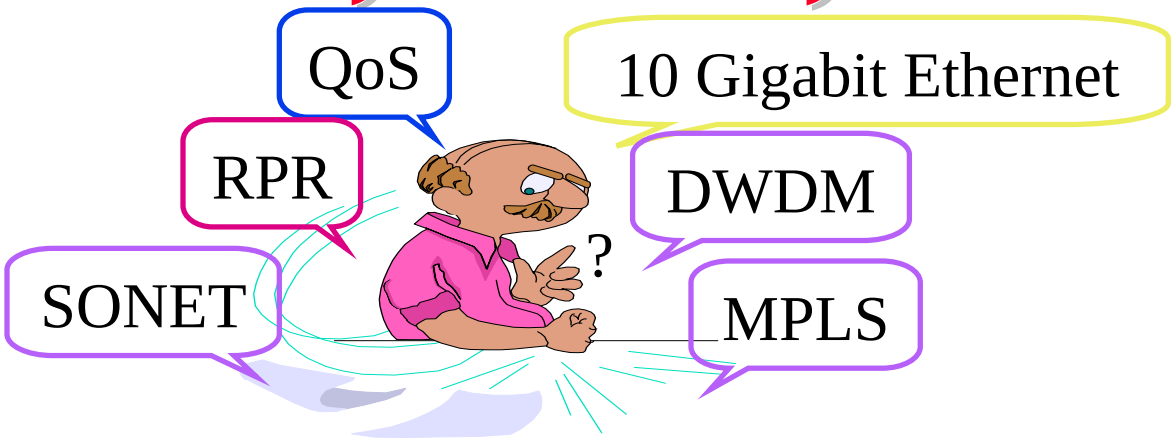
Computer Networking: Recent Advances, Trends, and Issues



Raj Jain

Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/

www lu/~jain/

NAYNA Networks

Overview

- Traffic vs Capacity
- Trend: Everything over IP
- Multiprotocol Label Switching (MPLS)
- Trend: Ethernet Everywhere
- Optical Networking

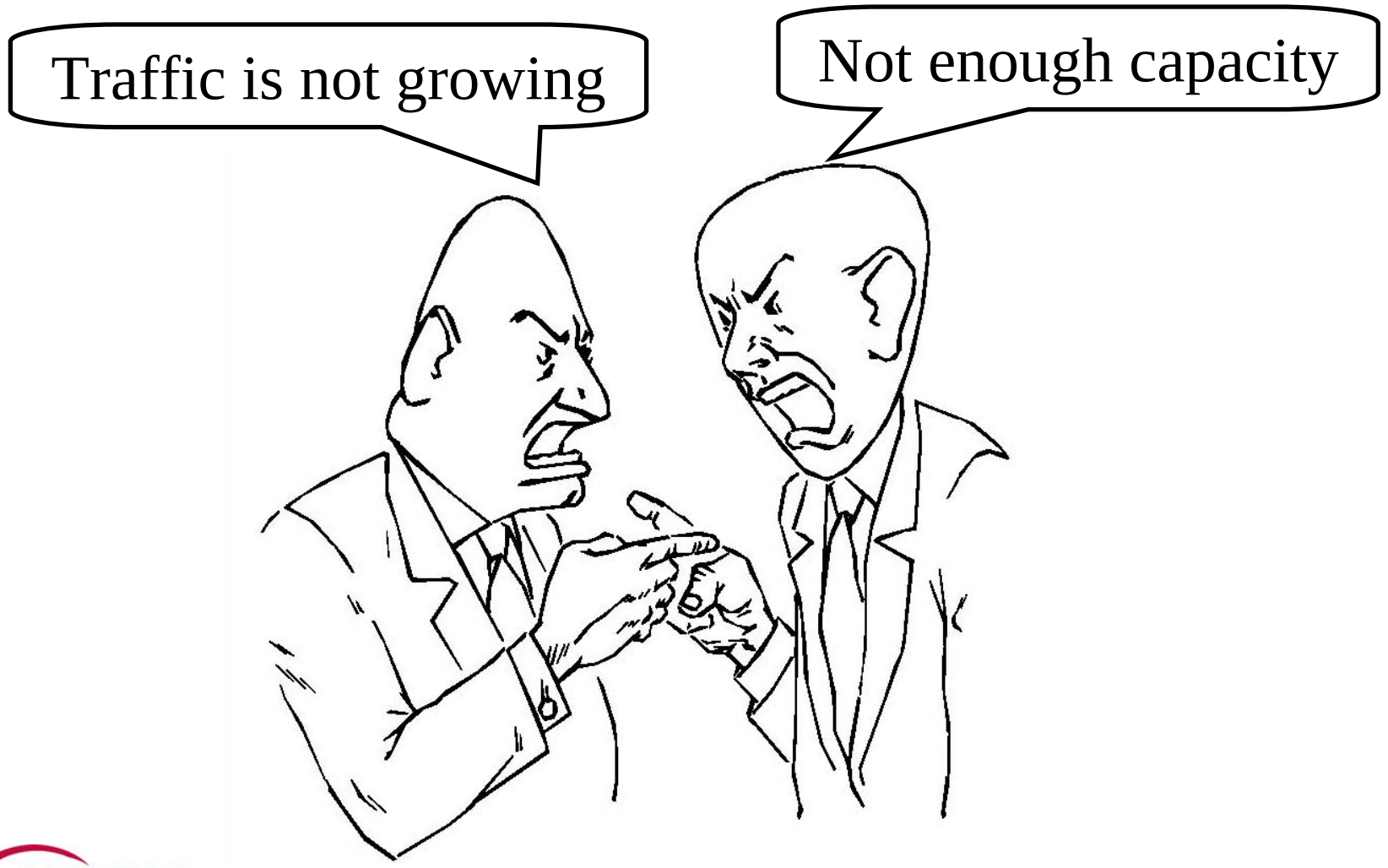
Future

White House Astrologer

Joan Quigly

All I want you to tell me is what will be the networking technology in the year 2002.

Glut-sters vs Gap-sters



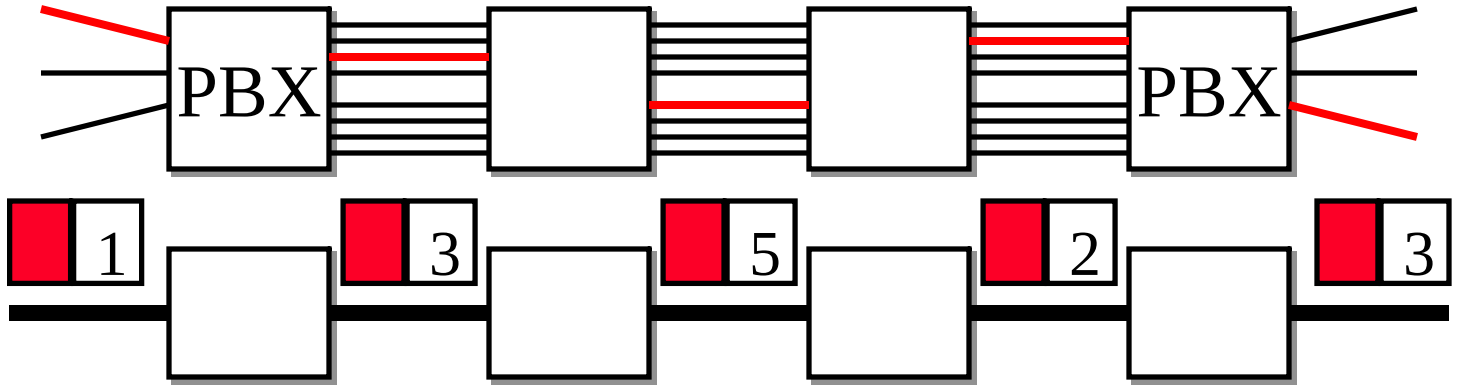
Trend: Traffic > Capacity

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: Everything over IP

- Data over IP ⇒ IP needs Traffic engineering
- Voice over IP ⇒ Quality of Service, Signaling, virtual circuits (MPLS)
- Internet Engineering Task Force (IETF) is the center of action. www.ietf.org

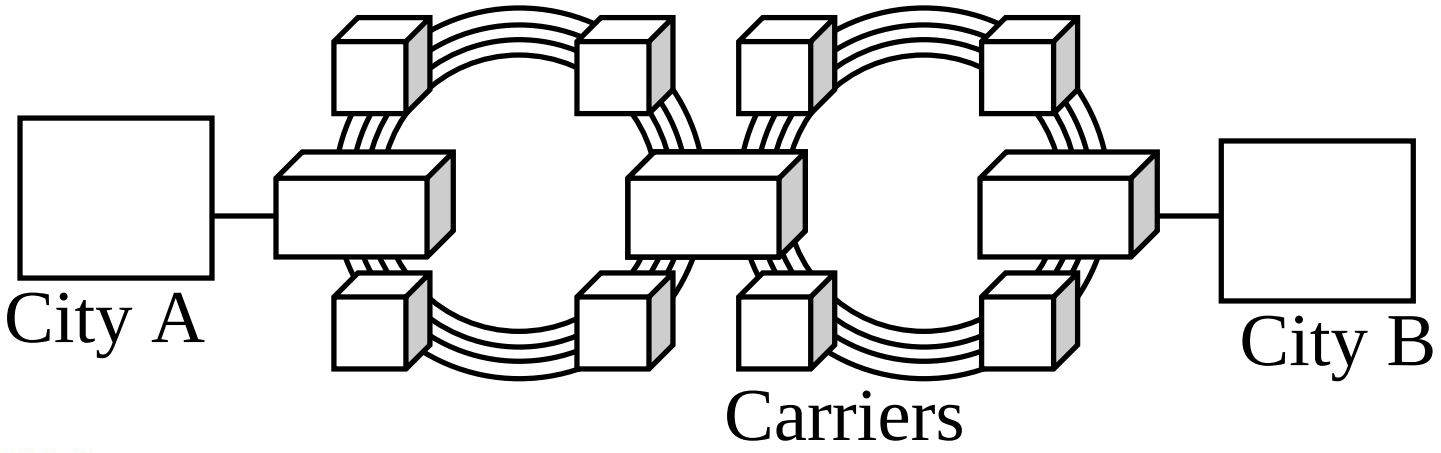
Multiprotocol Label Switching (MPLS)



- 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)

SONET

- Synchronous optical network
- Also known as Synchronous Digital Hierarchy (SDH)
- OC-*n* = *n*×51 Mbps, OC-48=2.5G, OC-192=10G
- You can lease a SONET connection from carriers
- Ring topology common



Trend: Ethernet Everywhere

- Ethernet vs SONET in Metro:
  - 10 G Ethernet
  - Survivability, Restoration ⇒ Ring Topology
- Ethernet in Access: EFM
- Ethernet vs phone network in homes:
  Power over Ethernet

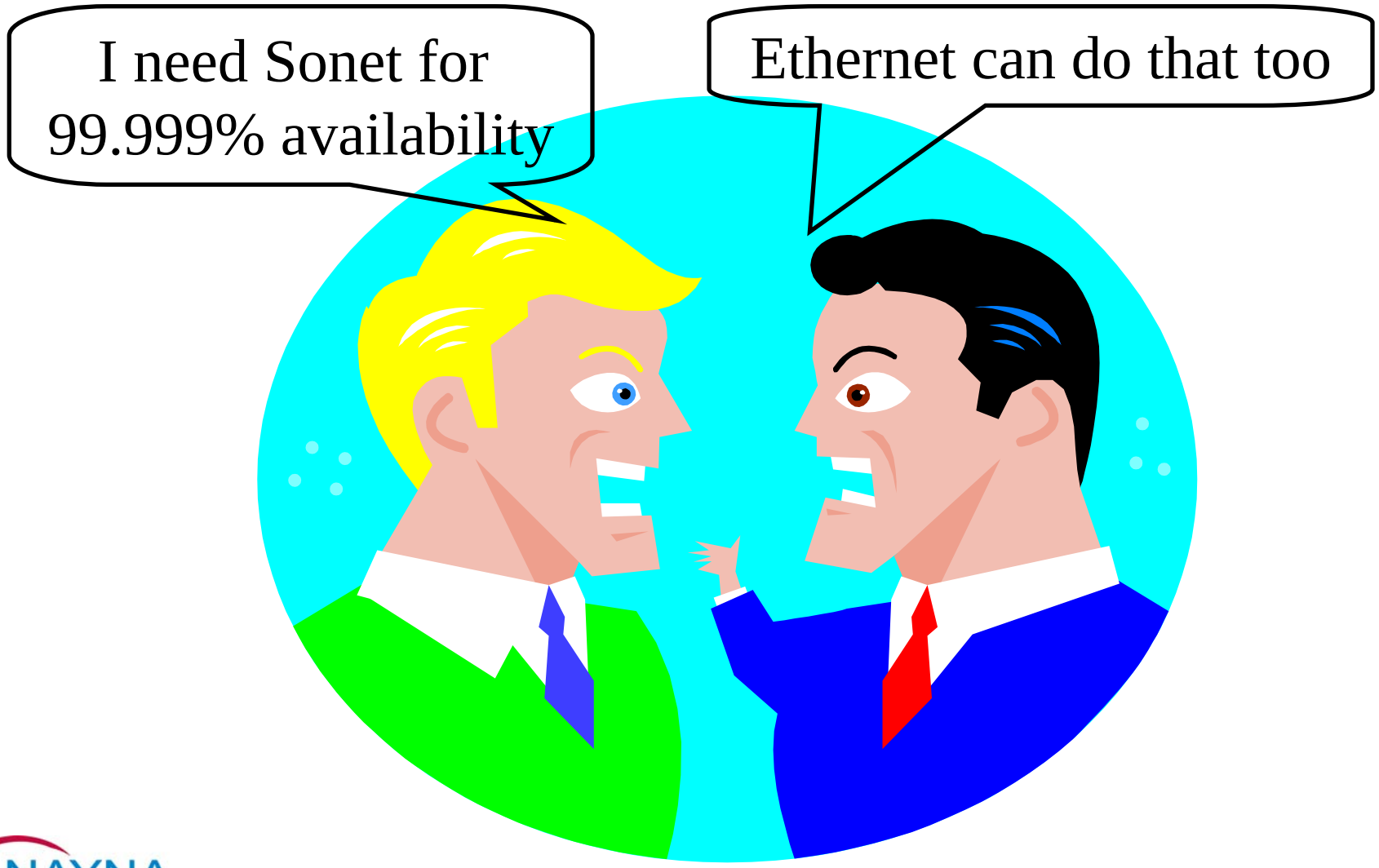
10 G Ethernet

- Two versions: LAN (10 Gbps), WAN (9.5 Gbps)
- Point-to-point full duplex only
- Several different physical layer designs for different distances
- 9.5 Gbps WAN version compatible with SONET in data rate but incompatible in clock jitter

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

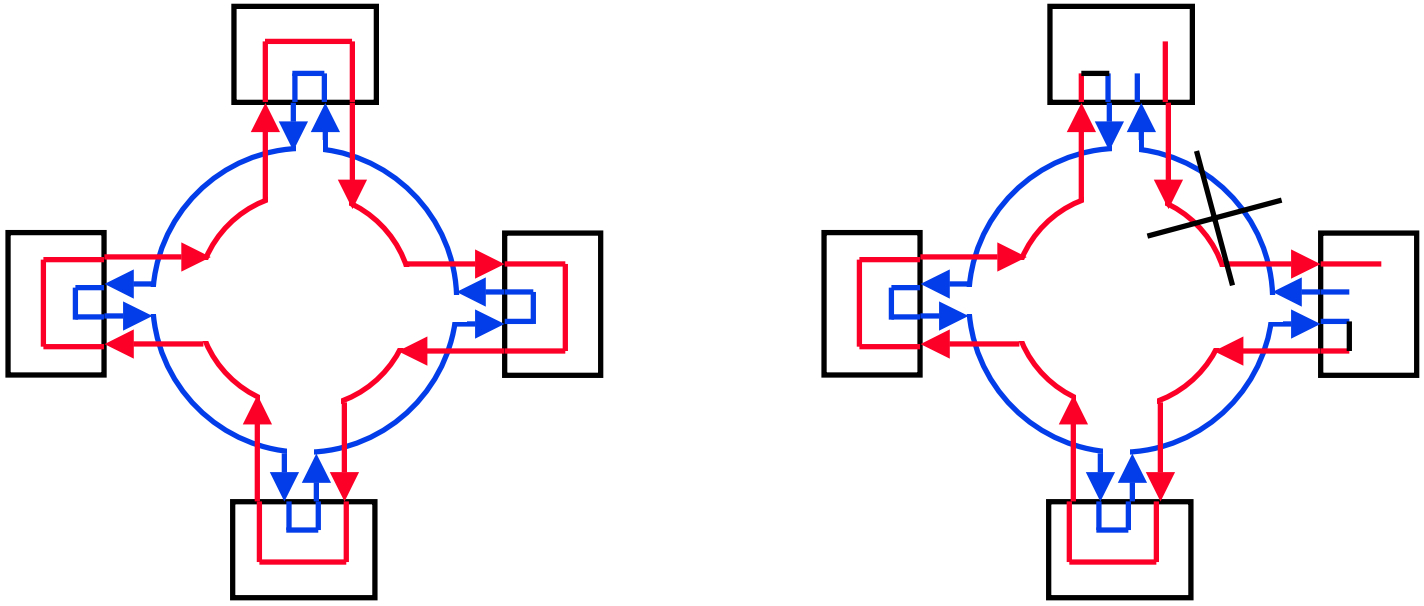
Ethernet vs Sonet



Networking and Religion

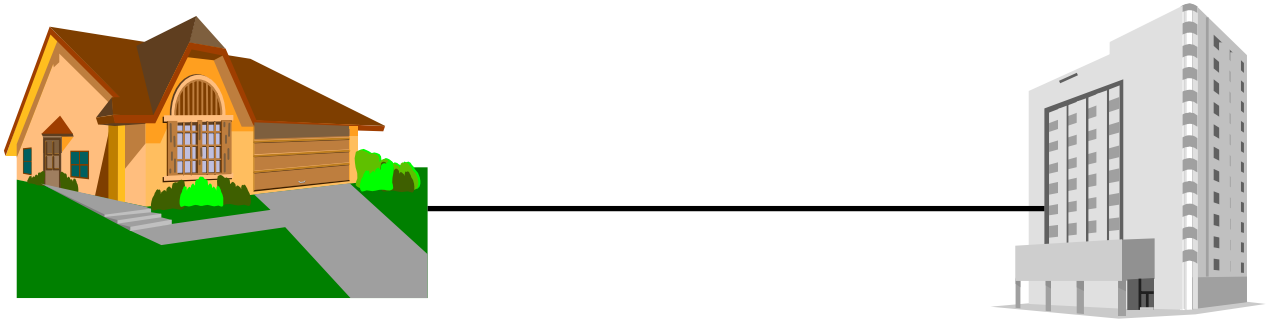
Both are based on a set of beliefs

Resilient Packet Rings



- Dual Counter-rotating rings help protect against failure
- Used in SONET and FDDI
- Need to bring these concepts to Ethernet and IP

Ethernet in the First Mile

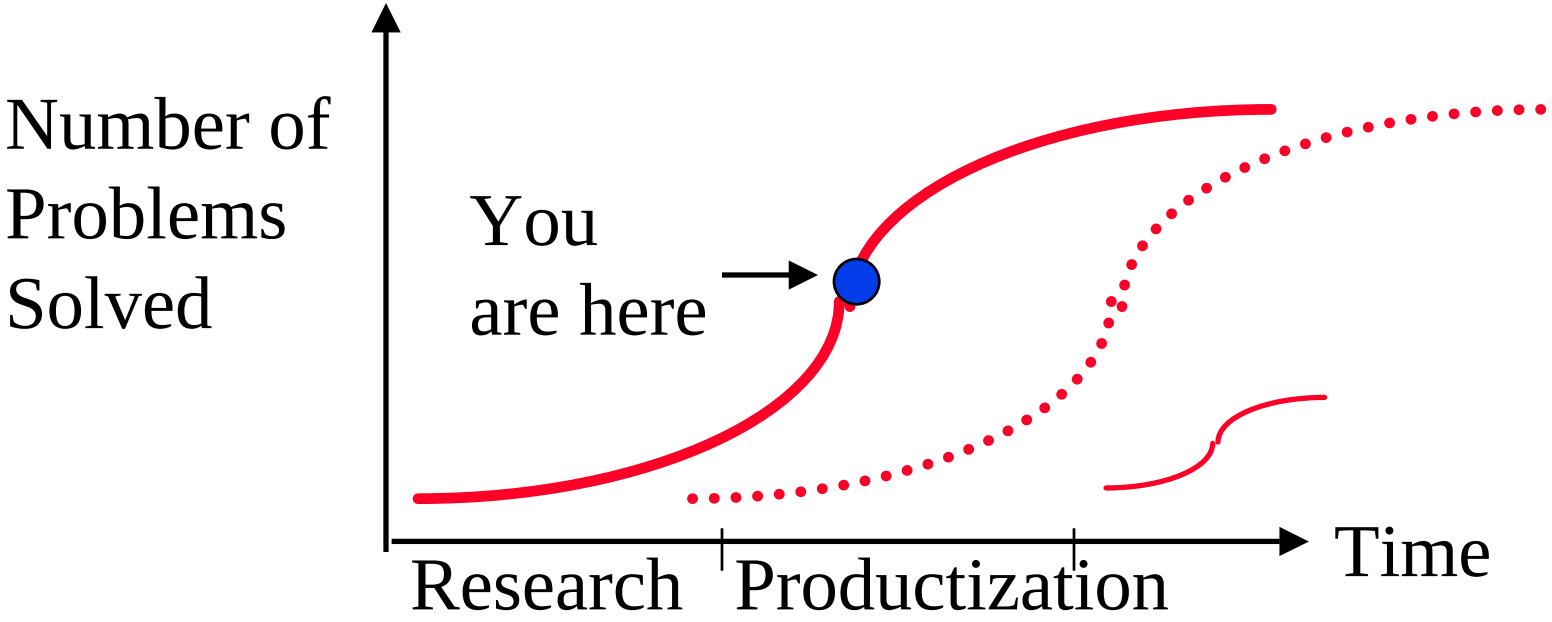


- IEEE 802.3 Study Group started November 2000
- Originally called Ethernet in the Last Mile
- Current Technologies: ISDN, xDSL, Cable Modem, Satellite, Wireless
- EFM Goals: Media: Phone wire, Fiber, Air
  - Speed: 125 kbps to 1 Gbps
  - Distance: 1500 ft, 18000 ft, 1 km - 40 km
- Ref: http://www.ieee802.org/3/efm/public/index.htm

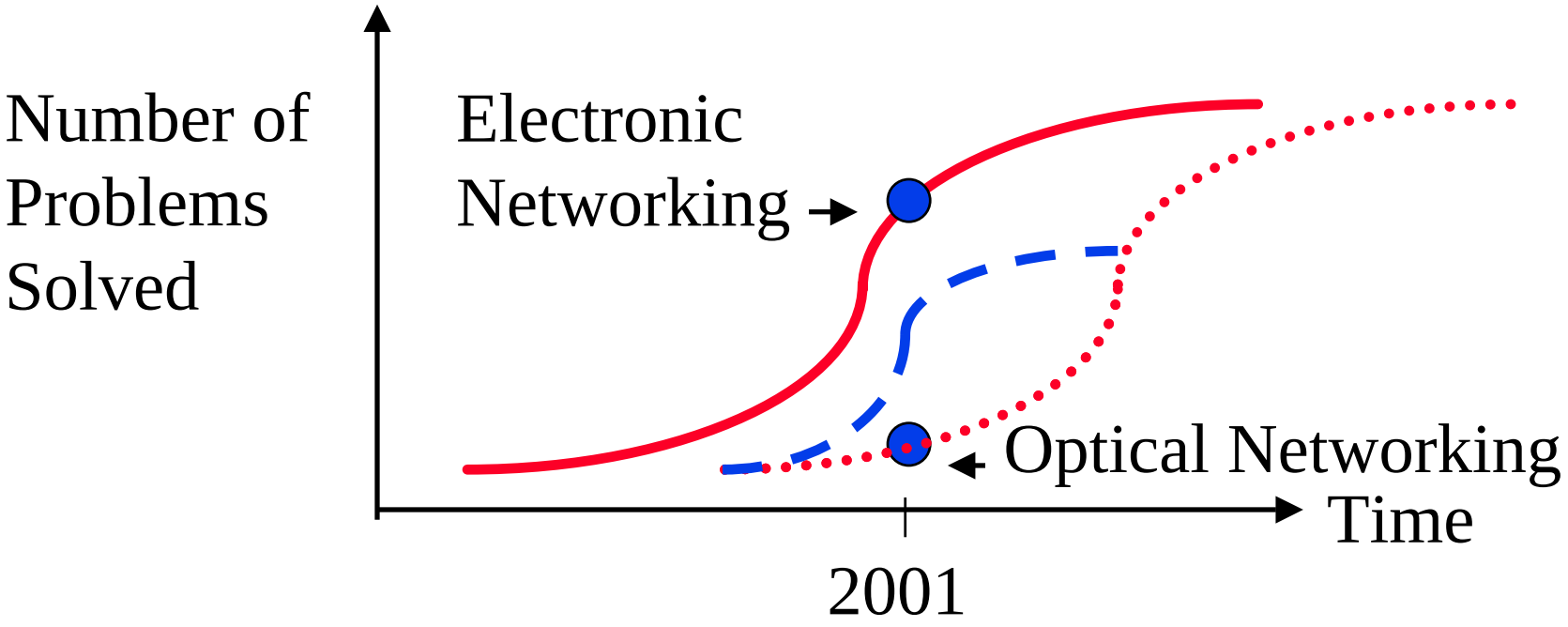
Power over Ethernet

- 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

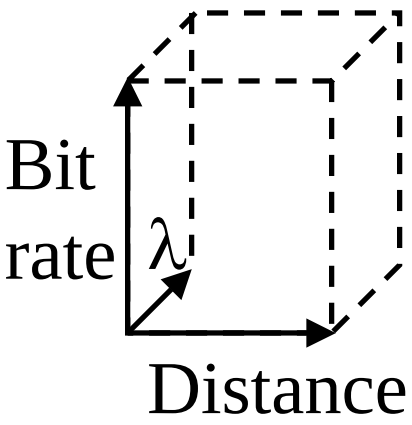
Life Cycles of Technologies



Life Cycles of Technologies



Recent DWDM Records

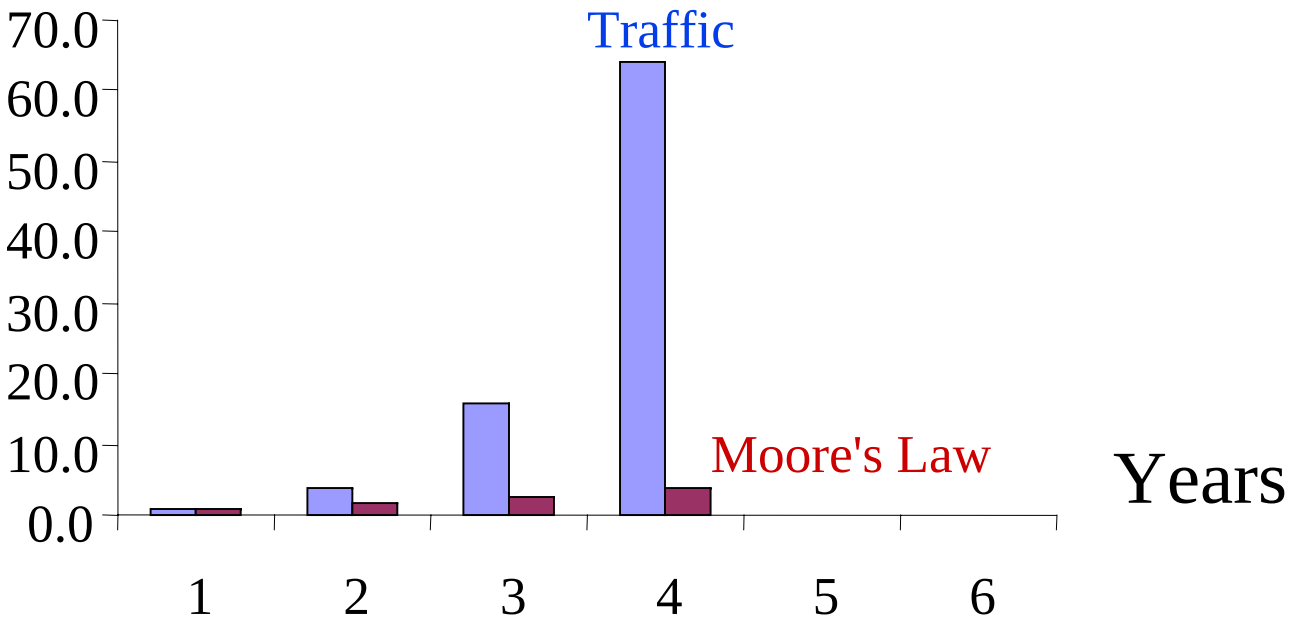


- 32λ× 5 Gbps to 9300 km (1998)
- 16λ× 10 Gbps to 6000 km (NTT'96)
- 160λ× 20 Gbps (NEC'00)
- 128λ× 40 Gbps to 300 km (Alcatel'00)
- 32λ× 40 Gbps to 2400 km (Alcatel'01)
- 19λ× 160 Gbps (NTT'99)
- 7λ× 200 Gbps (NTT'97)
- 1λ×1200 Gbps to 70 km using TDM (NTT'00)
- 1022 Wavelengths on one fiber (Lucent'99)

Potential: 58 THz = 50 Tbps on 10,000 λ's

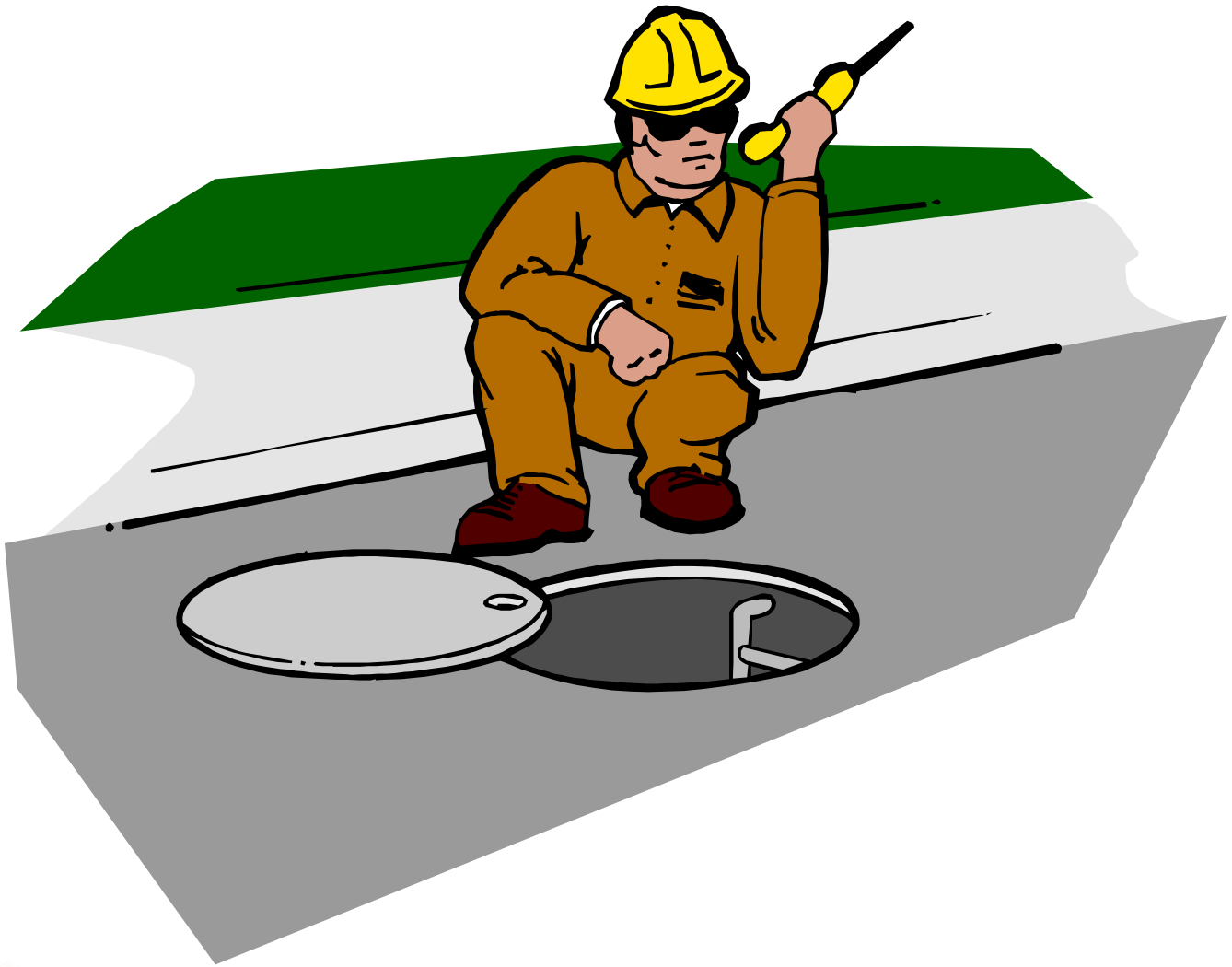
Ref: IEEE J. on Selected Topics in Quantum Electronics, 11/2000.

Moore's Law is Too Slow



- Moore's Law: Factor of 2 every 1.5 years
  $\Rightarrow$ 60%/year
- Internet Traffic: Factor of 4 per year
  $\Rightarrow$ Need Optical Switching

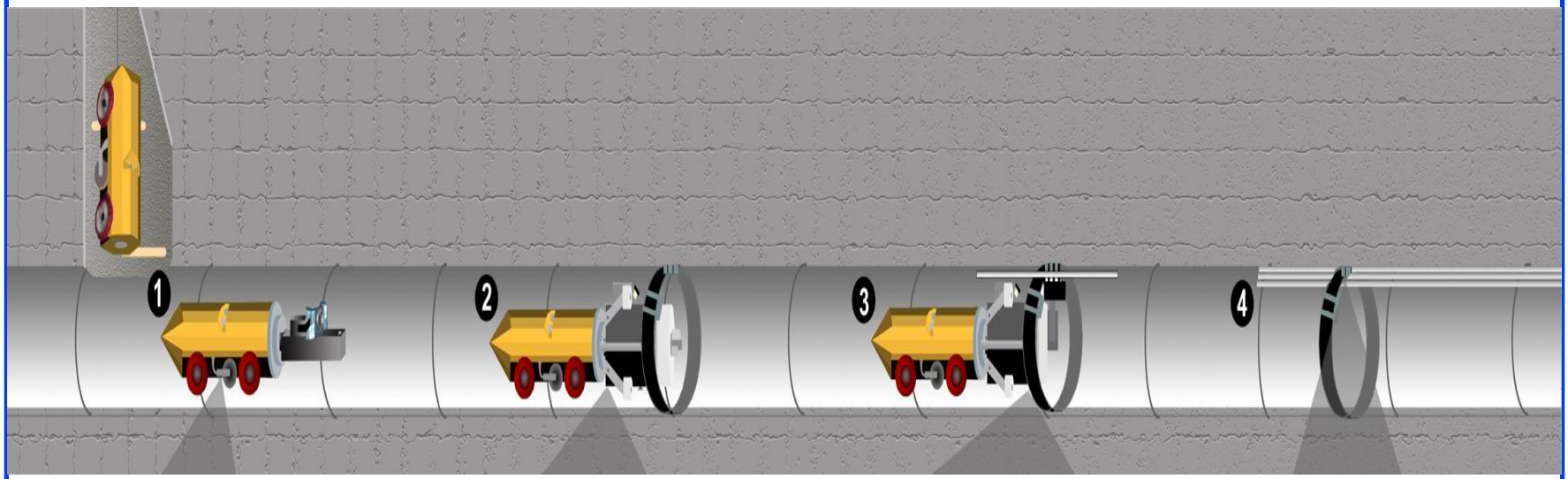
Sewer Networking



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 growth is more than capacity leading to need for QoS and Traffic Engineering in WAN
- EFM and Power over MDI will allow Ethernet every where
- Resilient packet rings to increase availability of Ethernet
- MPLS allows packets to be switched based on tags (circuit numbers)
- Traffic growth is faster than Morse Law

  ⇒ Need Optical networking

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


Thank You!