Building modern 100G transport networks for Mobility, Video and Cloud applications

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This presentation is using results from Orange-Labs

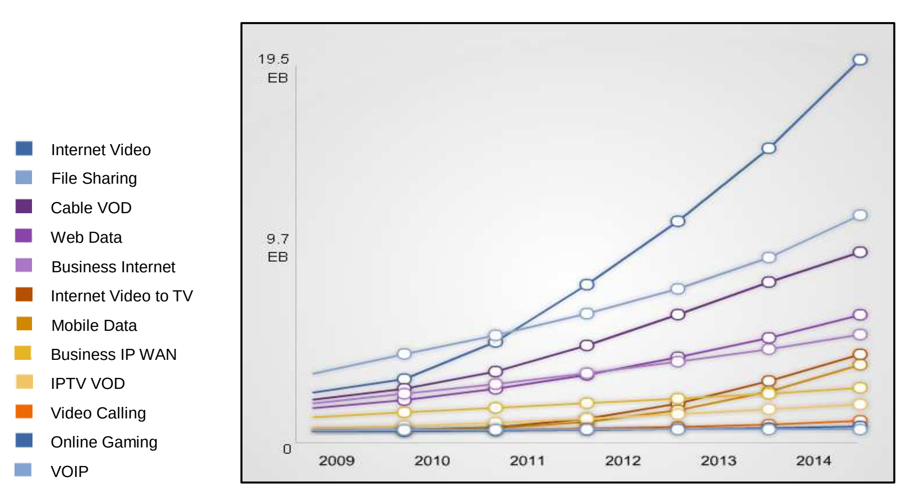
Agenda

- Drivers & enablers for optical network evolution
- The FT/Orange NGN Photonics evolution program and strategy
- 40G/100G Evolution
  - Drivers, technological reminders
  - 100G strategy, guidelines and challenges
  - Deployments within Orange
- IP/Optic convergence
  - Why and which benefits?
  - Solutions

Optical network context
Bandwidth trends

- Renewal or upgrade of optical transport networks needed in many countries
  - More bandwidth needed: traffic growth essentially due to unicast streaming, especially video (total traffic x 5 in 2015)
  - Need to reduce network TCO
    - CapEx savings with better network resources usage
    - OpEx savings with improved and simplified operations

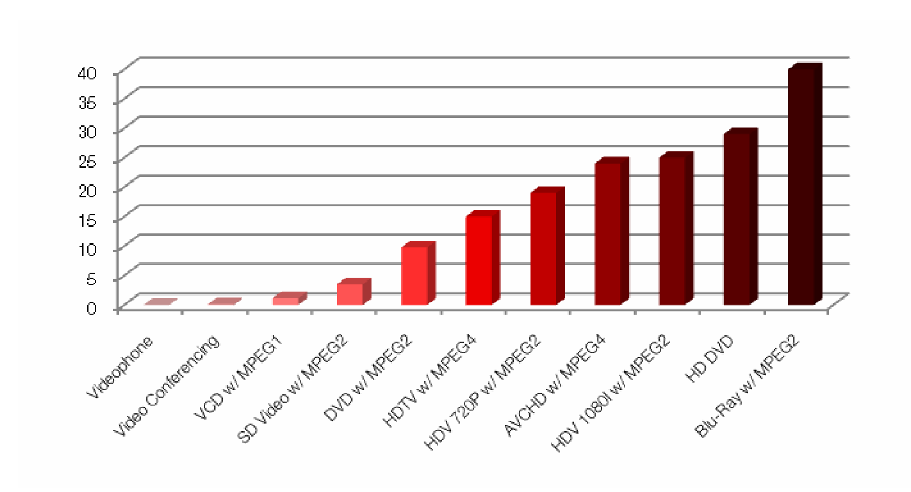
Network Bandwidth Projections



Sources: Cisco VPI, Wikipedia, Infonetics

- Requirement to enhance Quality of Service and user experience
  - Improved performance and SLAs (provisioning time, failure recovery)
- Advanced features from the optical suppliers
  - Optical flexibility and transparency
  - Control Plane

Speeds Required For Streaming a Single Video



Drivers & challenges for ONE*

Drivers:

- Rapid growth of packet traffic (L2/L3 services) - Transition from circuit to packet
- Support evolution of existing services (Triple-Play, Mobile, SAN interconnect, video transport,..) and new services (Bandwidth on Demand, Optical restoration, wholesale services) in a cost-effective way
- Meet the required quality of service and improve the user experience
- OpEx and CapEx optimization

Challenges:

- To provide more bandwidth with less investments while revenues are stable
- How to migrate efficiently from TDM to packet-based solutions?
- Reduction of Operational complexity and improvement of end-to-end QoS
- Obsolescence of legacy equipments or networks (e.g. WDM 1G,…)

Next-Gen optical transport will be the key to new bandwidth-intensive applications

*ONE: Optical Network Evolution

In a nutshell….

The requirements

- More bandwidth
- Keep existing infrastructure
- New meshed architecture
- Low CapEx and OpEx
- Flexibility (allocation, routing)
- Dynamicity and automation
- High resiliency
- Fast service delivery
- New services
- Green
- Packet and TDM transport
- Packet/optic synergies

The enablers

ROADM

CONTROL-PLANE

40G/100G

AGGREGATION /SWITCHING

The conditions

Service traffic

Number of services
Service splitting/volume
Location Egress/Ingress
Traffic distribution & forecasts
CoS & expected QoS

Service architecture

Capability to upgrade
Topology (i.e. meshed vs hub and spoke vs hierarchic vs ring)
Interfaces (speed, technology)

Transmission network

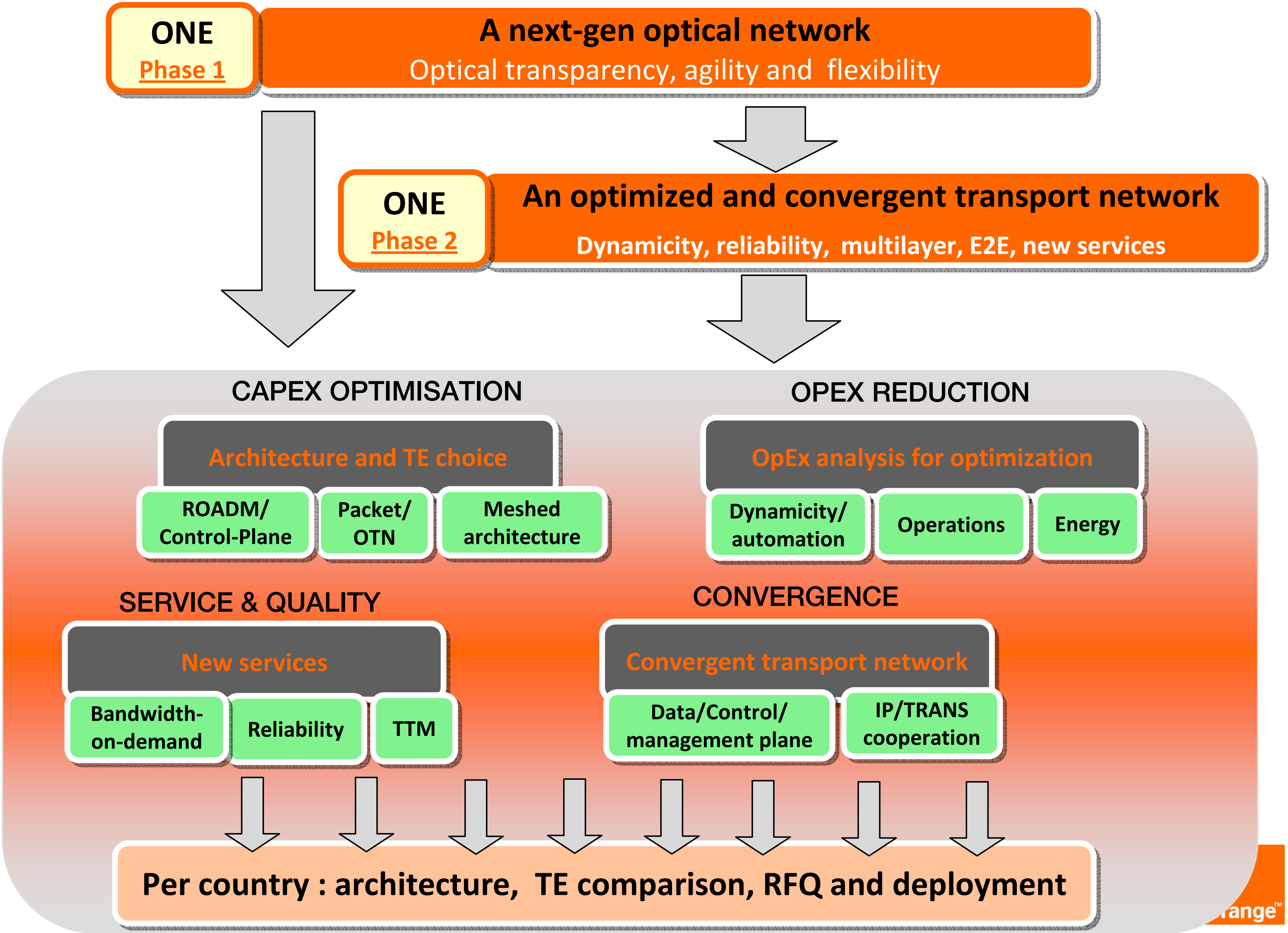
Nodes number & perenniality
Equipment number & policy of interconnection
Architecture (backhaul, Core)
Current deployed equipment

Infrastructure

Leased fibers or owner
Quality of fibers (impairments)
Connectivity degree (mesh)
Distance between nodes

The Orange strategy for ONE

Orange ONE program



ONE program achievements

Meshed Architecture / ROADM	✓ Architecture evolution in many countries to evolve from a point-to-point links towards a meshed transparent core optical network; average 15% CapEx savings (compared to WDM terminals) ✓ ROADM introduction today in Core networks, and under study in large backhaul ✓ Optical RFQs launched in 6 European countries in 2010/2011
Flexibility	✓ Optical flexibility (colourless/directionless) recommended to ease and speed provisioning and reconfiguration ✓ Proven OpEx savings
40G/100G	✓ New optical Core networks enable 40G and 100G introduction on the existing fiber infrastructure ✓ 40G deployed in Poland, 40G&100G in IBNF (EEN and RLD)
Sub-Lambda	✓ OTN switching today for sub-lambda grooming in Core and Packet switching for future packet transport optimization; enabler for a Control-Plane (Belgium)
Green	✓ ROADMs consume less power than classical WDM terminals (~5%) ✓ Reduction of transit in IP routers evaluated as a major source of power savings: Poland study case showed a 25% decrease on the global IP+Trans consumption
QoS / Availability	✓ Better resiliency thanks to a control-plane: restoration at transmission level deployed in France ✓ Improved TTM

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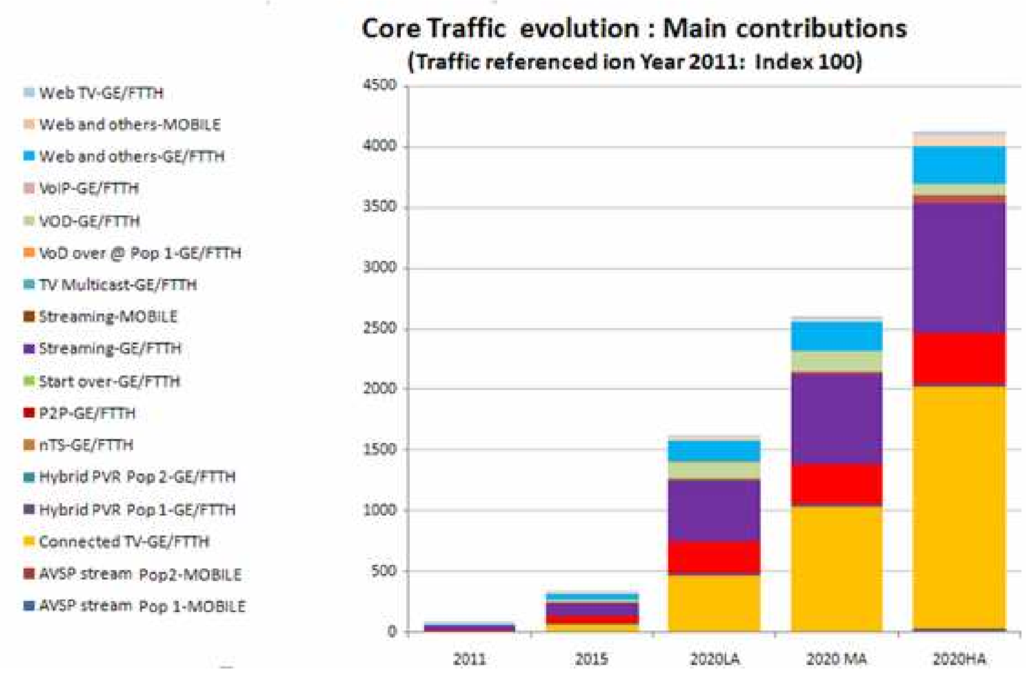
Different renewal solution in FT group

	Key driver(s)	Business case	Network Renewal	Flexibility	Speed
France	BW needed with less investments	Solve congestion & end of support of WDM terminals	ROADM in the Core	Optic: fixed Electric: OTN OXC	100G only
Poland	BW needed with less investments	Too costly to upgrade existing optical network Equipment end of support	ROADM in the Core	Optic: Colourless & directionless Electric: SDH OXC	40/100G only
Spain	Reduce TCO Improve resiliency	Mono-supplier strategy	ROADM in the Core	Optic: Colourless	10G
Romania	More BW needed	End of repair	ROADM in the Core	Optic: fixed at beginning	10G
Moldova	Capacity needed Improve resiliency & Operations	Lack of fibers & costly SDH upgrade	ROADM in the Core	Optic: Colourless (target)	10G
Slovakia	Bandwidth needed	ROADM Colourless; possible upgrade of existing network	ROADM in the Core	Optic: Colourless	10G
Belgium	BW needed	Too costly to upgrade existing optical network (20 k€ per 10G vs 3,7 k€ for 10G port on ROADM)	ROADM in the Core	Optic: colourless	10G 40G soon

40G/100G Evolution

40G/100G for higher capacity

The Orange France Case



Source: OLabs 2011 studies

- 2020: 13M fixed & 30.5M mobile subscribers
- Main growth is unicast streaming resulting from service delinearisation
- Connected Elements extend their footprint in households and will play a major role
- Traffic spatial distribution is highly impacted by the success of OTT services
- Considering traffic hypothesis, upgrade of the WDM trunks is required in BACKHAUL in 2018/2019
  - either to higher rate : 40 Gbps would be sufficient
  - And/or to a higher number of channels – We could then keep 10Gbps rate
- ….And we must upgrade the CORE network at 100 G
  - From 2014 for dense trunks
  - From 2016 to 2017 for sparse trunks
- One 100G key application in transport network is for router interconnection at 100 GbE

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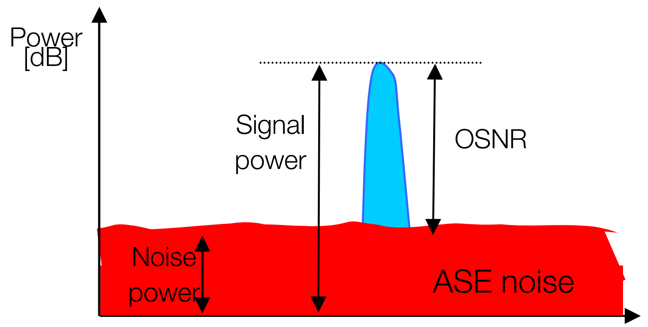
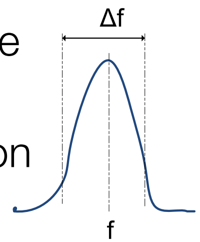
Some basics related to 100G

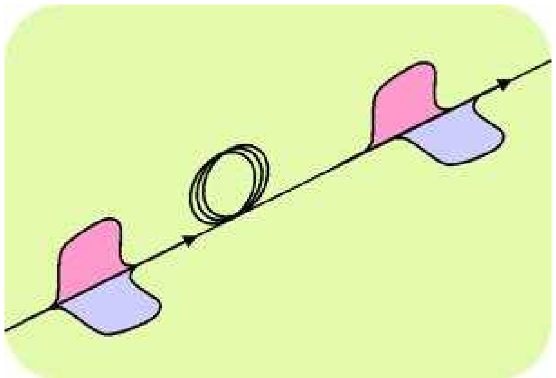


$$OSNR = \frac{\text{Signal power}}{\text{Noise power}}$$

- Optical Signal to Noise Ratio (OSNR)
  - More OSNR required at higher bit rate.
- Chromatic Dispersion (CD)
  - Lasers do not emit a light at a single wavelength but in a band of spectrum width
  - Different frequencies travel over fiber with a different speed. As a result they arrive to the receiver not at the same time. As a result each impulse is broader
  - With this impulse overlap, the receiver can not properly get the original information
  - The higher speed of the signal, the bigger is this problem.
  - 40G is 16 times more impacted by CD than 10G, while 100G is 6 times more impacted than 40G

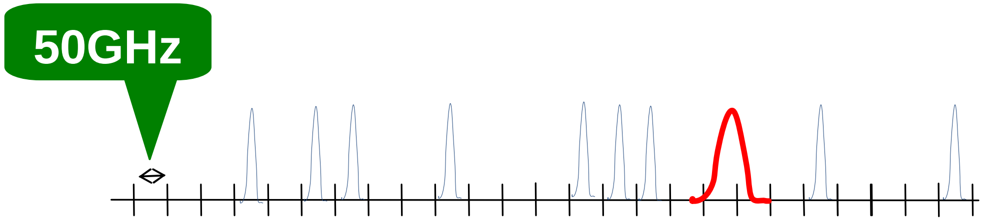


- Polarization dispersion (PMD)
  - Different polarization modes travel at a different speed
  - As a result the single impulse is wider. For high frequencies the receiver cannot properly receive the original information.
  - The higher speed of the signal, the bigger is this problem.
  - 40G is 4 times more impacted by PMD than 10G, while 100G is 2,5 times more impacted than 40G
  - PMD is not linear and difficult to compensate. It can change over time



Some basics related to 100G

- WDM Grid
  - WDM grid is divided into 50GHz slots.
  - A signal must fit into the slot. The higher frequency the wider is a signal.
  - For 100G we need to have a different modulation that will let us squeeze into 50GHz space.



- To deploy 40/100G we need to:
  - Have better OSNR
  - Be more resilient to CD
  - Be more resilient to PMD
  - Squeeze into 50GHz spacing

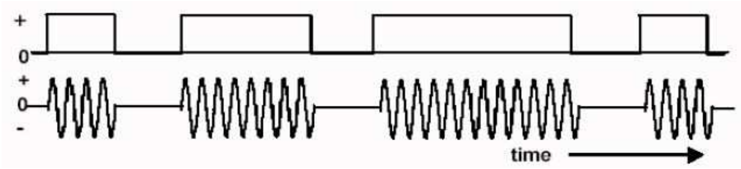
- To achieve this we need to:
  - Select another modulation format
  - Decrease baud rate*
  - Use more electronics

coherent technology
is the breakthrough
that solves these issues!

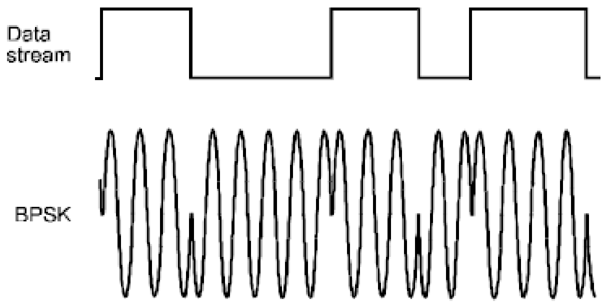
* baud rate is a speed at which the date is sent

Modulation formats

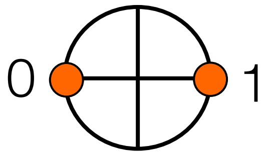
- Amplitude shift keying (ASK)
  - This traditional modulation format is not sufficient for 40G/100G transmission



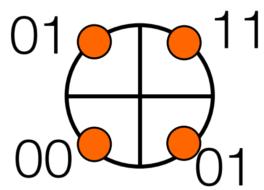
- Phase Shift Keying (PSK)
  - Data is encoded by a change of phase
  - Better resilience against non-linear effects (an amplitude remains almost constant over time)
  - BUT, increases complexity (multiple signal states need to be detected by a receiver)



  - BPSK
    - Binary PSK – change of phase encodes one bit (0 or 1)



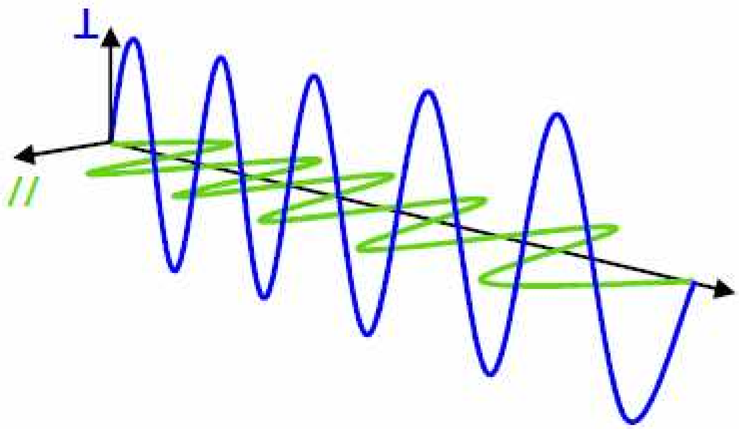
  - QPSK
    - Quaternary PSK – change of phase encodes two bits (00, 01,10 or 11)
    - Baud rate is decreased by half

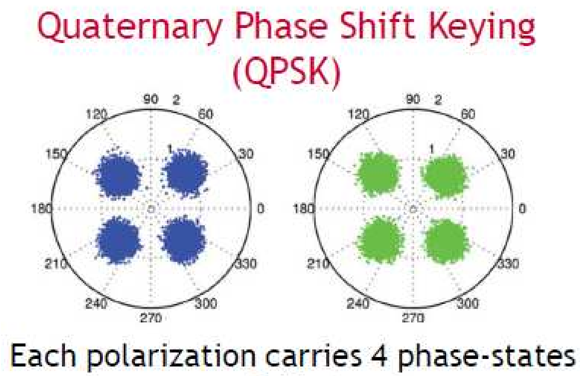


  - 16QAM
    - Further reduces the baud rate by a factor 2 wrto QPSK but with a limited reach (<700km)

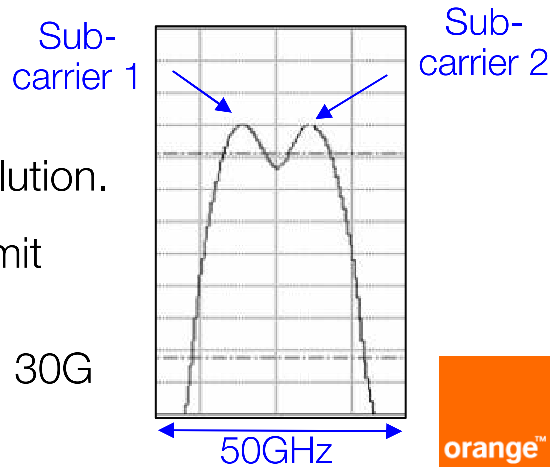
Polarization Dual Multiplexing (PDM)

- Signal may also be sent in two polarization states. Half of the data would be sent horizontally while the other half vertically.





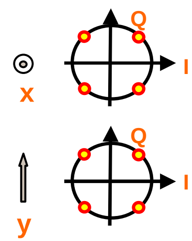
- PDM allows to further reduce the baud rate by a factor 2.
- PDM is enabled by coherent digital signal processing: a digital tracking loop follows and correct the rotations and mixing of the 2 polarizations. PDM is not practical without digital signal processing and associated coherent receivers.
- 100G PDM QPSK signal has a typical 28G baud rate (with HDFEC).
- Additional way to limit baud rate is to implement a dual sub-carrier solution.
  - For 100G 2C PDM-QPSK, the baud rate is reduced to ~14G (limit electronic cost & complexity)
  - For 400G 2C PDM-16QAM, the baud rate is maintained around 30G



100G Coherent optical technology

- Coherent technology mixes a received optical signal with a local oscillator approximately centered on the signal's frequency band.
- With coherent detection, full information is retrieved (polarization, phase, amplitude); and thanks to digital processing, it is then possible to compensate linear degradations, PMD and CD.
- If 100G was implemented with NRZ OOK, it would require 10dB more OSNR margins, while with coherent PDM-QPSK only +5dB is typically required.

Modulation format	PMD Tolerance @ 1 dB OSNR Penalty	Back-to-Back OSNR	50 GHz Compliant (# 50 GHz ROADM traversed)	CD Tolerance @ 1 dB OSNR Penalty	Transmission Reach @ 50 GHz Spacing	10/100 GCross Nonlinearities Sensitivity	Complexity Cost
NRZ *100 Gbaud*	1 ps	Reference	No (NA)	15 ps/nm	NA	NA	+++
Coherent Dual-Pol QPSK *28 Gbaud*	> 25 ps	-5 dB	Yes (# 10)	Several thousands of ps/nm	1200 km*	++++	+++++



- Essentially one 100 G solution implemented and standardized (40G experience)
  - Coherent PDM-QPSK (standardized by OIF): transmission reach reduced of 40% when compared to 40G
  - (*) But with powerfull soft-decision 25 % FEC leading extra OSNR margin of more than 2dB, coherent 100G DP-QPSK could increase the 1200 Km reach

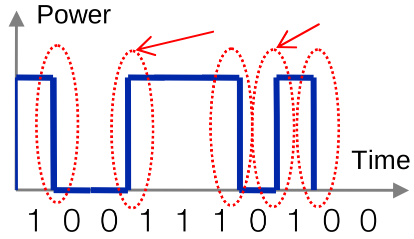
→ Coherent 100G PDM-QPSK is convenient for both metro & LH applications.

40G/100G strategy in FT Orange Group

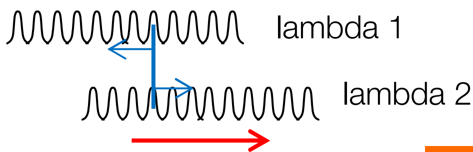
- FT Orange 40G/100G deployment strategy is based on coherent technology
  - 50 GHz compliant and same PMD target (12-15ps) as 10G to keep existing infrastucture (Mux/Demux stages, EDFA, 50GHz ROADM and fiber)
  - Coherent DPM QPSK or BPSK modulation formats

- In Greenfield deployment of 100G coherent (no 10G), a new line design allows to maximize performance, with DCM removal and associated new single stage amplifiers
  - Lower CapEx, lower power consumption, higher system availability, reduced latency

- 100G coherent deployment over existing 10G network is challenging since existing 10G channels cause higher non linear penalties for coherent signals
  - 10G power transitions cause non linear phase shift for the coherent signal
  - 10G channels require dispersion compensation (DCF), which is penalizing because it limits the walk off between channels.
  - On the contrary, in DCU free systems, each lambdas travel at different speeds, meaning the associated penalty is averaged and reduced over a higher number of symbols.
  - At higher bit rate, the walk-off is increased: 100G PDM QPSK is more resilient than 40G PDM QPSK to 10G interactions



10G NRZ OOK



Walk off = symbols of λ 2 travels at a different speed than symbols of λ 1

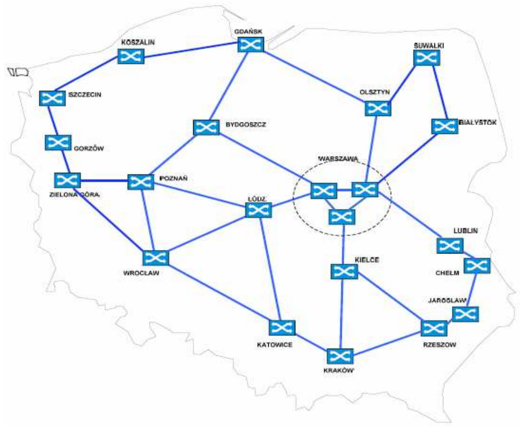
100G upgrade of legacy 10G links

Guidelines

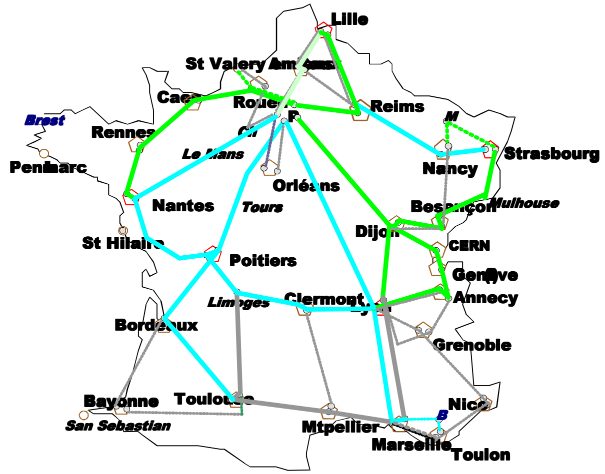
- Allocate one part of the spectrum to 10G channels (preferentially higher frequency channels) and the other to coherent signals: do not mix 10G and coherent channels across the spectrum.
- N channels guard band may be required (depending on the suppliers): tests required
  - Colourless feature of ROADM could provide flexibility to release a guard band without on-site operations and with limited traffic impact
  - In case of dynamic restoration, the restoration paths have to skip the guard band
- Reduce 10G channel power: reengineering of the line is required. This may compromise 10G reach.
  - to maximize coherent reach (higher transponder cost)
  - same reach for coherent and 10G => 10G power is reduced until its reach is lowered to that of coherent.
- Use Raman amplification on long SMF spans above 25dB loss and even more on G655 (LEAF, TW…) spans from 22dB span loss. Raman amplification favors 10G power reduction while maintaining reach.

100G deployment in FT Orange Group

- Deployment of coherent 40G and 100G is progressing in the biggest Orange countries
- Poland new optical network (deployed)
  - ROADM colourless/directionless
  - High PMD on some links (25 ps)
  - Only coherent 40G/100G network (no DCM)
  - Meshed network GMPLS-ready

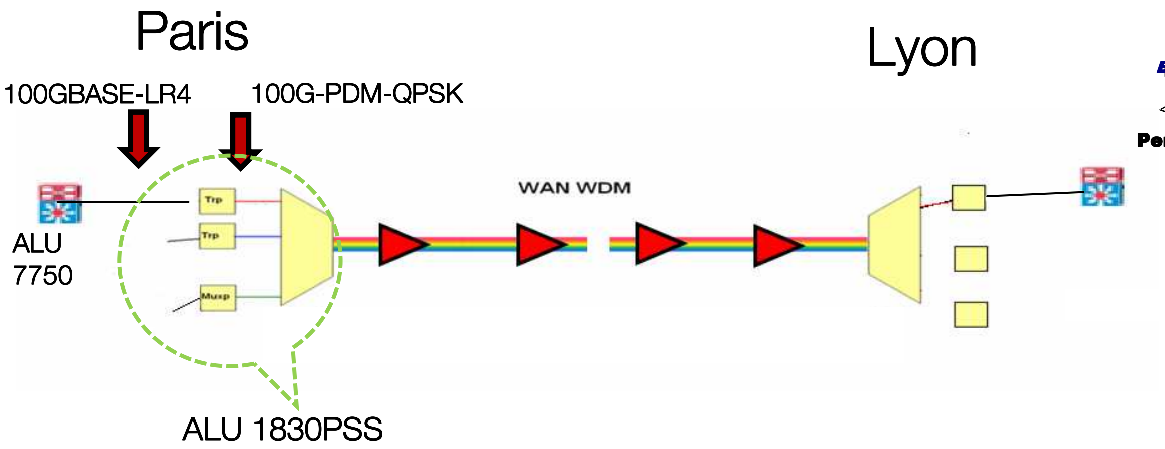


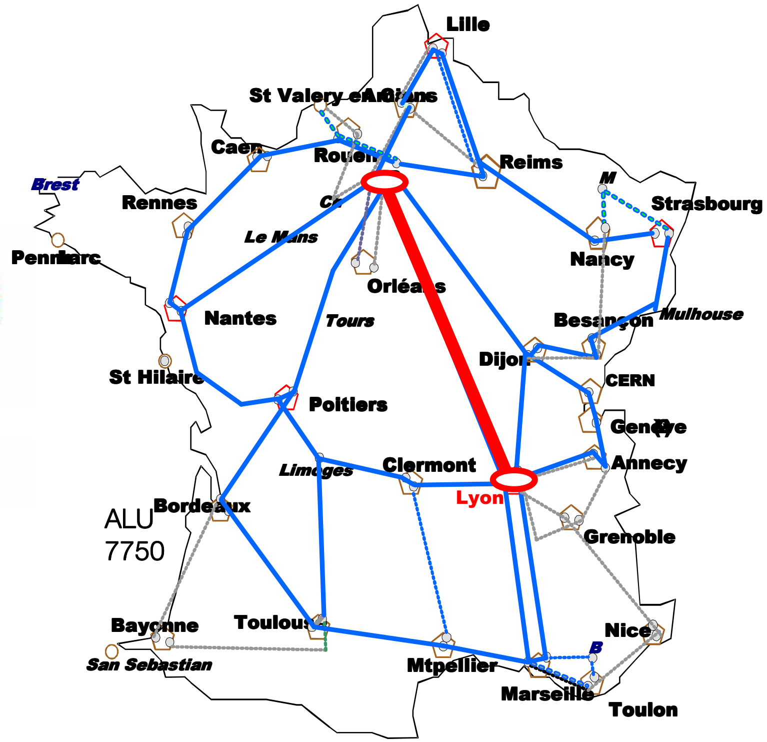
- France new optical network (coming soon)
  - Evolution to 100G with new ROADM infrastructure
  - Cost reduction with less regeneration
  - 100G link Paris-London already deployed (ALU in Alien)
  - Field-trial IP + TRANS at 100G



- Cost considerations
  - 40G: cost attractive when 40G/10G transponder cost ratio lower than ~3.5
  - 100G: the 10G/100G cost ration needs to be close to 7.
  - but, also other benefits: Opex savings, capacity exhaust, reuse of the existing fibers,…
- IP strategy tends to skip 40G and jump directly from 10G to 100G.

Field trial 100G IP + TRANS: Paris - Lyon



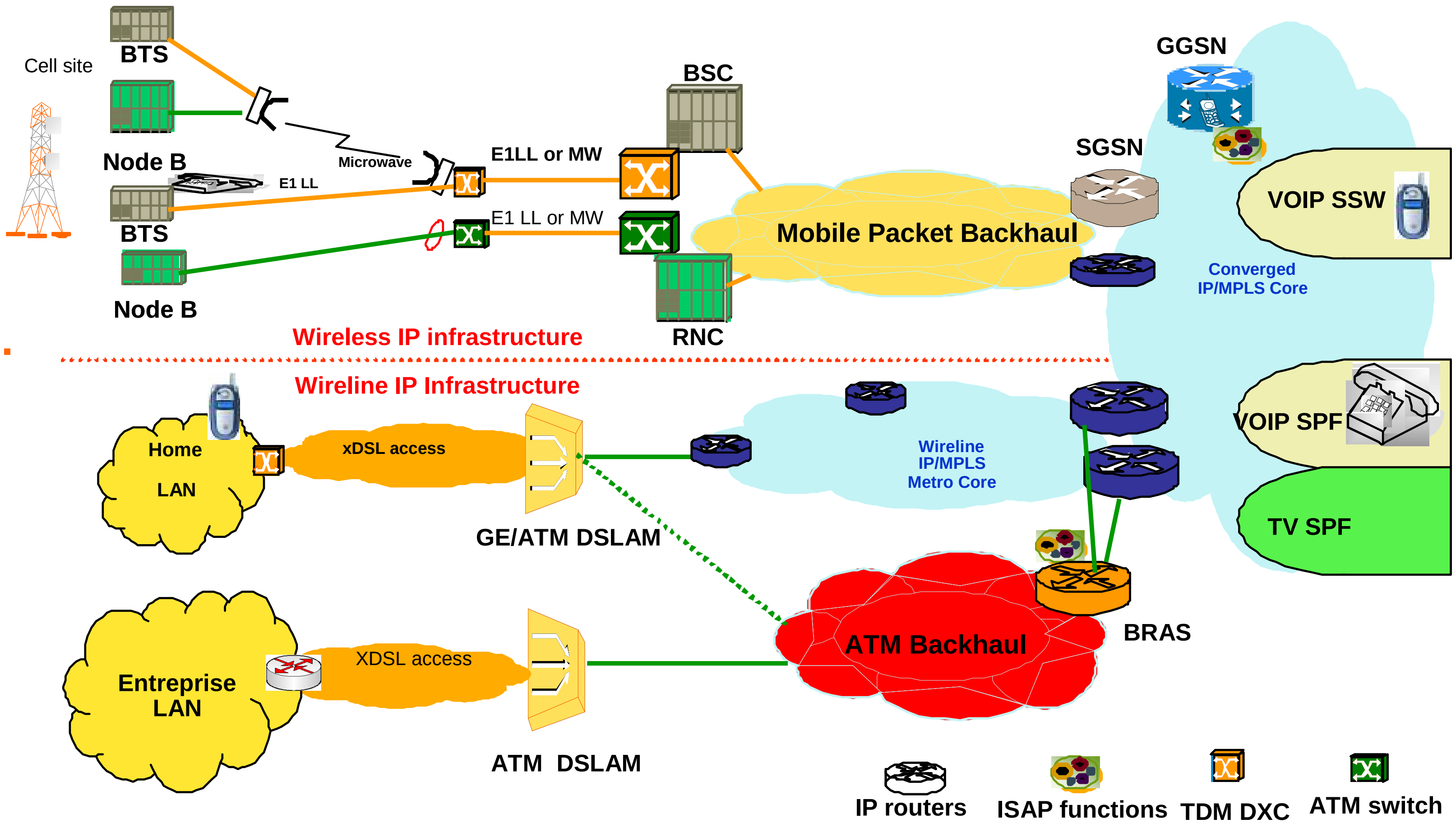


- 100GbE service transported over 100G WDM
- Transport solution: ALU 1830 PSS with 100G coherent PDM-QPSK without regeneration (# 500 Km)
- Real 100GbE traffic → commercial exploitation after field trial
- first tests: 100GbE ALU 7750 router achieved end 2011
- 2nd step tests: 100GbE IP + WDM interworking tests: beginning 2012

Next evolution is IP/Optic convergence

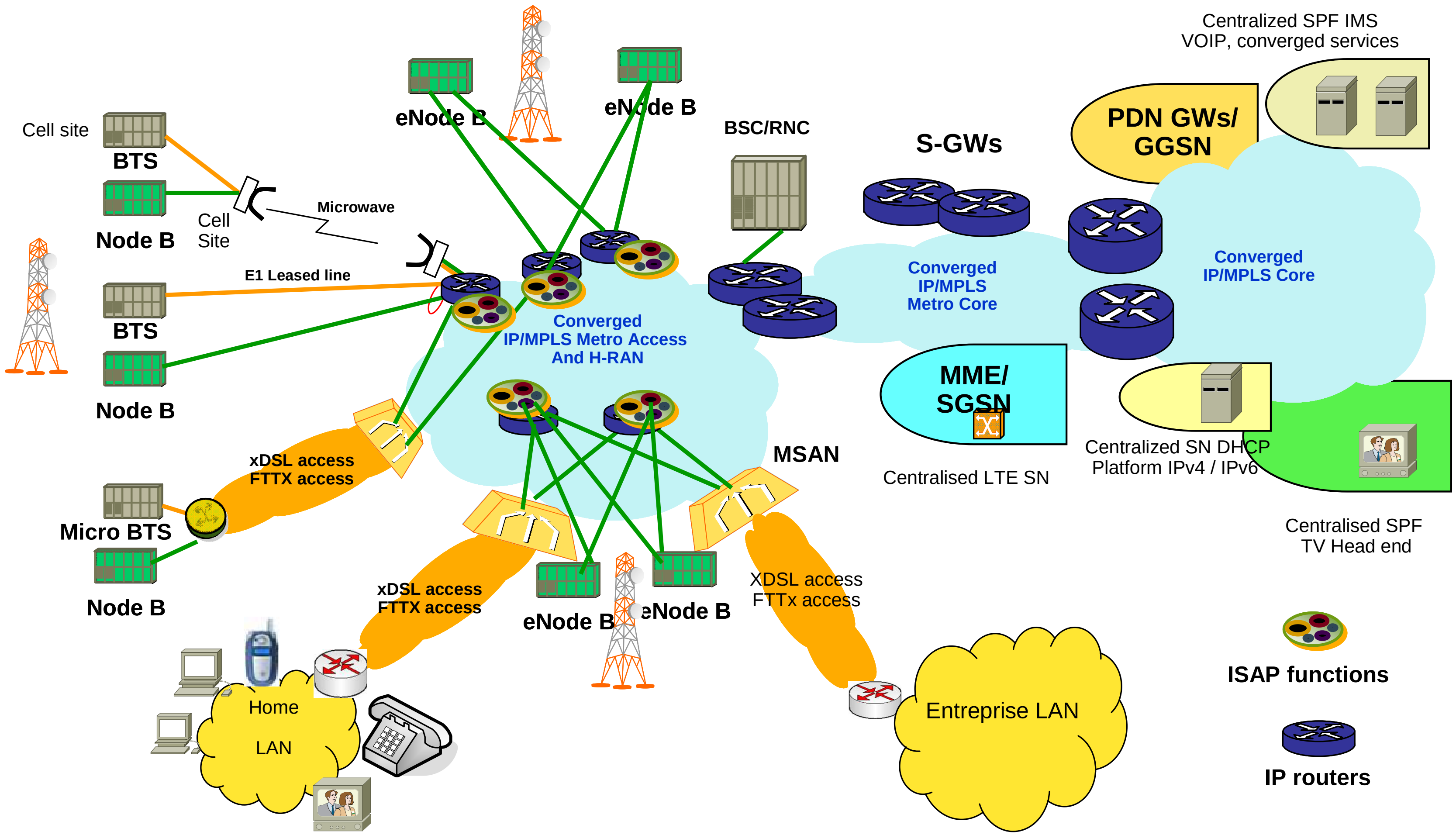
Context: Towards a converged IP/MPLS infrastructure (1/2)

From…



Context: Towards a converged IP/MPLS infrastructure (2/2)

To…



The ultimate objective is convergence

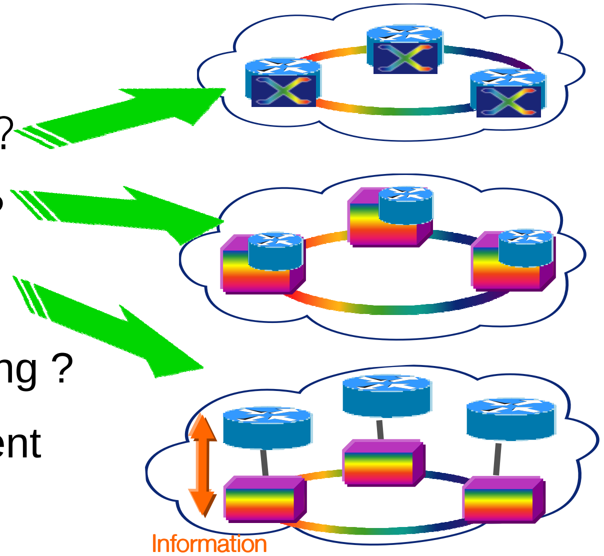
ONE
Phase 2

An optimized and convergent transport network for further CapEx and OpEx savings

Dynamicity, reliability, multilayer, E2E, new services

- IP/MPLS convergence happens progressively from Core to Metro-Core to Metro-Access

- Strategy is synergies between IP and optic at data plane, and/or control plane and/or management plane, for network efficiency and Total Cost of Ownership optimization
  - Is a GMPLS Control Plane as promising as initially thought?
  - optic integrated into packet (e.g. WDM interface in routers)?
  - packet integrated into optic (e.g. L2/MPLS-TP in ROADM)?
  - Still 2 separate equipments which cooperate?
  - Is IPoWDM with coloured interfaces in routers really interesting ?
  - Once the transmission enablers are in place, how to implement the generic recommendations for core optimization ?



➔ Definitive answer to the above questions require the study of real case TCO scenarios

Benefits expected with IP/TRANS Synergies

Transport traffic in the most cost-efficient layer
IP transit by transmission layer

IP, OTN and WDM layers operated as a single transport layer
simpler operations, optimised planning, easier path computation, E2E provisioning, easier troubleshooting (fault correlation between layers), …

Dynamicity and automation across layers
better provisioning time and new BoD services, network resources sharing,…

Reliability and availability
Less human errors, restoration, protection coordination between layers

CapEx OpEx

Data/management/control planes convergence
Some considerations

- Data plane integration, like the so-called “alien wavelengths”: e.g. WDM interface integrated into routers, for expected CapEx/OpEx savings… But
  - IP router needs to support colored interface
  - Impact on network engineering resulting in additional costs (interworking tests)
  - Impact on planning and future network evolution (100G)
  - Problems with the share of responsibility
  - Impact on electrical features (legacy transponders provides grooming features)
  - Impact on the organization for operational management and maintenance

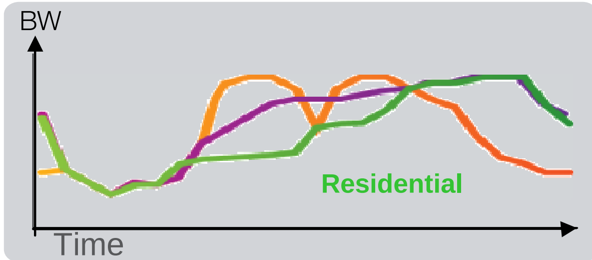
For the time being, no clear profits for coloured interface into routers (IPoWDM) at 10G and 40G for our studied cases.

- Management plane integration
  - Today proprietary NMS solution implies then a mono-vendor approach
  - Cooperation needed between vendors but few solution today
- Control-plane integration
  - Next slides

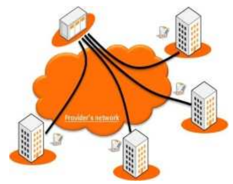
A Control-Plane for transmission

Opportunities & challenges

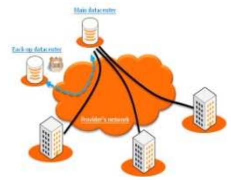
- Network optimization and better performance
  - Simplified operation and maintenance (auto-discovery, I&C, reduced on-site interventions).
    … but limited number of interventions in core networks
  - Enhanced network's availability thanks to restoration features (multiple failures, disaster recovery)
  - Reduced service set-up time, due to flexibility and automation
    … but limited number of interventions in core networks
  - Sharing of resource: allocated/released dynamically



- Enhancement of existing services
  - Better SLAs, TTM, performance and QoS
- New services
  - Bandwidth-on-demand (set-up/modification)

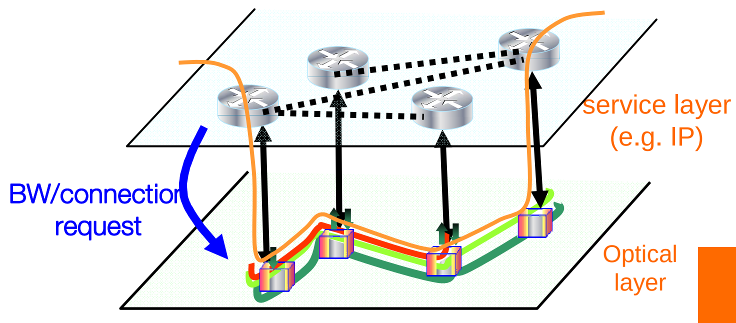


Scheduled bandwidth



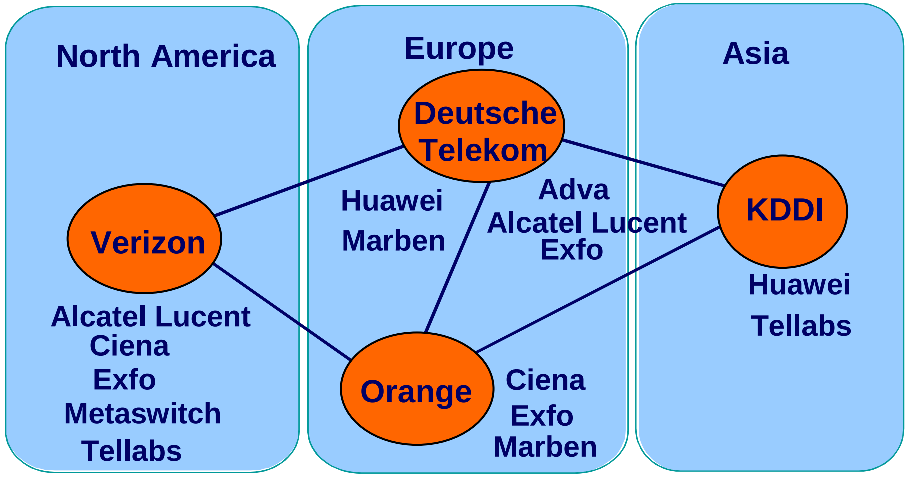
Datacenter restoration

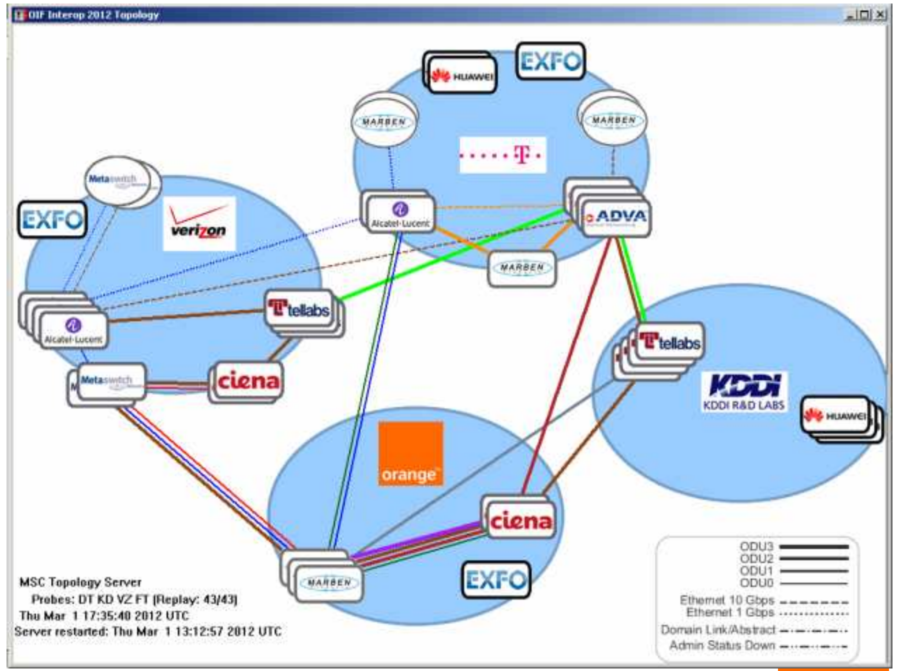
- Muti-layer synergies and optimization with IP
  - Multilayer connection (diverse) routing
  - Inter-layer service provisioning (w/ GMPLS UNI)
  - Optical circuit faults known by routers
  - set-up or BW modification triggered by routers



OIF Interoperability Demo 2012

- Dynamic transport of Ethernet services thanks to a multi-layer and multi-vendor Control-Plane
- End-to-end provisioning of Ethernet Private Line (EPL) over OTN using OIF UNI 2.0 & E-NNI 2.0
- Demo shows that OTN could be an Ethernet- and packet-friendly transport technology (from 1 to 100Gbps).
- It shows that a multi-vendor networking is achievable through control plane nodes.
- End-to-end control of multi-domain and multi-layer connections is eased when using standardized control plane interfaces.





Conclusion

- Optical network evolution is required to allow more bandwidth with less investment and to reduce TCO
- This evolution relies on: ROADM, 40G/100G, OTN, Control-Plane
- Introduction of 100G is a mandatory step at least in the Core. Coherent technology is recommended by Orange
- 100G deployment over existing 10G infrastructure leads to engineering challenges to interwork with legacy 10G. A 100G-only greenfield network allows new DCM-less infrastructure
- IP/Optic convergence is the next step, to allow synergies for a global transport optimization.
- Synergies at data/control/management plane are recommended
- Control-Plane is a key enabler for this convergence and OIF demonstrated its benefits


thank you!