Networking Trends and Their Impact

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Overview

- 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 ⇒ 20-30% of revenue spent on networking
- High bandwidth ⇒ More bits per second
  Hundreds of telegrams per day ⇒ Fast pace of life

Impact on R&D

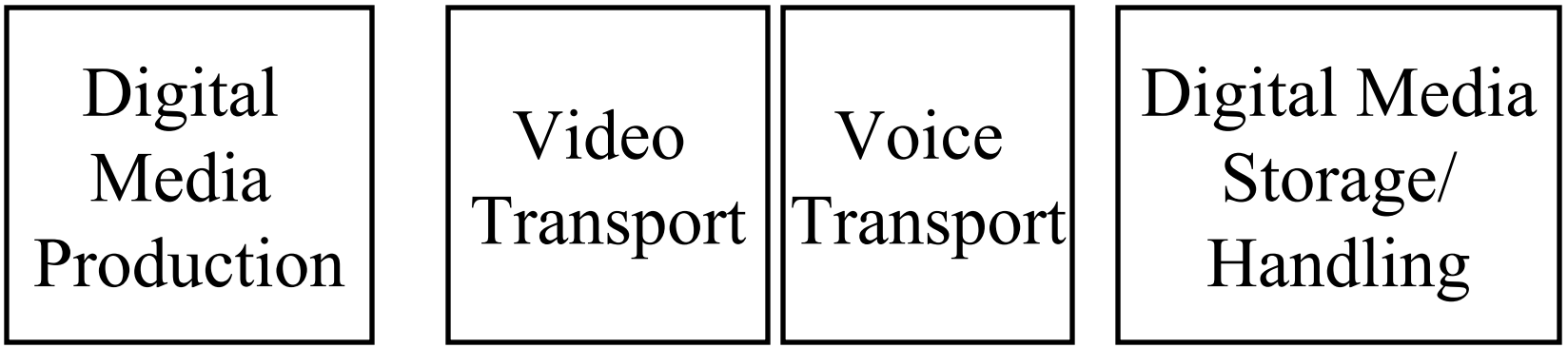
- Too much growth in one year
  $\Rightarrow$ Can't plan too much into long term
- Long term = 1_2 year or 10_2 years at most
- Products have life span of 1 year, 1 month, …
- Short product development cycles.
  Chrysler reduced new car design time
  from 6 years to 2.
- Distance between research and products has narrowed
  $\Rightarrow$ Collaboration between researchers and developers
  $\Rightarrow$ Academics need to participate in industry consortia

Impact on Education

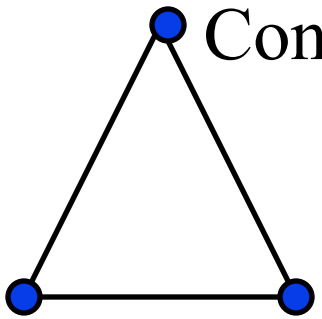
- Technology is changing faster than our ability to learn
  $\Rightarrow$ Your value (salary) decreases with experience (years out of college)
- Recent graduates know C++, HTML, Java, TCP/IP, ...
- Need personal career management strategies
- New Opportunities/Challenges for educators
- New challenges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

Trend: Convergence

Entertainment
Video Games
Publishing
News
Advertising



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

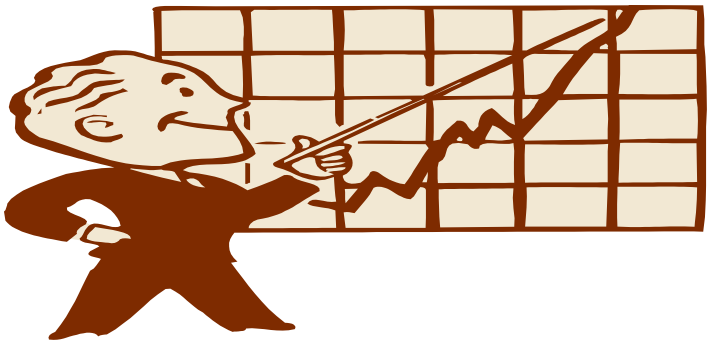
Trend: Faster Media

- 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×OC-192 = 0.6 Tbps
  OC-768 = 40 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	Cheap Bandwidth
❑ Sharing	No sharing
❑ Multicast	Unicast
❑ Virtual Private Networks	Private Networks
❑ Need QoS	QoS less of an issue
❑ Likely in WANs	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 ⇒ IP needs Traffic engineering
- Voice over IP ⇒ Quality of Service and Signaling
- Internet Engineering Task Force (IETF) is the center of action.
  Attendance at ATM Forum and ITU is down.

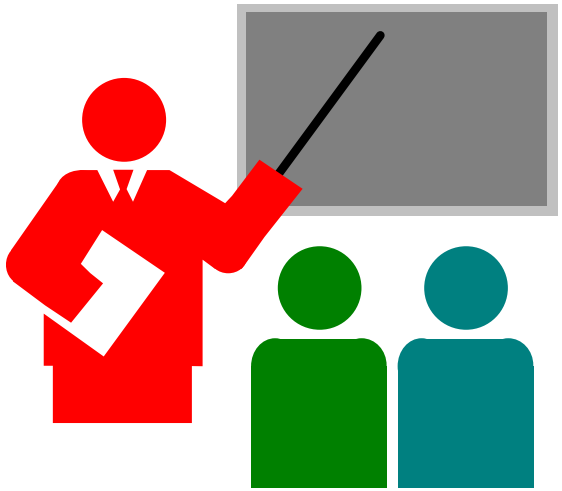
Trend: Traffic Engineering

- 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 ⊇ 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 ⇒ 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