WELCOME

The Road Towards Packet Optical Transport Networks:
Optical Transport Networks Evolution to OTN/DWDM

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Alcatel-Lucent
April 9th – ISCTE-IUL

AGENDA

1. BANDWIDTH DRIVERS
2. OPTICAL TRANSPORT NETWORK EVOLUTION
3. OTN OVERVIEW
4. IP OVER OTN/DWDM
5. WHAT'S NEXT

BANDWIDTH DRIVERS
TRANSFORM THE OPTICAL NETWORK

MORE THAN

80%

OF ALL NEW SOFTWARE WILL BE AVAILABLE AS **CLOUD SERVICES** BY 2014*

*Bell Labs – Value of Cloud for a Virtual Service Provider study, 2011

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APPROXIMATELY

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OF ALL INTERNET TRAFFIC **WILL BE VIDEO** BY 2015**

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**Informa Telecoms and Media, 2011

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OF ALL NEW SOFTWARE WILL BE AVAILABLE AS **CLOUD SERVICES** BY 2014*

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OF ALL INTERNET TRAFFIC **WILL BE VIDEO** BY 2015**

MORE THAN

20 BILLION

SMART DEVICES WILL BE **CONNECTED** BY 2020***

*Bell Labs – Value of Cloud for a Virtual Service Provider study, 2011 **Informa Telecoms and Media, 2011 ***Strategy Analytics

BANDWIDTH DRIVERS
TRANSFORM THE OPTICAL NETWORK

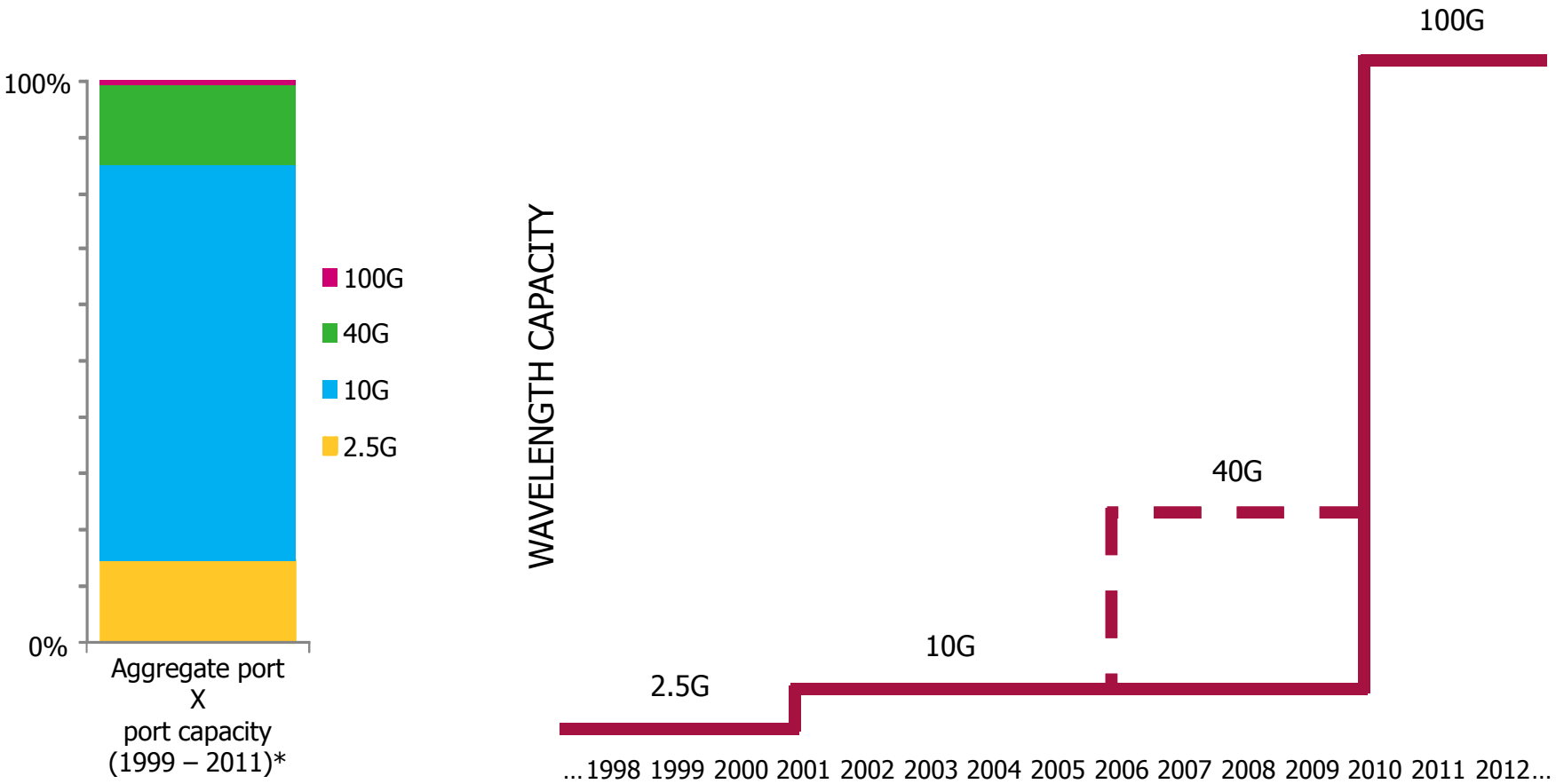
MASSIVE SCALE

INCREASED **AGILITY**

EFFICIENT NETWORKING

GREATER **INTELLIGENCE**

ONCE IN A DECADE
TRANSITION IS UPON US



* Dell'Oro: O25A Optical Forecast Tables, January 2012

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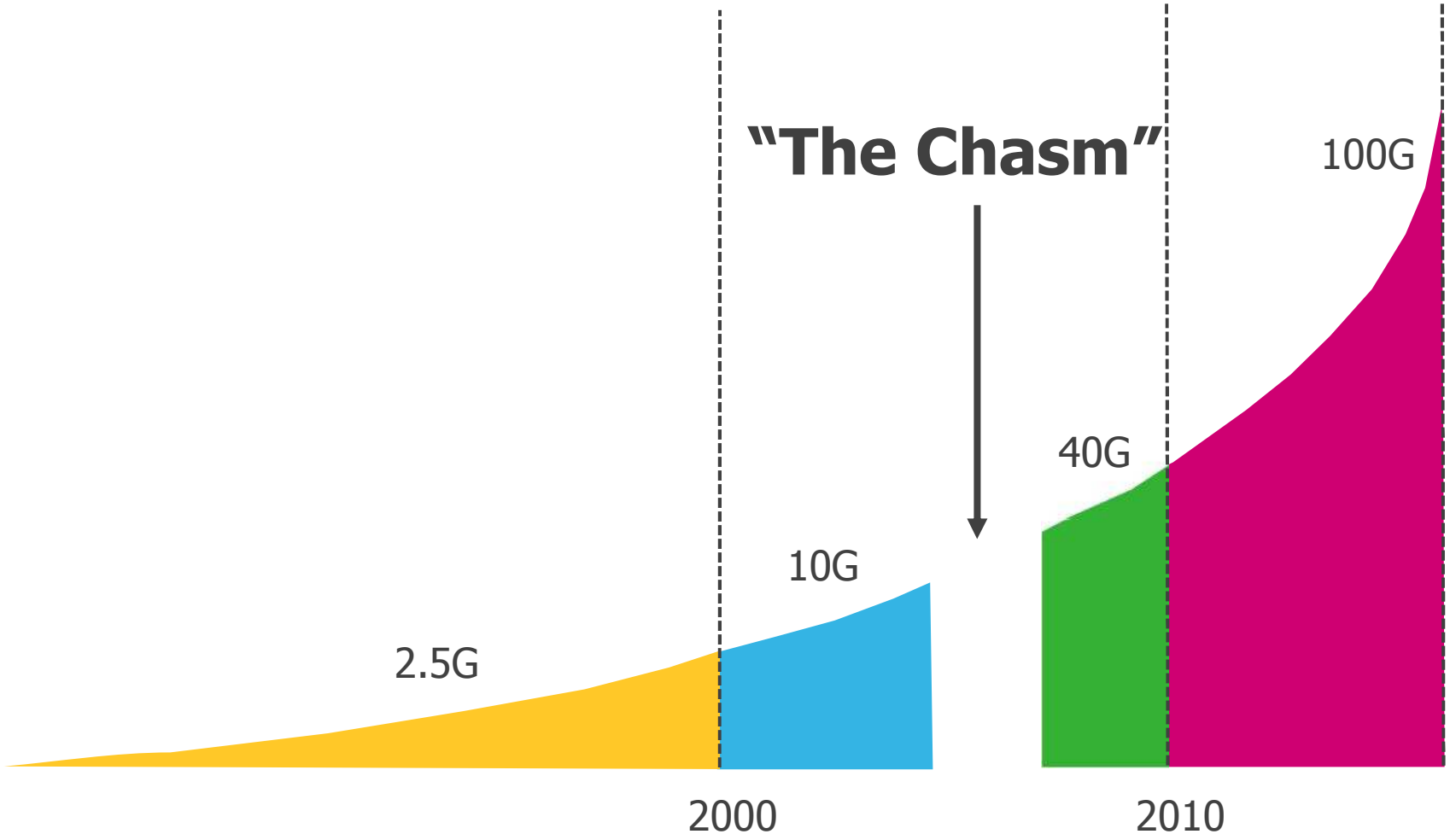

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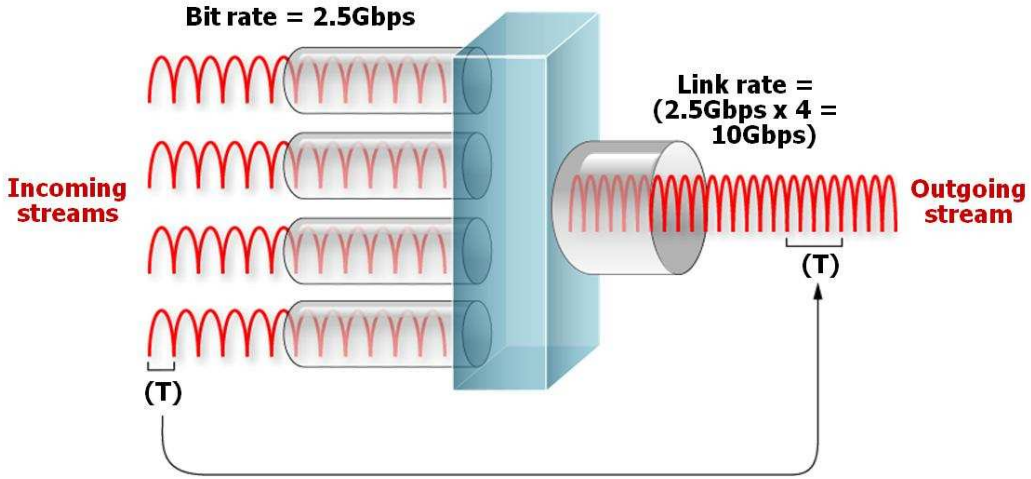
OPTICAL TRANSPORT NETWORK EVOLUTION

Types of Multiplexing

- **TDM/SDH**

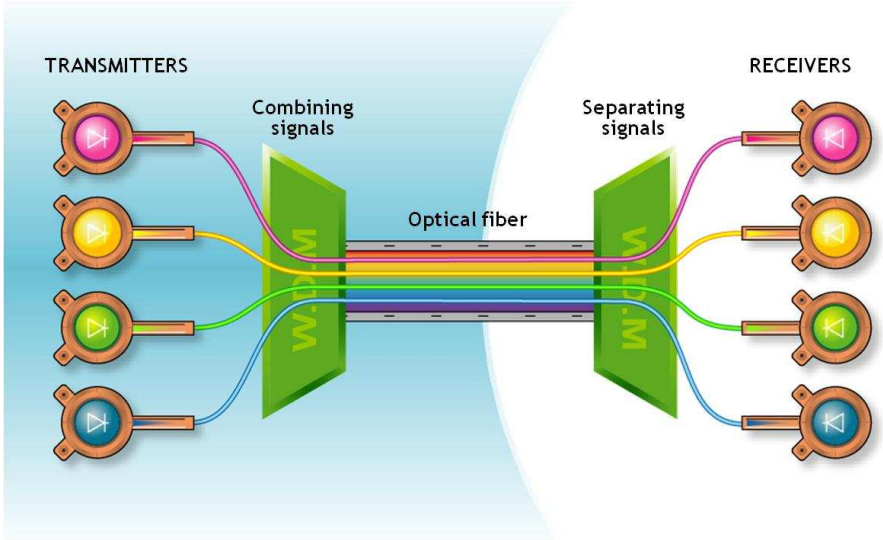
Time Division Multiplexing

An example of TDM Application is SDH



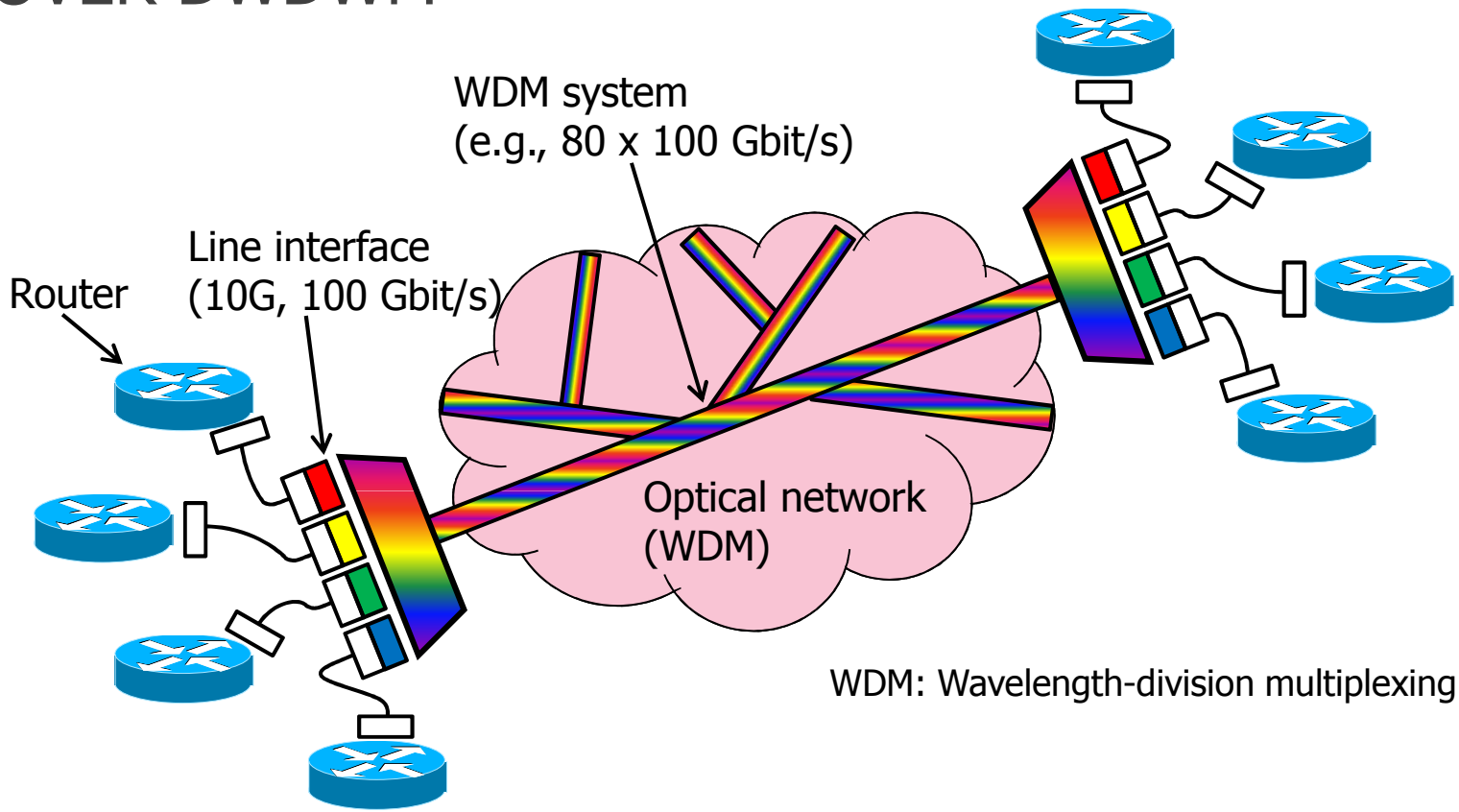
- **WDM**

Wavelength Division Multiplexing



OPTICAL TRANSPORT NETWORK EVOLUTION

IP OVER DWDWM



Key Technology #1: WDM = Solution to reach multiterabit/s capacity

Key Technology #2: OTN = Solution to transport IP over DWDM

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OPTICAL TRANSPORT NETWORK (OTN)

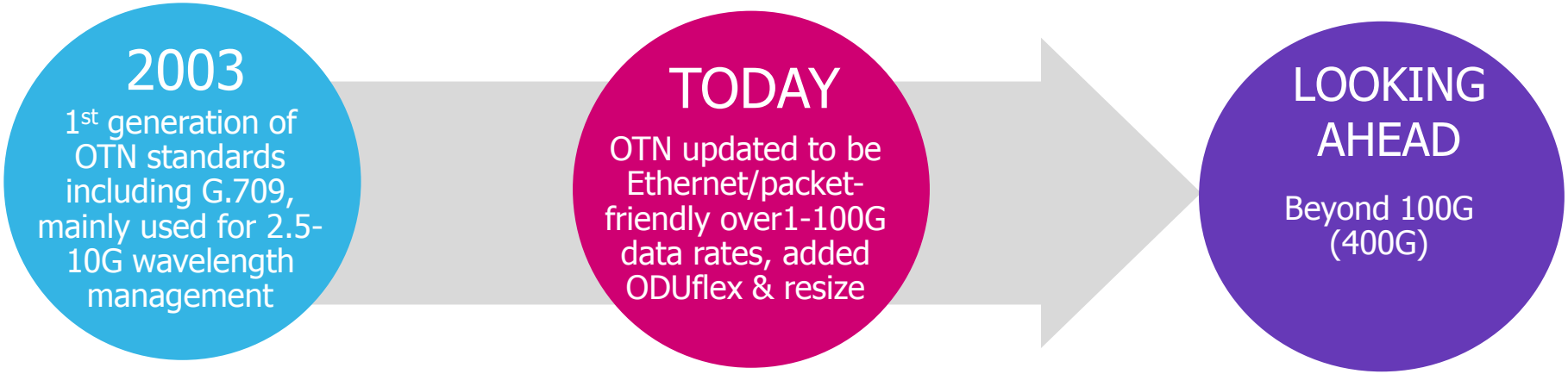
What is it?

- Integrated switching and multiplexing structure with electronic and photonic layers

Benefits

- Reliable switching and transparent transport for all client types:
  - **Ethernet** (1-100 GbE, VLAN), IP-MPLS/MPLS-TP, Data Center/Video/SAN, SDH/SONET
- Maximizes wavelength utilization, reducing capex and extending network lifetime
- Full suite of OAM (Operations, Administration and Management) features

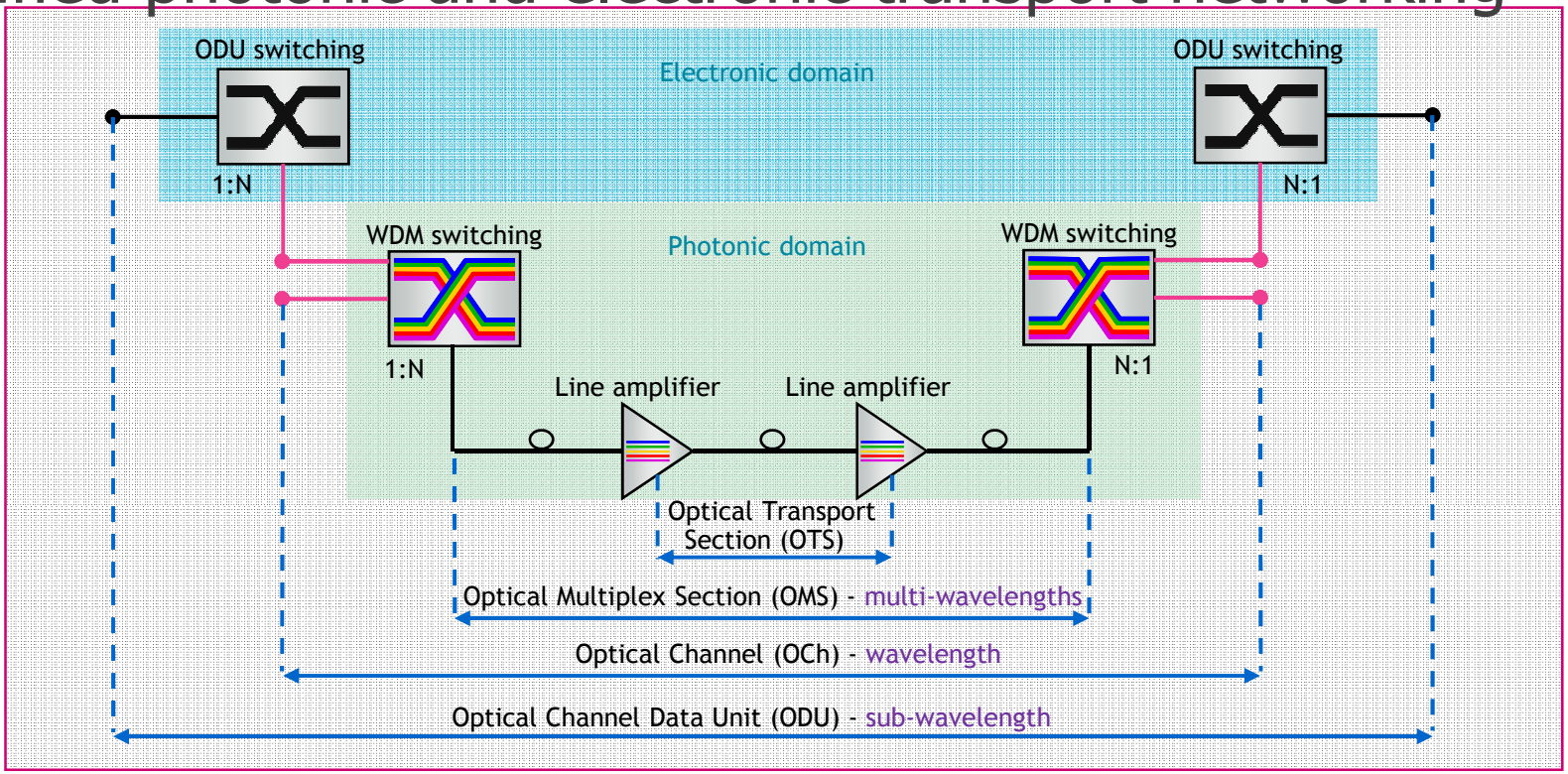
OTN BACKGROUND



OTN provides a multi-service capable backbone infrastructure supporting lambda and sub-lambda services with guaranteed quality

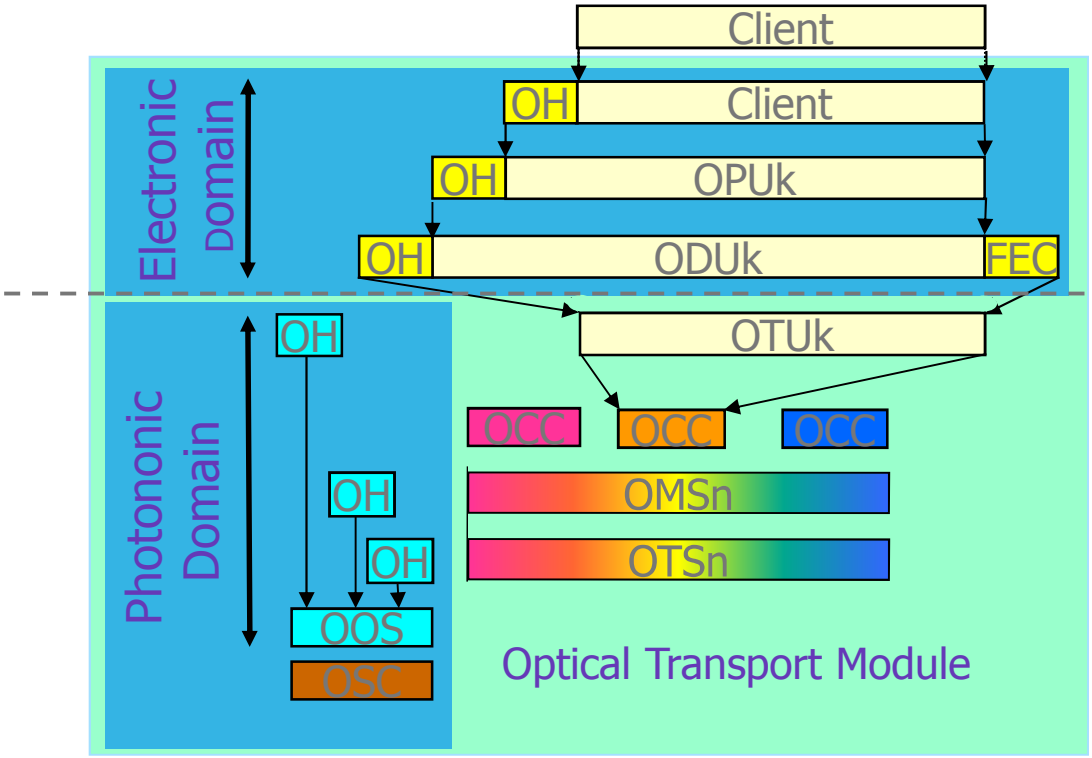
OTN HIERARCHY

Unified photonic and electronic transport networking



- OCh provides end-to-end bandwidth management for a wavelength signal in the photonic domain
- ODU provides end-to-end bandwidth management for a sub-wavelength signal in the electronic domain
  - is a fixed-sized container with in-band OAM tools for quality supervision and SLA assurance
  - functions as primary bearer for client traffic
  - Lower Order (LO-ODU) transparently carries 1.25G, 2.5G, 10G, 40G, 100G client signal rates
  - Higher Order (HO-ODU) transparently carries multiple (multiplexed) LO-ODUs

OTN HIERARCHY
OPTICAL TRANSPORT MODULE



OCh Payload Unit (OPUk)

OCh Data Unit (ODUk)

OCh Transport Unit (OTUk)

Optical Channel (OCh)

Optical Channel Carrier (OCC)

Optical Multiplex Section

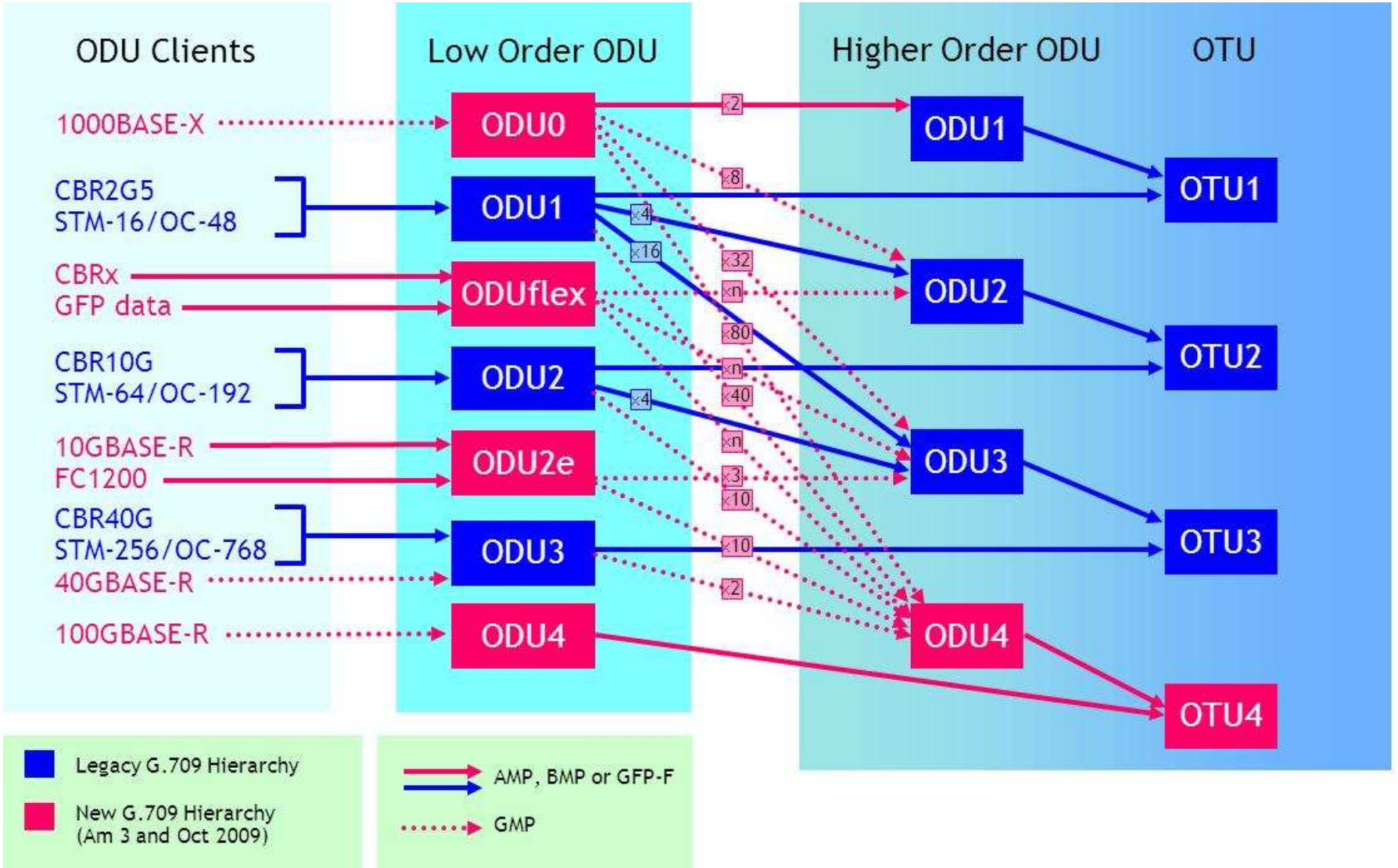
Optical Transmission Section

Optical Supervisory Channel

ITU-T G.709 (December 2009): Highlights
OTH Rates

OTUk	ODUk	Marketing Rate	True Signal (OTU)	True Payload (OPU)	ITU-T G.709
NA	ODU-0	1.25Gb/s	NA	1.238Gb/s	Dec 2009
NA	ODU-flex	n*1.25Gb/s	NA	n*1.238Gb/s	Dec 2009
OTU-1	ODU-1	2.5Gb/s	2.666Gb/s	2.488Gb/s	Jan 2003
OTU-2	ODU-2	10Gb/s	10.709Gb/s	9.953Gb/s	Jan 2003
OTU-2e	ODU-2e	11Gb/s	11.096Gb/s	10.312Gb/s	Dec 2009
OTU-3	ODU-3	40Gb/s	43.018Gb/s	39.813Gb/s	Jan 2003
OTU-4	ODU-4	100Gb/s	111.809Gb/s	104.794Gb/s	Dec 2009

ITU-T G.709 (December 2009): Highlights
Optical Transport Hierarchy (OTH)



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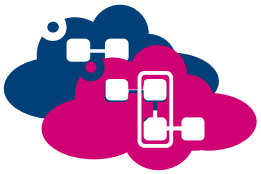
IP-OPTICAL CONVERGENCE
STRATEGIC QUESTIONS

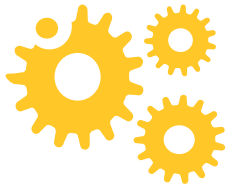


PHYSICAL NETWORK EVOLUTION

How will currently separate IP and Optical networks evolve into a single converged IP-Optical architecture?

LOGICAL NETWORK EVOLUTION

What opportunities exist to simplify layer network architecture by converging or eliminating layers?



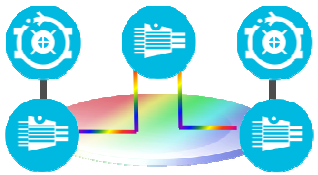
OPERATIONAL CONSOLIDATION

Are there opportunities to converge and streamline operational management tasks across IP and Optical?

IP over DWDM
DIFFERENT OPTIONS

1

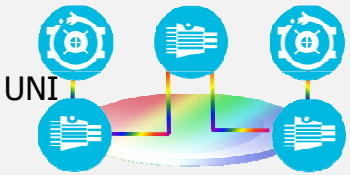
IP and DWDM



- IP OVER DWDM BASED PHOTONIC ARCHITECTURE
- NO OPTICAL RESTORATION

2

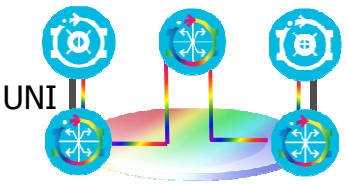
IP over DWDM



- IP OVER DWDM-BASED PHOTONIC ARCHITECTURE
- LAMBDA GROOMING
- PHOTONIC RESTORATION

3

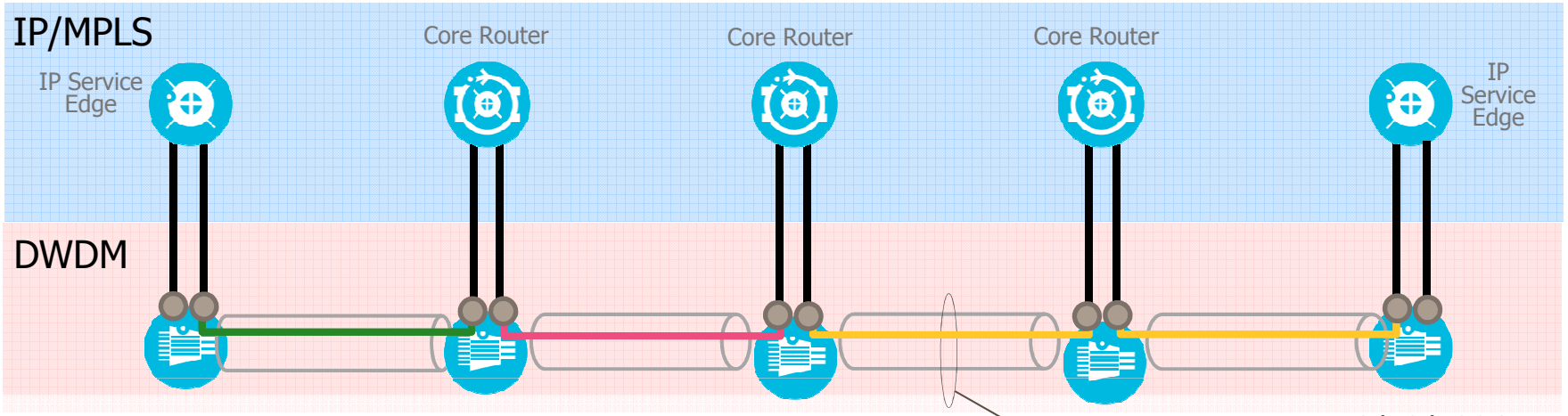
IP over OTN



- IP OVER OTN/DWDM BASED SWITCHED/PHOTONIC ARCHITECTURE
- SUBLAMBDA/LAMBDA GROOMING
- MULTILAYER RESTORATION (MRN)

IP AND DWDM
TRANSPONDER INTEGRATED IN DWDM

1



Core Router interfacing
Requires optical transponders in DWDM
Many Electrical-Optical Conversions

Traffic grooming
Statistical multiplexing in the IP core
Fairly low fill grade (~50-60%)

Core Router Topology
Strongly meshed topology to minimize # of router hops. No bypass

Service protection
IP and MPLS fast reroute mechanisms

IP AND DWDM
APPLICABILITY

1

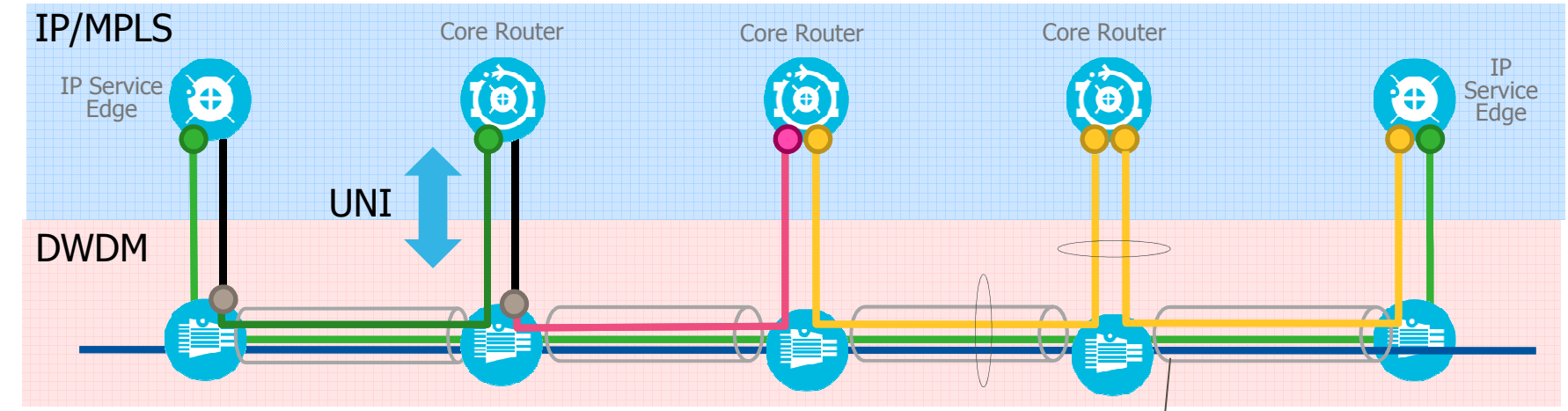
- **Advantages**
  - Low cost router optics
  - Minimal IP-optical interworking need

- **Drawbacks**
  - Scaling cost (meshing cost, low fill grade)
  - No "leased line" service support
  - Costly due to many E-O-E conversions
  - No IP visibility on transport performance
  - IP interfaces/links need to be manually mapped on photonic layer resources

Simple but inflexible and costly to scale
Least amount of IP – optical integration

IP OVER DWDM
TRANSPONDER INTEGRATED IN ROUTER

2



Core Router Interfacing
Colored interfaces into ROADM
Fewer Electrical Conversions

Traffic grooming
Statistical multiplexing in the IP core
Lambda switching in ROADM

PORT AND λ SWITCHING

Core Router Topology
Selective bypass as needed using
10, 40 or 100G optical shortcuts

Service protection
IP and MPLS fast reroute mechanisms
Optical layer protection mechanisms

IP OVER DWDM
APPLICABILITY

2

Advantages

- Reduce need for EOE conversions
- IP layer has direct visibility on optical transport layer performance
- UNI allows IP layer to dynamically request lambdas in photonic layer
- Lambda leased line services

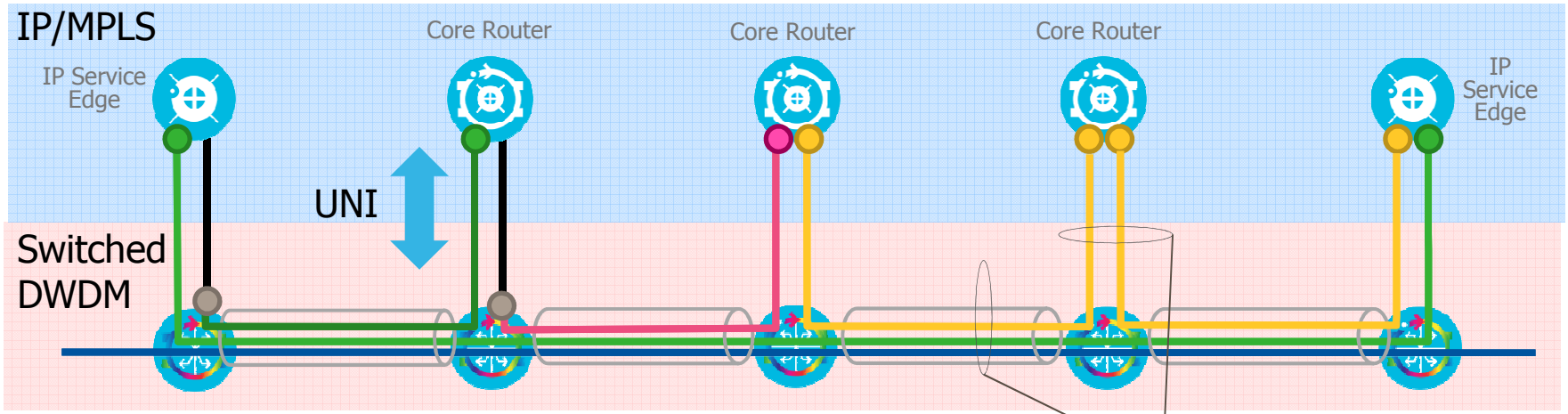
Drawbacks

- Colored router optics are more costly
- Must resolve IP-optical interworking challenges at data and control plane
- No native TDM (sublambda) service support
- Ties the capacity of the DWDM layer to the router speed port.

Better scale & flexibility but more exposed to IP – optical interworking issues

IP OVER OTN (OVER DWDM)
GRANULAR GROOMING AND TRUE TDM

3



Core Router Interfaces
Colored interfaces or black & white
Fewer Electrical Conversions

Traffic grooming
Statistical multiplexing in IP layer and grooming at photonic/electrical layer

Flexible grooming

Core Router Topology
Selective bypass as needed through electrical or photonic layer

Service protection
IP and MPLS fast reroute mechanisms
Electrical/Photonic restoration

IP OVER OTN
APPLICABILITY

Advantages

- IP layer has indirect visibility on digital transport layer issues
- UNI allows IP layer to dynamically request lambdas/circuits from Switched WDM
- Flexible, granular and highly efficient traffic grooming with selective IP shortcut options
- Sublambda/Lambda leased lines services

Drawbacks

- IP layer has direct visibility on optical transport layer issues
- Colored router optics are more costly
- EOE conversion to access sublambda layer
- Must resolve IP-optical interworking challenges at data and control plane

Best scale, flexibility and service versatility.
Most exposed to IP – optical integration issues.

IP-OPTICAL CONVERGENCE
CONCLUSION

- In the real world 'one solution does not fit all'

'IF THE ONLY TOOL YOU HAVE IS A HAMMER EVERYTHING LOOKS LIKE A NAIL'

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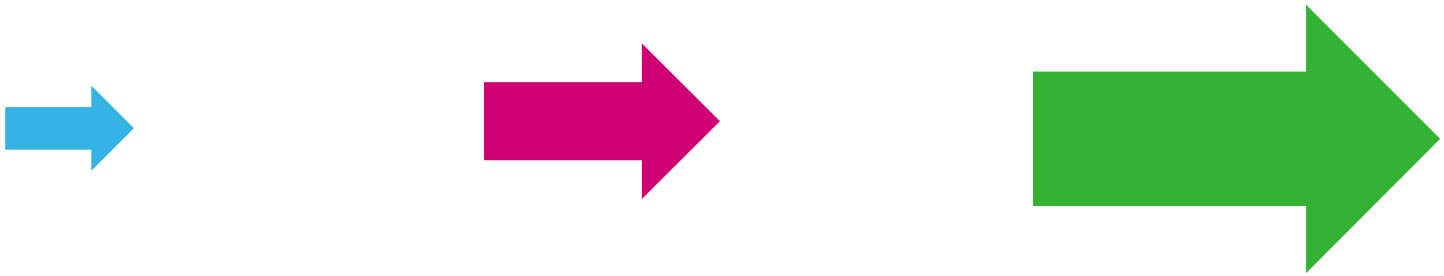
WHAT'S NEXT

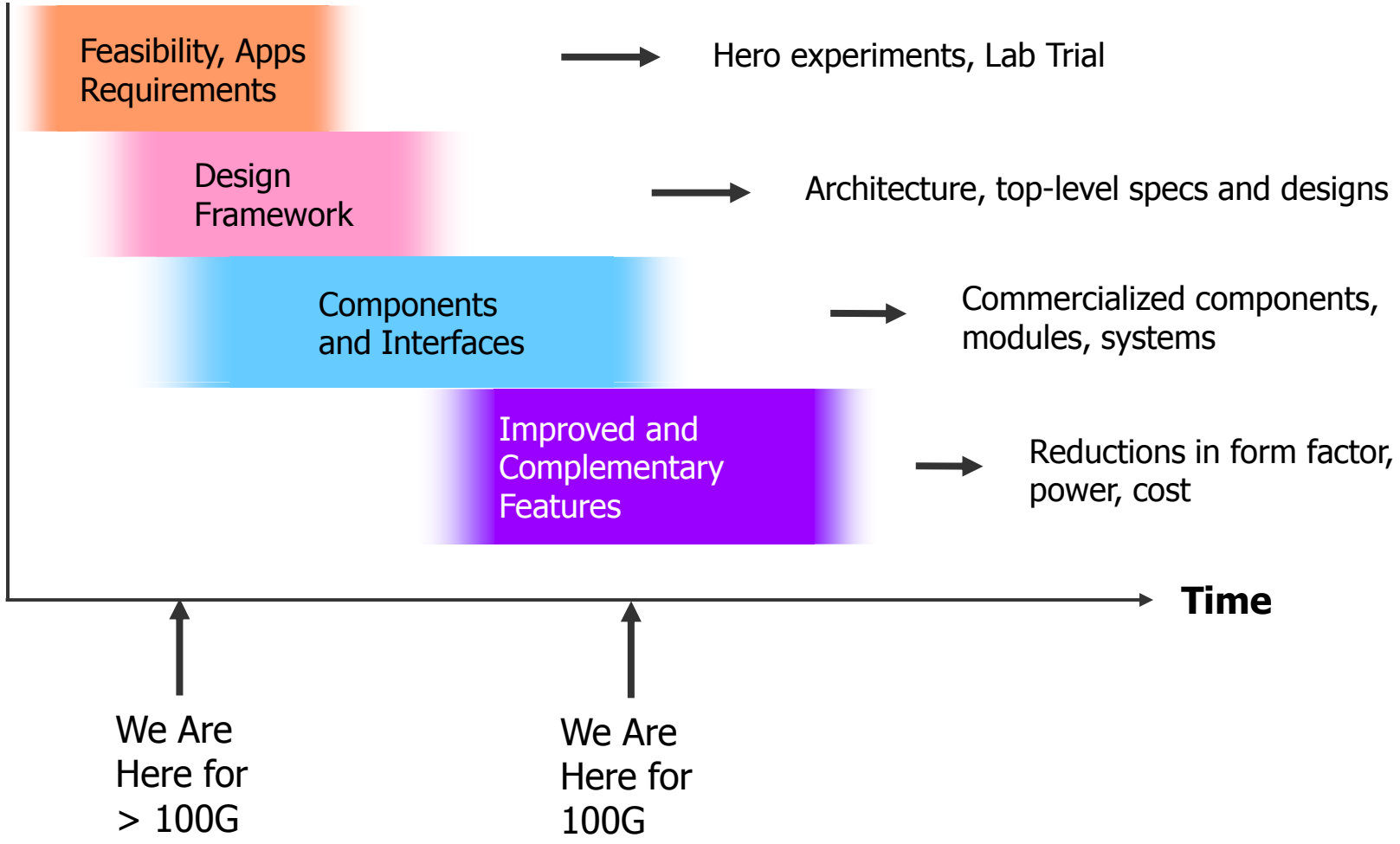
100 GIGABIT

400 GIGABIT

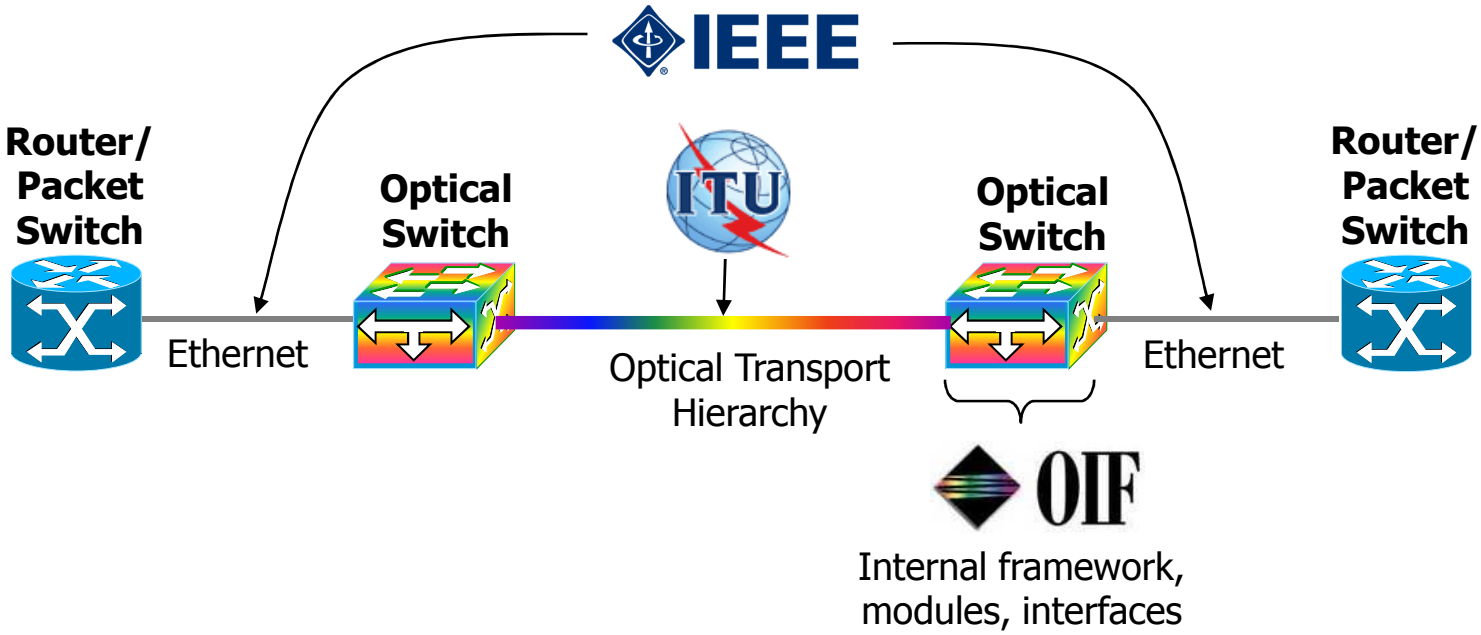
1 TERABIT



WHAT'S NEXT
HIGH SPEED STANDARDIZATION CYCLE



WHAT'S NEXT
HIGH SPEED STANDARDIZATION GROUPS

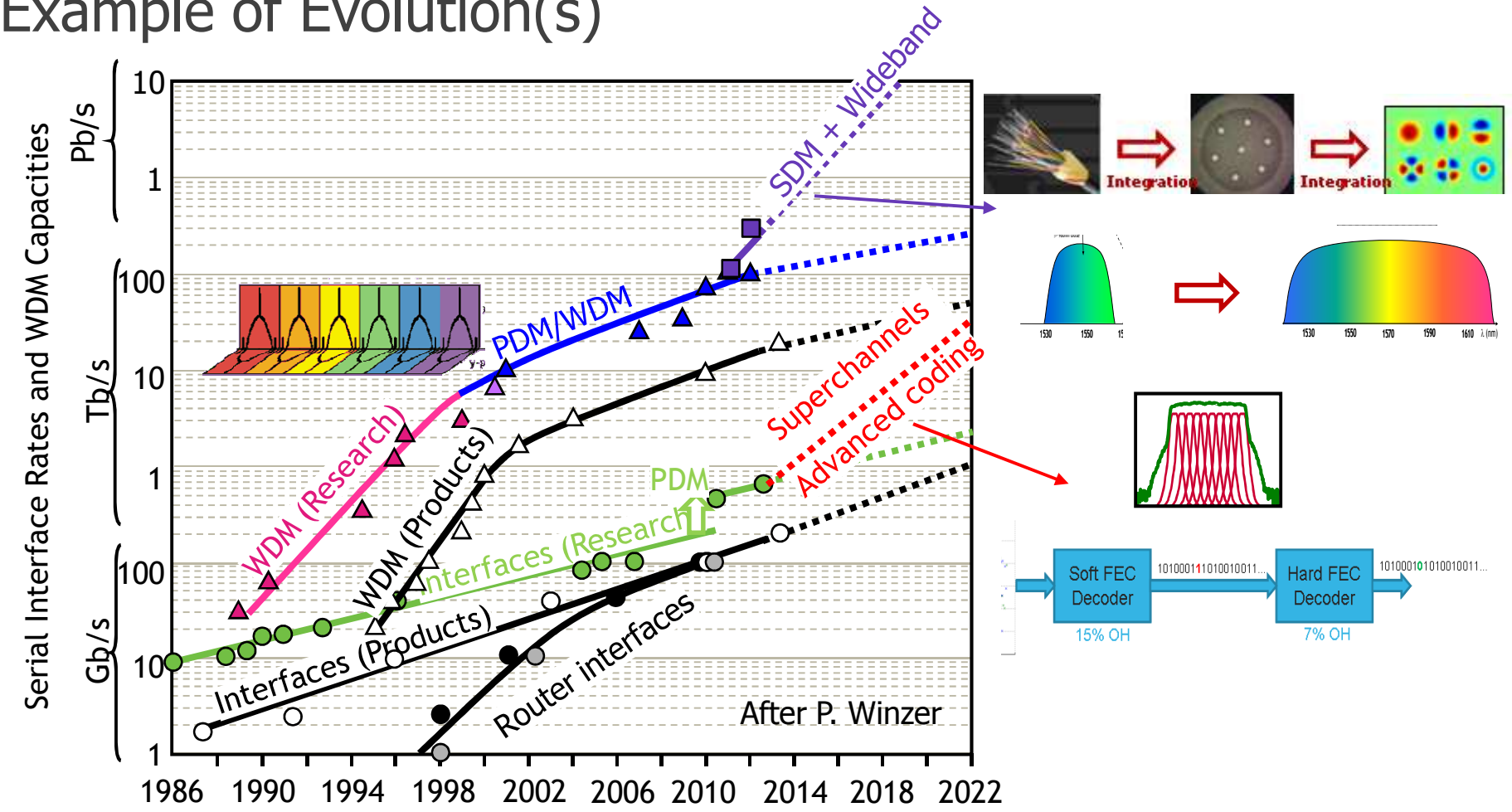


- Global leader of transport standardization: infrastructures, systems, equipment, optical fibers, control and management
- OTN, SDH, TDM, packet transport

- 802.1 leadership in Ethernet architecture and networking protocols
- 802.3 leadership for 40GbE/ 100GbE and Beyond

WHAT'S NEXT

Example of Evolution(s)



THE DREAM: 10Tbit/s optical interface and 10Pbit/s transport capacity

- The transition to 100G is upon us
- **Alcatel-Lucent** is shining a light on the path to 400G, 1Terabit and beyond

AT THE SPEED OF IDEAS

Alcatel·Lucent

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