Computer Networking: Recent Advances, Trends, and Issues

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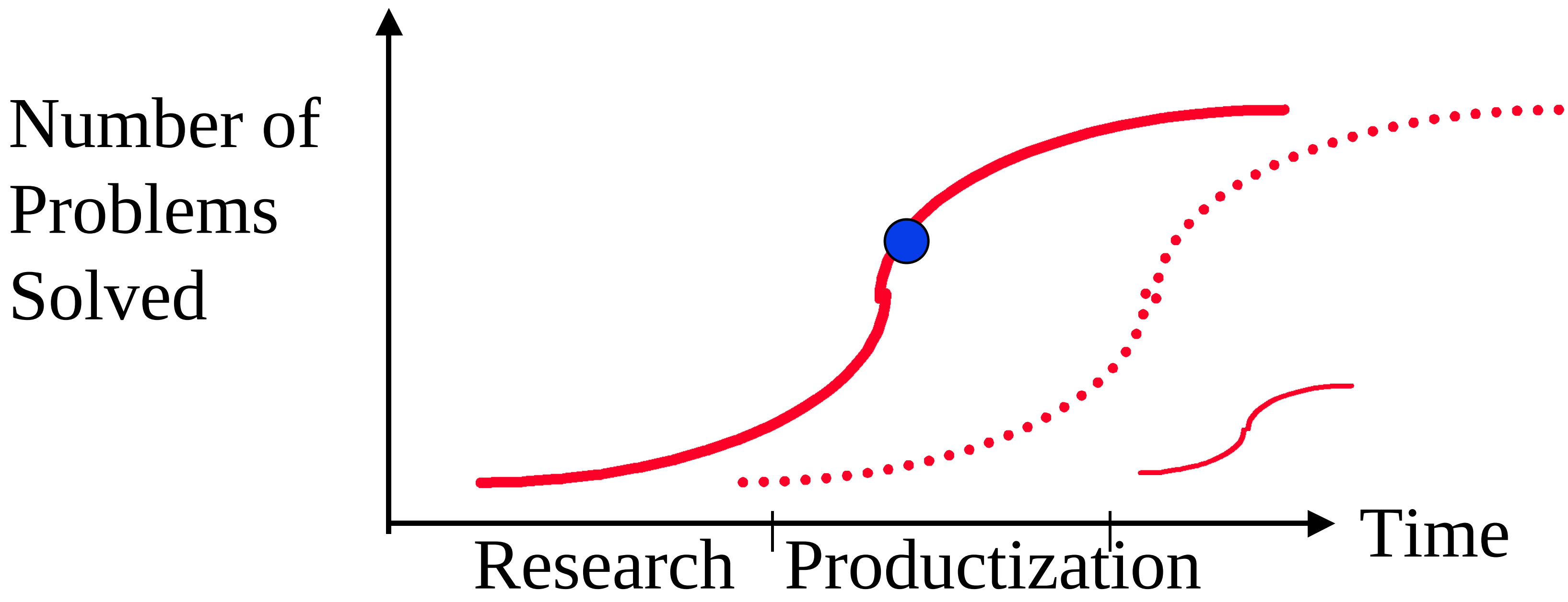
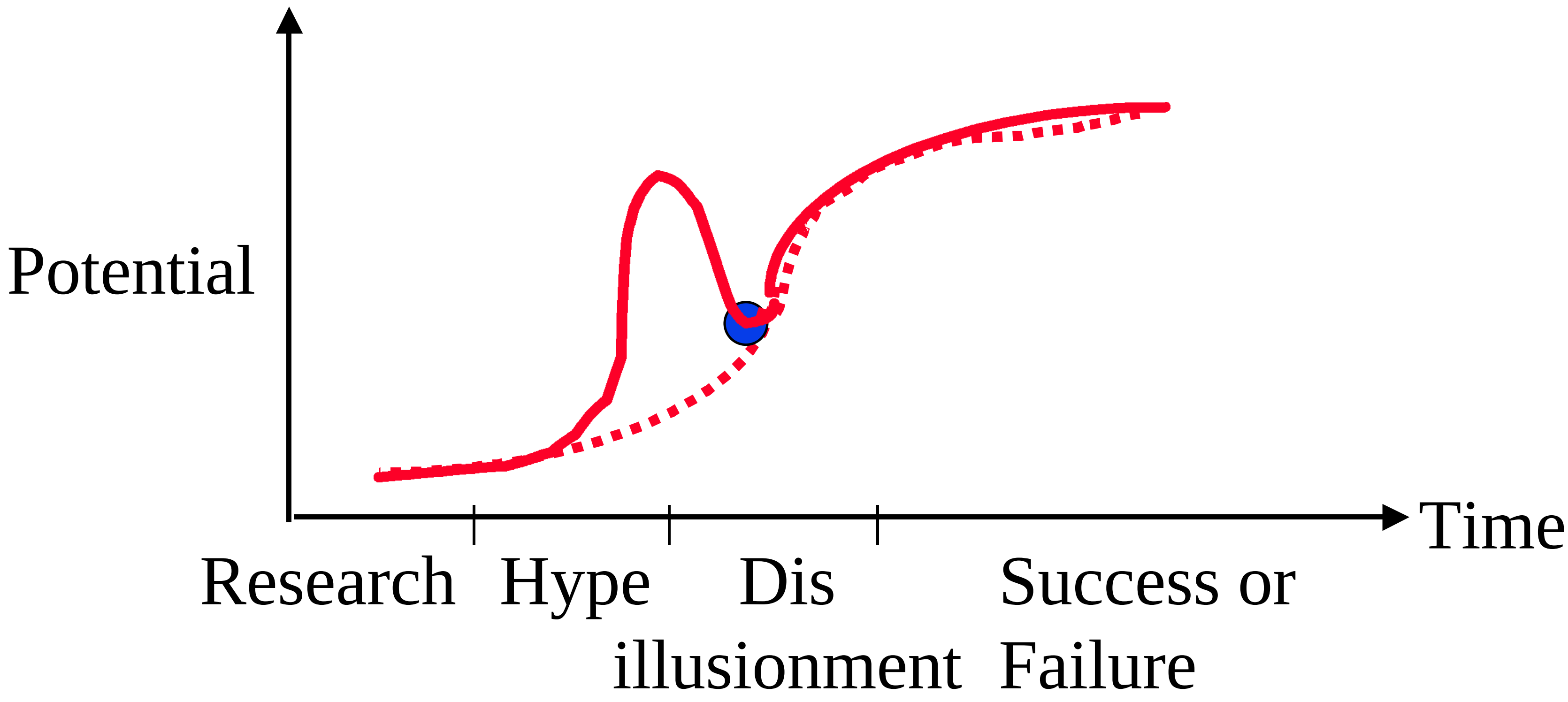
Overview

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

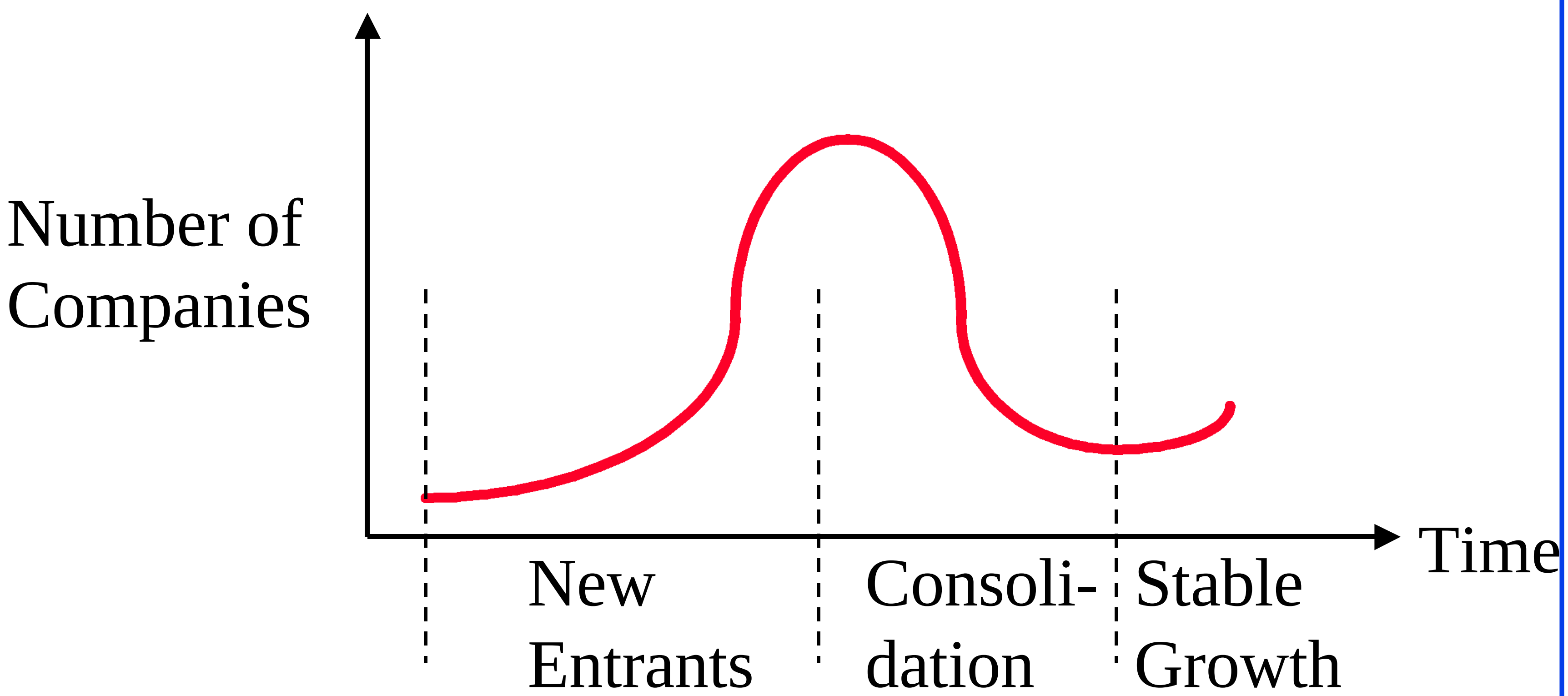
Life Cycles of Technologies



Hype Cycles of Technologies



Industry Growth



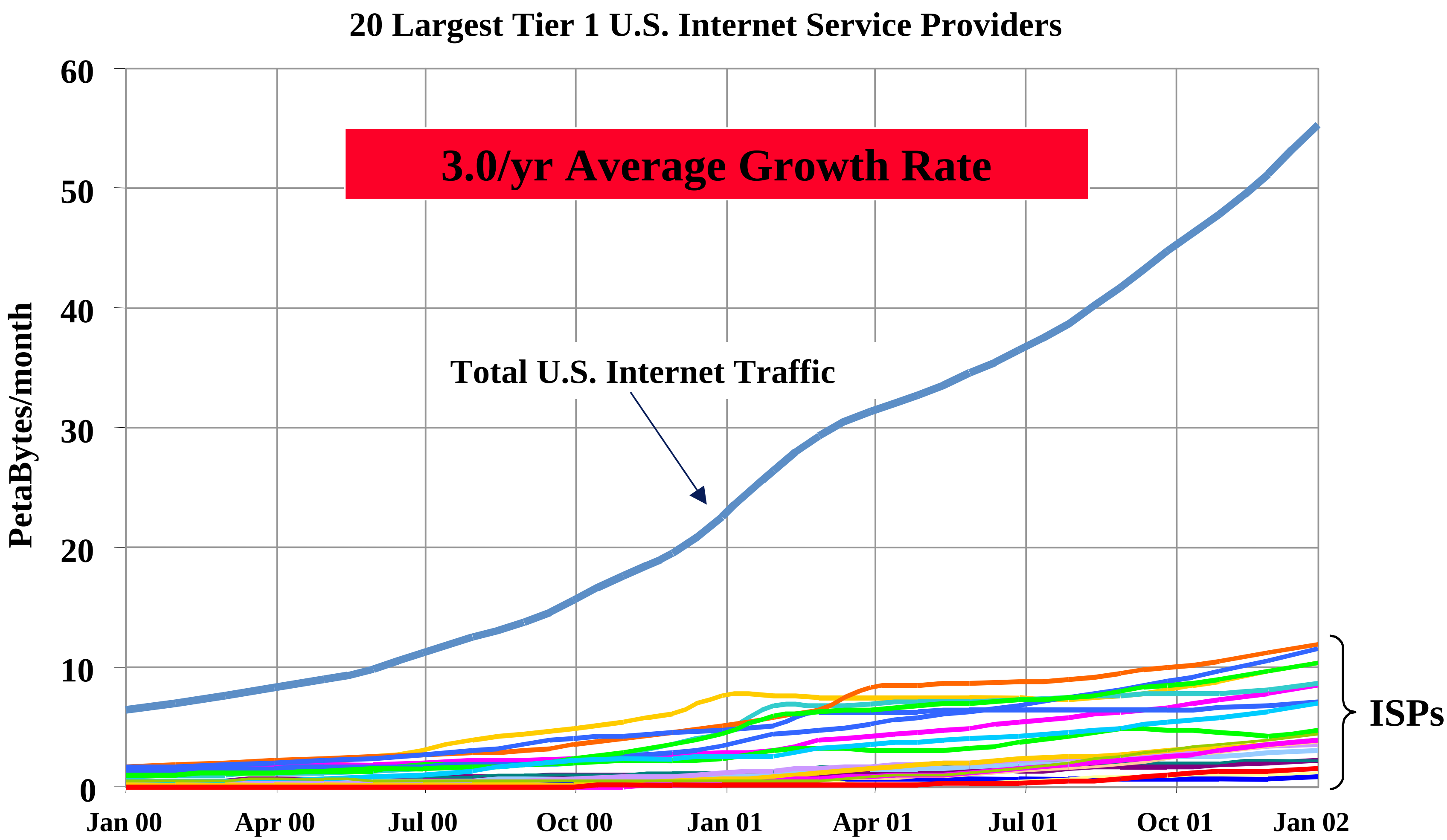
Traffic vs Capacity Growth

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

Is Internet Traffic Growing?

- IP Traffic Growth will slow down from 200-300% per year to 60% by 2005
  - McKinsey & Co and JP Morgan, May 16, 2001
- 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, Marril 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



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)

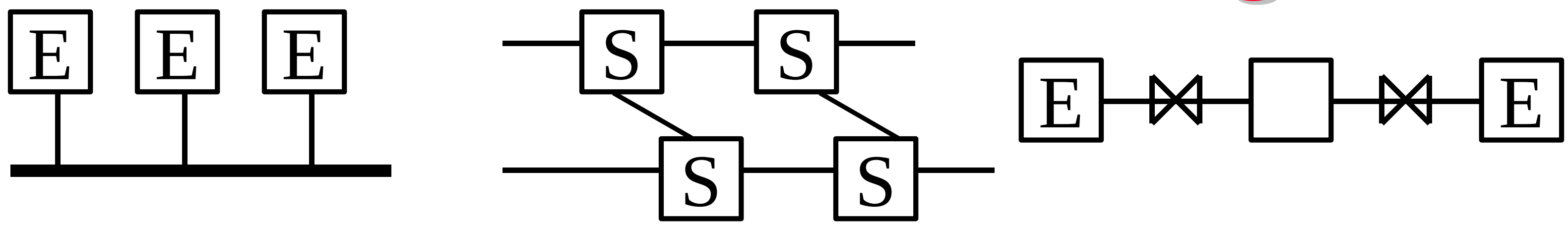
Requirements for Success

- Low Cost: Low startup cost ⇒ 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

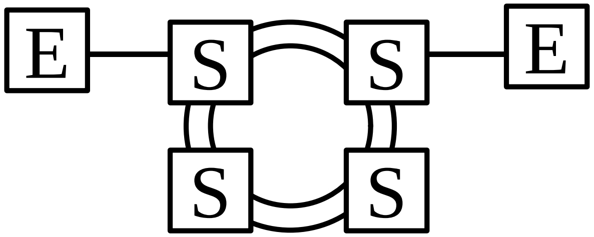
- Priority: 802.1p
- Virtual LANs: 802.1Q
- Higher Speed: Gigabit Ethernet

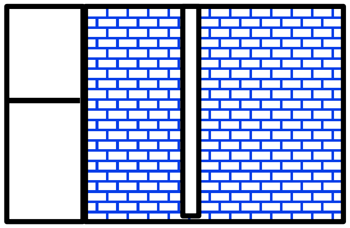
Trend: LAN - WAN Convergence



- 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



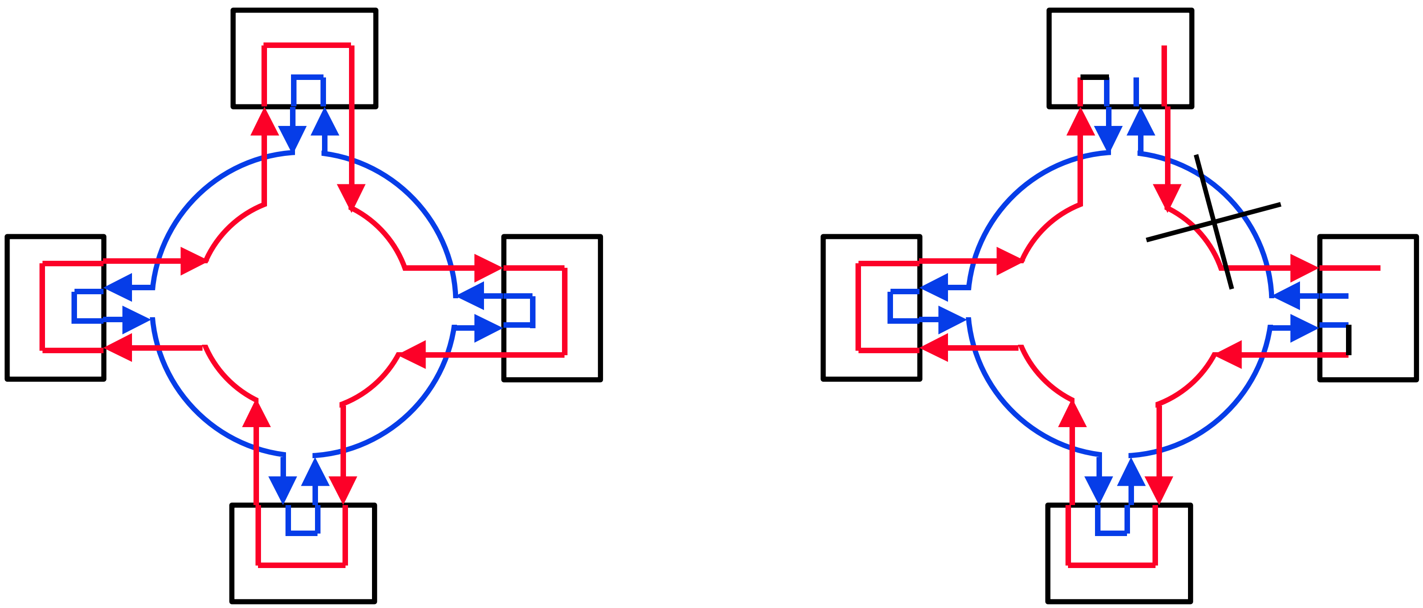


- Protection: Allows redundant Line or paths
- Fast Restoration: 50ms using rings
- Sophisticated OAM&P
- Ideal for Voice: No queues. Guaranteed delay
- Fixed Payload Rates: 51M, 155M, 622M, 2.4G, 9.5G
  Rates do not match data rates of 10M, 100M, 1G, 10G
- Static rates not suitable for bursty traffic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

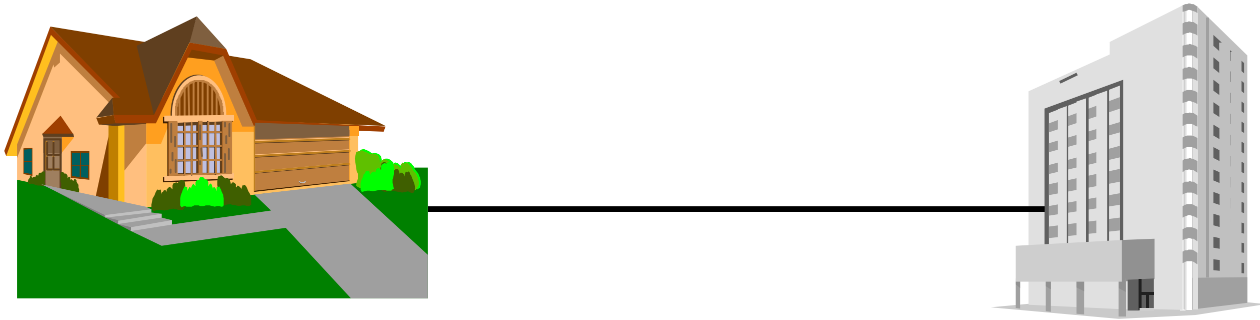


- Dual Counter-rotating rings help protect against failure
- Allows TDM traffic like T1, T3, SONET over RPR
- Will Ethernet with RPR be cheaper than SONET?

Ethernet: Future Possibilities

- 40 Gbps
- 100 Gbps:
  - 16λ×6.25 Gbps
  - 8λ × 12.5 Gbps
  - 4λ × 12.5 using PAM-5
- 160 Gbps
- 1 Tbps:
  - 12 fibers with 16λ × 6.25 Gbps
  - 12 fibers with 8λ × 12.5 Gbps
- 70% of 802.3ae members voted to start 40G in 2002

Ethernet in the First Mile

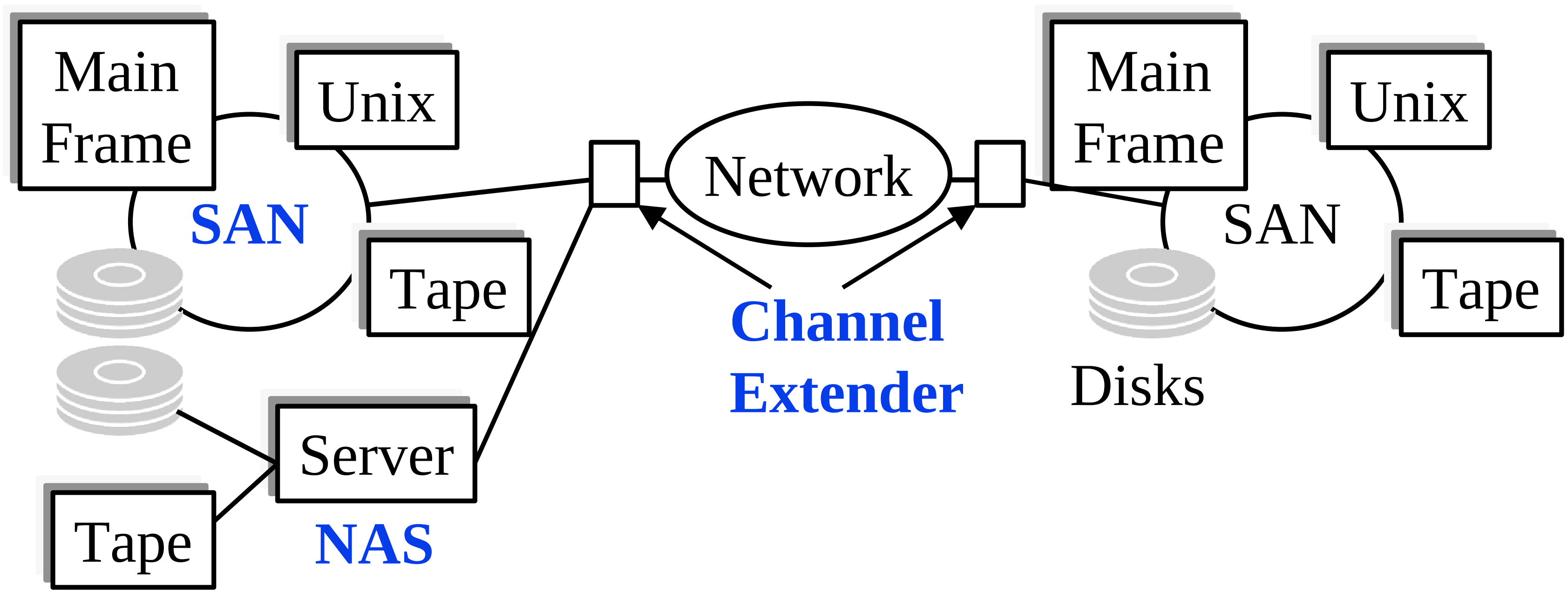


- IEEE 802.3 Study Group started November 2000
- Originally called Ethernet in the Last Mile
- Current Technologies: ISDN, xDSL, Cable Modem, Satellite, Wireless, PON
- EFM Goals: Media: Phone wire, Fiber, Air
  - Speed: 125 kbps to 1 Gbps
  - Distance: 1500 ft, 18000 ft, 1 km - 40 km
- Ref: http://www.ieee802.org/3/efm/public/index.htm

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

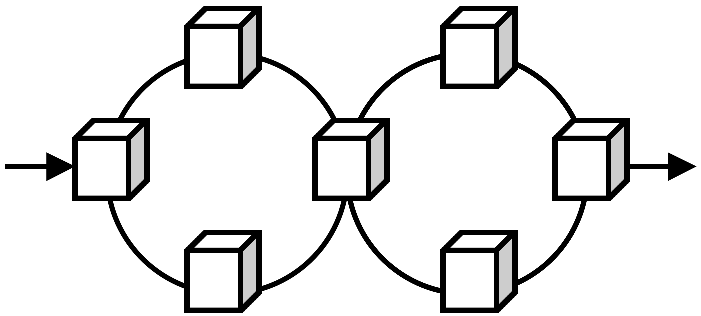
Storage: New Traffic Demands

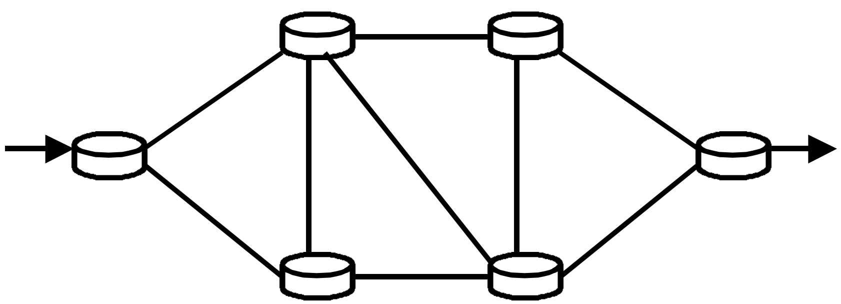


- Fiber Channel SAN limited to 10 km
- Cheap bandwidth ⇒ Outsourced storage
- Multiservice switches allow IP, ATM, SONET, ESCON, ...

Telecom vs Data Networks

	Telecom Networks	Data Networks
Topology Discovery	Manual	Automatic
Path Determination	Manual	Automatic
Circuit Provisioning	Manual	No Circuits
Transport & Control Planes	Separate	Mixed
User and Provider Trust	No	Yes
Protection	Static using Rings	No Protection



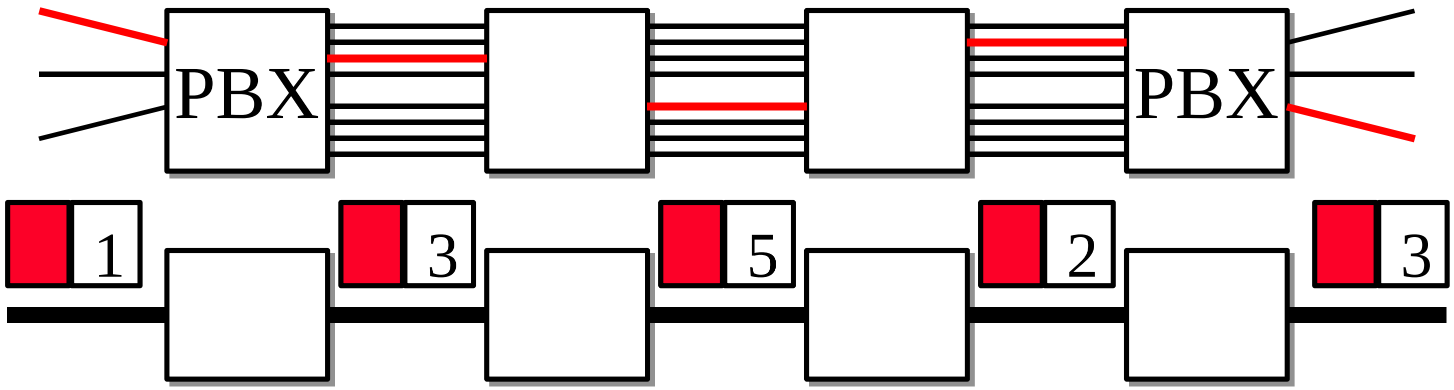


Trend: IP Everywhere

IP Needs:

1. Circuits
2. Traffic Engineering
3. Data and Control plane separation
4. Signaling and Addressing
5. Protection and Restoration

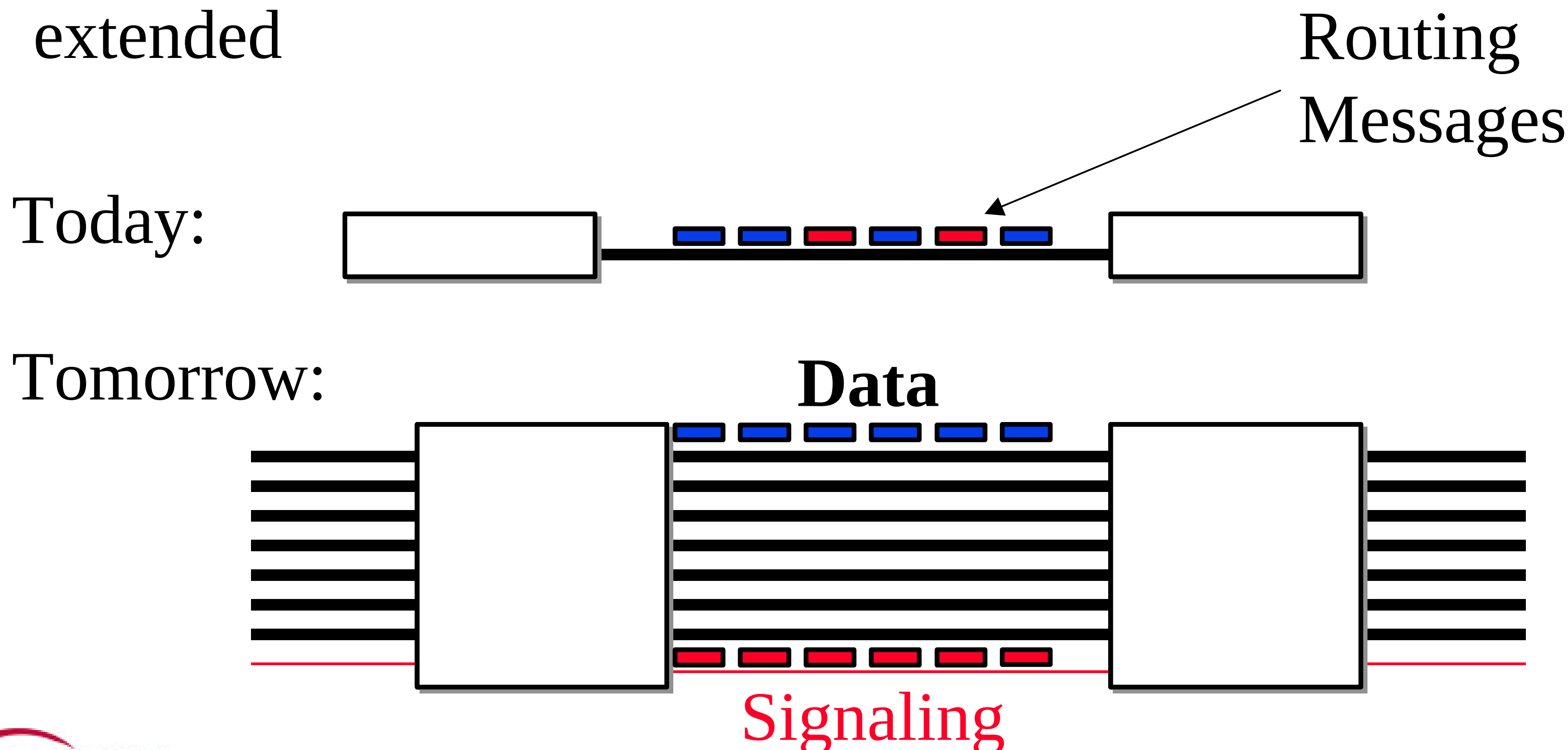
Multiprotocol Label Switching (MPLS)



- 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)

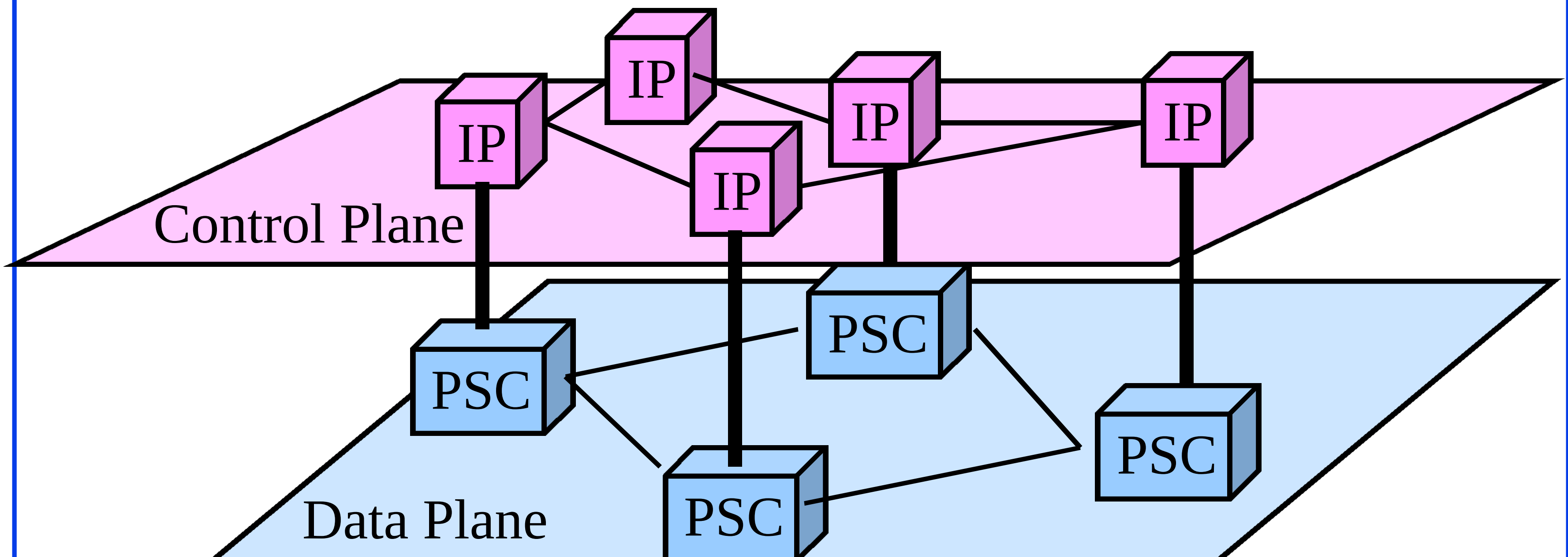
Issue: Control and Data Plane Separation

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



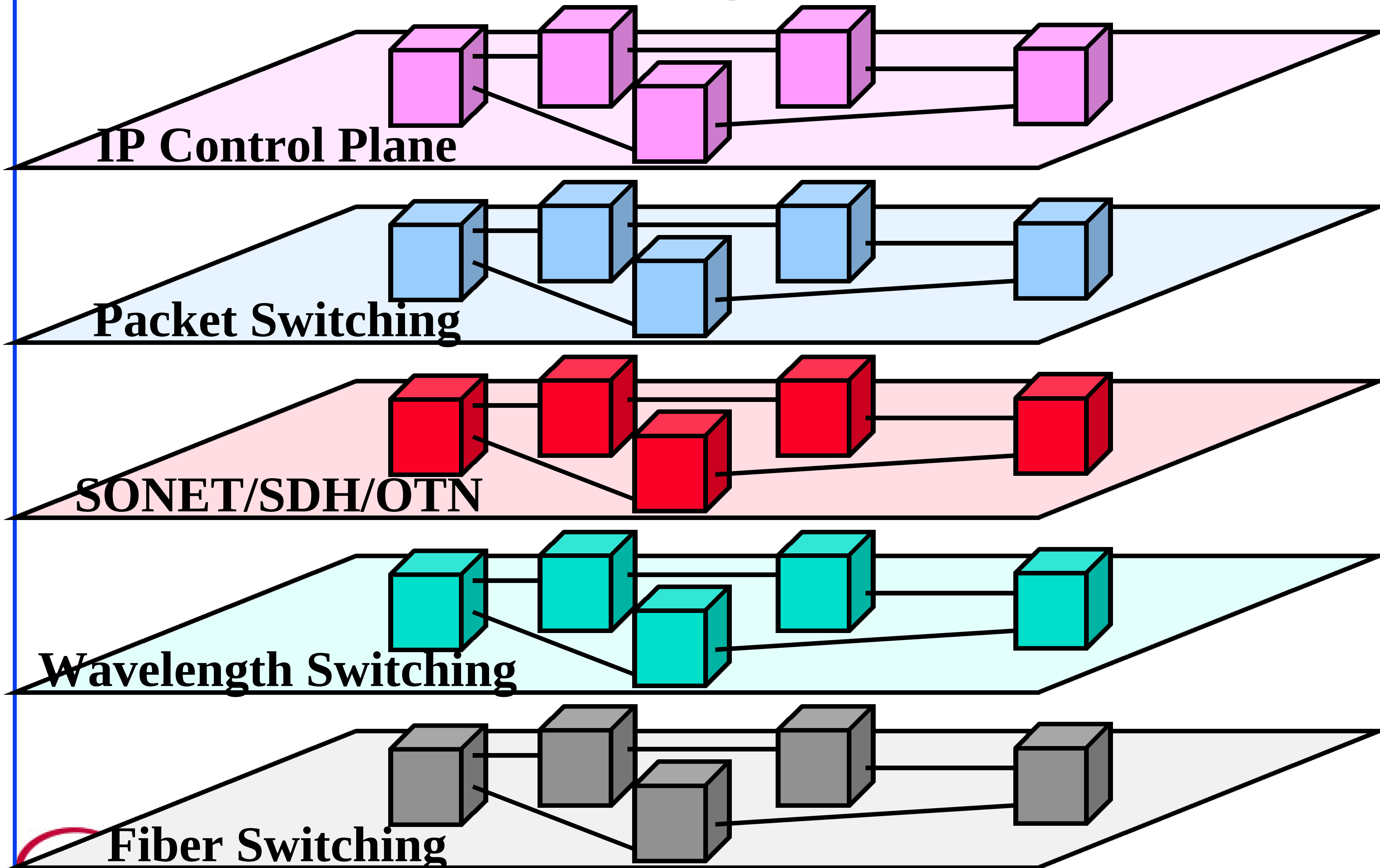
IP-Based Control Plane

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



PSC = Packet Switch Capable Nodes

GMPLS: Layered View



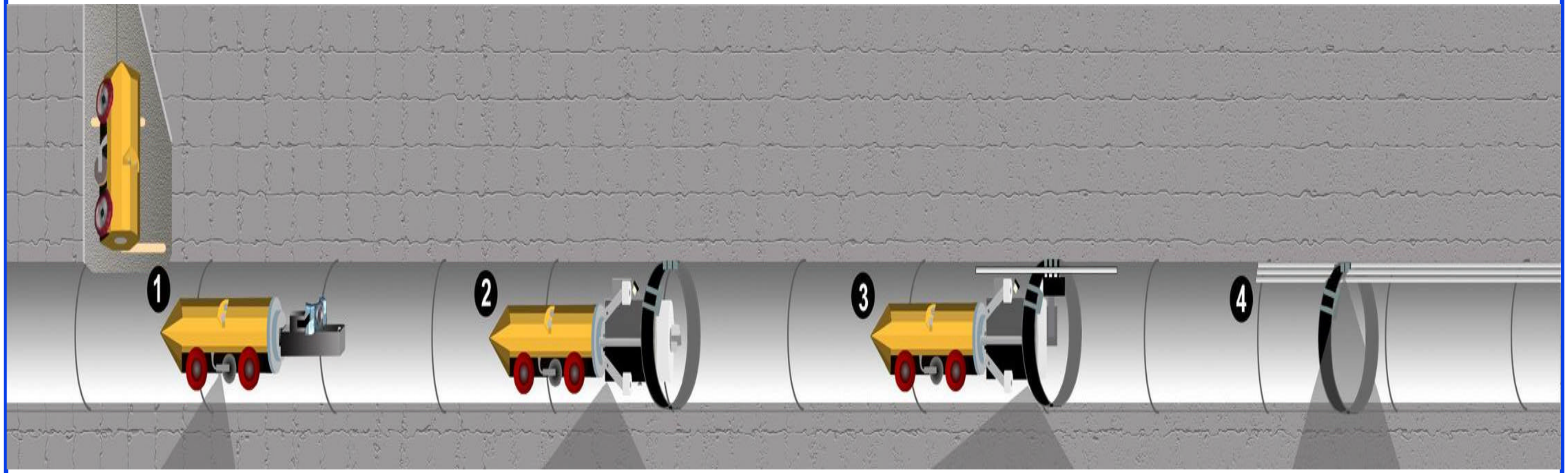
Optical Networking Developments

- Higher Speed: 40 Gbps
- More Wavelengths: 160 Announced. 1023 possible.
- Longer Distances: 4000 km
- Fiber Everywhere

Fiber Access Thru Sewer Tubes (FAST)

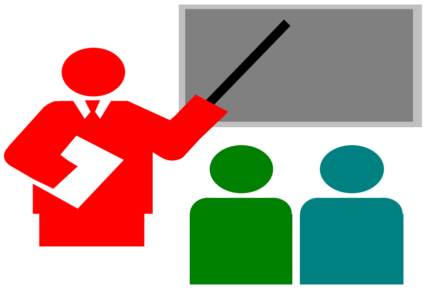
- Right of ways is difficult in dense urban areas
- Sewer Network: Completely connected system of pipes connecting every home and office
- Municipal Governments find it easier and more profitable to let you use sewer than dig street
- Installed in Zurich, Omaha, Albuquerque, Indianapolis, Vienna, Ft 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, 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



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
- Recommended books on networking, http://www.cis.ohio-state.edu/~jain/refs/hot_book.htm
- Search http://www.cis.ohio-state.edu/~jain