Recent Developments in Optical Networking

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Overview

- All-Optical Networking
- IP over DWDM
- UNI
- ASTN/ASON
- MPLS, MPλS, GMPLS
- Upcoming optical technologies
ATM Networks

- Asynchronous Transfer Mode
- Best of packet switching and circuit switching
- All cells are 53 bytes long (48 bytes payload + 5 bytes header)
- Connection oriented technology. ATM Switches.
- Allows both voice and data on the same network
Virtual Circuit Switching

- Original phone networks have real circuit switching
- X.25, Frame Relay, ATM have virtual circuits
- Each ATM cell has a virtual circuit (VC) number
- VC # determines the cell’s queuing and forwarding
- VCs have to be set up before use
IP over DWDM (Past)
## IP over DWDM: Protocol Layers

<table>
<thead>
<tr>
<th>Year</th>
<th>IP</th>
<th>ATM</th>
<th>SONET</th>
<th>DWDM</th>
<th>Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>IP</td>
<td>ATM</td>
<td>SONET</td>
<td>DWDM</td>
<td>Fiber</td>
</tr>
<tr>
<td>1996</td>
<td>IP</td>
<td>PPP</td>
<td>SONET</td>
<td>DWDM</td>
<td>Fiber</td>
</tr>
<tr>
<td>1999</td>
<td>IP/MP(\lambda)S</td>
<td>PPP</td>
<td>SONET Framing</td>
<td>DWDM</td>
<td>Fiber</td>
</tr>
<tr>
<td>2001</td>
<td>IP/GMPLS</td>
<td>Ethernet</td>
<td>SONET Framing</td>
<td>DWDM</td>
<td>Fiber</td>
</tr>
</tbody>
</table>
| 2005 | IP/GMPLS | Ethernet | DWDM | Fiber |}

- IP is good for routing, traffic aggregation, resiliency
- ATM for multi-service integration, QoS/signaling
- SONET for traffic grooming, monitoring, protection
- DWDM for capacity
- Problem: Restoration in multiple layers, Sonet Manual

⇒ Intersection of features and union of problems

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IP over DWDM (Future)
## Telecom vs Data Networks

<table>
<thead>
<tr>
<th></th>
<th>Telecom Networks</th>
<th>Data Networks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology Discovery</td>
<td>Manual</td>
<td>Automatic</td>
</tr>
<tr>
<td>Path Determination</td>
<td>Manual</td>
<td>Automatic</td>
</tr>
<tr>
<td>Circuit Provisioning</td>
<td>Manual</td>
<td>No Circuits</td>
</tr>
<tr>
<td>Transport &amp; Control Planes</td>
<td>Separate</td>
<td>Mixed</td>
</tr>
<tr>
<td>User and Provider Trust</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Protection</td>
<td>Static using Rings</td>
<td>No Protection</td>
</tr>
</tbody>
</table>

![Topology Diagram](image1)

![Path Determination Diagram](image2)
IP over DWDM Issues

1. Data and Control plane separation
2. Circuits
3. Signaling
4. Addressing
5. Protection and Restoration
Issue: Control and Data Plane Separation

- Separate control and data channels
- IP routing protocols (OSPF and IS-IS) are being extended

Today:

Tomorrow:
Multiprotocol Label Switching (MPLS)

- Allows virtual circuits in IP Networks (May 1996)
- Each packet has a virtual circuit number called ‘label’
- Label determines the packet’s queuing and forwarding
- Circuits are called Label Switched Paths (LSPs)
- LSP’s have to be set up before use
- Allows traffic engineering
Label Switching Example

Ethernet Header | IP Header | Payload
---|---|---

Ethernet Header | Label | IP Header | Payload
---|---|---|---

64 | 3 | 5

<64> | <3> | <5>

A | R1 | B

5 | <3> | 3

<5> | R2 | <3>

5 | 3 | 2

R3 | C

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Label Assignment

- Unsolicited: Topology driven $\Rightarrow$ Routing protocols exchange labels with routing information. Many existing routing protocols are being extended: BGP, OSPF

- On-Demand:
  $\Rightarrow$ Label assigned when requested, e.g., when a packet arrives $\Rightarrow$ latency

- Label Distribution Protocol called **LDP**

- **RSVP** has been extended to allow label request and response
IP-Based Control Plane

- Control is by IP packets (electronic).
  Data can be any kind of packets (IPX, ATM cells).
  ⇒ MPLS

PSC = Packet Switch Capable Nodes

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Control is by IP packets (electronic). Data plane consists of wavelength circuits \( \Rightarrow \) Multiprotocol Lambda Switching (October 1999)

LSC = Lambda Switch Capable Nodes = Optical Cross Connects = OXC
GMPLS

- Data Plane = Wavelengths, Fibers, SONET Frames, Packets (October 2000)
- Two separate routes: Data route and control route
GMPLS: Hierarchical View

- Packets over SONET over Wavelengths over Fibers
- Packet switching regions, TDM regions, Wavelength switching regions, fiber switching regions
- Allows data plane connections between SONET ADMs, PXC. FSCs, in addition to routers
### MPLS vs GMPLS

<table>
<thead>
<tr>
<th>Issue</th>
<th>MPLS</th>
<th>GMPLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data &amp; Control Plane</td>
<td>Same channel</td>
<td>Separate</td>
</tr>
<tr>
<td>Types of Nodes</td>
<td>Packet</td>
<td>PSC, TDM, LSC, FSC, …</td>
</tr>
<tr>
<td>and labels</td>
<td>Switching</td>
<td></td>
</tr>
<tr>
<td>Bandwidth</td>
<td>Continuous</td>
<td>Discrete: OC-n, λ’s, ..</td>
</tr>
<tr>
<td># of Parallel Links</td>
<td>Small</td>
<td>100-1000’s</td>
</tr>
<tr>
<td>Port IP Address</td>
<td>One per port</td>
<td>Unnumbered</td>
</tr>
<tr>
<td>Fault Detection</td>
<td>In-band</td>
<td>Out-of-band or In-Band</td>
</tr>
</tbody>
</table>
Issue: UNI vs Peer-to-Peer Signaling

- Two Business Models:
  - Carrier: Overlay or cloud
    - Network is a black-box
    - User-to-network interface (UNI) to create/destroy light paths (in OIF)
  - Enterprise: Peer-to-Peer
    - Complete exchange of information
Automatically Switched Transport Networks

UNI = User-Network Interface
NNI = Network-Network Interface
CCI = Control Channel Interface

Router

Network manager

Optical Switch Controller

Optical Switch

Optical Switch

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Upcoming Technologies

- Higher bit rate, more wavelengths, longer distances
- Optic Wireless
- Optical Packet Switching
Free Space Optical Comm

- Uses WDM in open air
- Sample Product: Lucent WaveStar OpticAir: 4×2.5Gbps to 5 km Available March'00.
- EDFA = Erbium Doped Fiber Amplifier

Laser Source

EDFA Telescope Receiver
Free Space Optical Comm

- No FCC Licensing required
- Immunity from interference
- Easy installation
  ⇒ Unlimited bandwidth, Easy Upgrade
- Transportable upon service termination or move
- Affected by weather (fog, rain)
  ⇒ Need lower speed Microwave backup
- Example Products: Optical Crossing Optibridge 2500
  2.5Gbps to 2km, Texas Instruments TALP1135
  Chipset for 10/100 Mbps up to 50m
Optical Packet Switching

- Header Recognition: Lower bit rate or different $\lambda$
- Switching
- Buffering: Delay lines, Dispersive fiber
Fiber Access Thru Sewer Tubes (FAST)

- Right of ways is difficult in dense urban areas
- Sewer Network: Completely connected system of pipes connecting every home and office
- Municipal Governments find it easier and more profitable to let you use sewer than dig street
- Installed in Zurich, Omaha, Albuquerque, Indianapolis, Vienna, Ft Worth, Scottsdale, ...
- Corrosion resistant inner ducts containing up to 216 fibers are mounted within sewer pipe using a robot called Sewer Access Module (SAM)

Ref: http://www.citynettelecom.com, NFOEC 2001, pp. 331
FAST Installation

1. Robots map the pipe
2. Install rings
3. Install ducts
4. Thread fibers

Fast Restoration: Broken sewer pipes replaced with minimal disruption

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Summary

1. High speed routers
   ⇒ IP directly over DWDM
2. Separation of control and data plane
   ⇒ IP-Based control plane
3. Transport Plane = Packets ⇒ MPLS
   Transport Plane = Wavelengths
   ⇒ MP\(\lambda\)S
   Transport Plane = \(\lambda\), SONET, Packets
   ⇒ GMPLS
4. UNI allows users to setup paths on demand
What’s on the Web Site

- Audio/Video recordings of all lectures
  - Storage Area Networks
  - Wireless Networks
  - ATM Networks
  - Frame Relay
- Latest Books on networking topics
- Links to other sites on networking topics
- See http://www.cis.ohio-state.edu/~jain/