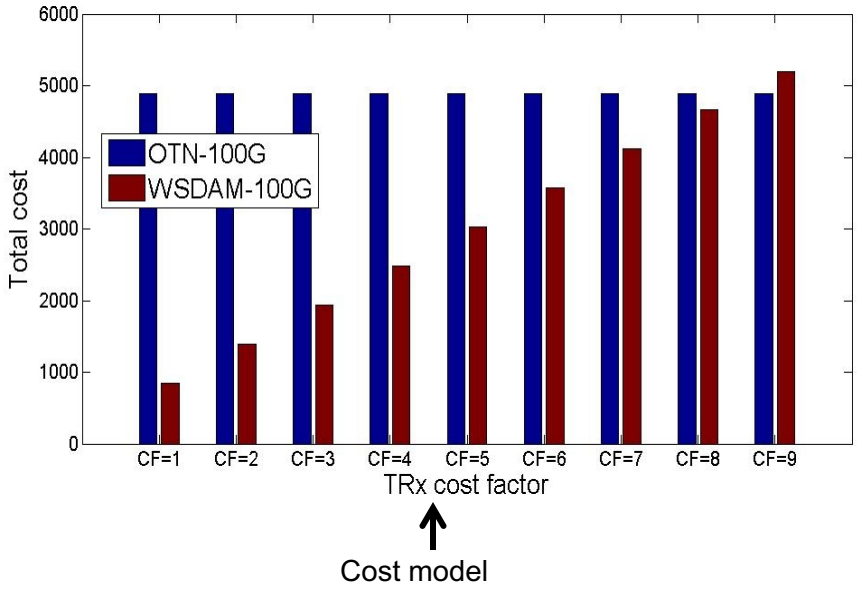
- The number of TRx is higher for 10G-WSADM and POADM that use many device arrays but impact on cost is low thanks to the benefits of integration.

Impact of array vs single transponder cost

Homogeneous traffic (year 10)



Heterogeneous traffic (year 10)



- The total cost depends on the cost factor between an array of 10 TRx and a single TRx. In the heterogeneous (resp. homogeneous) traffic case, WSADM-100G is cheaper than OTN-100G for a cost factor up to 8 (resp. 4).

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Conclusion

- Wavelength Slotted Add/Drop Multiplexer technology seems very promising as a cost-effective solution for metro/aggregation network
  - Cost effective compared to OTN and other slotted OPS technologies
  - Use of WDM packets on-line with trends in optoelectronic integration
- The results are based on well-consolidated cost models and are quite robust for the considered use case
- They could be different with major changes among the main hypothesis, e.g.:
  - In a core network with more distributed traffic, the efficiency of TWIN would be improved
  - In metro-access or X-haul networks, 10G-WSADM would probably be cheaper
  - Wavelength cost depends highly on the local context

QUESTIONS?

We acknowledge our n-green partners!