What Ciena learns from Research Participation

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Powerful market forces are driving our innovation

The majority of traffic is now packet

Significant proliferation of mobile broadband

Workforce mobility & increased connectivity

Enterprise IT is shifting to the cloud

Video, video and more video

Real-time, low latency applications

First we Connected Places, Then People, Then Things
Coherent by Analogy

Non-Coherent Optics

Morse Code:
Power (on/off) carries info.
Dumb receiver.

Coherent Optics

Digital Radio:
Amplitude & phase carry info.
Tunable receiver. Digital enhancements.
Capacity Scale

2005:
• 10G eDCO, 1st 10G uncomp network

2009:
• 40G submarine, ULH terrestrial (DP BPSK), 100G LH (CoFDM DP QPSK)

2008:
• 40G metro, reg’l, long haul, regional submarine (QPSK)

2010:
• 100G metro, regional, submarine (2,000km)

Higher performance high-capacity solutions
• DSP in both Tx and Rx
• Integrated soft-decision forward error correction

WaveLogic T2 & R2

WaveLogic T3 & R3

WaveLogic T4 & R4

880G per fiber

8.8T per fiber

>20T per fiber

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Not all Coherent is Created Equal

Ciena WaveLogic™
Coherent Optical Processors

Nearly ten years expertise from the pioneers of coherent optics

Unique IP:
- Advanced coherent DSP
- Ultra-high performance FEC
- High-speed, high-resolution A/D
2008: 100G & Supercomputing (> 8Tb/s per fiber)

- Single Carrier 100G @ 50Ghz Spacing
- Full C-Band Tunable
- Asynchronous Multiplexing 10x10G
  - Any 10G Client on Any Port
- 100G 8dB+ Enhanced FEC
- Dual Polarization QPSK Modulation Format
- Low Latency
- Commercial Form Factor

1 Petabyte of data transfer in 12 hours on 1 carrier
Verizon’s 100G Deployments

New York to Chicago

North American first 100G/100GbE over 1500 km of mixed and high PMD fiber

Lesson #3: Use Ethernet for Both Service & Infrastructure

Key attributes

- Global
- Ubiquitous
- Affordable
- Multi-rate
Lesson #4: Use OTN as a Common Container

- **OTN**
  - Wavelength
  - SDH
  - GbE
  - VLAN 1
  - VLAN 2
  - VLAN 3
  - TE-Tunnels

- **Carrier Ethernet**

- **Network-Based IP VPNs**
  - Ethernet
  - ATM
  - Frame Relay
  - Private Lines

- **SONET/SDH**

- **OTN Network Substrate**

- **Evolution**

Source: Ciena, Vertical Systems

- **$Billions**
  - 2005
  - 2006
  - 2007
  - 2008
  - 2009
  - 2010

- **Network Substrate Evolution**

- Carrier Ethernet

- TE-Tunnels
OTN Enables Transparent Transport of Services

Variety of Optical Formats

- Storage
- Ethernet
- SONET/SDH
- Digital Video

Software Definable Bandwidth Containers using OTN G.709 Encapsulation

Supports any mix of supported services allowing a smooth transition from Circuit to Packet

- Service Transparency
- Multi-layer Management
- Flexibility

Software Definable Bandwidth Grooming using OTN switching

- Efficiency
- Growth

Data, Voice, Storage, Legacy TDM, and HD Video: One Platform…One Wavelength
OTN Enables Mesh Control Plane Automation

1. Automated Self-Inventory
2. Automated Connection Management
3. Efficient Operations
4. Self-Healing Network

Automation significantly reduces network OpEx
At Verizon Business, any impact to customer traffic was averted by its optical meshed infrastructure in Asia and across the Pacific, according to Linda Laughlin, director of media relations for Verizon Business’ Global Network Services Group.

“Verizon also participates in several submarine cables throughout the Asia-Pacific region, so if we need to move traffic to alternate network routes, we have the capability to reroute customer traffic using a technology called ‘meshing.’ Meshing creates additional paths to seamlessly reroute traffic in the event of multiple undersea cable breaks or network disruptions,” Laughlin said, adding that Verizon currently operates eight different paths across the Pacific.

Verizon also operates two local networks in Japan – Tokyo and Osaka, Laughlin added, both of which are still online. “All of our networks are operating normally.”
100G Connectivity from Ciena Ottawa to Starlight Gigapop in Chicago.

Ability to show simultaneous data-flows sourced from major collaborators.
Using 100G Network Technology in Support of Petascale Science
A Collaborative Initiative Among NASA, NLR, Northwestern/ICAIR, SCinet & UIC/NCDM

J. P. Gary 5/27/10
Route Plan for Terena demo May 16

Prove 40G over foreign waves CERN to Stockholm
Three Dimensions of Capacity Evolution

Increase

- Symbol rate
- Constellational multiplicity
- Subcarrier multiplicity

Exploit all 3Ds in order to Optimize Spectral Efficiency, Performance, Cost & Reliability
2010: 1Tb/s per Wavelength

Advanced Modulation Formats

Test Channel Transmitter

WDM Transmitter

1.12Tbps

X and Y Pols

50GHz spacing

Demux Filter

Programmable Spectral window

Coherent Receiver

Data Capture & Post Processing

Eb/No (dB)

Spectral Efficiency (b/s/Hz)

100G

40G

10G

200G

400G

1T

1.12Tb/s

160 GHz channel spacing

SE >6 B/s/Hz
Coherent receivers deployed today

> 7,000 Coherent receivers deployed today

Building the new global information infrastructure
Ciena’s Earliest Public 100G Milestones

- **SC08 - Supercomputing**
  - Nortel 100G in SCinet
  - Carried live traffic for the duration of the event

- **JANET/Verizon Business**
  - London, Reading 103km
  - 25ps mean DGD added
  - 10G/40G/100G over existing network

- **VERIZON**
  - 890km, >30 x 10G λ
  - LIVE DEPLOYMENT!

- **OFC/NFOEC**
  - 5 λ: 10G (2), 40G (2), 100G, 1000km, 50GHz
  - 3 fiber types, no comp

- **NEOS Networks**
  - Manchester – London
  - 705km, no regens
  - 10G/40G/100G over existing network

- **COMCAST**
  - Carrying live Internet for IETF
  - Philadelphia - Washington
  - 335km, 4 x 50GHz ROADM
  - 100G error-free 7 days
  - Foreign 40G live video traffic

- **2008**
  - **FEB**
    - **MAR**

- **2009**
  - **OCT**
    - **NOV**
      - **DEC**

- **2010**
  - **MAR**
    - **APR**
      - **MAY**
      - **JUN**
      - **JUL**
    - **DEC**

- **NEOS Networks**
  - Manchester – London
  - 705km, no regens
  - 10G/40G/100G over existing network

- **BANVERKET**
  - Sundsvall - Stockholm
  - 810km, no regens
  - 10G/40G/100G over existing network

- **SURFNET**
  - Amsterdam, Hamburg
  - 1244km, no regens
  - 80ps DGD
  - 10G/40G/100G over existing network

- **Ciena’s Earliest Public 100G Milestones**
  - 100GE over 100G
    - World’s 1st: 100GE over 100G wavelength
    - 800km, PMD 60ps DGD
    - 10G/40G/100G, 50GHz

- **VERIZON**
  - 100G over fibre that could not carry 10G, 73km
  - Passed 107ps DGD PMD

- **OFC/NFOEC**
  - 10x10GE over 100G λ
  - 800km, 4 x 50GHz ROADM
  - Colorless OADM with coherent receiver

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- **100G Demo over Challenging Conditions**
- **100G over same challenges carrying live traffic**
- **100G over worst span in network**
- **100GE over 112Gbps λ**
- **10 x 10GE over 112Gbps λ**
- **Record Distance**
- **100G requiring No Network Re-Engineering**