

Networking Trends and Their Impact



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- ❑ Technology Trends
- ❑ Networking Trends

Technology Trends

1. Networking Bottleneck
2. Fast Immediacy
 - Impact on R&D
 - Impact on Education
3. Convergence
4. Information Glut

Trends: Networking Bottleneck

- ❑ Communication is more critical than computing
 - Greeting cards contain more computing power than all computers before 1950.
 - Genesis's game has more processing than 1976 Cray supercomputer.
- ❑ Networking speed is the key to productivity
- ❑ E-Commerce \Rightarrow 20-30% of revenue spent on networking
- ❑ High bandwidth \Rightarrow More bits per second
Hundreds of telegrams per day \Rightarrow Fast pace of life

Impact on R&D

- ❑ Too much growth in one year
⇒ Can't plan too much into long term
- ❑ Long term = 1₂ year or 10₂ years at most
- ❑ Products have life span of 1 year, 1 month, ...
- ❑ Short product development cycles.
Chrysler reduced new car design time
from 6 years to 2.
- ❑ Distance between research and products has narrowed
⇒ Collaboration between researchers and developers
⇒ Academics need to participate in industry consortia

Impact on Education

- ❑ Technology is changing faster than our ability to learn
 - ⇒ Your value (salary) decreases with experience (years out of college)
- ❑ Recent graduates know C++, HTML, Java, TCP/IP, ...
- ❑ Need personal career management strategies
- ❑ New Opportunities/Challenges for educators
- ❑ New challenges for learners

Trend: Convergence

Entertainment

Video Games

Publishing

News

Advertising

Cable TV

Telephone

Computer

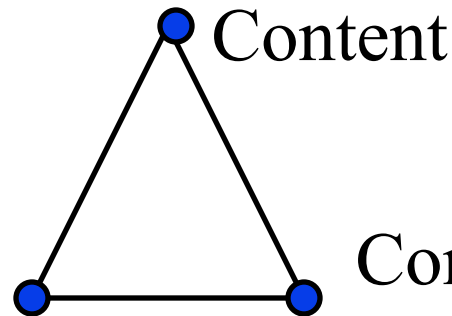
Digital
Media
Production

Video
Transport

Voice
Transport

Digital Media
Storage/
Handling

Convergence (Cont)



- ❑ Merging of Content Providers and Content transporters
- ❑ Phone companies, cable companies, entertainment industry, and computer companies
- ❑ Single department for telephone and computer networking
- ❑ LAN/WAN convergence

Trend: Information Glut

- ❑ Web \Rightarrow Information production and dissemination costs are almost zero
 - \Rightarrow Too much information
 - = Needles in the haystack
- ❑ Thousands of hits on each search
- ❑ Need tools for summarizing the information
- ❑ Opportunities for artificial intelligence
- ❑ Need to express information so that both human and computers can understand

Networking Trends

- ❑ Faster Media
- ❑ More Traffic
- ❑ Traffic $>$ Capacity
- ❑ ATM in Backbone
- ❑ Everything over IP
- ❑ Traffic Engineering
- ❑ All-layer Routing

Trend: Faster Media

- ❑ One Gbps over 4-pair UTP-5 up to 100 m
10G being discussed.
Was 1 Mbps (1Base-5) in 1984.
- ❑ Dense Wavelength Division Multiplexing (DWDM)
64×OC-192 = 0.6 Tbps
OC-768 = 40 Gbps over a 1λ to 65 km [Alcatel98]
400 Gbps using 80λ products.
Was 100 Mbps (FDDI) in 1993.
- ❑ 11 Mbps in-building wireless networks
Was 1 Mbps (IEEE 802.11) in 1998.
2.5 Gbps to 5km using light in open air

Trend: Faster Media

- ❑ One Gbps over 4-pair UTP-5 up to 100 m
Was 1 Mbps (1Base-5) in 1984.
- ❑ Dense Wavelength Division Multiplexing (DWDM)
allows 64 wavelengths in a single fiber
 $64 \times \text{OC-192} = 0.6 \text{ Tbps}$
 $\text{OC-768} = 40 \text{ Gbps}$ demonstrated in 1998.
Was 100 Mbps (FDDI) in 1993.
- ❑ 11 Mbps in-building wireless networks
Was 1 Mbps (IEEE 802.11) in 1998.

Trend: More Traffic



- ❑ Number of Internet hosts is growing super-exponentially.
- ❑ Traffic per host is increasing:
 - Cable modems allow 1 to 10 Mbps access from home
 - 6-27 Mbps over phone lines using ADSL/VDSL
- ❑ Bandwidth requirements are doubling every 4 months

Trend: Traffic > Capacity



Expensive Bandwidth

- Sharing
- Multicast
- Virtual Private Networks
- Need QoS
- Likely in WANs

Cheap Bandwidth

No sharing
Unicast
Private Networks
QoS less of an issue
Possible in LANs

Trend: ATM in Backbone

- ❑ Most carriers including AT&T, MCI, Sprint, UUNET, have ATM backbone
- ❑ Over 80% of the internet traffic goes over ATM
- ❑ ATM provides:
 - Traffic management
 - Voice + Data Integration: CBR, VBR, ABR, UBR
 - Signaling
 - Quality of service routing: PNNI
- ❑ ATM can't reach desktop: Designed by carriers. Complexity in the end systems. Design favors voice.

Trend: Everything over IP

- ❑ Data over IP \Rightarrow IP needs Traffic engineering
- ❑ Voice over IP \Rightarrow Quality of Service and Signaling
- ❑ Internet Engineering Task Force (IETF) is the center of action.

Attendance at ATM Forum and ITU is down.

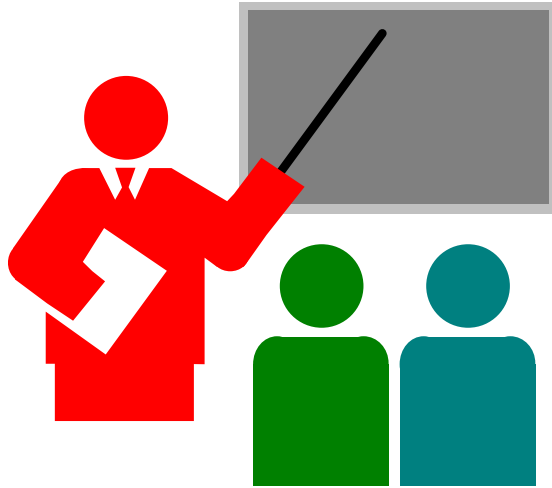
Trend: Traffic Engineering

- ❑ User's Performance Optimization
 - ⇒ Maximum throughput, Min delay, min loss, min delay variation
- ❑ Efficient resource allocation for the provider
 - ⇒ Efficient Utilization of all links
 - ⇒ Load Balancing on parallel paths
 - ⇒ Minimize buffer utilization
 - Current routing protocols (e.g., RIP and OSPF) find the shortest path (may be over-utilized).
- ❑ QoS Guarantee: Selecting paths that can meet QoS
- ❑ Enforce Service Level agreements
- ❑ Enforce policies: Constraint based routing \supseteq QoSR

Trend: All-Layer Routing

- ❑ Old: All packets followed the same path, stood in the same FIFO queue. Path based on Destination IP Address.
- ❑ New: Buffering, Queueing, Scheduling, and path based on Destination IP address, Source IP address, TCP Ports, Type of Service, ...

Summary



- ❑ Networking is growing exponentially
- ❑ It is impacting all aspects of life \Rightarrow Networking Age
- ❑ Profusion of Information
- ❑ Virtualization, Globalization, Immediacy

References

- ❑ See Reference on Networking history and trends,
http://www.cse.ohio-state.edu/~jain/refs/ref_trnd.htm
- ❑ Books on Networking history and trends,
http://www.cse.ohio-state.edu/~jain/refs/trn_book.htm