Computer Networking: Recent Advances, Trends, and Issues

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Overview

- Life Cycles of Technologies
- Traffic and Capacity growth
- Ethernet Everywhere
- Storage Area Networks
- Optical Networks
- Data and Telecom Convergence: Changes in IP
Life Cycles of Technologies

Number of Problems Solved

Research  Productization  Time

Time

Number of Problems Solved

Research  Productization  Time

Time
Hype Cycles of Technologies

Potential

Research  Hype  Dis  Success or Failure
illusionment
Industry Growth

Number of Companies

<table>
<thead>
<tr>
<th>Time</th>
<th>New Entrants</th>
<th>Consolidation</th>
<th>Stable Growth</th>
</tr>
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# Traffic vs Capacity Growth

<table>
<thead>
<tr>
<th>Expensive Bandwidth</th>
<th>Cheap Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Sharing</td>
<td>- No sharing</td>
</tr>
<tr>
<td>- Multicast</td>
<td>- Unicast</td>
</tr>
<tr>
<td>- Virtual Private Networks</td>
<td>- Private Networks</td>
</tr>
<tr>
<td>- Need QoS</td>
<td>- QoS less of an issue</td>
</tr>
<tr>
<td>- Likely in WANs</td>
<td>- Possible in LANs</td>
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</table>

**Expensive Bandwidth**: Bandwidth is costly, so sharing and QoS are important. Likely in WANs.

**Cheap Bandwidth**: Bandwidth is inexpensive, so sharing is not necessary. Likely in LANs.
Is Internet Traffic Growing?

- IP Traffic Growth will slow down from 200-300% per year to 60% by 2005
- 98% of fiber is unlit - WSJ, New York Times, Forbes
- Carriers are using only avg 2.7% of their total lit fiber capacity - Michael Ching, Merrill Lynch & Co. in Wall Street Journal
- Demand on 14 of 22 most used routes exceeds 70%
  - Telechoice, July 19, 2001
- Traffic grew by a factor of 4 between April 2000-April 2001 - Larry Roberts, August 15, 2001
Total U.S. Internet Traffic

20 Largest Tier 1 U.S. Internet Service Providers

3.0/yr Average Growth Rate

Source: Roberts et al., 2002
Trend: Ethernet Everywhere

- Ethernet in Enterprise Backbone
  - Ethernet vs ATM (Past)
- Ethernet in Metro: Ethernet vs SONET
  - 10 G Ethernet
  - Survivability, Restoration $\Rightarrow$ Ring Topology
- Ethernet in Access: EFM
- Ethernet in homes: Power over Ethernet
Networking: Failures vs Successes

- 1980: Broadband (vs baseband)
- 1984: ISDN (vs Modems)
- 1986: MAP/TOP (vs Ethernet)
- 1988: OSI (vs TCP/IP)
- 1991: DQDB
- 1994: CMIP (vs SNMP)
- 1995: FDDI (vs Ethernet)
- 1996: 100BASE-VG or AnyLan (vs Ethernet)
- 1997: ATM to Desktop (vs Ethernet)
- 1998: Integrated Services (vs MPLS)
- 1999: Token Rings (vs Ethernet)
Requirements for Success

- Low Cost: Low startup cost \(\Rightarrow\) Evolution
- High Performance
- Killer Applications
- Timely completion
- Manageability
- Interoperability
- Coexistence with legacy LANs
  Existing infrastructure is more important than new technology
Ethernet Developments: 1995-1999

- Priority: 802.1p
- Virtual LANs: 802.1Q
- Higher Speed: Gigabit Ethernet
**Trend: LAN - WAN Convergence**

- **Past:** Shared media in LANs. Point to point in WANs.
- **Future:** No media sharing by multiple stations
  - Point-to-point links in LAN and WAN
  - No distance limitations due to MAC. Only Phy.
  - Datalink protocols limited to frame formats
- **10 GbE over 40 km without repeaters**
- **Ethernet End-to-end.**
- **Ethernet carrier access service:** $1000/mo 100Mbps
SONET Functions

- Protection: Allows redundant Line or paths
- Fast Restoration: 50ms using rings
- Sophisticated OAM&P
- Ideal for Voice: No queues. Guaranteed delay
- Fixed Payload Rates: 51M, 155M, 622M, 2.4G, 9.5G
  Rates do not match data rates of 10M, 100M, 1G, 10G
- Static rates not suitable for bursty traffic
- One Payload per Stream
- High Cost
SONET: 2001 Developments

- Fixed Payload Rates: 51M, 155M, 622M, 2.4G, 9.5G
  Virtual concatenation allows any multiple of T1/STS1
  10M = 7 T1, 100M=2 STS-1, 1G=7 STS-3c’s

- Static rates not suitable for bursty traffic
  Link Capacity Adjustment Scheme (LCAS) allows
dynamic adjustment of number of T1’s or STS’s

- One Payload per Stream
  Generic Framing Protocol (GFP) allows multiple
  payloads per stream

- High Cost
  ASICs are being developed to reduce cost
Resilient Packet Rings

- Dual Counter-rotating rings help protect against failure
- Allows TDM traffic like T1, T3, SONET over RPR
- Will Ethernet with RPR be cheaper than SONET?
Ethernet: Future Possibilities

- 40 Gbps
- 100 Gbps:
  - $16\lambda \times 6.25$ Gbps
  - $8\lambda \times 12.5$ Gbps
  - $4\lambda \times 12.5$ using PAM-5
- 160 Gbps
- 1 Tbps:
  - 12 fibers with $16\lambda \times 6.25$ Gbps
  - 12 fibers with $8\lambda \times 12.5$ Gbps
- 70% of 802.3ae members voted to start 40G in 2002
Ethernet in the First Mile

- IEEE 802.3 Study Group started November 2000
- Originally called Ethernet in the Last Mile
- Current Technologies: ISDN, xDSL, Cable Modem, Satellite, Wireless, PON
- EFM Goals: Media: Phone wire, Fiber, Air
  - Speed: 125 kbps to 1 Gbps
  - Distance: 1500 ft, 18000 ft, 1 km - 40 km
Power over Ethernet

- IEEE 802.3af group approved 30 January 2000
  Power over MDI (Media Dependent Interface)
- Applications: Web Cams, PDAs, Intercoms, Ethernet Telephones, Wireless LAN Access points, Fire Alarms, Remote Monitoring, Remote entry
- Power over TP to a single Ethernet device:
  10BASE-T, 100BASE-TX, 1000BASE-T (TBD)
- Interoperate with legacy RJ-45 Ethernet devices
- Standard Expected: November 2002

Ref: http://grouper.ieee.org/groups/802/3/power_study/public/nov99/802.3af_PAR.pdf
Storage: New Traffic Demands

- Fiber Channel SAN limited to 10 km
- Cheap bandwidth $\Rightarrow$ Outsourced storage
- Multiservice switches allow IP, ATM, SONET, ESCON, ...

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## Telecom vs Data Networks

<table>
<thead>
<tr>
<th></th>
<th>Telecom Networks</th>
<th>Data Networks</th>
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<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>
Trend: IP Everywhere

IP Needs:
1. Circuits
2. Traffic Engineering
3. Data and Control plane separation
4. Signaling and Addressing
5. Protection and Restoration
Multiprotocol Label Switching (MPLS)

- Allows circuits in IP Networks (May 1996)
- Each packet has a circuit number or label
- Circuit number determines the packet’s queuing and forwarding
- Circuits have be set up before use
- Circuits are called Label Switched Paths (LSPs)
**Issue: Control and Data Plane Separation**

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

Today:

Tomorrow:

Routing Messages

Data

Signaling
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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Optical Networking Developments

- Higher Speed: 40 Gbps
- Longer Distances: 4000 km
- Fiber Everywhere
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](http://www.citynettelecom.com), NFOEC 2001, pp. 331
1. Robots map the pipe
2. Install rings
3. Install ducts
4. Thread fibers

Fast Restoration: Broken sewer pipes replaced with minimal disruption
Summary

- Traffic > Capacity
  ⇒ Need QoS, traffic engineering in WANs

- Ethernet everywhere
  ⇒ Rings, many rates, longer distances, Power

- SONET is also adapting to data traffic
  ⇒ SONET will stay longer than expected.

- Convergence at L3 ⇒ Everything over IP
  ⇒ IP needs circuits, traffic engineering, data and control plane separation
References

- Detailed references in http://www.cis.ohio-state.edu/~jain/refs/hot.refs.htm
- Search http://www.cis.ohio-state.edu/~jain