Optical Network Architecture
& Protection Switching Scenarios

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NEC Corporation
Contents of Talk

1) Future WDM Based Network Evolution

2) General Issues

3) Protection Architecture Issue

NEC’s proposal of

4 Fiber Bi-directional/Wavelength path based WDM ring
Objectives

To achieve **flexible/reliable/cost-effective** photonic network with **open** architecture

More cost-effective **multi-layer network** (photonic router, photonic ATM, etc)

- **flexible**: software configurable wavelength allocation
- **reliable**: high-speed (msec order) protection
- **network**: ring/mesh, etc. with EMS
- **open**: connectable to any NE’s

Independent photonic layer
- Reconfiguration
- Protection
- MUX/DEMUX
New Transport Architecture
- NEC Proposal -

Voice Service
(64Kb/s Unique Service)

Data Services
- Mb/s Various Services

Future Services

- Gb/s Bandwidth Access Point/
  Bit Rate Independence, IF Format Independence

Transport Network
Long Distance
Regional Transport.
NEC’s Proposal on WDM Network Road Map

Present
Point-to-Point

Next Step
Single Ring

Features:
• DWDM and ILA

Advantages:
• Low-cost bandwidth increase

Features:
• OADM ring with fast protection
• Wavelength path based protection

Advantages
• Low-cost accommodation of any NEs (direct OADM and ATM/Router connection)

Photonic Network Era
Multiple Rings

Features:
• OXC, network design

Advantages:
• Wide deployment of photonic network
• OXC/Photonic switch (Photonic router, Photonic ATM)
General Issues

- Role of New Transmission/Switching Network
  Create New Simple/Cost-effective Network

- Protection Architecture
  Ring protection(OADM) / Mesh restoration(OXC)

- Network Management Issues
  Fault/Configuration/Performance (Information Modeling)
  ex. Fault isolation, Performance monitoring
  Account/Security

Others….

- Interface Issues
- Network design/Cost evaluation
WDM Network Architecture Future Issue

Role of TR & SW NW (Client: ATM SW case)

Current Configuration

Transmission NW

Switching NW

ATM  SONET  SONET  ATM

WDM

- Network protection is provided by SONET
- Transmission line is terminated by SONET
  - Synchronization
  - PMs, Alarms
- WDM is a simple transport pipe

Transmission network & Switching network are completely separated.

ATM over WDM Configuration (NEW)

Transmission NW

Switching & Transmission NW

ATM  WDM  ATM

WDM

- WDM & ATM protection
- Simple LTE function by WDM NE
  - Pointer processing?
  - What kind of PMs, Alarms?
- New WDM transport network

Clear role definition of new transmission & Switching network is necessary. How to make a simple and cost effective transport ???
Protection Architecture

Ring protection (OADM-based)
Path and Line in SONET/WDM Network

a) SONET Network

- Line Monitoring (B1 monitoring)
- Individual Path monitoring

Optical Fiber

b) WDM Network

- Line Monitoring (?)
- Individual Path monitoring based

Optical Fiber

WDM = Fiber

Wavelengths
# WDM Self-healing Ring Category

<table>
<thead>
<tr>
<th>Protection unit</th>
<th>Uni-Directional (U)</th>
<th>Bi-Directional (B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength Path Protection (WP)</td>
<td>1+1 Protection Easy to realize</td>
<td>1:1 Protection</td>
</tr>
<tr>
<td>Fiber Line Protection (FL)</td>
<td>Not Effective</td>
<td>1:1 Protection</td>
</tr>
</tbody>
</table>

3 categories: UWPSR /BWPSR/BFLSR
## Comparison among WDM Self-Healing Ring Network

<table>
<thead>
<tr>
<th></th>
<th>Bi-Directional Fiber Line Protection (BFSR)</th>
<th>Uni-Directional Wavelength Path Protection (UWPSR)</th>
<th>Bi-Directional Wavelength Path Protection (BWPSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength Path Utilization</td>
<td>Excellent</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Star DP*</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Mesh DP</td>
<td>Excellent (1 wavelength)</td>
<td>Good</td>
<td>Excellent (1 Wavelength)</td>
</tr>
<tr>
<td>Cyclic DP</td>
<td>Perfect</td>
<td>Good</td>
<td>Perfect (1 Wavelength)</td>
</tr>
<tr>
<td>Initial NEs Cost (Cost for near Future Demand)</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Protection Speed</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Ring Length without Regenerators</td>
<td>Fair</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Reconfiguration after Failure Recovery</td>
<td>Necessary (Revertive)</td>
<td>Not Necessary (Non-Revertive)</td>
<td>Necessary (Revertive)</td>
</tr>
</tbody>
</table>

* DP: Demand Pattern
Efficient Wavelength Accommodation(1)

Mesh Connection Demand Pattern Case

Uni-Directional Ring

- **Dedicated 1+1 Protection**
- 6 Wavelengths
- UWPSR

Bi-Directional Ring

- **Shared 1:1 Protection**
- 3 Wavelengths
- BWPSR/BFLSR
Efficient Wavelength Accommodation (2)

Cyclic Demand Pattern Case

Uni-Directional Ring

Dedicated 1+1 Protection
4 Wavelengths

Bi-Directional Ring

Shared 1:1 Protection
1 Wavelength

BWPSR/BFLSR

EWAPSR
# Wavelength Accommodation Efficiency
(Necessary wavelength numbers vs. node number n)

<table>
<thead>
<tr>
<th></th>
<th>UWPSR(2F)</th>
<th>BFLSR(4F)</th>
<th>BWPSR(4F)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cyclic type demand pattern</strong></td>
<td>n Fair</td>
<td>1 Perfect</td>
<td>1 Perfect</td>
</tr>
<tr>
<td><strong>Star type demand pattern</strong></td>
<td>n-1 Good</td>
<td>(n-1)/2 n: odd n/2 :even Good</td>
<td>(n-1)/2 n:odd n/2 :even Good</td>
</tr>
<tr>
<td><strong>Mesh type demand pattern</strong></td>
<td>n(n-1)/2 Good</td>
<td>(n+1)(n-1)/8 n: odd n(n+2)/8 n: even Excellent</td>
<td>(n+1)(n-1)/8 n: odd n(n+2)/8 n: even Excellent</td>
</tr>
</tbody>
</table>
Evaluated Example
Regenerator span : L
Span between nodes : L/4

*: Regenerator (O/E,E/O conversion)
NEC's WDM Ring Proposal

4 Fiber Bi-Directional/Wavelength-Path based WDM Ring

(4 Fiber BWPSR)

Good points:

- Efficient wavelength allocation (wavelength reuse for disjoint path)
- Expansion of ring length (no loop-back switch)
- Smooth introduction (on each wavelength basis introduction)
Protection Operation Process for Bi-directional/Wavelength-based Protection Network

- Fibers Cut
- Working
- Protection
- Failure Detection
- AIS Transfer (ex. AIS-O)
- Protection Switch Request (ex. using signaling channel)
- Switching to Protection Fiber (path by path basis)
- Failure Restored
- Working Fiber
- Protection Fiber
Summary

1. **WDM Ring Network with Self-healing Functions** are discussed. (Ring Network base.)
   - B(F)LSR
   - U(W)PSR
   - B(W)PSR (NEC’s proposal)

2. **B(W)PSR** is the best solution for the future capacity explosion.

3. Clarification of WDM Self-healing transport networks’ role is necessary to be discussed.