

# Potential of WDM packets

ONDM 2017, Invited paper

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- 17-05-2017

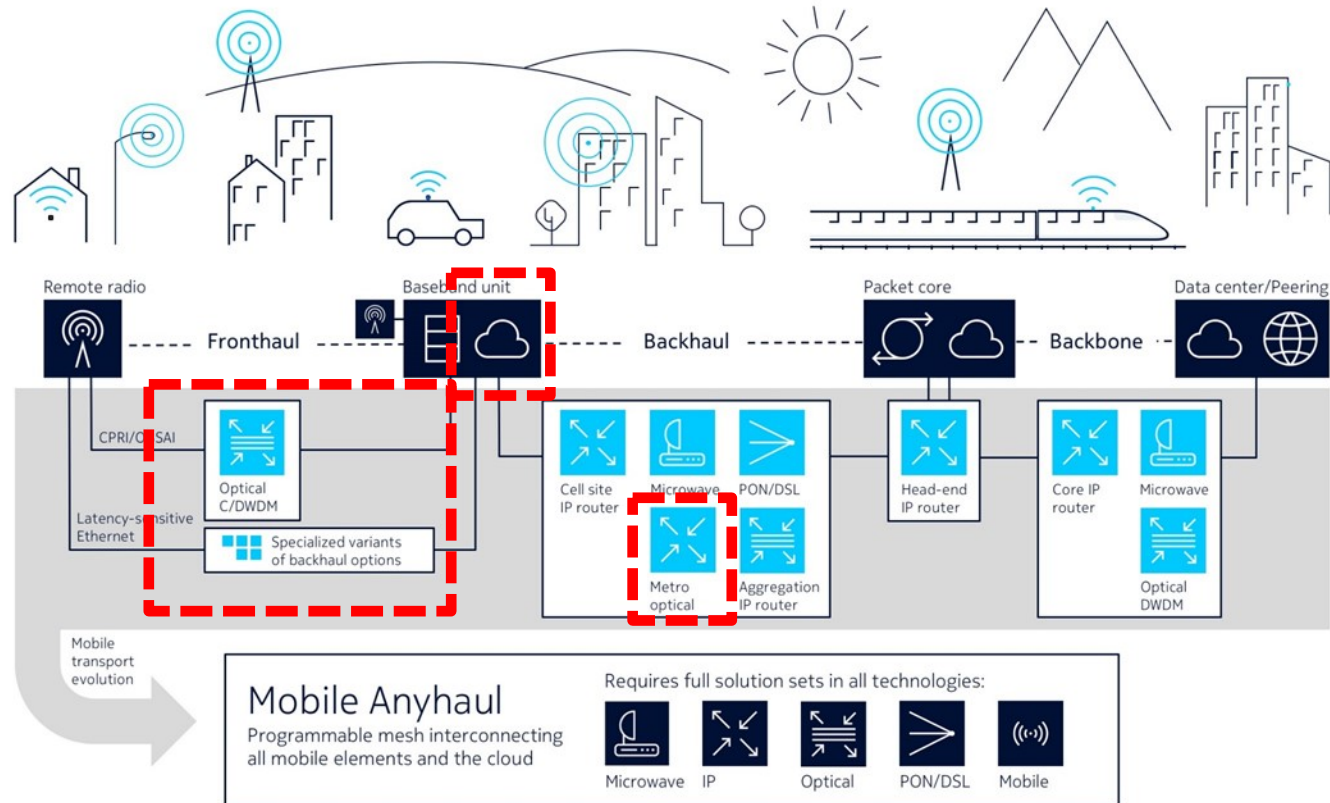
# Outline

- Introduction
- Optical technology potential: recall of the main directions adopted
- Towards WDM packets
- Previous tentatives for WDM packets
- Where WDM packets and advantages expected?
- Previous tentatives to reduce the complexity of OADMs
- N-GREEN in few words
  - N-GREEN project objectives
  - WSADM technology
  - Benefits of WDM packets
  - WSADM results
  - Modular Self-protected WDM backplane based on WDM packets
- Conclusion

# Introduction

- Need for new approaches for the ICT
- Main motivations:
  - The **traffic will grow mainly in the metro area in the next decade**, where new constraints have to be taken into account:
    - **Easy scalability and capacity**
    - **Energy consumption**
    - **Cost issues**
    - **Ultra-low latency for 5G**
  - **Provide “zero latency” interconnection systems for data centers**
  - **In the core, need to identify new technologies to support 100Tbit/s+ switching capacities for longer term approaches**

# 5G: new opportunities for optical technologies



- Orange labs presented at PS2015 a study comparing electrical aggregation versus optical aggregation
- The result is that, at any traffic scale, the optical technology designed for core networks does not show strong cost reductions when compared to electronic aggregation
- In cost sensitive areas, dominated by electronic technologies, like the aggregation, there is a need for a different approach and technology



# The energy is also a big issue

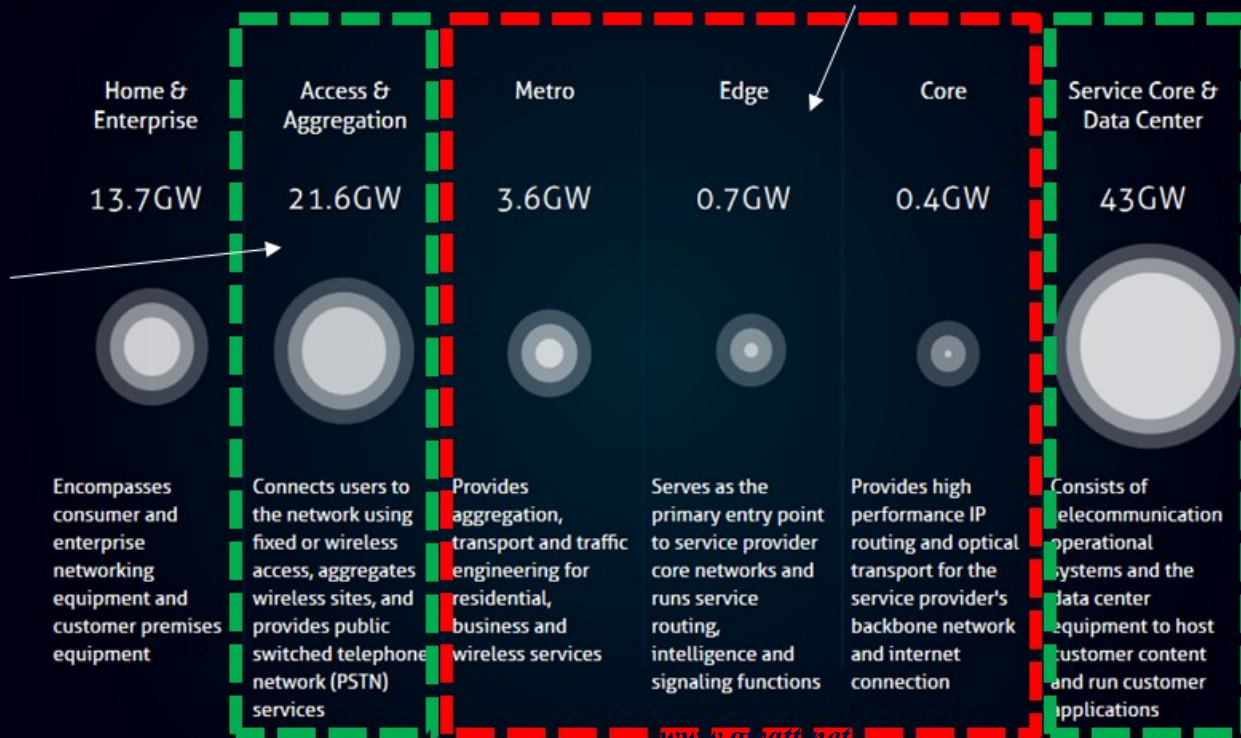
As of 2013, world-wide telecommunications networks consumed around 83 gigawatts, the equivalent of 12 New York Cities.<sup>5</sup>

Less sensible to high energy efficient technologies

NEXT >

SKIP >

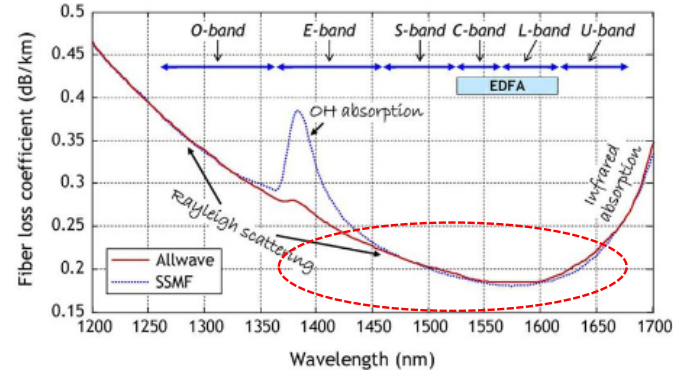
Need for high energy efficient technologies



# Optical technology potential: recall of the main directions adopted

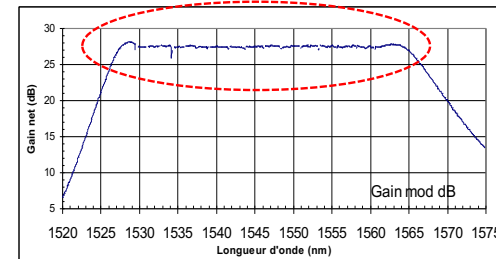
- When trying to find new optical solution helping electronic to go beyond in terms of bit rate and capacity, one dimension makes a big difference: the **optical bandwidth**
- The exploitation of the wide optical bandwidth is at the origin of the success of optical technologies:
  - The first one is the **fiber**, offering **Tbits of optical bandwidth** to transport capacities, with several order of magnitude higher than a coaxial cable
  - The second one is the **optical amplifier** allowing an **amplification of ten's of wavelengths**

Need to come back to the fundamentals to better exploit optical technologies



Silica glass fibers provide extremely low-loss transmission over tens of Terahertz!  
- contrast to electrical cables: 100s of dB/km loss (at GHz frequencies)

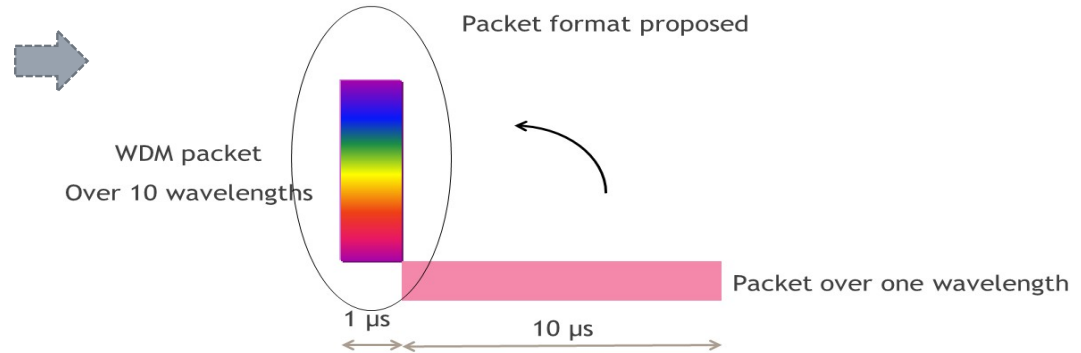
R.-J. Essiambre, G. Kramer, P.J. Winzer, G.J. Foschini, and B. Goebel,  
"Capacity Limits of Optical Fiber Networks," Journal of Lightwave Technology 28, 662-701 (2010)



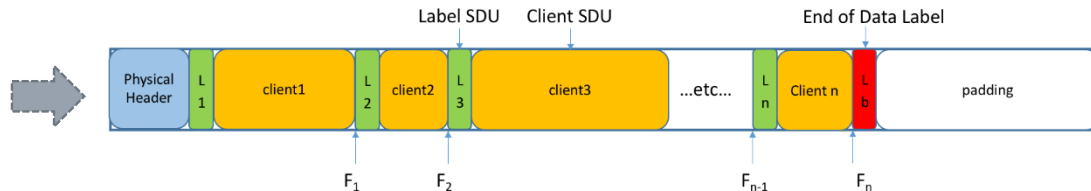
EDFA optical  
bandwidth after  
equalisation

# Towards WDM packets

- **A WDM packet is a packet encoded over N wavelengths**
- The packet can have an **in-band header** or an **out-of-band header**
- In the case of an out-of-band header, and a fixed duration data packet; the packet is called **slot**
- **Each wavelength has a specific format** to support a burst reception. It includes in particular a **guard band** and a **preamble**.



Zoom on one wavelength

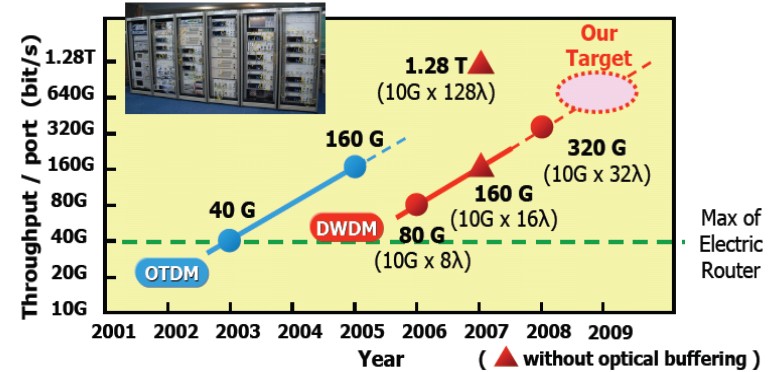
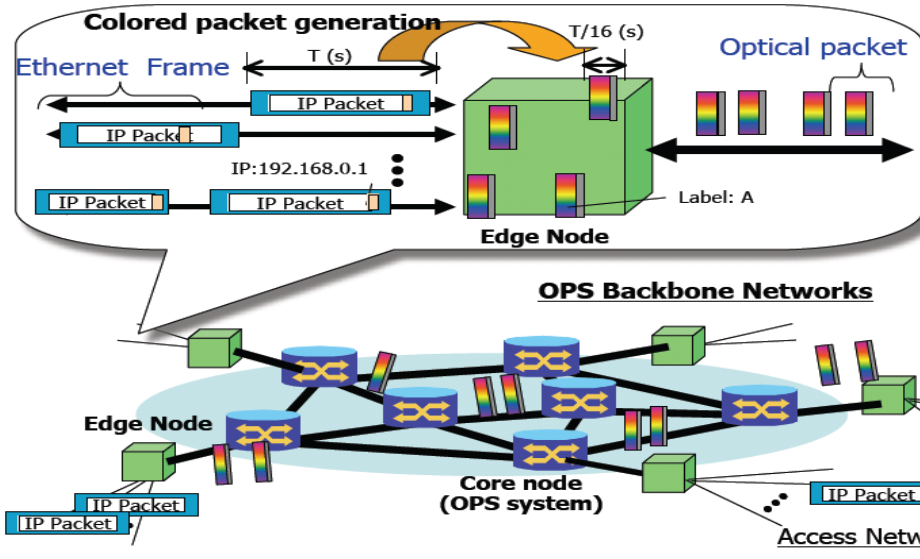




# Previous tentatives for WDM packets

## Prof. Naoya Wada et al.:

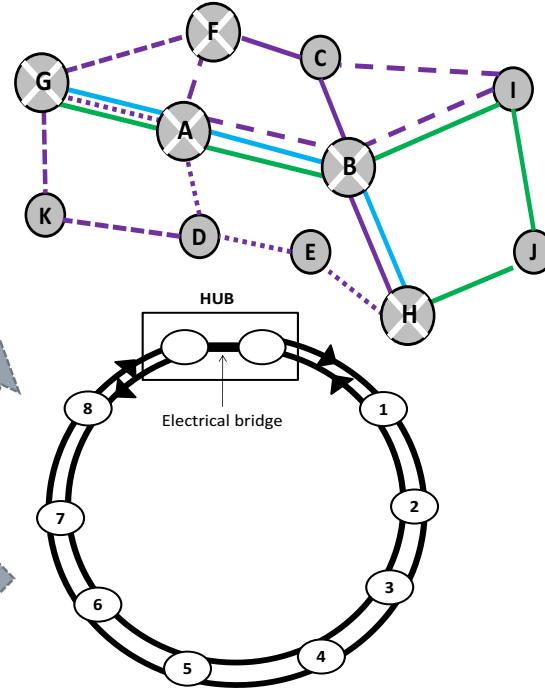
- Proposal for **multi-color packets** to increase the transport capacity without impacting the distance



Naoya Wada, "WDM-colored Packet Switching," OFC/NFOEC 2008, OWL1, 978-1-55752-855-1/08. San Diego, USA, Feb. 2008, courtoisie

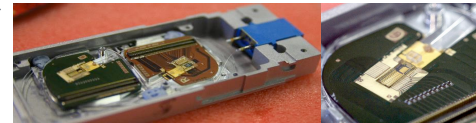
# Where WDM packets ?

- **WDM packets will better exploit the existing optical bandwidth** to create a strong differentiators with respect to electronic technologies
- **WDM packets** are suitable for network segments:
  - targeting **ultra-high transport capacities over long distances**
  - In the **aggregation network segments**
- Fundamental advantages of the approach:
  - **WDM packets require WDM TRX**, which goes in the direction of the industry to satisfy the needs of the access or the data com
  - **WDM packets reduce dramatically the complexity of the system managing the optical bypass**



Long haul  
backbones,  
with mesh  
topologies

Ring  
topology for  
access  
aggregation,  
fronthaul,  
backhaul and  
metro



CFP2 10x10G TRX  
module proposed by Effect  
Photonics, (*Robert Hughes  
courtoisie*)

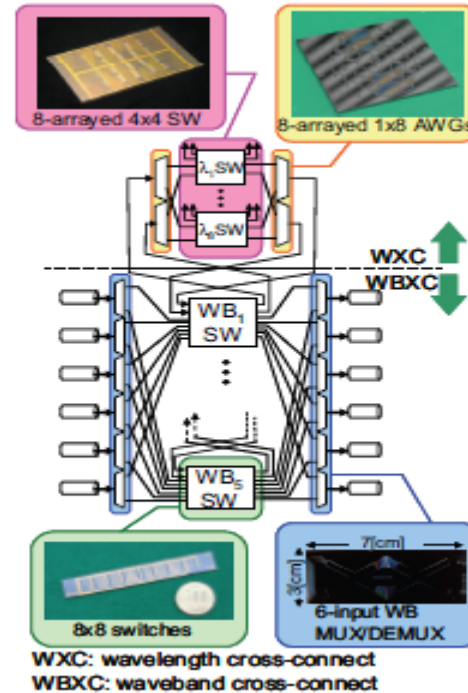
**NOKIA** Bell Labs

# Previous tentatives to reduce the complexity of OADM

*Kiyo Ishii, Osamu Moriwaki, Hiroshi Hasegawa, Ken-Ichi Sato, Yoshiteru Jinnouchi, Masayuki Okuno, Hiroshi Takahashi, "Efficient ROADM-ring connecting node switch architecture that utilizes waveband routing and its realization with PLC technologies," in ECOC 2009, Sept. 2009. Courtoisie*

## Prof. Ken-Ichi Sato et al.:

- **Sub-band optical cross-connects** were initially proposed to make OADMs more compact
- Several studies have been done, in particular through **multi-granular OADM** splitting the granularity into:
  - Fibers
  - Sub-bands
  - Wavelengths
  - Packets



Hybrid Optical Cross-Connect

# An historical tendency of the optical packet switching technology: from complexity to simplicity

## In the 1990's strong emphasis in All-Optical Networks

- Exploration phase for the optical technology.  
Only point to point systems are deployed

## In the 2000's, reorientation towards hybrid systems and networks

- The optical technology is investigated as a complementary technology to electronics.  
ROADMs are introduced in the network.

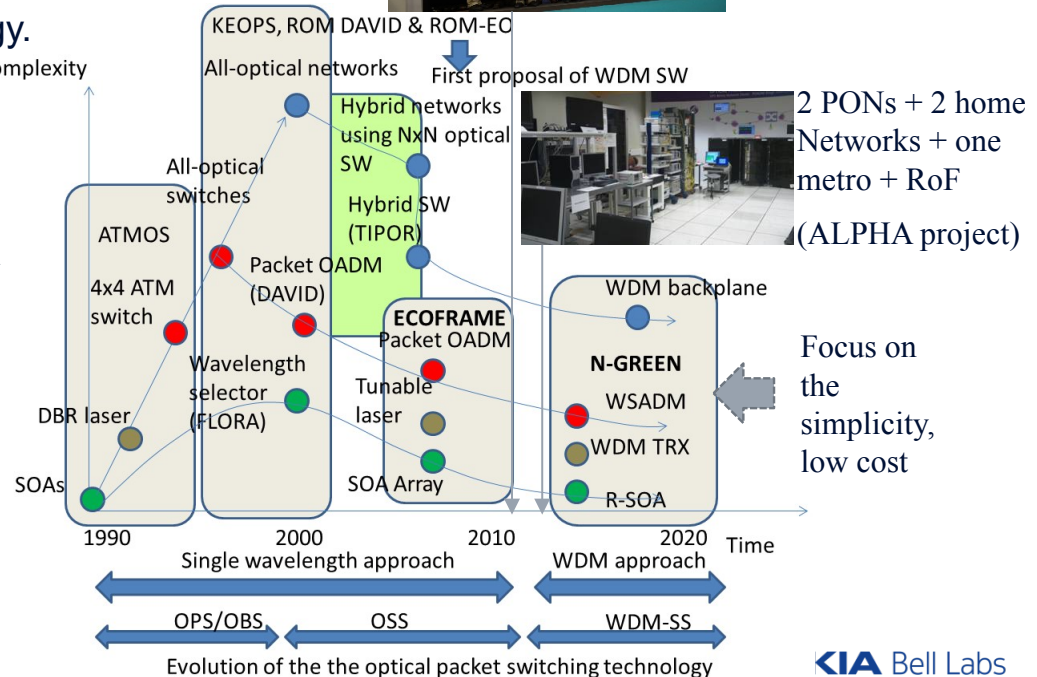
## In the 2010's, second reorientation for more simplicity

- Strong emphasis in the optical integration, and in the simplification of the systems.  
Opportunity for new products.



ECOC 2010

Interconnexion of 2 ring networks at the exhibition of ECOC with NTT labs



# N-GREEN project in few words: New-Generation of Routers for Energy Efficient Networks



Type of project: PCRE (Collaborative project between Univ. and Entreprise)

Real cost: 2,096 Meuros

Founded: 632,7 Keuros

Sponsors:

Duration : 2-3 years, T0 : January 2016

Partners:

- Alcatel-Lucent Bell Labs France project leader, WP0 leader and WP2 leader
- III-V Lab : WP4 leader
- Institut Mines Telecom (IMT) : WP1 leader
  - Including : Telecom ParisTech, Telecom Bretagne and Telecom SudParis
- University of Versailles : WP3 leader



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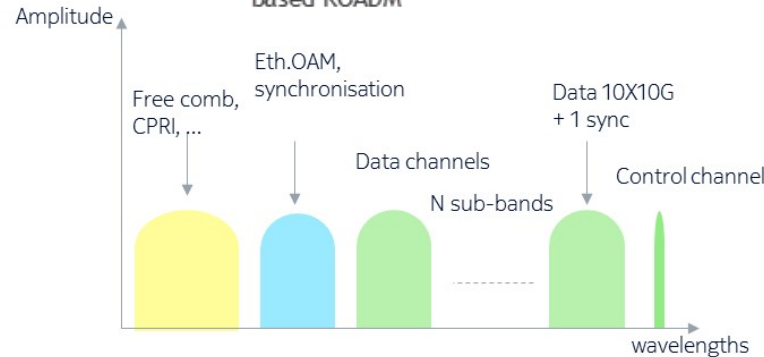
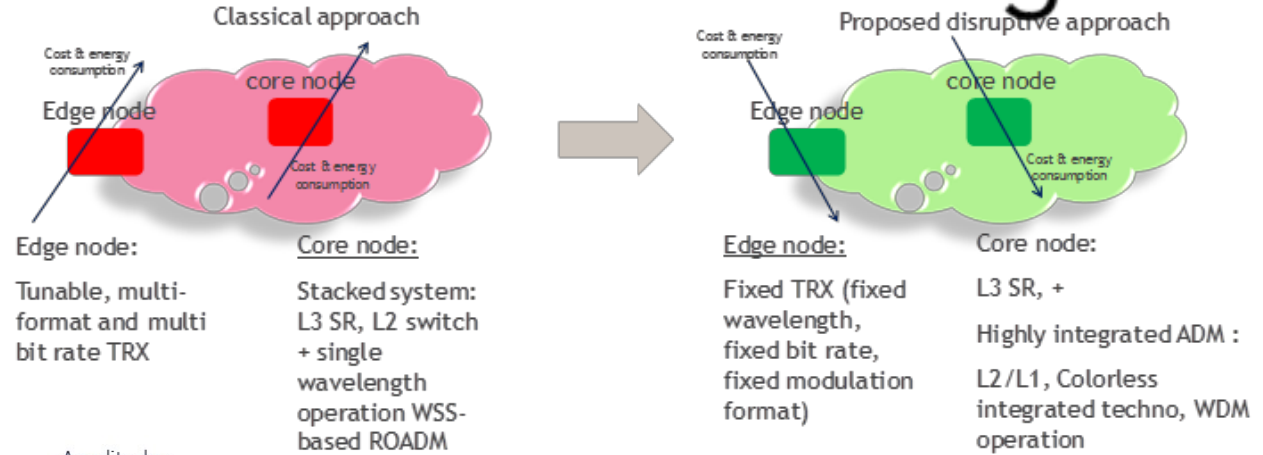


Technical objective of the project: demonstrate the feasibility of two innovations:

- **“WDM Slotted Add/Drop Multiplexer for a dynamic optical bypass”**
- **“Self protected high capacity (>100Tbit/s) and fully modular WDM backplane for switch/routers”**

# N-GREEN project objectives

- **Desire to reduce the cost and the power consumption of metro networks**
- **Towards a simplified technology compliant with the existing one**
- **Look for new opportunities to target new market shares**

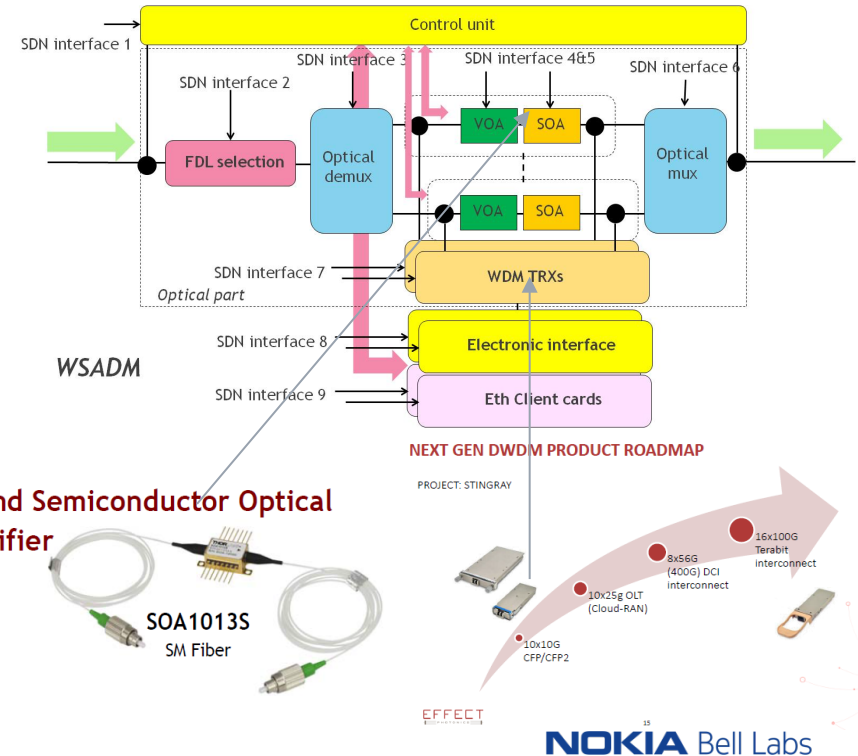


Sharing of the spectrum to support different technologies

**xhaul applications for 5G**

# WDM Slotted Add/Drop Multiplexer (WSADM)

- WDM packets are proposed to realize very **simple Add/Drop multiplexers**
- **Modular structure** operating at a **frequency / 10** through a optical parallelism
- System composed of **transparent boards** and bit rate dependent boards
- Programmable system **supporting L2 protocols but also Broadcast-and-Select mechanisms (L1.5)**
- Optical components available on the market place or in the roadmap of component makers

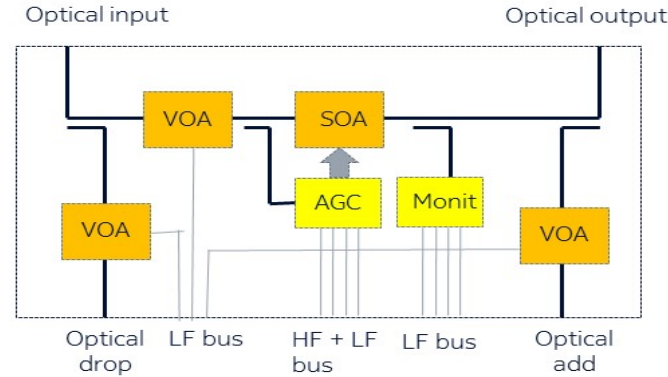




# Benefits expected



- **Simplified optical technology:** no need for critical components : fast tunable lasers or wavelength blockers
- Towards a **simple optical add/drop multiplexer** architecture
- Lower **frequency electronic** interfaces
- **Better network performance**
- **Easy upgrades** offered
- **Compliant with SDN** through programmable systems



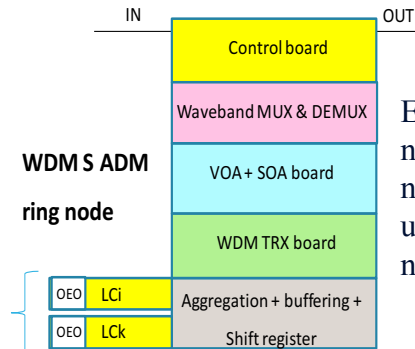
Very simple board to manage 100's of Gbit/s



Boards designed for a long life time

Modular boards

Client boards



Easy upgrade: no need to open the network to upgrade the node capacity

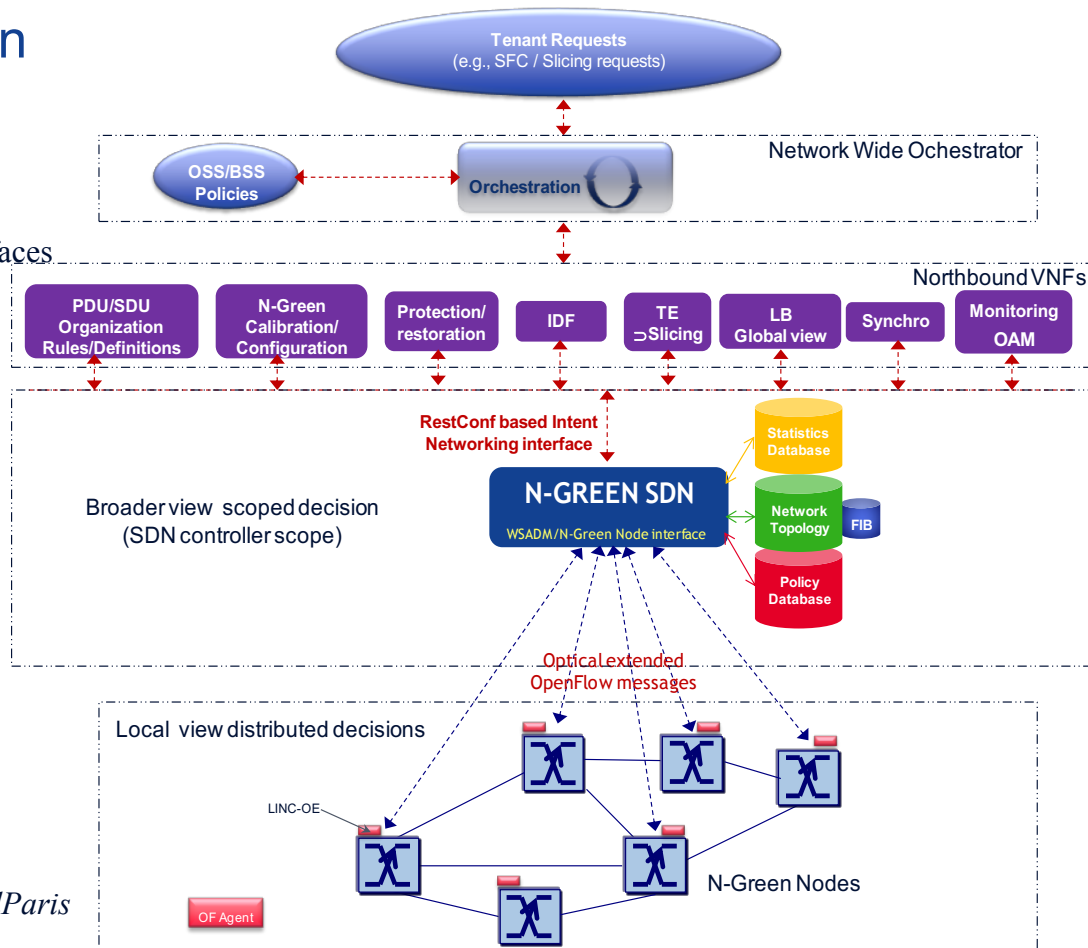


# SDN orchestration

## SDN

Identification of SDN interfaces

Proposal for the SDN orchestrator



Djamal Zeglache, Telecom SudParis

# CAPEX + OPEX of the WSADM technology

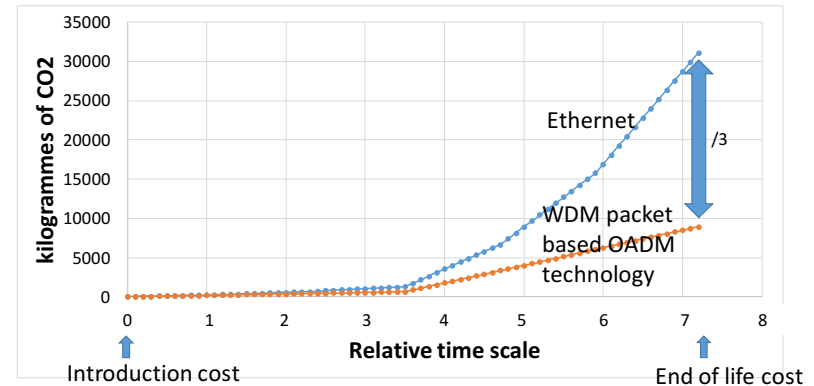
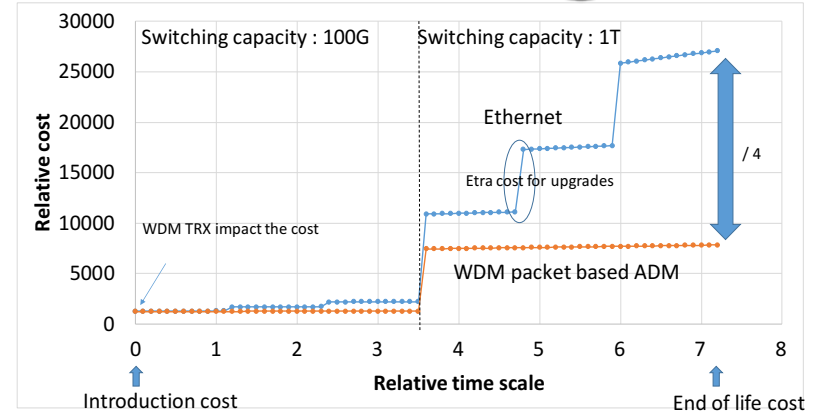


## Benchmarking for one node

- At the installation, the WSADM technology has the same introduction cost for a higher capacity
- The management of the capacity growth is performed by the SDN control plane
- The Ethernet requires regular on site upgrades, increasing the OPEX
- When changing the bite rate, the cost gains are even higher for WSADM, since a part of the node is not changed (control + mux/demux+ VOA&SOA boards).

## Reduction of CO2 emissions

The WSADM node emits less CO2 than the Ethernet technology



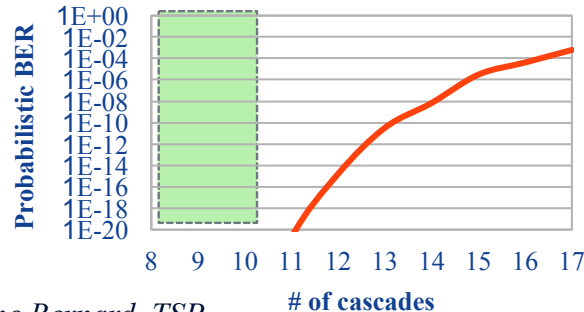
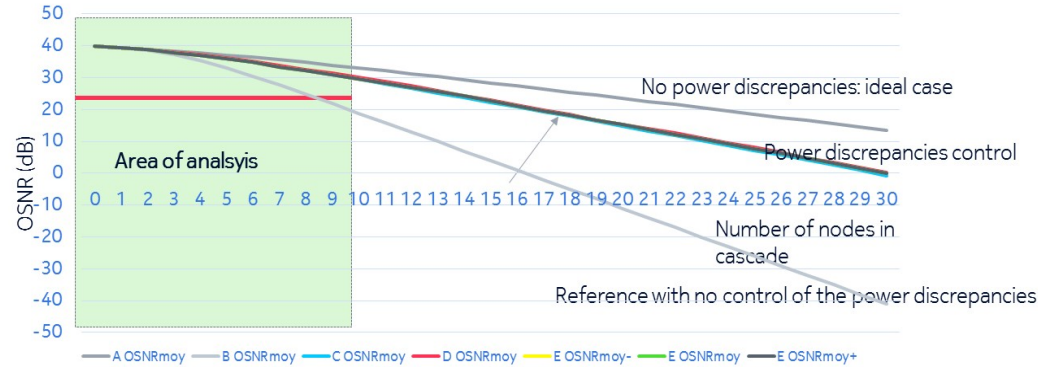
Julien Violet, Franck Plazanet & Mathieu Lucas, TSP

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# Physical performance of the WSADM technology



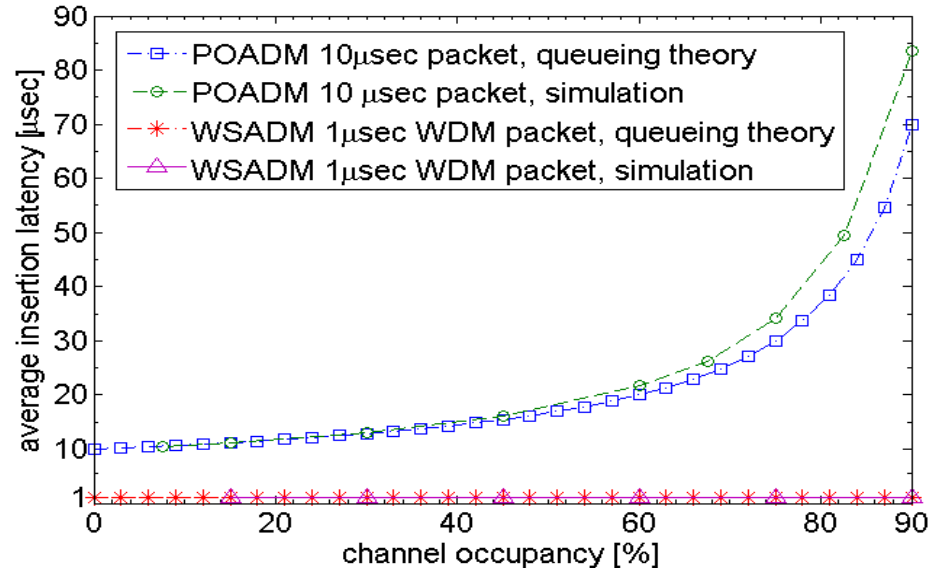
- Use case under study:
  - **Fronthaul/backhaul for 20 km of circumference**
  - **10x10Gbit/s TRX**
  - **SOA** with linear characteristics
- Cascade of nodes taking into account power discrepancies of slots, applying some correction at each node
  - **OSNR evolution**
  - Quantification of the Probability Error Function to estimate the Bit Error Rate and verify that a  $10^{-20}$  can be obtained without FEC, to have system margins vs  $10^{-15}$



Antoine Bernard, TSP

## Performance analysis and benchmarking with a POADM technology (single channel approach)

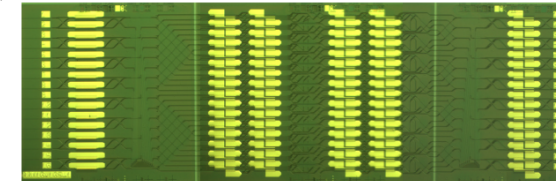
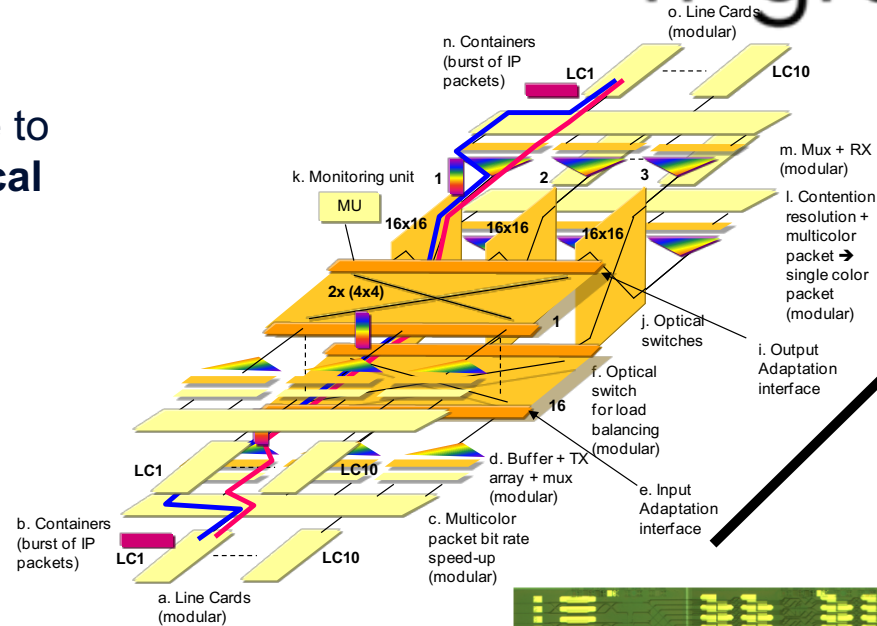
- Target: **Insertion latency evolution** versus the channel occupancy (the channel is defined as a virtual resource that can be a single wavelength slot or a multi-wavelength slot).
- Observation: the WDM Slotted A/D multiplexer has a better performance in terms of latency than a POADM technology. The Insertion delay is quite independent to the load, thanks to the speed up created.



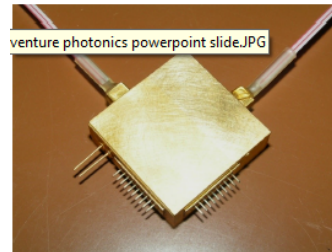
# WDM Modular Self-Protected backplane for a longer term approach



- **WDM dimension** exploited in that case to **reduce the connectivity of Fast Optical Switches (FOS)**
- Proposal for a **backplane based on 16x16 and 4x4 FOS** to build internal switching capacities up to 1 Petabit/s
- The structure offers **simplified fiber interconnection, modular approach, self-protection at low cost, reliability increased, simplified scheduling**



16x16 optical switch from TuE (Prof. Kevin Williams courtoisie)



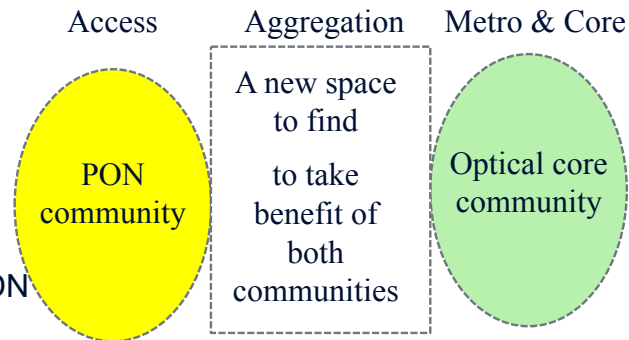
4x4 from Venture Photonics (James Regan courtoisie)

WDM packets contribute to reduce the optical switch connectivity and to simplify the fiber interconnexion

# Conclusion and perspectives

## WDM packets:

- Can **really create a breakthrough with respect to classical approaches**
- **exploit WDM TRX** that are targeted for the access and for the data com
- **simplify the node structure**, goes in the direction of past successful stories through an optimized exploitation of the optical bandwidth (fiber, optical amplifier)
- **offer higher system performance** through a higher overprovisioning at low cost
- offer the possibility to have **fully programmable systems** through an efficient SDN orchestrator
- have the potential to create **new opportunities of market** in highly cost sensitive market segments like access aggregation and xhaul
- **Offer better energy efficiencies**



Tries to find this new space

## Perspectives:

- **Demonstrate a new xhaul technology satisfying the KPIs of the 5G (in the N-GREEN project)**



# THANK YOU !

## NOKIA

Acknowledgments

Colleagues of Nokia Bell Labs ION and Wireless

Partners of the French ANR N-GREEN project, Effect Photonics & Venture Photonics

Antoine Bernard, Julien Violet, Franck Plazanet and Mathieu Lucas, Students of Telecom SudParis

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