

ANR N-GREEN project: Eco-designed solutions for a greener ICT in high sensitive network segments

GreenDays@Sophia

- Dominique CHIARONI, Nokia Bell Labs, and partners of the N-GREEN project
- 26-06-2017



Outline

- Context
- Power consumption of ICT
- Eco-design: towards a new generation of optimized systems and networks
- GreenTouch, an international initiative targeting high network efficiencies
- N-GREEN: a national project focusing on a new generation of sustainable optical systems and networks
- Partnership
- Key innovations proposed
- Where are the new directions to reduce cost and energy consumption?
- Towards WDM packets and advantages expected
- WSADM : a promising technology for different network segments
- Modular Self-protected WDM backplane for a new generation of sustainable Petabit switching capacity systems
- Conclusion and perspectives

Context and problematic

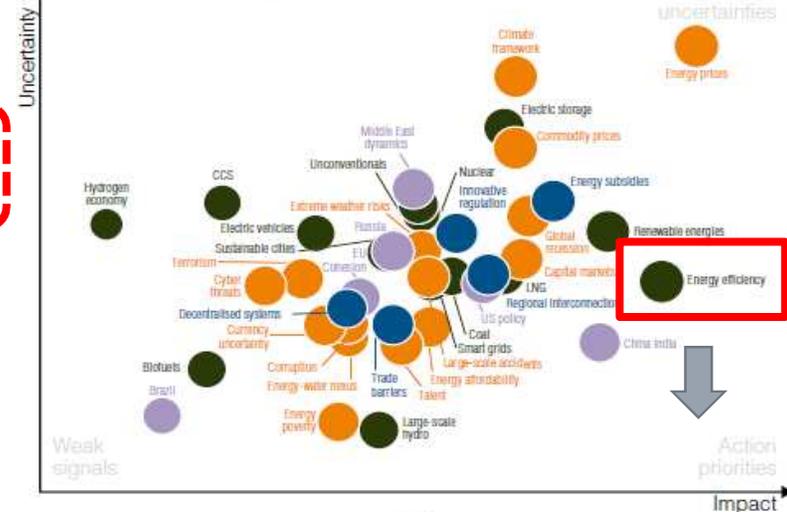
Context

- Digitalisation is driving the economy of countries

- Energy efficiency is a direction that will have a major impact

WEC's Global Energy Issues Monitor 2015: highlighting 40 issues and their perceived impact, uncertainty, and urgency for global energy leaders and experts globally

2015 World Energy Issues Monitor report



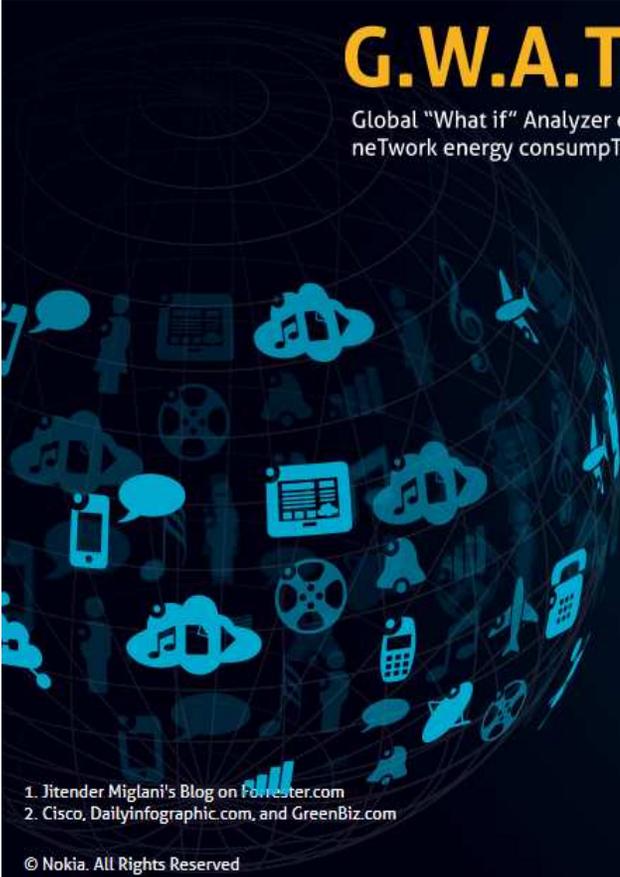
Pre-determined elements	Factors that shaped world energy 1970 to 2015	Pre-determined elements 2015 to 2060
Population / Workforce	<ul style="list-style-type: none"> • Global population grew 2x (1.7%) 	<ul style="list-style-type: none"> • Global population will grow by 40% (0.7%)
New Technologies	<ul style="list-style-type: none"> • ICT revolution • Productivity growth rate of 1.7% p.a. 	<ul style="list-style-type: none"> • Pervasive digitalisation • combinational impacts and productivity paradox
Planetary Boundaries	<ul style="list-style-type: none"> • Four planetary boundaries already crossed • 1,900+ GtCO₂ consumed 	<ul style="list-style-type: none"> • Water stress in high risk regions • 1,000 GtCO₂ to 2,100 to avoid 2°C
Shifts in power	<ul style="list-style-type: none"> • Rapid growth of non-OECD countries • Growing role for global institutions e.g. UNEFCCC, IMF, WTO and G20 	<ul style="list-style-type: none"> • 2030: India is most populous country • 2035-45: China is the world's largest economy

WEC : World Energy Scenario 2016

Energy context

- The ultra-connected society is accessing information in the cloud, mainly from smart phones, tablets and other mobile devices using ultra-broadband technologies.
- From the Cloud:
 - People are socializing on-line, watching video and listening to music;
 - Companies and organizations are running their businesses.
 - Users will rely on an average of 5 devices per person, with more than 20 billion devices connected.
 - Over time, **the digital universe will grow by a factor of 32 in 2020 when compared to 2012 and mobile data traffic will grow 13 times.**
- More than 5 zettabytes will be shortly stored in the cloud (a zettabyte is a thousand billion gigabytes), the equivalent of storing 10 billion years of music.

GWATT: a tool to evaluate and predict the energy consumption of ICT



G.W.A.T.T.
Global "What if" Analyzer of
neTwork energy consumpTion

The ultra-connected society will access information in the cloud, mainly from smart phones, tablets and other mobile devices using ultra-broadband technologies.

From the Cloud, children will access education through open online courses; people will access healthcare using remote online diagnosis; people will socialize on-line, watching video and listening to music; Companies and organizations will run their businesses. Users will rely on an average of 5 devices per person, with more than 20 billion devices connected. Over time, the digital universe will grow by a factor of 32 in 2020 compared to 2012 and mobile data traffic will grow 13 times. ¹

By 2017 more than 1.4 zettabytes will pass through the network (a zettabyte is a thousand billion gigabytes), the equivalent of everyone on earth tweeting nonstop for more than 100 years. ²

[LEARN MORE >](#)

[EDIT NETWORK >](#)

NOKIA

1. Jitender Miglani's Blog on Forrester.com
2. Cisco, Dailyinfographic.com, and GreenBiz.com

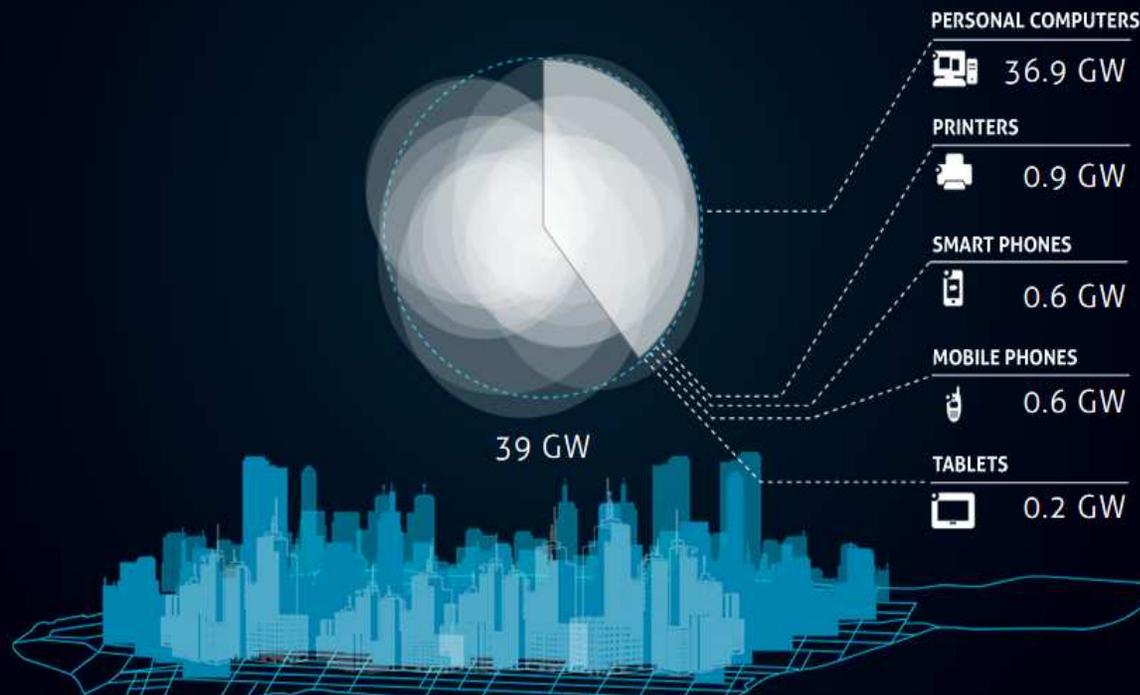
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Terminal are responsible for a large part of the ICT power consumption

As of 2013, devices consumed approximately 39 gigawatts (1GW is the typical capacity of 1 nuclear plant), **the equivalent of 7 New York Cities.** ⁵

NEXT >

SKIP >



The energy consumption has to be optimized

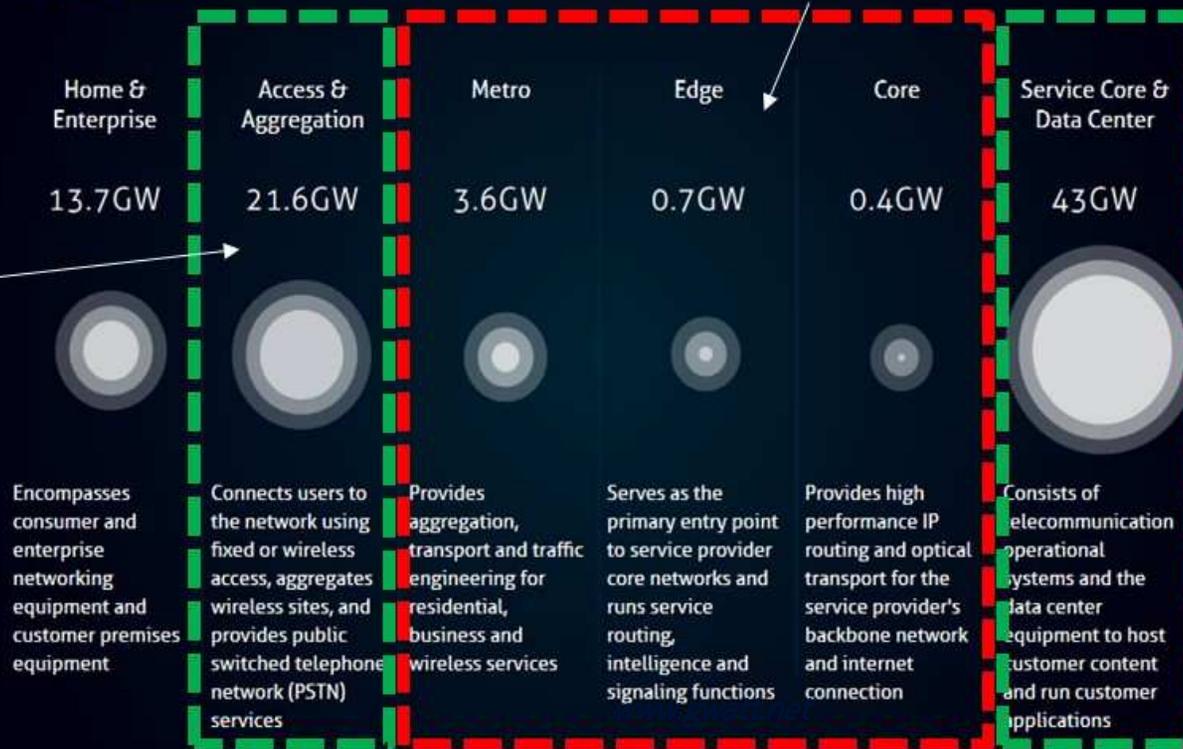
As of 2013, world-wide telecommunications networks consumed around 83 gigawatts, the equivalent of 12 New York Cities.⁵

Less sensible to high energy efficient technologies

NEXT >

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Need for high energy efficient technologies



Network split into network segments

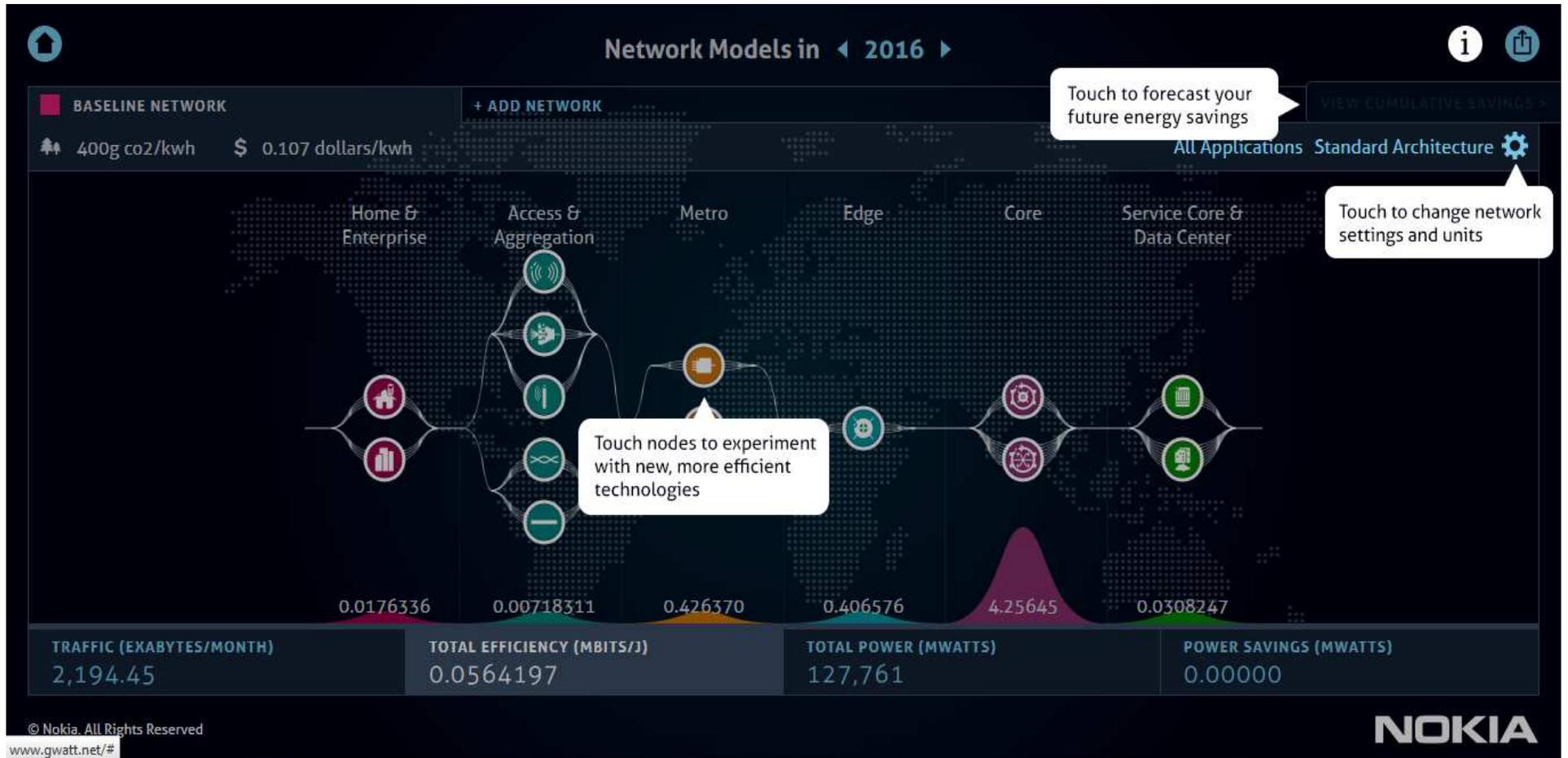
Smartphones and tablets will drive mobile traffic to grow up to **88.6** times by **2020** from 2010, causing energy use to grow exponentially. ⁶

NEXT >

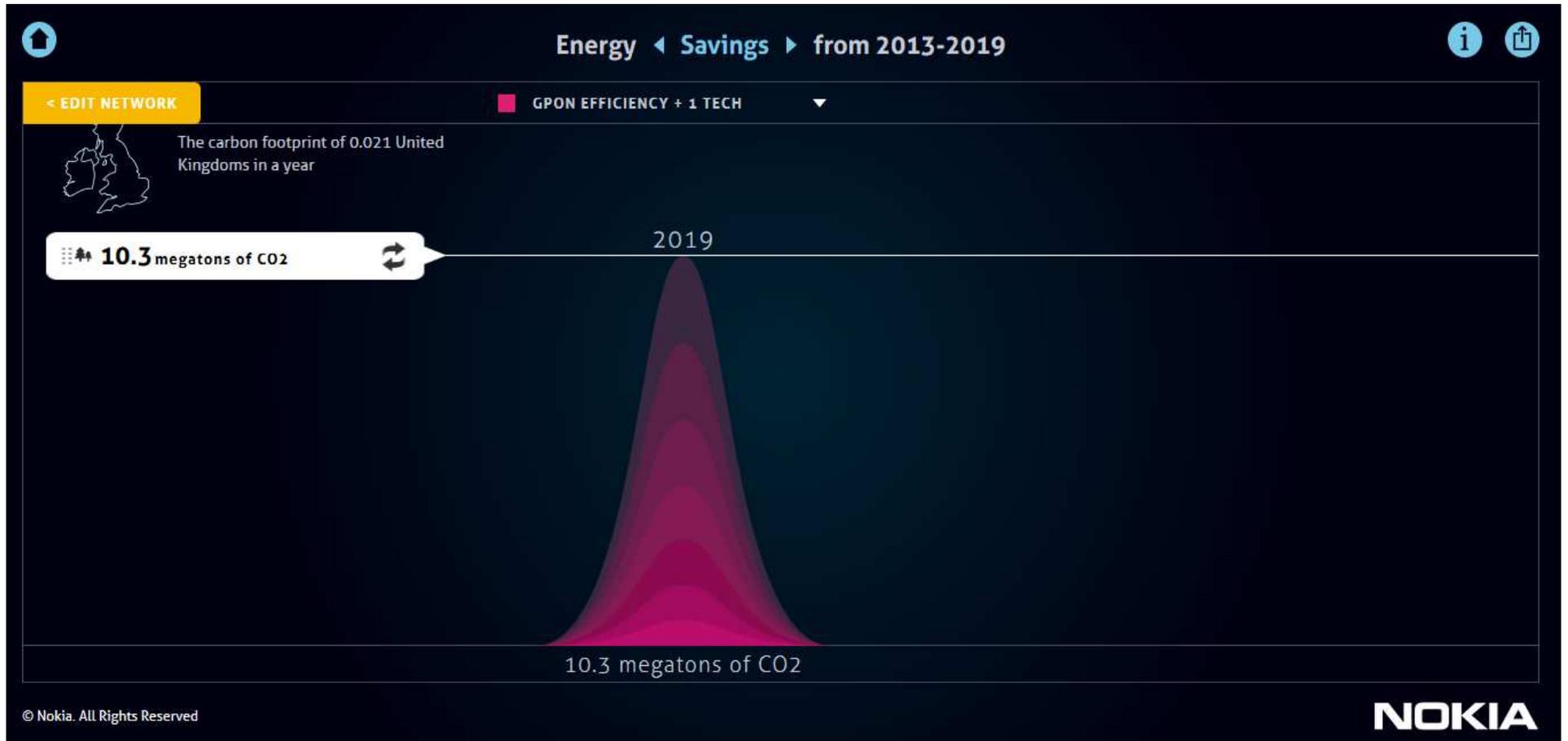
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Selection of the technologies per network segment

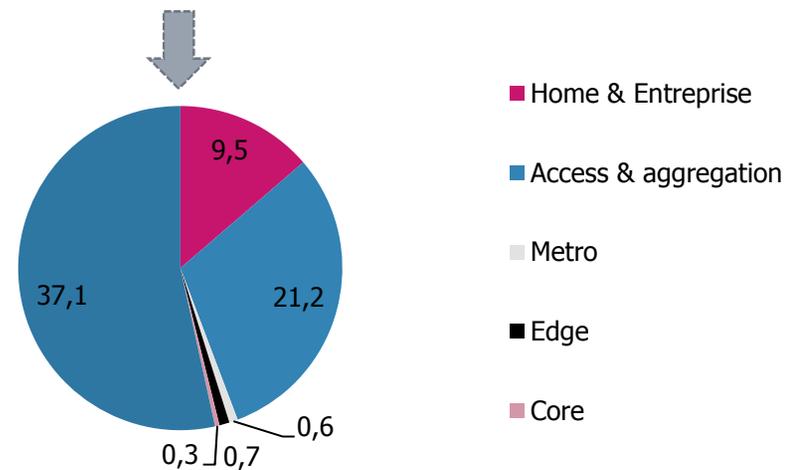


Cumulative view to anticipate the energy gains when using a new technology



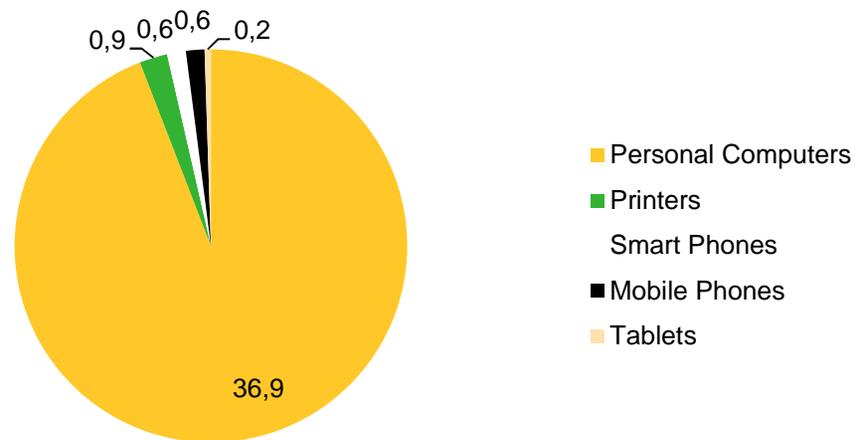
The energy consumption is mainly at the periphery

- **Information Communication Technologies consumed 6% of global energy in 2013**, and represents approximately 108,4 Gigawatts
- As of **2013**, devices and terminals consumed approximately **39 Gigawatts** (1 GW is the typical capacity of 1 nuclear power plant, **more than one third on the entire ICT**), the equivalent of 7 New York Cities.
- As of **2013**, world-wide telecommunication networks consumed around **69 Gigawatts** (the equivalent of 12 New York Cities).
- Repartition in 2013, worldwide:



Personal computers: a need to optimise them

- Eco-design is required for homes and apartments to limit the energy consumption
- BUT we need to pay attention to the terminals and in particular Personal Computers that are today impacting dramatically the energy consumption



2013 data
from the worldwide
device energy
consumption part

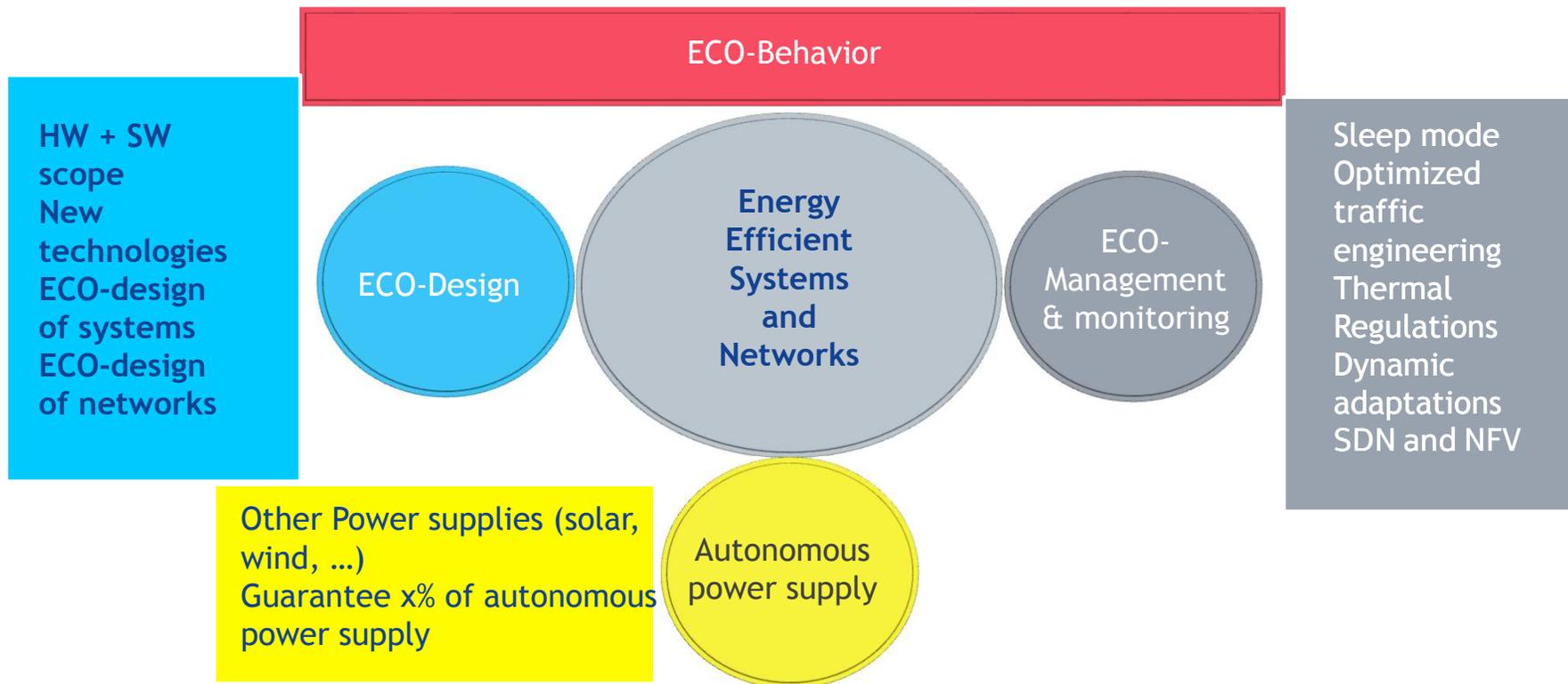
→ Total : 39 GW

Why do we need to improve the energy efficiency of products ?

- Electricity production reaches limits
- The traffic is regularly increasing creating strong constraints on the energy consumption of the telecommunication network
- The current home boxes in the apartments are dominating the power consumption of the global telecommunication network.
- In parallel Data centers are becoming the second important network segment in terms of energy consumption.
- The mobile network is also a critical part of the network that requires new optimizations.

It is then mandatory to optimize the energy efficiency of ICT to minimize his energy consumption

Directions to improve the energy efficiency



GreenTouch initiative: Towards high energy efficient ICT





INITIATIVE (2010 – 2015)



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Join our mission to deliver the architecture, specifications and roadmap to increase network energy efficiency by a factor of 1000 compared to 2010 levels.



2 New Technologies

GreenTouch announces two new technologies that will reduce overall energy consumption in wireline access networks by an impressive 46 percent.

SUSTAINABLE ENERGY WEEK 23-27 JUNE 2014
ONE SMALL STEP FROM YOU, ONE GIANT LEAP FOR EUROPE.

EU SEW 2014

View presentations from the GreenTouch Workshop on a Sustainable and Energy Efficient Internet of Everything.



Green Meter Research

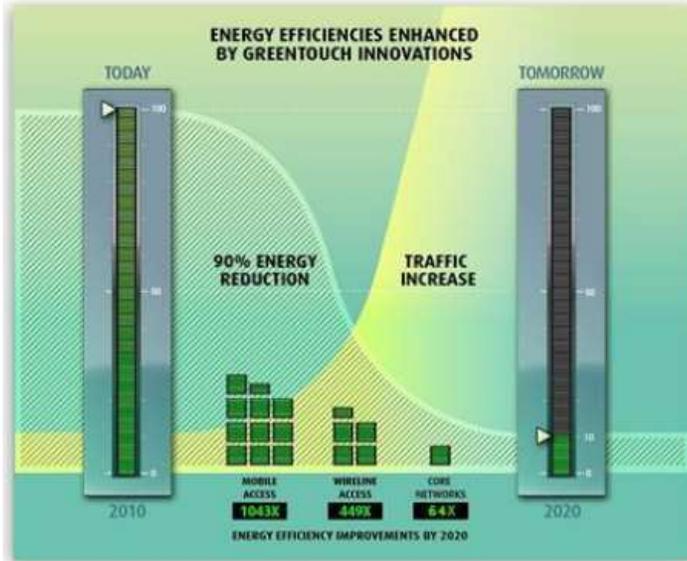
New details released of global study showing major reductions possible in net energy consumption by networks by 2020.



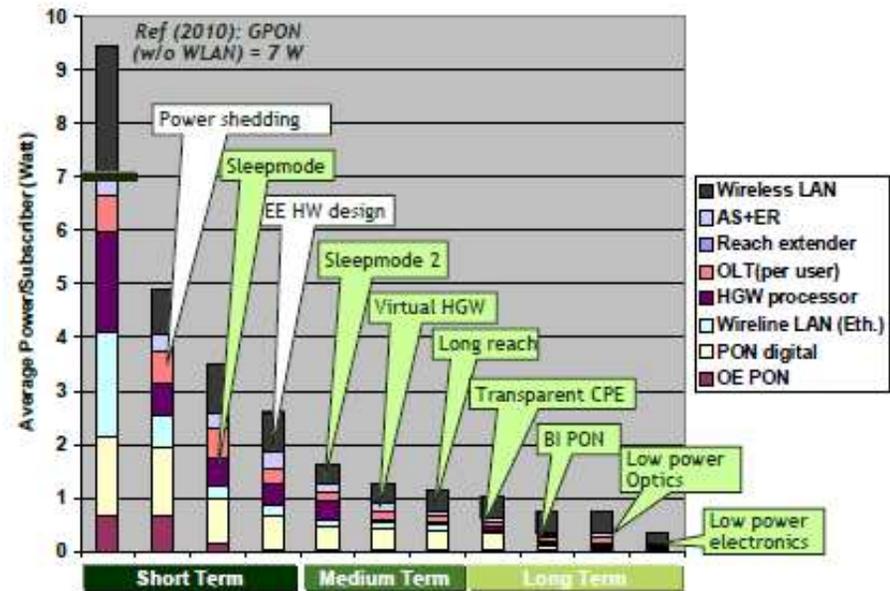
WEF Green Light Report

World Economic Forum Report spotlights the efforts of GreenTouch.

Green Meter: a metric proposed

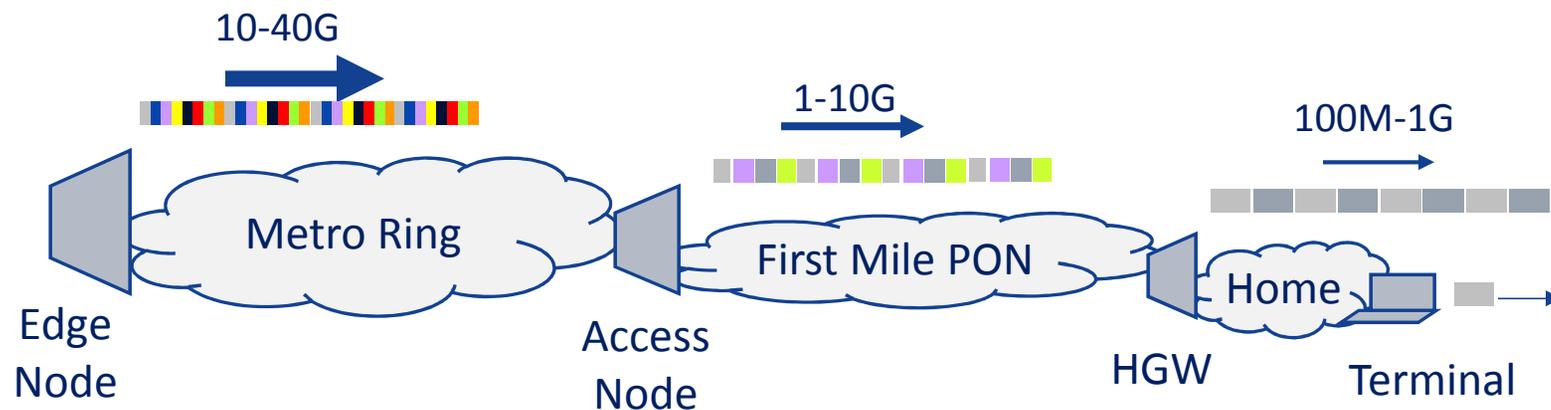


Example of potential improvement in access networks



Consumer: Cascaded Bi-PON proposed in GreenTouch for 2020

Repeater for long reach PON as alternative to optical amplification

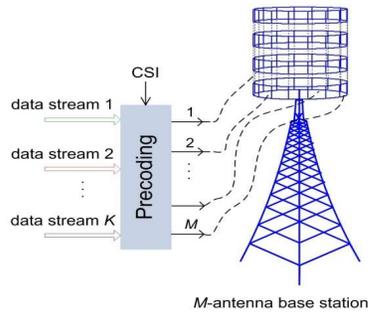


GreenTouch Approaches to a Sustainable 5G

Considering Exponential Traffic Growth



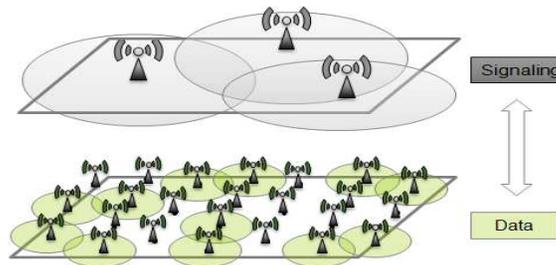
CoMP : Co-ordinated Emission/reception
 MIMO : Multiple Input Multiple Output
 RU : Radio Unit
 DU : Digital Unit



Massive MIMO Antenna Systems

Massive MIMO antenna arrays for directed transmission and minimized interference.

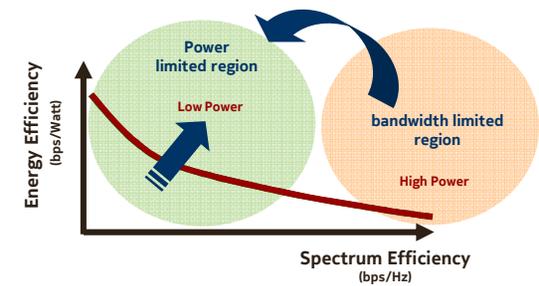
14,000x energy efficiency improvement in DU+ U



BCG² - Beyond Cellular Green Generation

Enabling fully dynamic operation of macro and small cell networks by introducing a separate control layer.

4,000-10,000x energy efficiency in U to Ru



GTT - Green Transmission Technologies

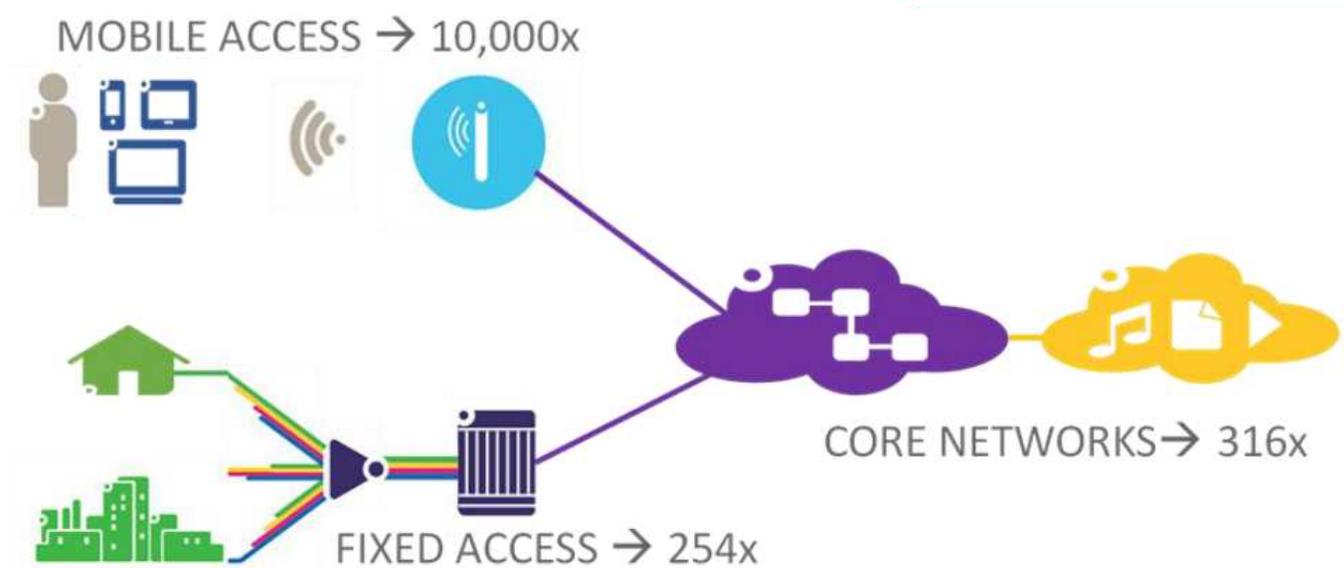
Leveraging Interference control, Multi-User MIMO and CoMP for adaptive radio transmission.

7,000-14,000x energy efficiency in U to RU combined with BCG²

Three technology directions studied and combined to the best possible mobile network architecture

GreenTouch Results

Shown at the Final Event, June 2015



Green Touch White Paper June 2015
www.greentouch.org

Results in 98% reduction in net energy consumption in the end-to-end network and prevents equivalent Green House Gas emissions from 5.8M cars

References

- www.greentouch.org
- “Reducing the Net Energy Consumption in Communications Networks by up to 98% by 2020 “, GreenTouch White Paper, June 2015.
www.greentouch.org/index.php?page=greentouch-green-meter-research-study
- GreenTouch Technical Solutions for Energy Efficient Mobile Networks: Improving the nationwide energy efficiency in 2020 by more than a factor of 10000 in relation to the 2010 reference scenario.
Green Touch White Paper Aug. 2015
www.greentouch.org/index.php?page=greentouch-green-meter-research-study
- “Power model for today's and future base stations“, C. Desset, B. Debaillie, E. De Greef; online Web-tool of the GreenTouch power model, www.imec.be/powermodel
- “A flexible and futureproof power model for cellular base stations,” B. Debaillie, C. Desset, and F. Louagie. Vehicular Technology Conference (VTC), May 2015.
- “Spatial analysis of mobile traffic hot spots,” H. Klessig, V. Suryaprakash, O. Blume, A. Fehske, and G. Fettweis. IEEE Wireless Communication Letters, 2014, vol. 3, pp. 537–540
- G.W.A.T.T. : “Global ‘What if’ Analyzer of neTwork energy consumpTion”, Online visualisation tool of GreenTouch results and network configurations. gwatt.greentouch.org
- “Mobile’s Green Manifesto 2012”, GSMA, June 2012
<http://www.gsma.com/publicpolicy/public-policy-resources/mobiles-green-manifesto>

N-GREEN project: towards greener optical switching systems



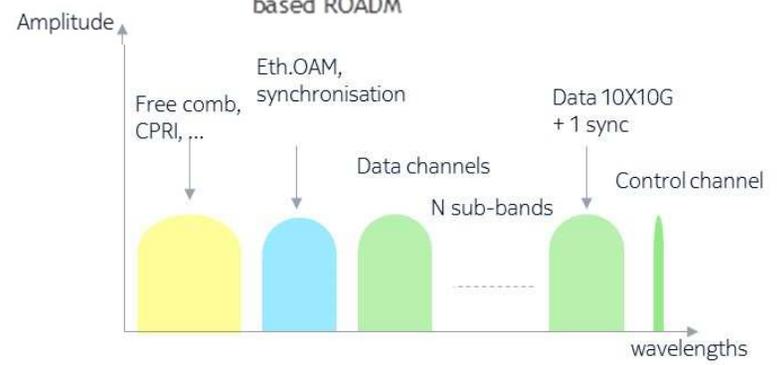
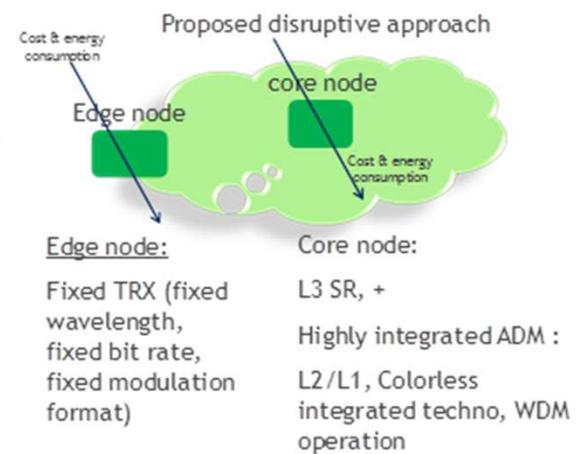
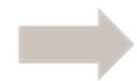
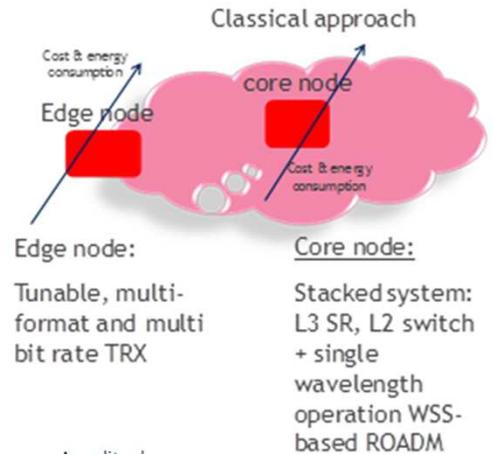
N-GREEN project in few words: New-Generation of Routers for Energy efficient networks

- 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, WPO leader and WP2 leader)
 - III-V Lab : WP4 leader
 - Institut Mines Telecom (IMT) : WP1 leader
 - Including : Telecom ParisTech, Telecom Bretagne et Telecom SudParis
 - Université de Versailles : WP3 leader
- 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”
 - “Module WDM XC to optimize the data placement (in perspective)”



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. Ex: 5G**



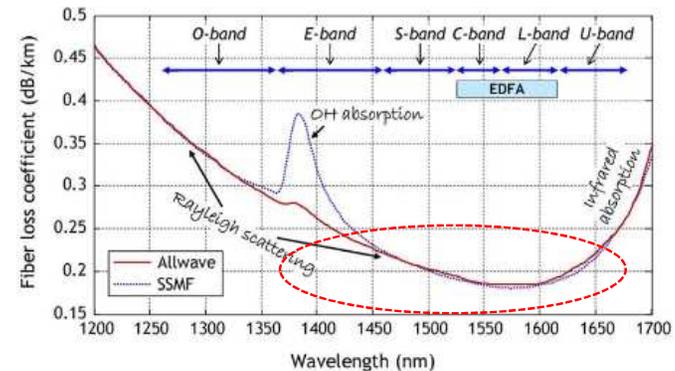
Sharing of the spectrum to support different technologies

haul applications for 5G

Come back to fundamentals (WDM dimension) to simplify optical technologies

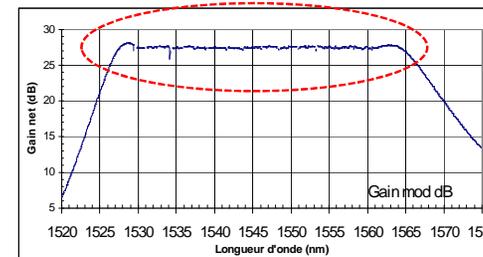
- When trying to find new optical solution helping electronic to go beyond in terms of bit rate and capacity, one dimension makes a big difference: the **optical bandwidth**
- The exploitation of the wide optical bandwidth is at the origin of the success of optical technologies:
 - The first one is the **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 (WDM) 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

An historical tendency of the optical 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.

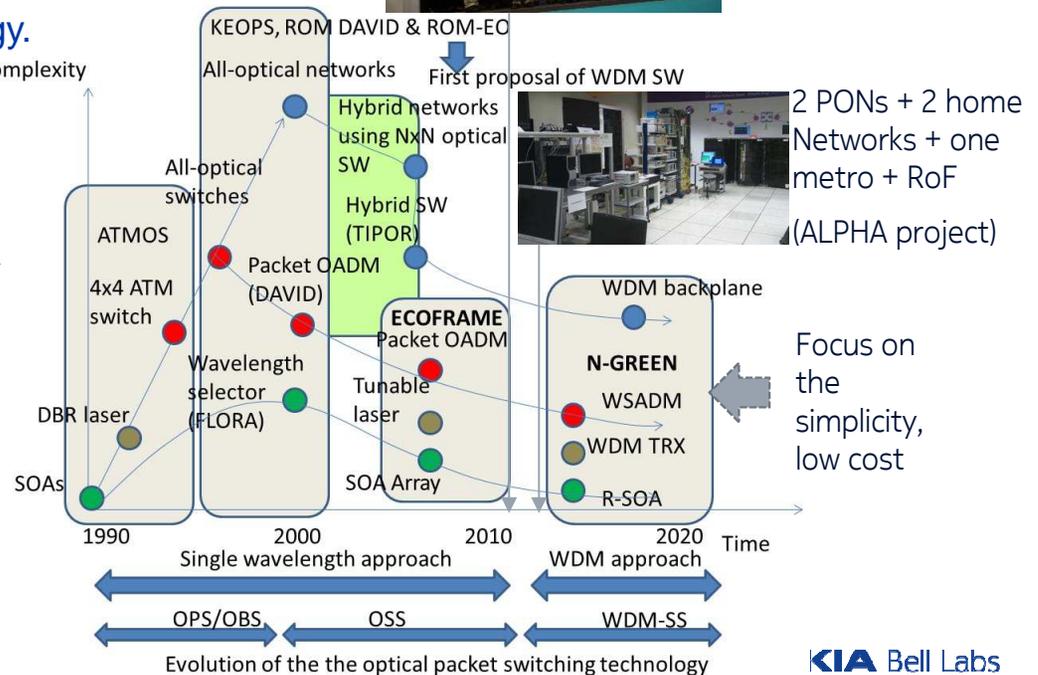
In the 2010's, second reorientation for more simplicity

- Strong emphasis in the optical integration, and in the simplification of the systems



ECOC 2010

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

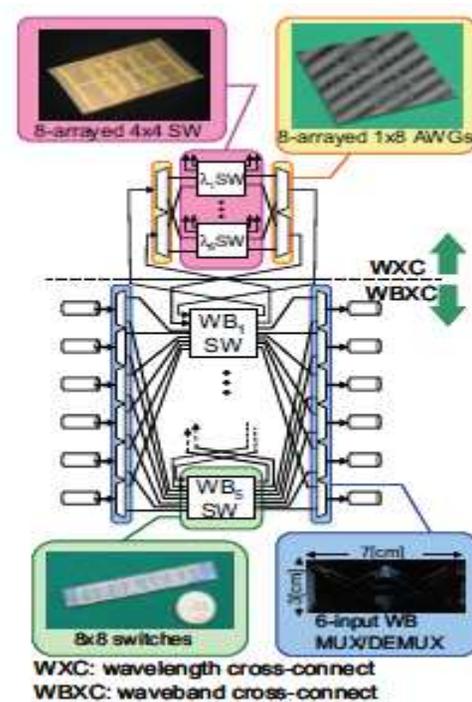


Previous tentatives to simplify OADM

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.:

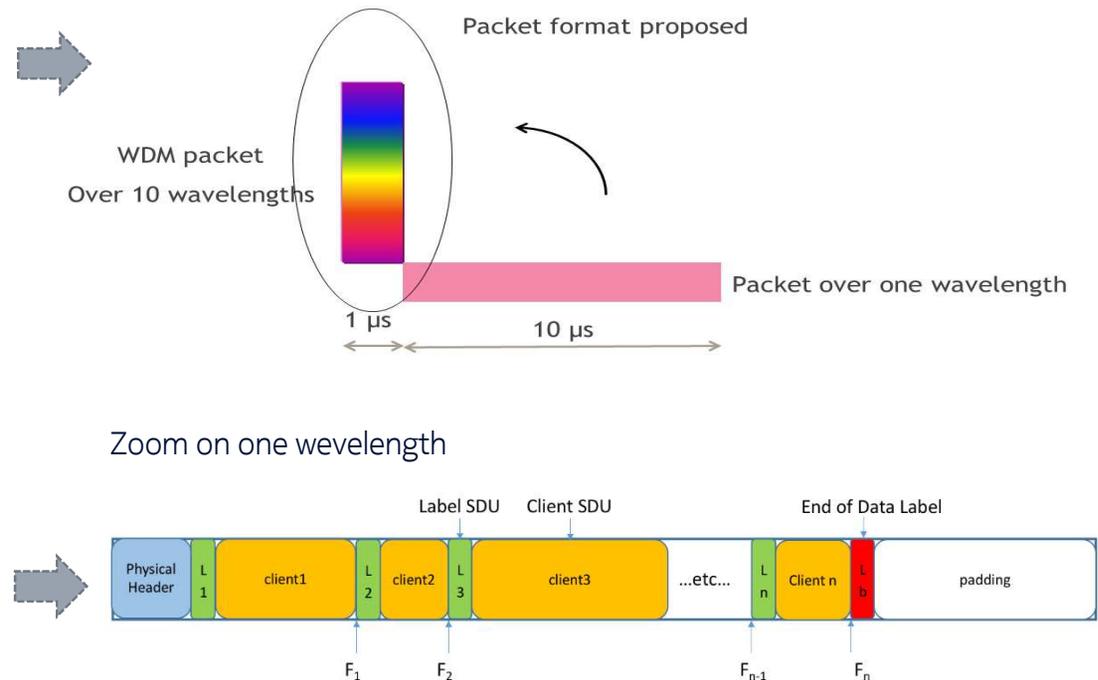
- **Sub-band optical cross-connects** were initially proposed to make OADMs more compact
- Several studies have been done, in particular through **multi-granular OADM** splitting the granularity into:
 - Fibers
 - Sub-bands
 - Wavelengths
 - Packets



Hybrid Optical
Cross-Connect

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**.

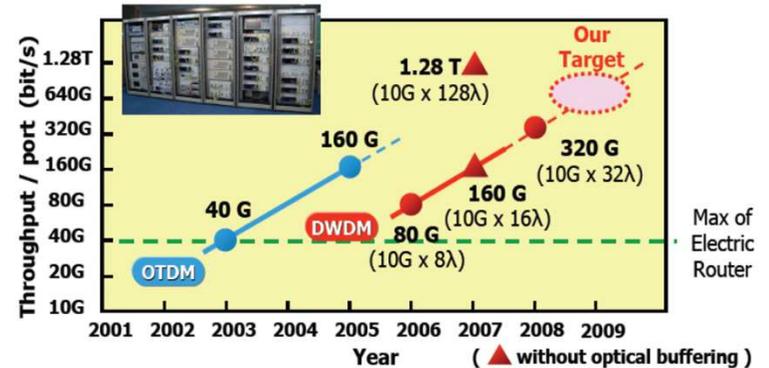
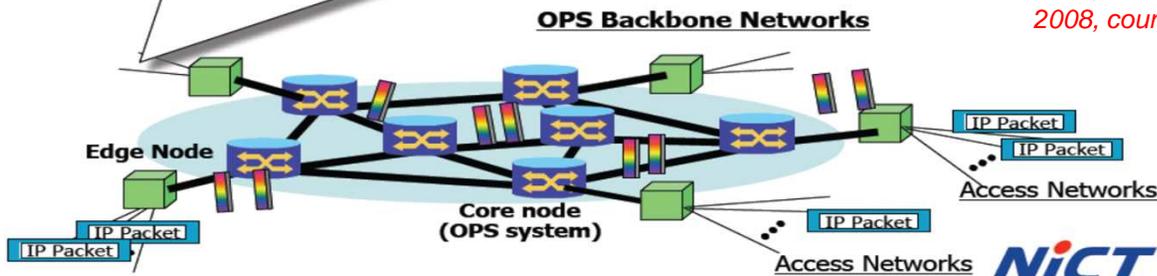
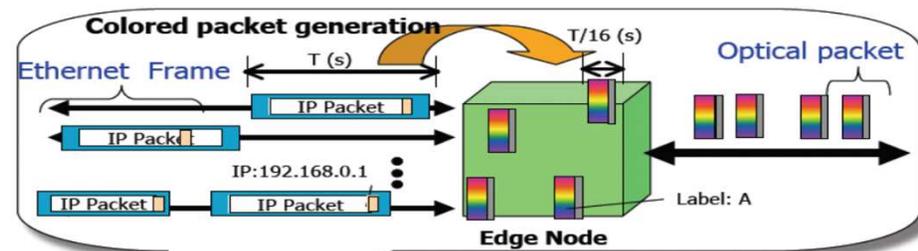


Annie & Philippe Gravey, Telecom Bretagne, courtoisie

WDM packets in the past

Prof. Naoya Wada et al.:

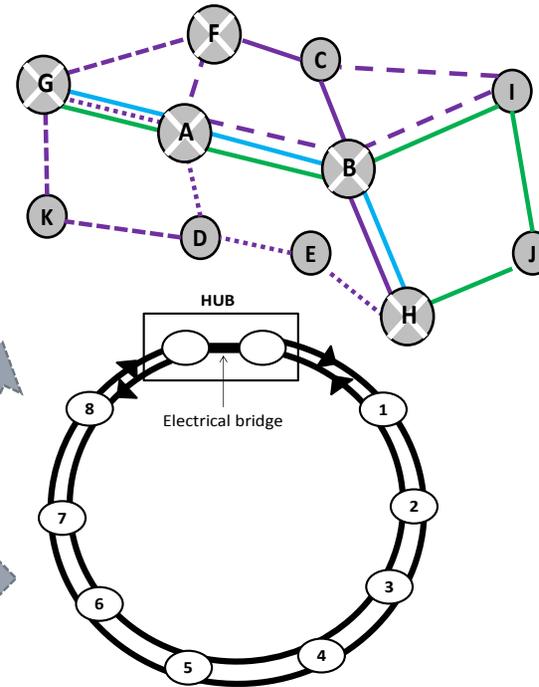
- Proposal for **multi-color packets** to increase the transport capacity without impacting the distance



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 advantage 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**



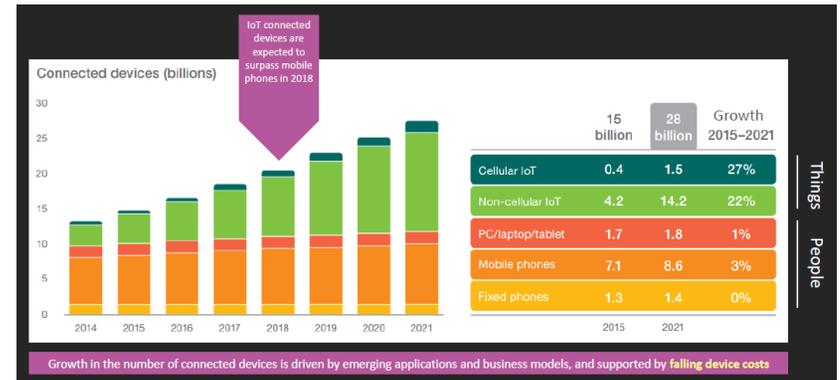
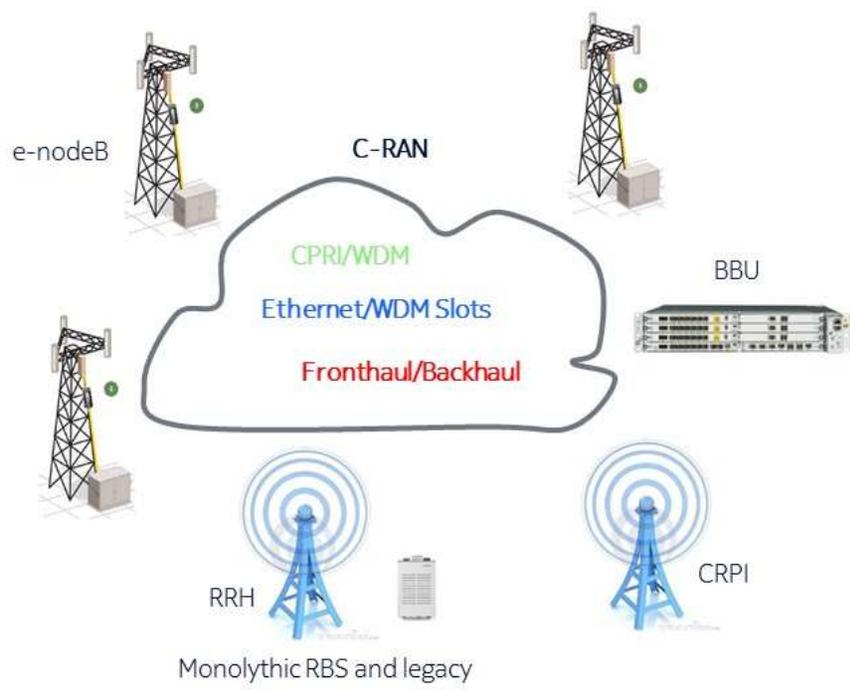
Long haul backbones, with mesh topologies

Ring topology for access aggregation, fronthaul, backhaul and metro



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

Use case targeted: Xhaul technology



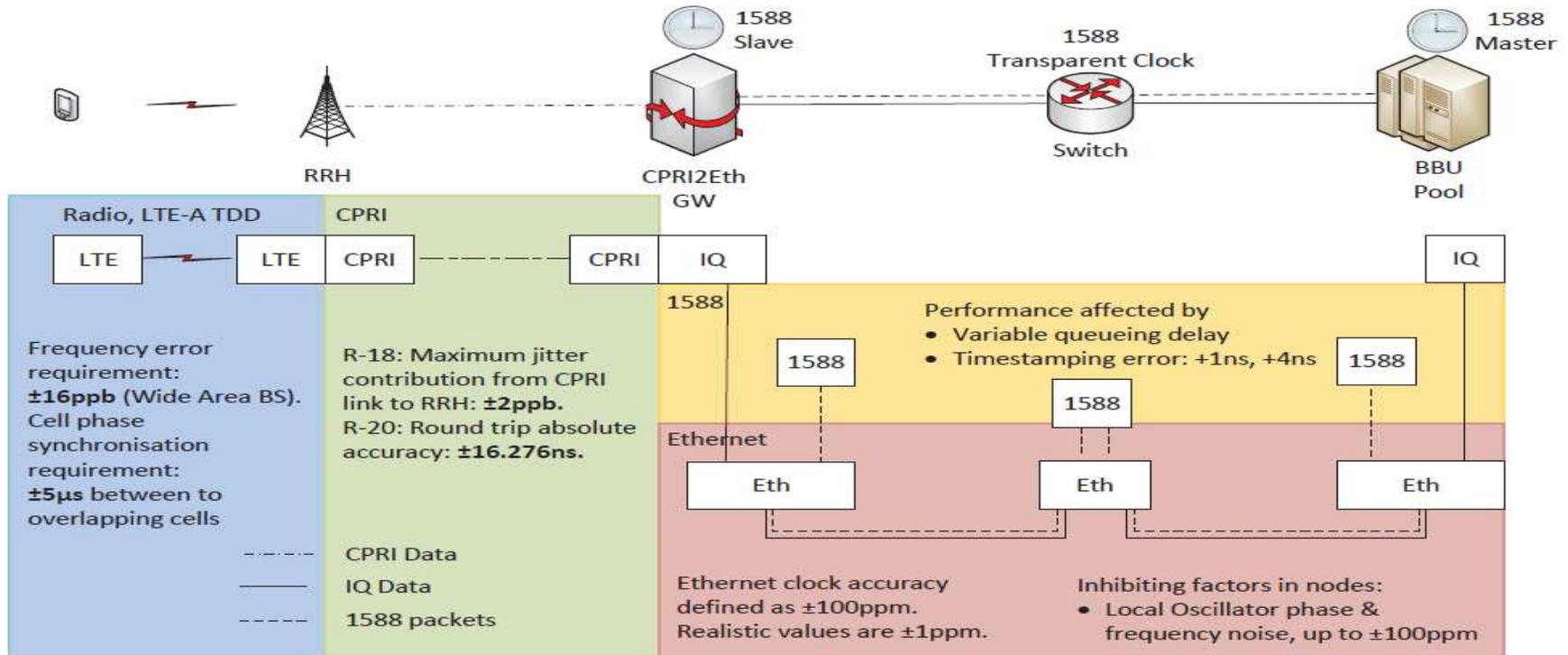
Photonics Systems and Technologies for 5G Mobile Networks, R. Sabella and A. Bianchi, Ericsson Research, ONDM 2017

KPIs of the 5G



Need for new technologies

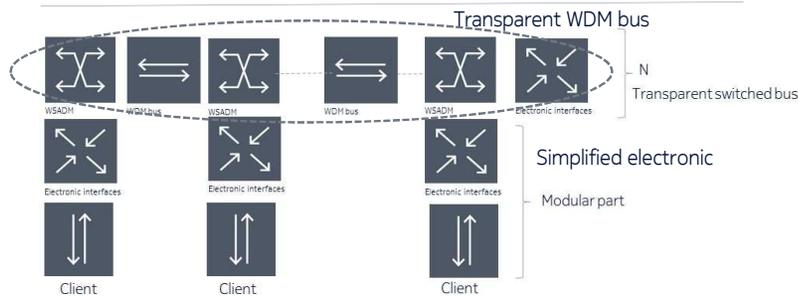
Why the Ethernet is challenging ?



« Synchronization Challenges in Packet-Based Cloud-RAN fronthaul for Mobile Networks », Aleksandra Checko et al.

Proposed solution: Xcast WDM Ethernet

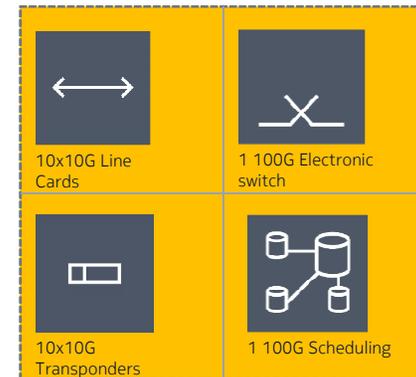
Xcast WDM Ethernet (N-GREEN solution)



Characteristics:

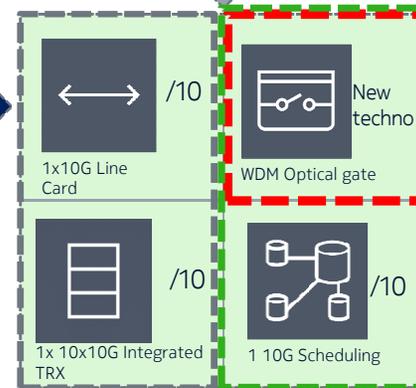
- Low cost, low power consuming approach
- Generic programmable optical system
- Easy scalability
- Minimum latency through Broadcast-and-Select routing mechanisms
- Based on available WDM technologies : SOAs, and WDM TRX
- Designed for : fronthaul/backhaul, access aggregation network segments

Ethernet solution



SDN interfaces

X-Cast WDM Ethernet solution

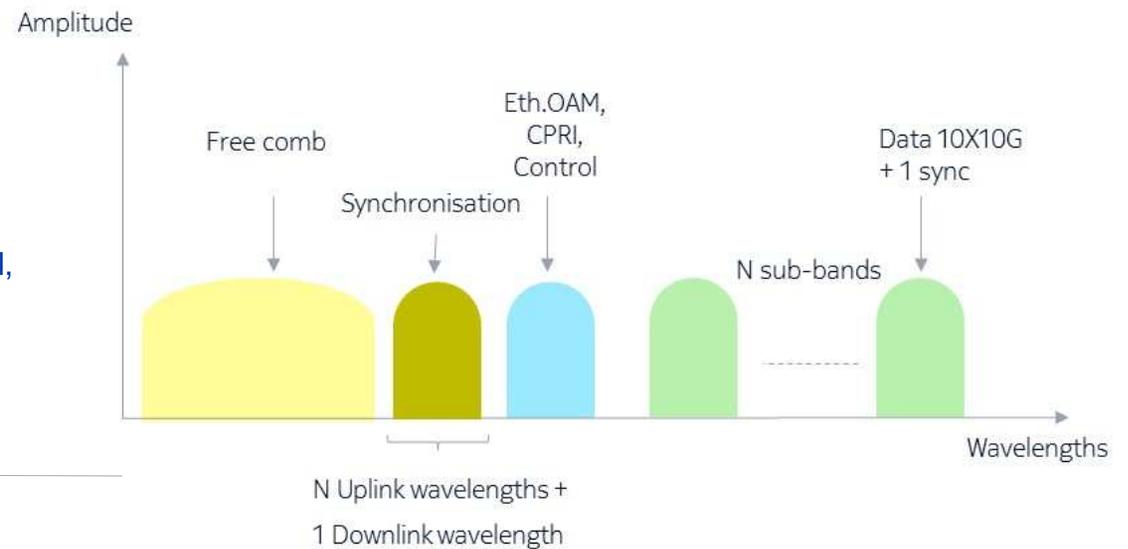


Spectrum

Spectrum distribution

The spectrum can include:

- sub-bands of 10x10G channels
- One sub-band to transport sync. channels
- One sub-band of wavelengths to transport : dedicated OAM channels, the control channel, CPRI channels, ...
- a free comb to transport wavelengths



Content of a sub-band

10 channels at a same bit rate and a bi-dir. synchronization channel (option)

N channels for the transport of specific information : OAM, CPRI, control channel

Model targeted

Network model

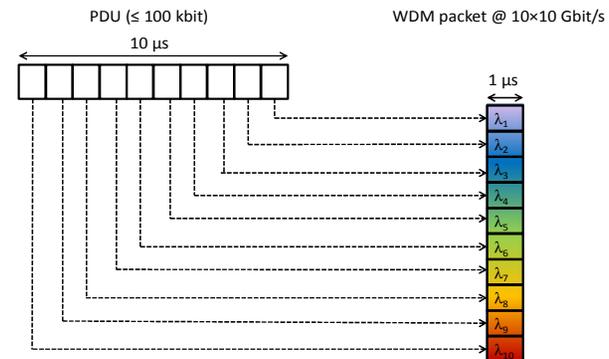
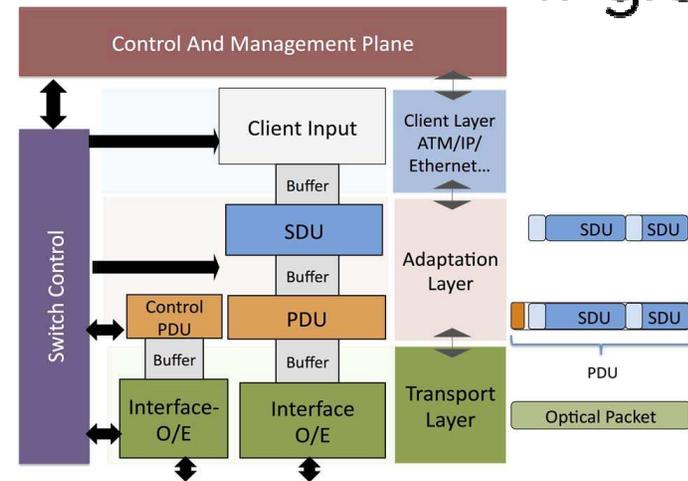
SDU encapsulated in a PDU called optical slot

Adaptation layer: time to time + wavelength transformation, adaptation for a burst mode transmission (guard band + preamble + other fields)

WDM slot

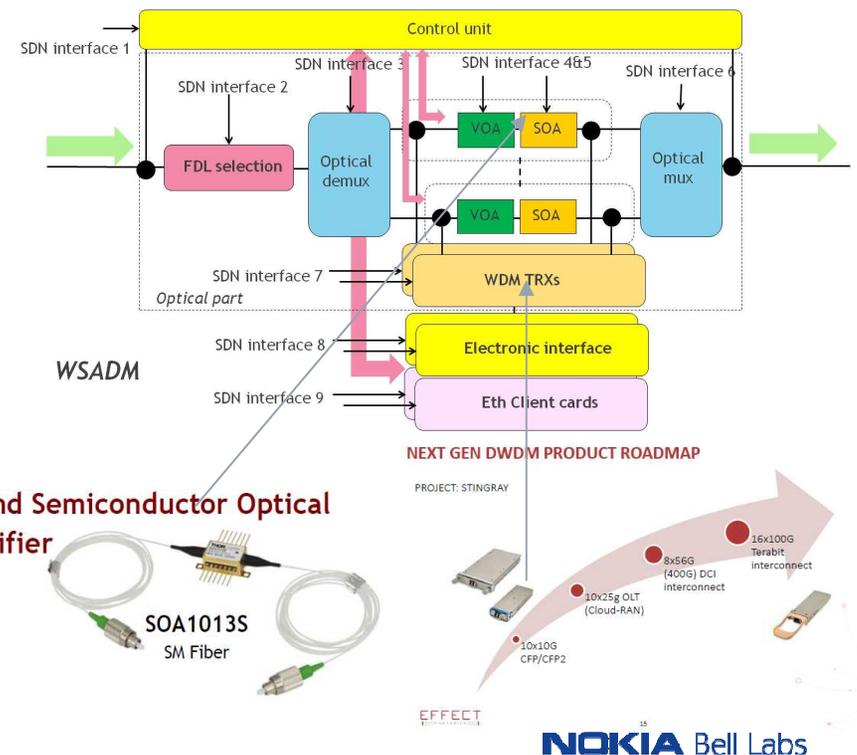
Dimensional transformation from time to time + wavelength

Interests: take benefit of integrated TRX, simplify the transit management to reduce cost and energy consumption



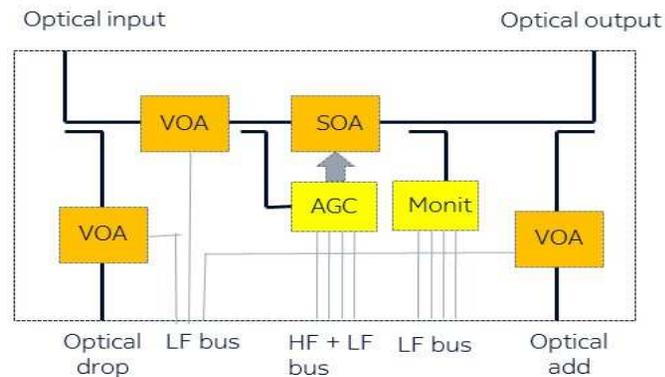
Functional description of the WDM Slotted Add/Drop Multiplexer (WSADM)

- WDM packets exploited 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 of the approach

- **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

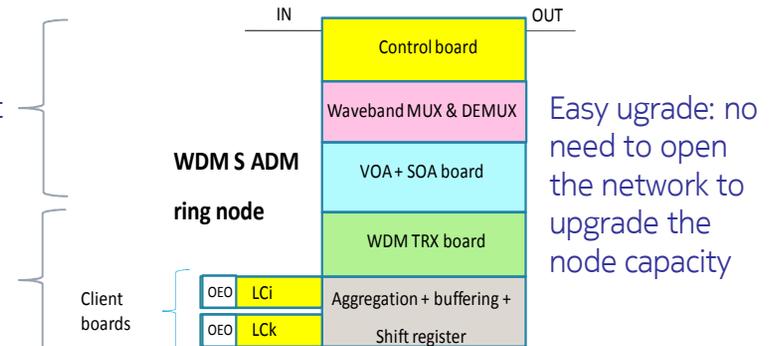


Very simple board to manage 100's of Gbit/s



Boards independent to the Data bit rate

Modular boards

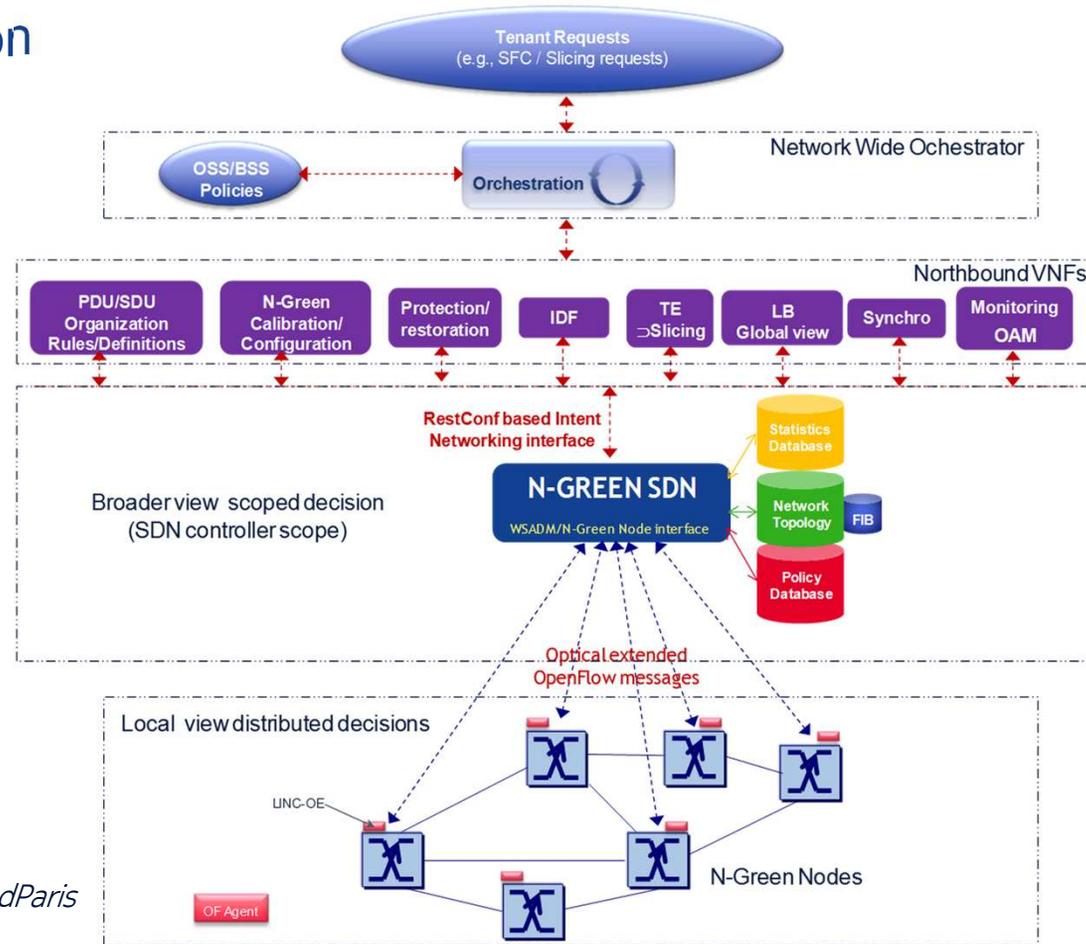


Easy upgrade: no need to open the network to upgrade the node capacity

SDN orchestration

SDN

Identification of SDN interfaces
 Proposal for the SDN orchestrator



Djamal Zeglache, Telecom SudParis



Cost evolution vs Ethernet

Benchmarking for one node, same bit rate

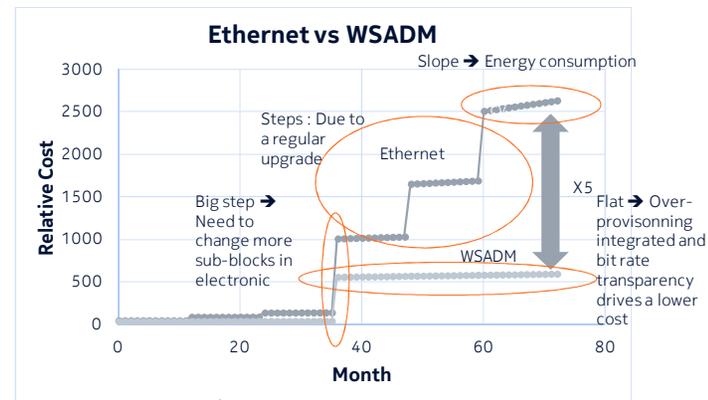
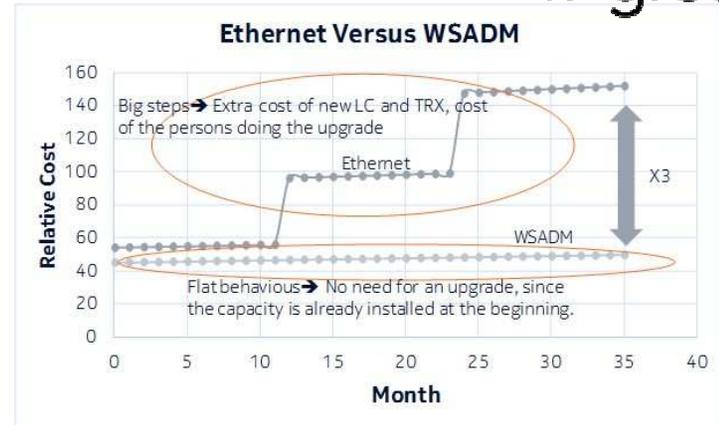
At the installation, the WSADM technology is less expensive for a higher capacity

The management of the capacity growth is managed by the SDN control plane with the WSADM

The Ethernet required regular on site upgrades, increasing the cost

Benchmarking for one node, bit rate change

When changing the bite rate the cost gains are even higher, since a part of the node is not changes (control + mux/demux+ VOA&SOA boards).

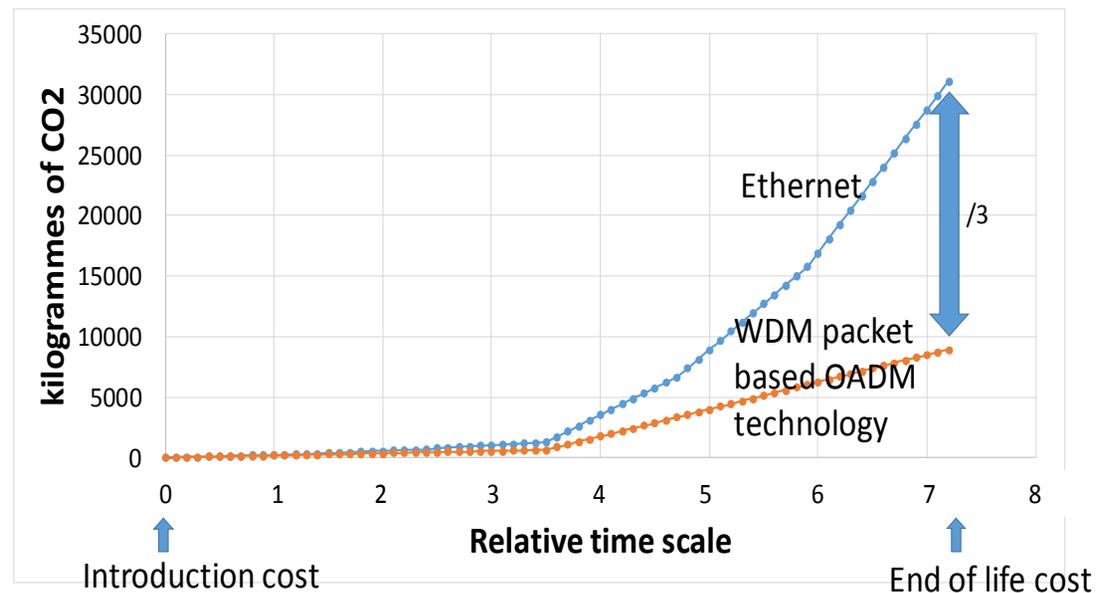


Power consumption evolution vs Ethernet

Reduction of CO2 emissions

The WSADM node emits less CO2 than the Ethernet technology

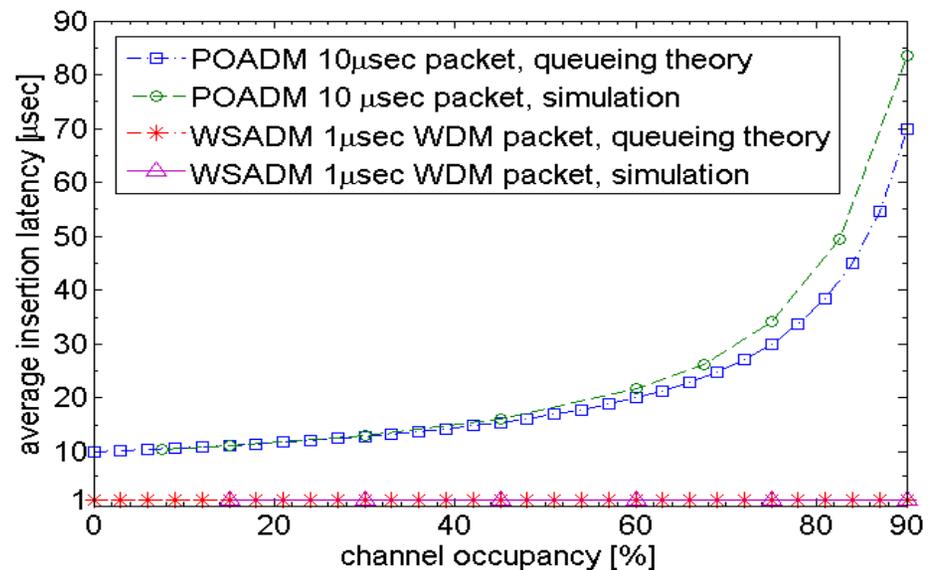
Conversion law adopted :
400 Kilo CO2 for 1 kW/h



Performance analysis and benchmarking for the WSADM

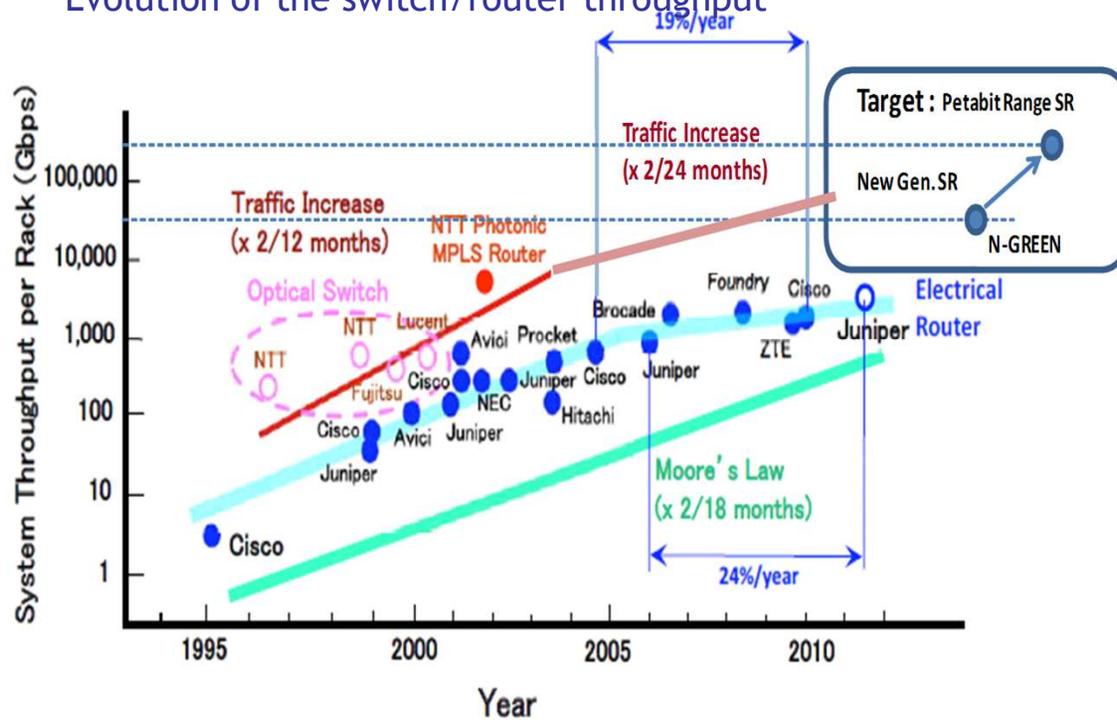
Performance analysis and benchmarking with a POADM technology (single channel approach)

- 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.



In the core of the network the capacity is becoming a problem

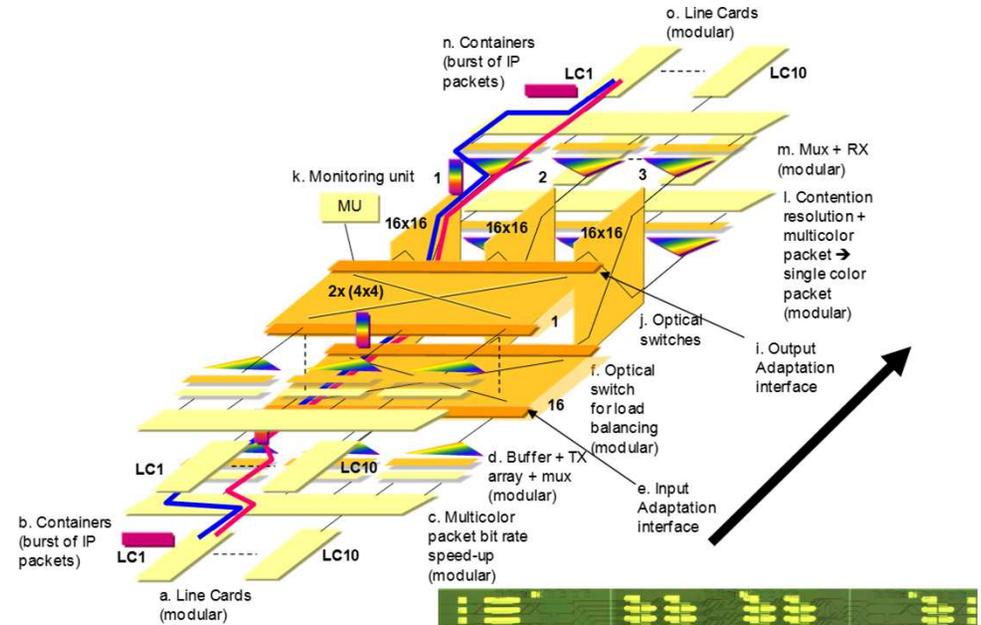
Evolution of the switch/router throughput



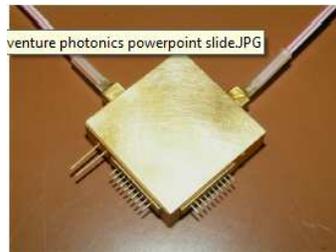
- This graphic shows two tendencies:
 - the system throughput per rack evolution is asymptotic
 - to offer 100 Tbit/s of throughput capacity this graphic indicates that there is a need for tens of racks
- What will be then the solution to go beyond the existing solutions

WDM Modular Self-Protected backplane for a longer term approach

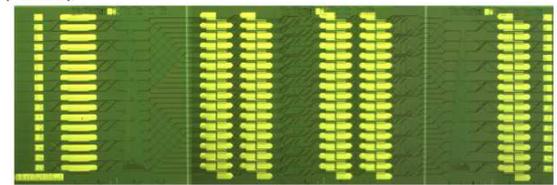
- **WDM dimension** exploited in that case to **reduce the connectivity of Fast Optical Switches (FOS)**
- Proposal for a **backplane based on 16x16 and 4x4 FOS** to build internal switching capacities up to 1 Petabit/s
- The structure offers **simplified fiber interconnection, modular approach, self-protection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



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



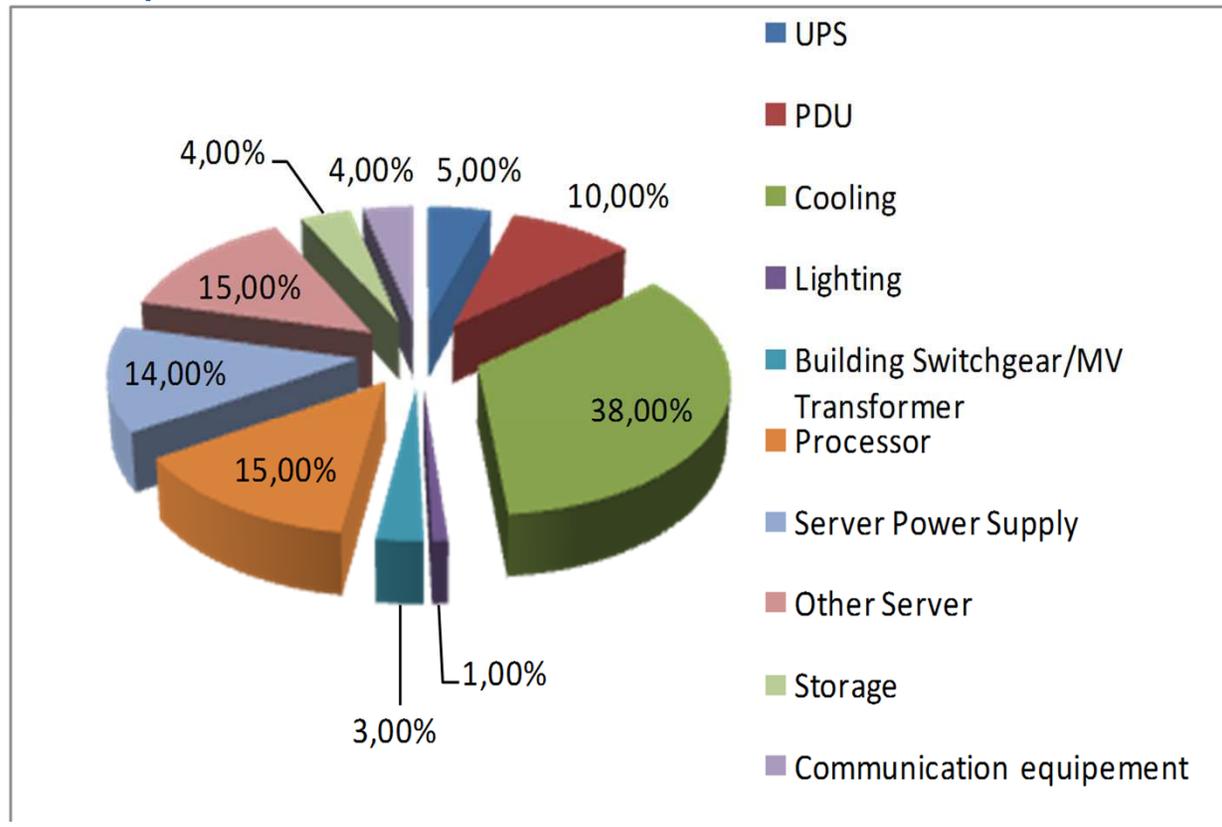
4x4 from Venture Photonics (James Regan courtoisie)



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

NOKIA Bell Labs

Repartition of the energy consumption in data centers: one example



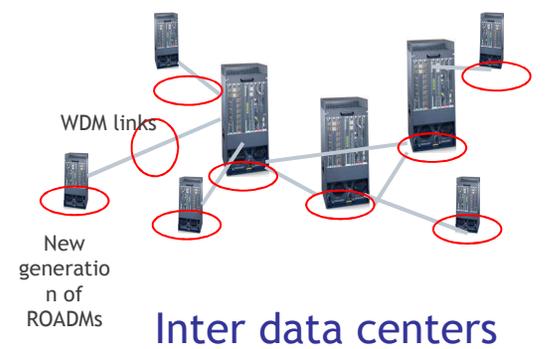
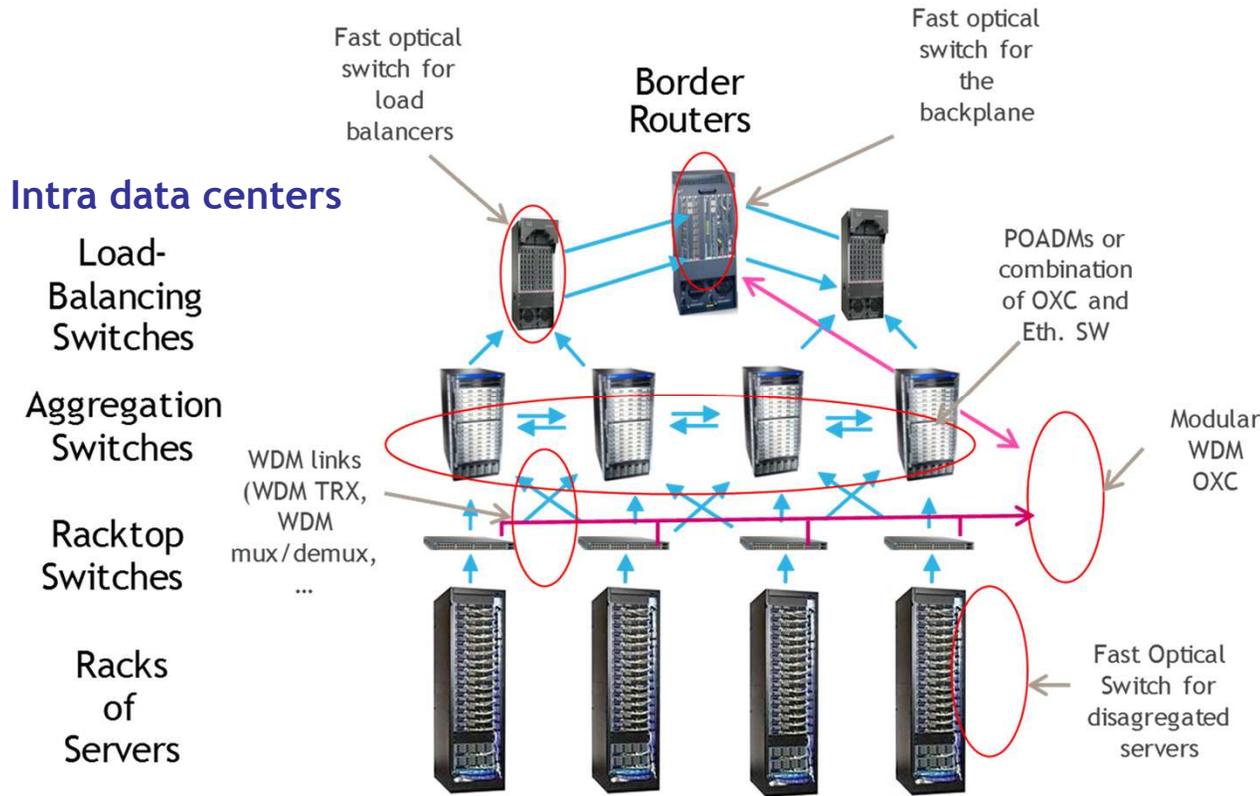
Computing equipments : 52%
Support equipments: 48 %

The storage represents the largest part

The communication part is only 3% !

Need to optimise the data location

Where optical technologies in data centers?



Major impact



Conclusion and perspectives

The N-GREEN project, through an eco-designed approach has the ambition to:

- Propose a new sustainable technology, in three main domains:
 - Add/Drop multiplexers
 - High capacity backplanes for 1Petabit range SR
 - New innovative solutions for DC

Perspectives:

- Propose new low cost and low power consuming optical systems to target different network segments
- Better exploit the WDM dimension to fully take benefit of the potential of optical technologies
- First target: demonstrate a new xhaul technology satisfying the KPIs of the 5G



NOKIA

Acknowledgments

Colleagues of Nokia Bell Labs ION and Wireless

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

Partners of the GreenTouch project

