Joint ITU-T / IEEE Workshop on The Future of Ethernet Transport

(Geneva, 28 May 2010)

Carrier Perspectives on Moving Beyond 100G

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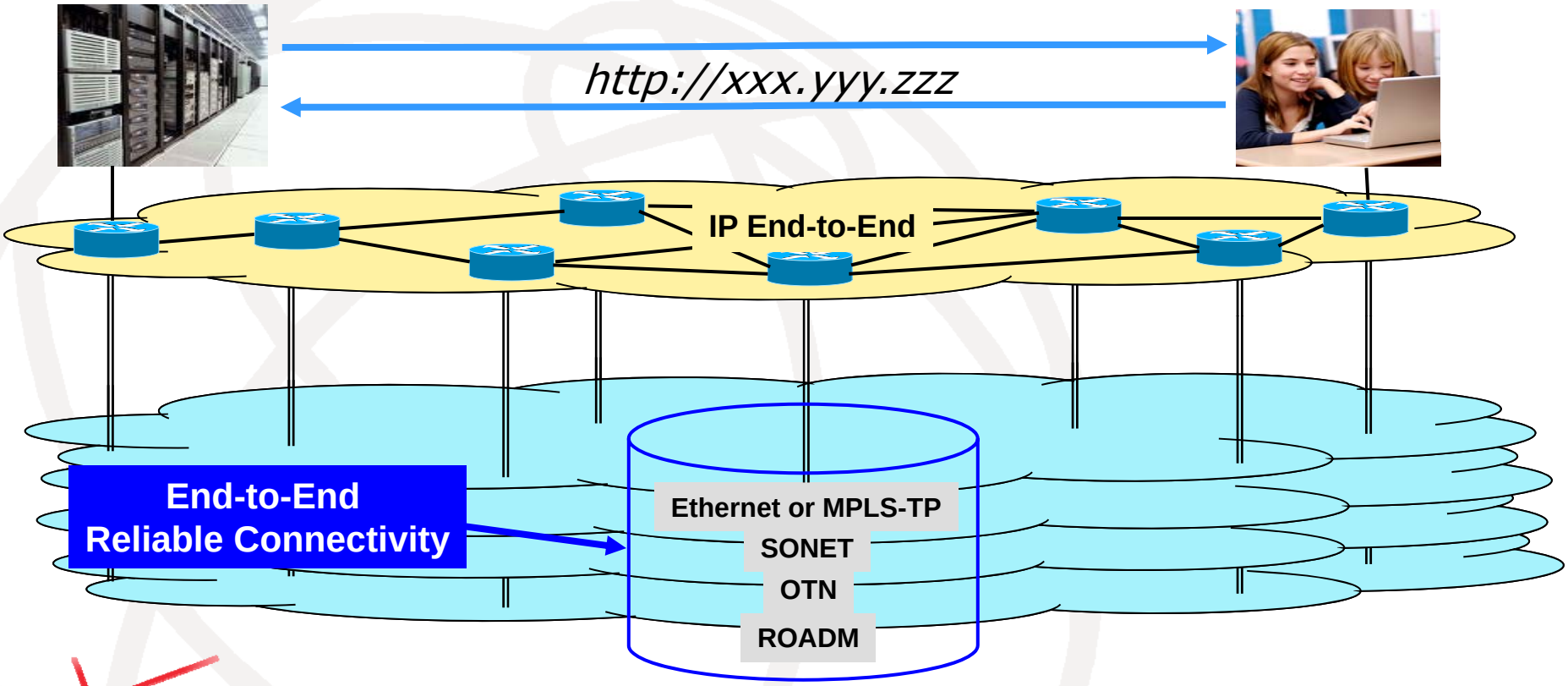
Network & Technology

Verizon

Putting it into Context



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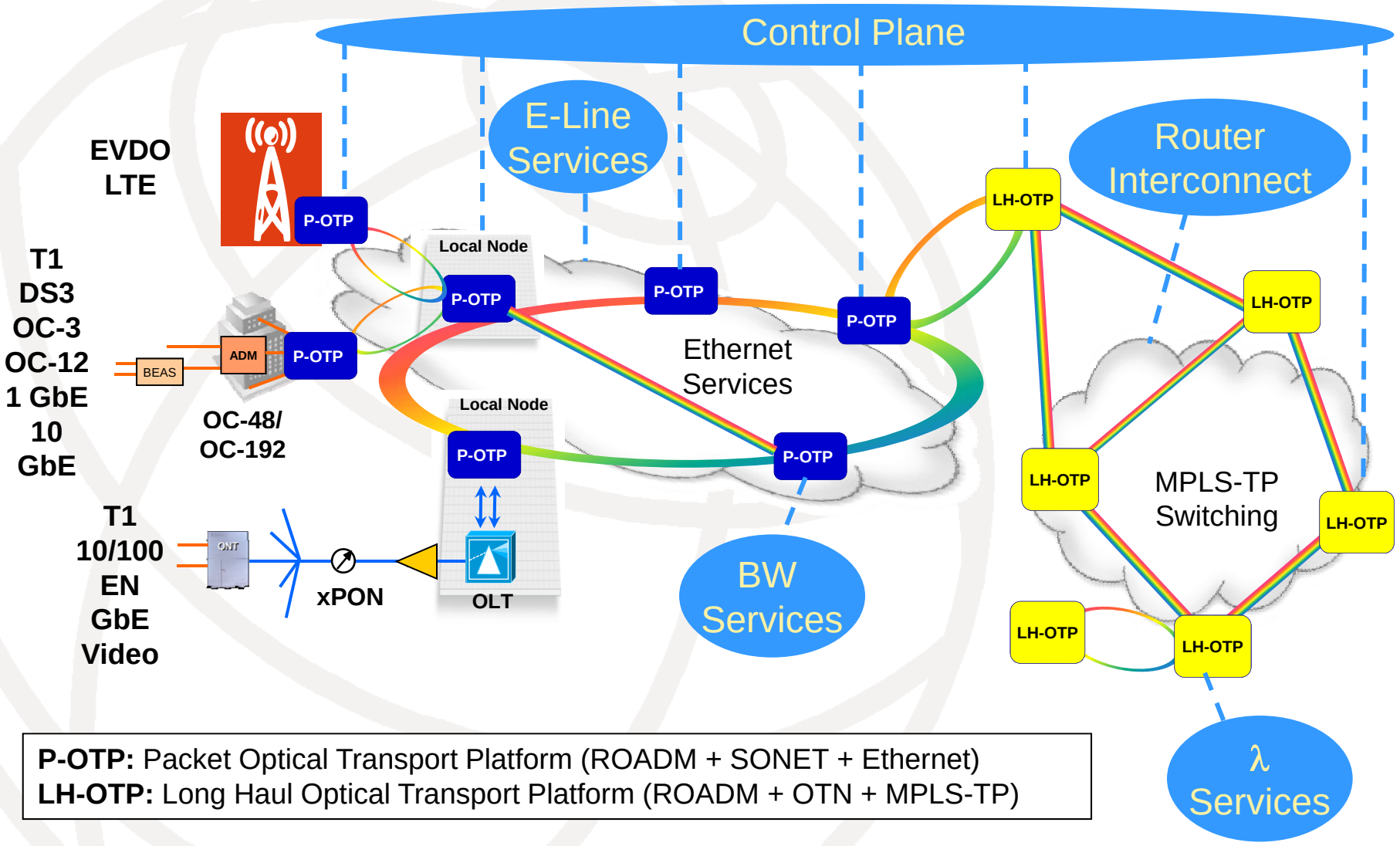
Serving
Residential
Enterprise
Wireless

- 50M wireline customers in 24 states
- 10M residential broadband; 3M FiOS TV customers (available to 11.7m)
- 92M wireless customers; largest 3G network
- 672K route miles of fiber globally; first commercial 100G deployment
- 200 data centers in 22 countries; IP services in 2700 cities / 159 countries
- Serve 98% of the Fortune 1000 customers; #1 provider to U.S. Government

Target Architecture



P-OTP: Packet Optical Transport Platform (ROADM + SONET + Ethernet)
LH-OTP: Long Haul Optical Transport Platform (ROADM + OTN + MPLS-TP)

Transported Services

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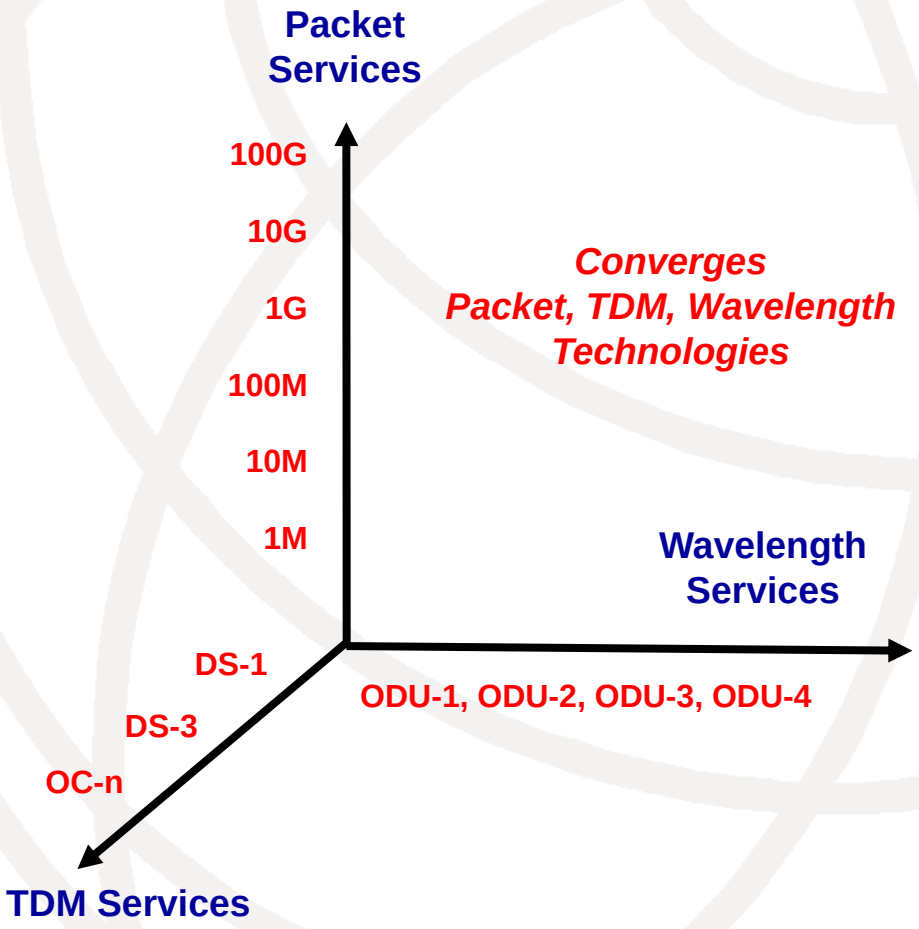
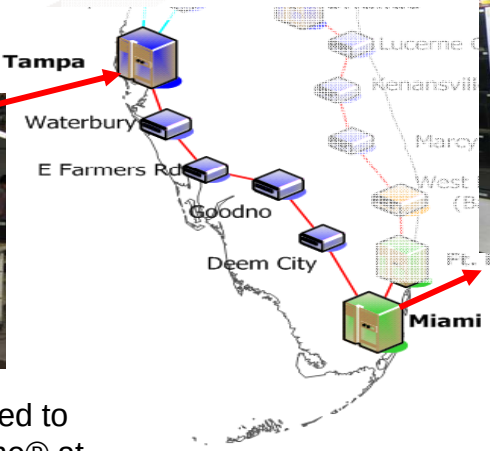
Integrated Optical Service



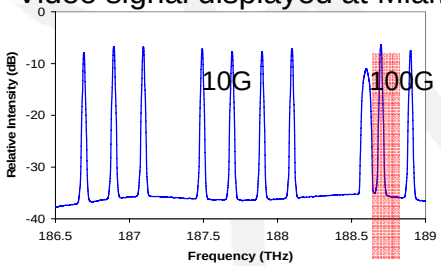
- Time Division Multiplexing (TDM)
  - DS-1 / DS-3
  - OC-3 / 3c
  - OC-12 / 12c
  - OC-48 / 48c
  - OC-192 / 192c
- Ethernet
  - 10M
  - Fast Ethernet
    - 50Mbps, 100Mbps
  - Gigabit Ethernet
    - 50Mbps, 100Mbps, 150Mbps, 300Mbps, 450Mbps, 600Mbps & 1000Mbps
  - 10 / 40 Gigabit Ethernet
- Ethernet Packet Ring Service
  - 10Mbps
  - 100Mbps
  - 1,000Mbps
- Storage
  - 1Gbps & 2Gbps Fiber Channel
- Digital Video
  - 270Mbps SDI
  - 1.485Gbps HD-SDI

100G Field Trials

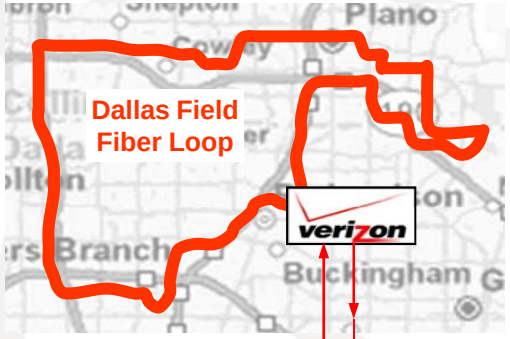
Video signal fed to LambdaXtreme® at Tampa



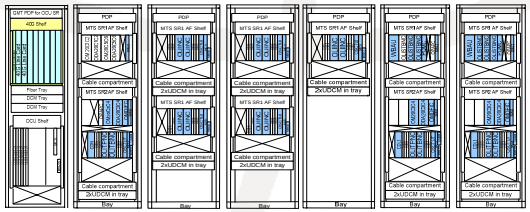
Video signal displayed at Miami

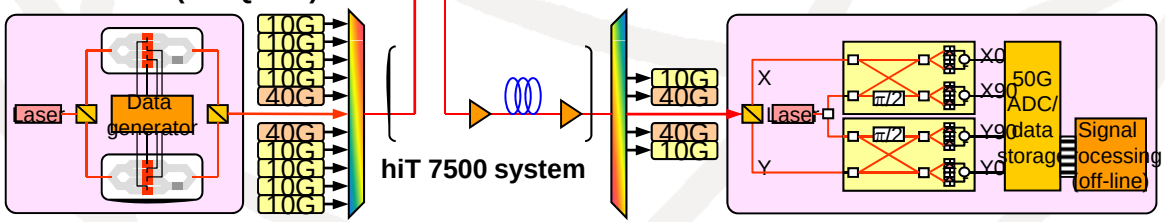


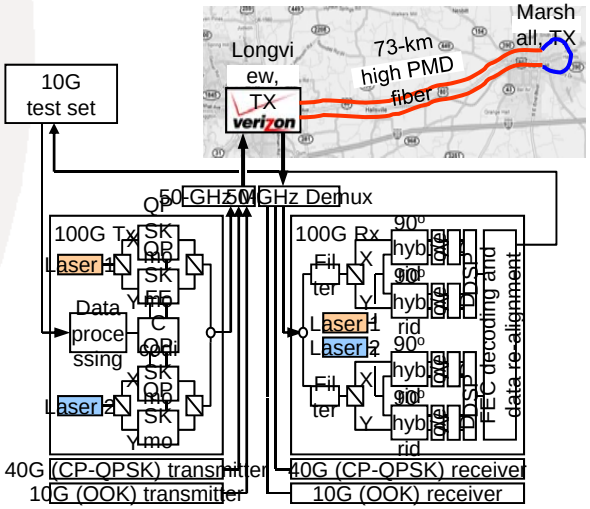
Nortel OME 6500 with 100G cards



Trial equipment in Lab 400, Richardson, TX

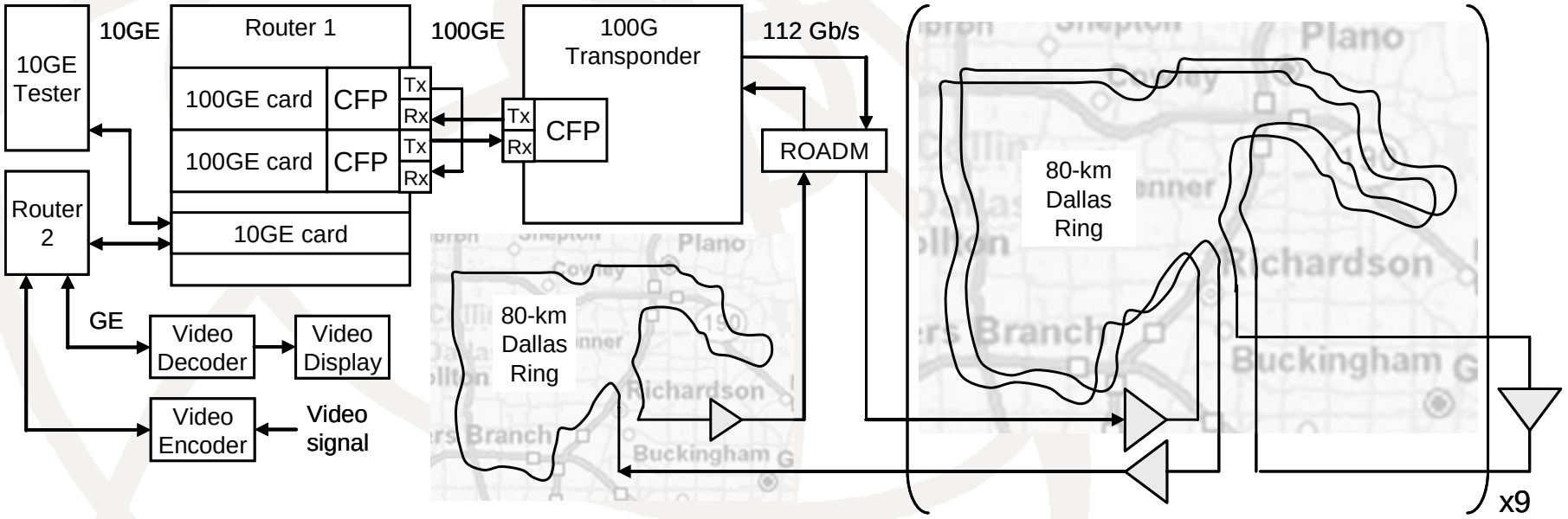






Verizon Business long-haul site at Longview, TX

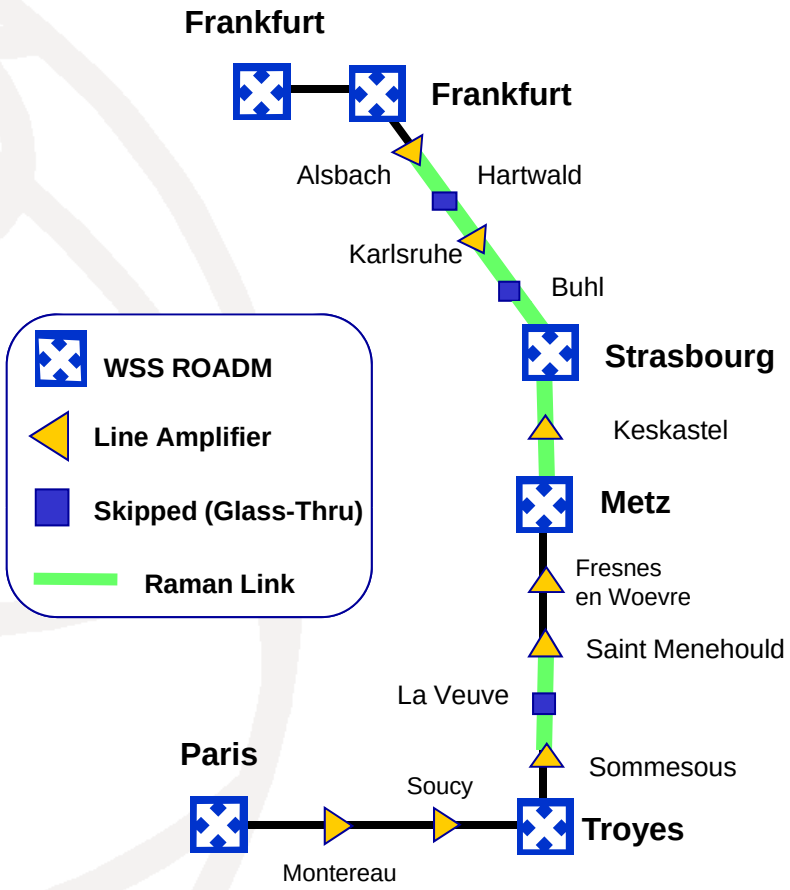
Multi-Vendor 100G Trial



Router:	Juniper T1600 router with 100GE cards
Client I/F:	Finisar LR4 industry standard 100G CFPs
Transport:	NEC 100G transponders and ULH DWDM system
Physical media:	1520Km of field deployed fiber in DFW metro area
Traffic verification:	10GE test set and High Def encoded video test traffic

100G Deployment

- 100Gb/s Live
  - Paris to Frankfurt
    - 893km route
    - 13 spans
    - No Regeneration
  - Operational December 2009
- Adding 100Gb/s routes in 2010



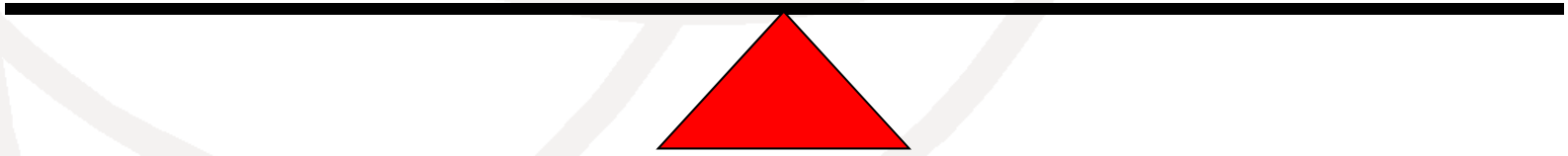
100Gb/s Roll-out Underway !!

Thirst for More

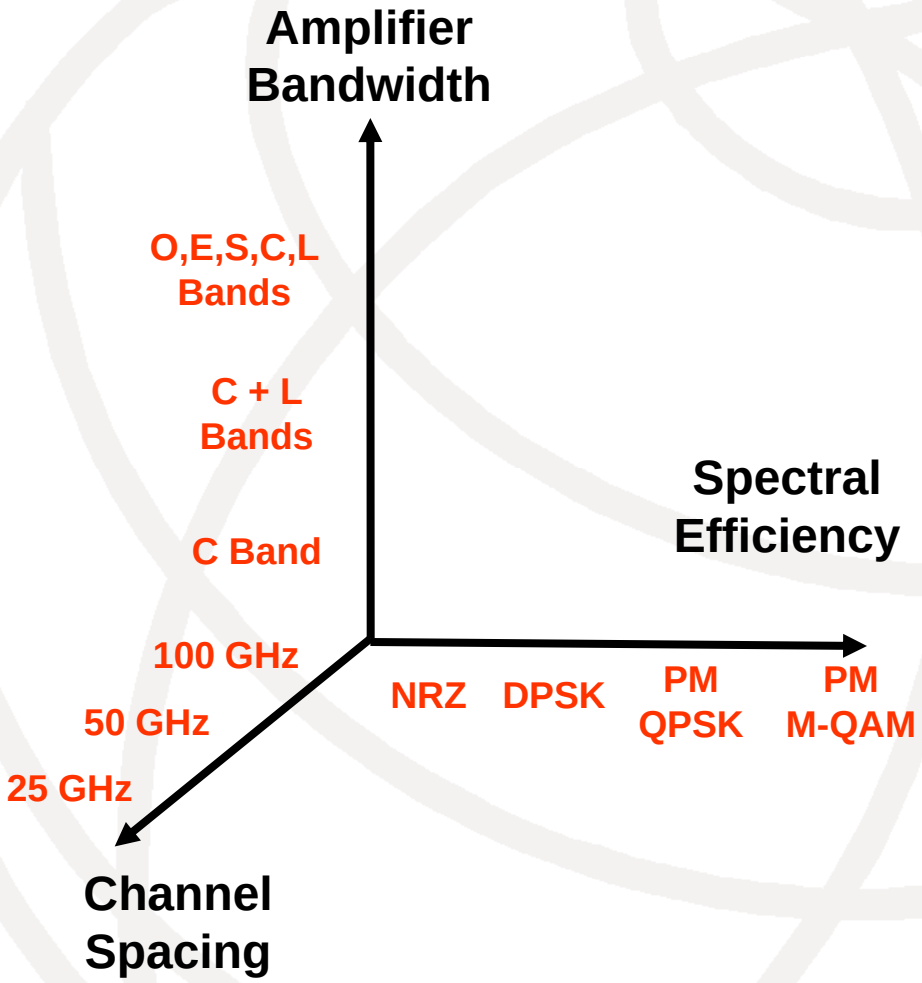
- Unrelenting network traffic growth pressure bandwidth increases
  - Higher speed data services; symmetrical
  - Commercial/residential video, HD/3D-TV, etc.
  - Fixed/mobile convergence; service mobility
  - Distributed computing; SANS
  - Route/service diversity
  - Wireless backhaul~ 3G, 4G explosion
- Demand for bundled services and access upgrades will trigger global FTTH/B subscriptions to reach 183.9 million by 2015 [Global Industry Analysts, Inc.]
- Forecast 10G/40G/100G port shipments together increasing 10-fold from 2009 to 2014 [Infonetics]
- Carriers will look to higher speed options

Considerations

- Higher rate needed in 2015/2016 timeframe to meet traffic projections
- Large customer/carrier's carrier services place additional requirements
- Major network changes will be required to support rates over 100G
  - Incompatible with existing ROADMs
  - Maximize new rate for demand window
- Line side vs. client side
  - Same or different rate step
  - Distance requirements may not be the same
  - Weigh implications, cost, availability timeframes

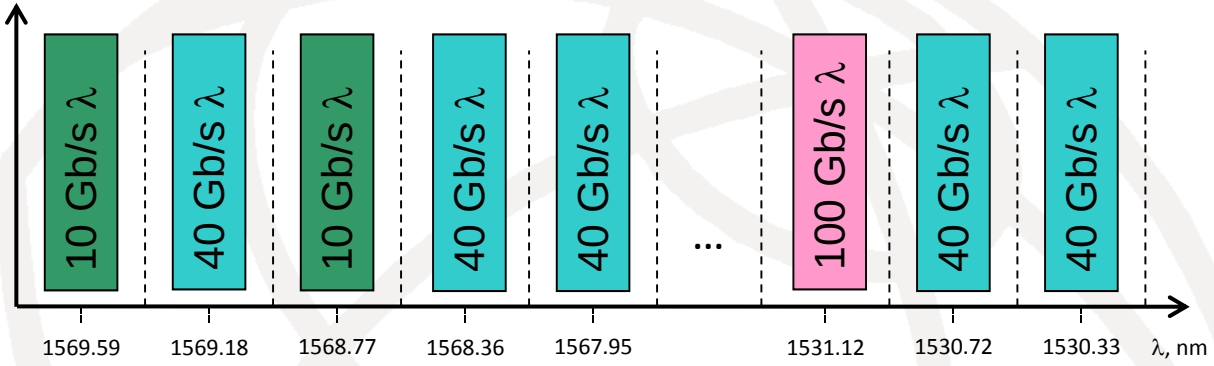


Bandwidth Scalability

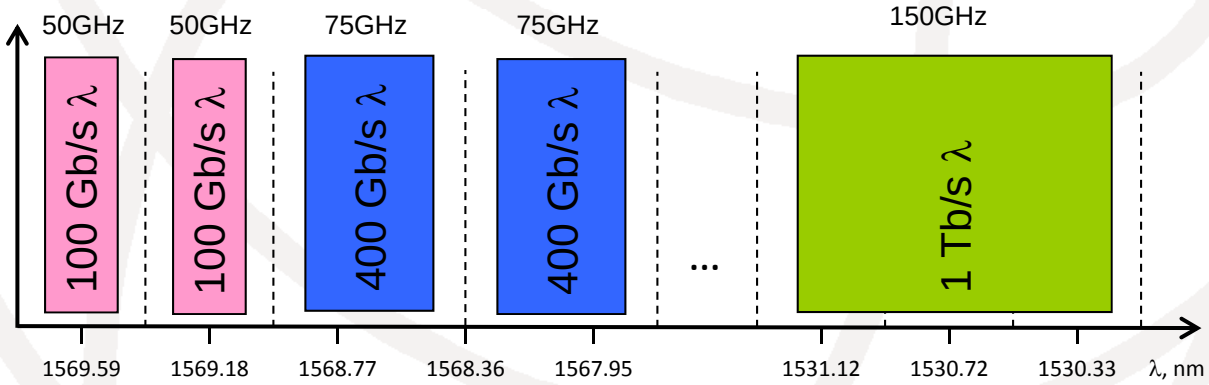


- Increasing spectral efficiency is the logical first step because it can be applied to existing line systems
- Adding amplifier bandwidth seems reasonable for next generation systems assuming Raman amplification is needed anyway
- Reducing channel spacing appears to be the best long term avenue for scalability assuming coherent detection systems

Flexible Bandwidth Grid



C-band, fixed 50 GHz grid

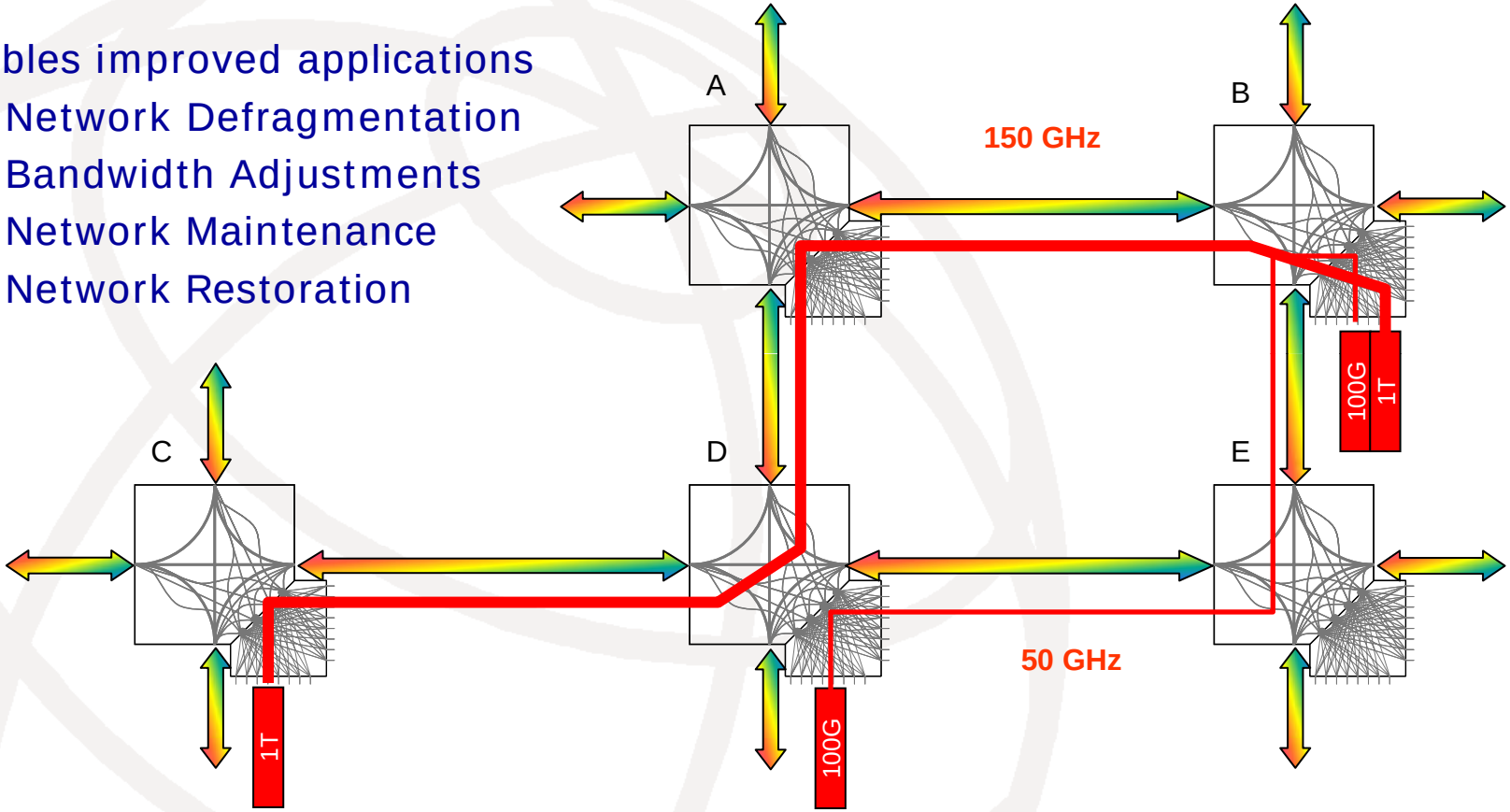


Example of a future C-band, 50-200 GHz Flexible Grid (in 25 GHz increments)

- Current generation WDM systems supported 10G, 40G and now 100G in service upgrades
- Future systems will be expected to support in service upgrades to at least 1T / channel
- Given the current view, more bandwidth is the only way to achieve this w/o paying a significant reach penalty due to OSNR requirements

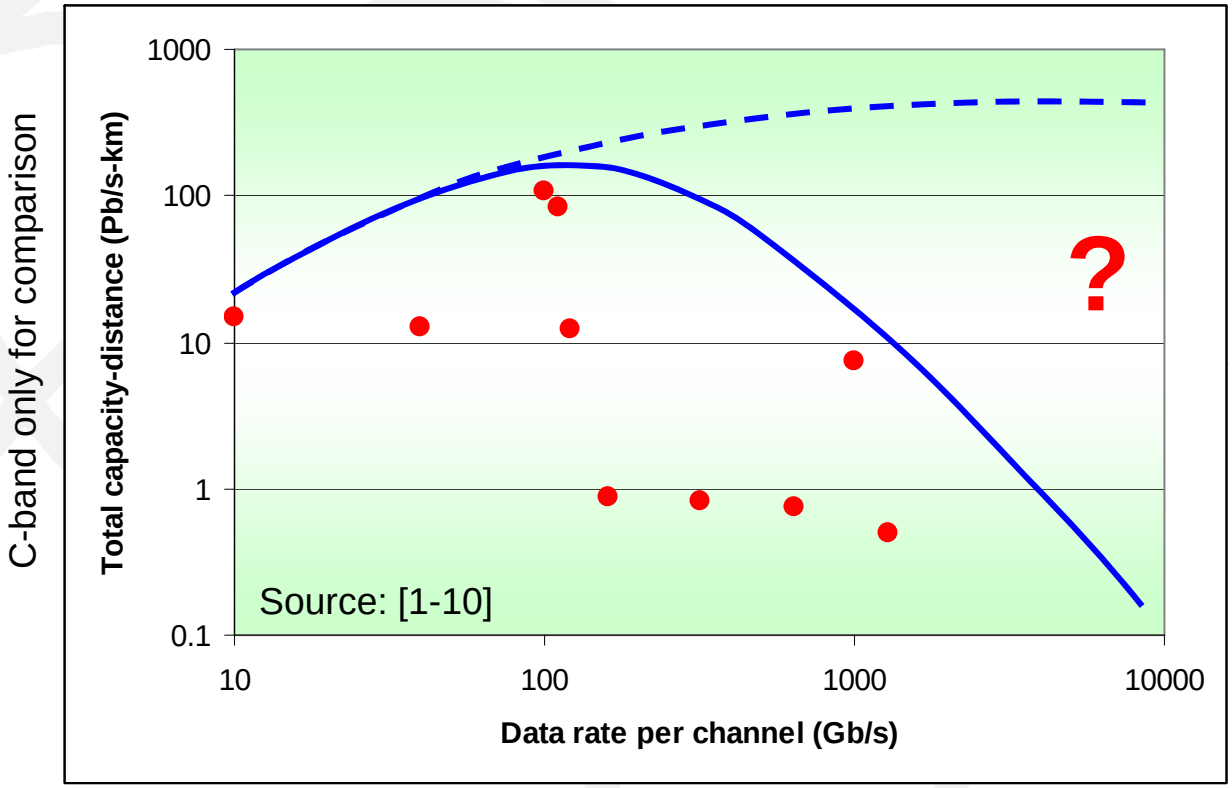
Flexible Layer 1 Network

- Enables improved applications
  - Network Defragmentation
  - Bandwidth Adjustments
  - Network Maintenance
  - Network Restoration



- Colorless/Directionless/Contentionless ROADM node with flexible grid
  - Colorless wavelength add/drop with directional routing
  - Choose the bandwidth of the light path to match the service bitrate
  - Use multiple copies of the same color wavelength on the add/drop structure

What's Next?



Homework for Industry Academia Government

- **400Gb/s may not be the right answer…**
- **Is 1Tb/s per channel an achievable target?**
- **If so, what would be the best modulation format?**
- **Can DSP based coherent receivers continue to scale?**
- **Would revisiting the ITU-T DWDM grid solve the problem?**
- **Is spectral efficiency worth the complexity of variable width channels?**

Summary

- 100G is a critical technology; beyond 100G will be required for transport scalability
- Flexible bandwidth grid architectures are required for upgradability
- Colorless, directionless & contentionless are required for flexibility
- TDM type connectivity is required for PL and EPL serviceability
- MPLS-TP is required for optimized router connectivity
- Integration is required to improve cost and reliability
- At the end of the day, we need a cost effective solution that gives us both scalability and backwards compatibility to some extent
- Due diligence is needed ~
  - Think through all the implications before plotting a path to get there
  - We should not make decisions on what comes next until there is experience to be bored with 100G – or we may sell ourselves short

References

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