Intelligent Metro Networking with Tunable Laser Technology

Applications at the Speed of Light

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Metro Applications

• Current high revenue services
  – Private line services
  – Voice/TDM services
  – Data services (Ethernet transport, CMTS aggregation, DSL data transport)
  – Wavelength services

• Emerging services
  – Ethernet services (TLS, MPLS VPN)
  – Video on demand
  – Voice over IP
  – Storage services
Cable MSO Network Architecture

- Internet
- Video On Demand
- SONET/DWDM Backbone
- Regional Switch
- Regional Head-End
- Video On Demand
- Email, Cache Servers
- Voice (TDM)
- Class 5 Switch
- Voice, Email, Cache Servers
- Video On Demand

- Internet Access
  CMTS Aggregation
  With Ethernet Switching, Rate Limiting
- Distribution Hub
- CMTS
- Fiber Node
- SONET/DWDM
- Fiber Ring
- SONET/DWDM
- HDT
- Transparent Lan Services
  VLANs
- Circuit and Packetized Voice

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Network Architecture

• Convergence is the trend
  – Cost savings from equipment and operations
  – Example: SONET, IP and DWDM
  – Physical network layer convergence vs logical layer convergence
  – Multiple protocols still used for various purposes
  – Tight integration among the layers is challenging and is typically the missing piece
Today’s Provisioning Model

Provisioning is not driven by higher layer applications
Integrated Provisioning

Increases the velocity of carrier-grade services
Today’s Multi-Layered Network

Internet

FE, GbE, IP

Core Routers

1 Tbps – 5 Tbps

100 - 500 λs

High Cost, Low Flexibility, Operational Inefficiency

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Next Generation: Converged Network

Switched architecture w/ traffic classification
Intelligent Architecture

- Ethernet
  - VoIP
  - IP
  - Data/Voice/Video
  - SONET/SDH
  - Tunable DWDM

- Private Line/TDM
  - ERP
  - Internet Access
  - DS-1
  - DS-3
  - OC-n

- Bandwidth Services
- L3 Services
- L2 Services
- SONET Framing
- WDM Services

Service Wavelengths

Customer

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Tunable Lasers

- Tunable lasers
  - Traditional use for efficient sparing
  - Emerging technology reaching maturity
  - Ability to tune to any wavelength from a finite set

- A new paradigm in networking
  - Enables the creation of multiple logical groups in a physical topology
  - Enables optical scaling by moving a node from one logical group to another
Application Driven Provisioning

**BW-on-demand**

Application

- Insufficient Bandwidth
- Must Dilate Pipe

Data Packets

SONET/SDH Layer

CO
**Tunable Optical Scaling**

- **Application**
  - **BW-on-demand**
  - **Data Packets**

- **WDM Layer**
  - **OC-48/STM-16**

- **CO**

**Splits the Network Into two Logical Rings**

- Insufficient Bandwidth at the SONET Layer

- Splitting the Network into two logical rings using OC-48/STM-16.
Tunable Reprovisioning

Switches Box to the Other Logical Ring

Data Packets

Application

BW-on-demand

WDM Layer
The Obvious way to do WDM-based reconfiguration: Tunable Tx/Tunable Rx

- Ring membership dictated by color: member must Rx and Tx on a particular color
- 5 Lambda rings, each ring uses only one color
- CO node terminates each ring: 5 Tx and 5 Rx’s

- Fewer nodes per ring => higher available BW per node=>dynamic bandwidth provisioning
- However, Tunable Rx => more complexity, more expense, more technology risk
The Practical Way: Tunable Tx’s without Tunable Rx’s

- 1 Fixed wavelength Rx; 1 Tunable Tx at each peer node.
- Aggregation node has 5-Tunable Tx and 5 fixed wavelength Rx
- Each LightPath Ring is made-up of transmission segments in which each segment of the logical interconnect is a distinct wavelength
- Fewer nodes/ring => higher available BW per node

<table>
<thead>
<tr>
<th>Lightpath Ring number</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Link Number (designated by node number at end of link)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
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<td>1</td>
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<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
</tbody>
</table>

Note: CO must receive on new lambdas 16, 17, 18, 19, 20
After Reconfiguration Involving Changes to 3 Logical Rings

This reconfiguration reduces the node-count of logical ring C to just 2 nodes. The bandwidth of this logical ring is now shared between node 8 and one of the add/drops in the CO. Thus the full ring bandwidth could now be added at the CO and dropped on the tributary side of node 8, and vice-versa. The number of nodes in logical rings B and D have been increased to 5 each from 4, thus reducing the bandwidth available to each of the nodes in these rings.
Optical Node Architecture

An optical amplifier is a product option for the optical layer.
Tunable Laser Technology

• Basic Types
  – Current tuning—DBRs, GCSRs, etc. (tuning time < 100 ns, potentially)
    • Agility, ADC/Altitun
  – Variable Cavity Length Lasers (tuning time < 10 ms)
    • Iolon
    • BW9
  – Temperature Tuning (tuning time > 100 ms)
    • Many vendors

• Issues
  – Wavelength stability
  – Wavelength spread (# of channels)
  – Power
  – Tuning speed
  – Cost
  – Manufacturability
Transmitter Signal Integrity Testing

Eye Mask Test

BERT-PG → E/O → Linecard Rx → Tx → DCA- Sampling Scope

SONET OC48 EYE-MASK
Random Wavelength Switching Test

Test setup: Automated PC controlled system, randomly switches wavelengths

Tunable laser module
Pass criteria is +−5 GHz
Scaling Reconfigurable WDM Networks

• Scaling reconfigurable WDM networks =>
  transparency => EDFAs => A few Challenges
  – For large numbers of nodes, will need cascaded
    amplifiers
  – Gain non-uniformities propagate
  – Amplified Spontaneous Emission (ASE)
    accumulates=>sets minimum signal power levels
    • ASE-signal beat noise
    • ASE-xtalk beat noise
  – Multipath Interference noise
  – Gain saturation limits total signal power
  – Transients from reconfiguration– propagate down the
    cascade
ROI Models

- CapEx savings
  - Converged solution vs multi-layered solution

- OpEx savings
  - Power & rack space
  - Provisioning simplicity & service velocity

- Increase ROI by increasing revenue
  - Increase service velocity and eliminate provisioning delay
    - Earn revenue earlier from new customers or from service changes
    - Decrease churn
  - Offer flexible bandwidth services
    - Match customer requirements for bandwidth
    - Offer burstable services and bandwidth on demand
    - Increase Revenue/Network Capacity ratio
Modeling Results
- Reduced CapEx

• Increase ROI through reduced capital expenditure
  – Integrated solution is 60% cheaper than Multi-box option
Modeling Results
- Reduced Operating Costs

- Increase ROI by decreasing operating costs
  - Integrated solution uses 600W less – 30% less than Multi-box
  - Integrated solution requires one less rack of space – 67% less than Multi-box
  - Integrated solution provides increased Service Velocity – 48% less provisioning costs
**Payback**

**Network Model**
- One metro (city)
- 6 rings

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**Graph**

- **Integrated** – 6.6 months
- **Multibox** – 21 months

**Cumulative Revenue & Opex Savings ($millions)**

- 0 5 10 15 20 25 30 35 40 45 50
- Months

- $0
- $20
- $40
- $60
- $80
- $100
- $120
- $140
- $160
Metro Application Delivery

- Application driven provisioning
  - Integrated, intelligent IP/SONET/WDM Platform
- Dynamic optical scaling
  - Tunable wavelength selection
- Application guarantee and billing
  - Per user, per application SLAs
- Ease of network management
  - Increased service velocity

App Layers
- IP
- SONET
- WDM

Application Layers
- IP
- SONET
- WDM

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Conclusions

• New methods for dynamic service provisioning and scaling in converged network infrastructure
  – Provides service guarantees for existing and new applications
  – Makes use of converged network architecture
  – Tight integration between network layers
  – ROI models and analysis lead to a compelling case
Conclusions

• Successful development of reconfigurable DWDM network element to dynamically provision bandwidth
  – A plethora of applications
• Tunable lasers are the key enabling technology
  – Technology is maturing rapidly and many vendors are offering/will soon offer fully Telcordia qualified parts
• Laser costs are coming down (and they must continue) to enable markets for reconfigurable networks
• “Islands of transparency” are required for this type of reconfiguration…Transparency
  – Optical amplifiers and associated constraints
• Stay tuned for more !!!
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