L9: Intro Network Systems

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Some slides are from lectures by Nick Mckeown, Ion Stoica, Frans Kaashoek, Hari Balakrishnan, Sam Madden, and Robert Morris

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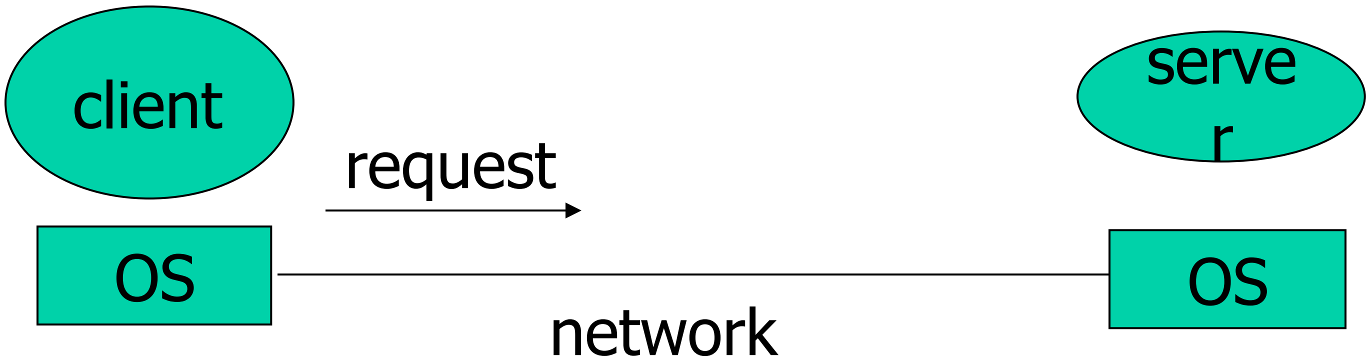
What have you seen so far?

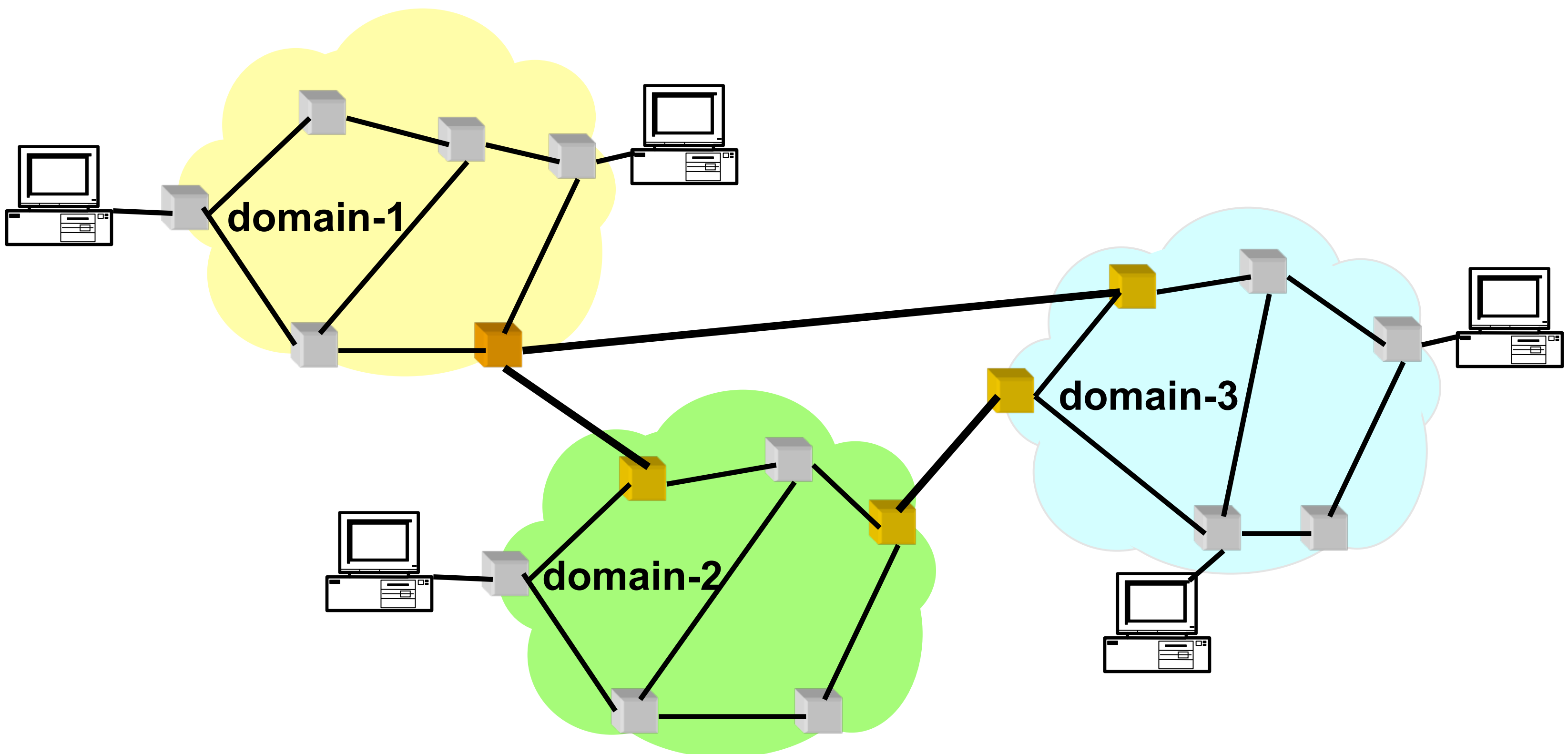
Systems	Complexity Modularity Dtechnology/dt	Hierarchy Therac-25
Naming systems	Gluing systems	File system name space
Client/service design	Enforced modularity	X windows
Operating systems	Client/service with in a computer	Eraser and Unix
Performance	Coping with bottlenecks	MapReduce

Client/service using network



- Sharing irrespective of geography
- Strong modularity through geographic separation

Network is a system too!



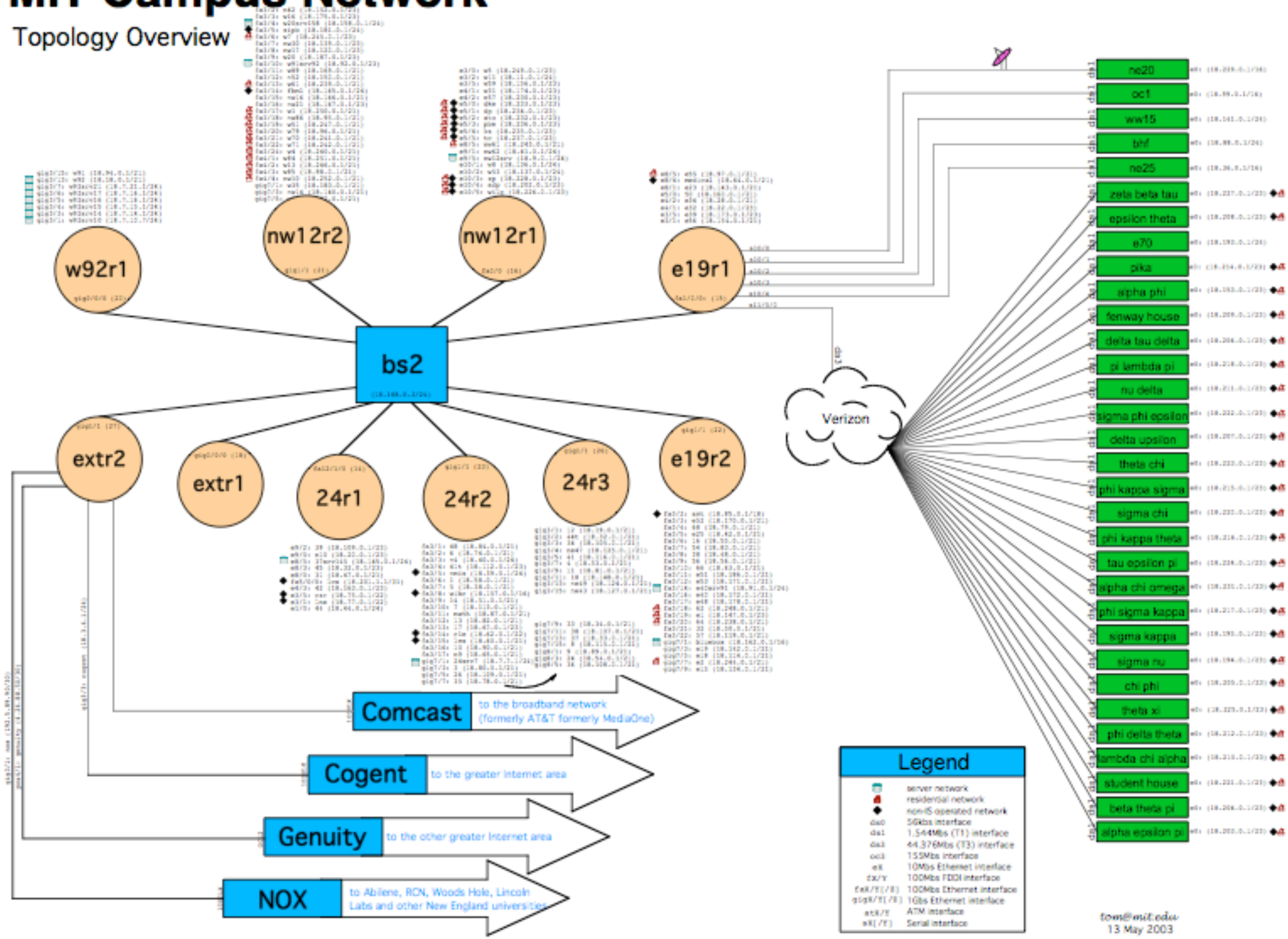
- Network consists of many networks, many links, many switches
- Internet is a case study of successful network system

Today's topic: challenges

- Economical:
  - Universality
  - Topology, Sharing, Utilization
- Organizational
  - Routing, Addressing, Packets, Delay
  - Best-effort contract
- Physical
  - Errors, speed of light, wide-range of parameters

MIT Campus Network

Topology Overview



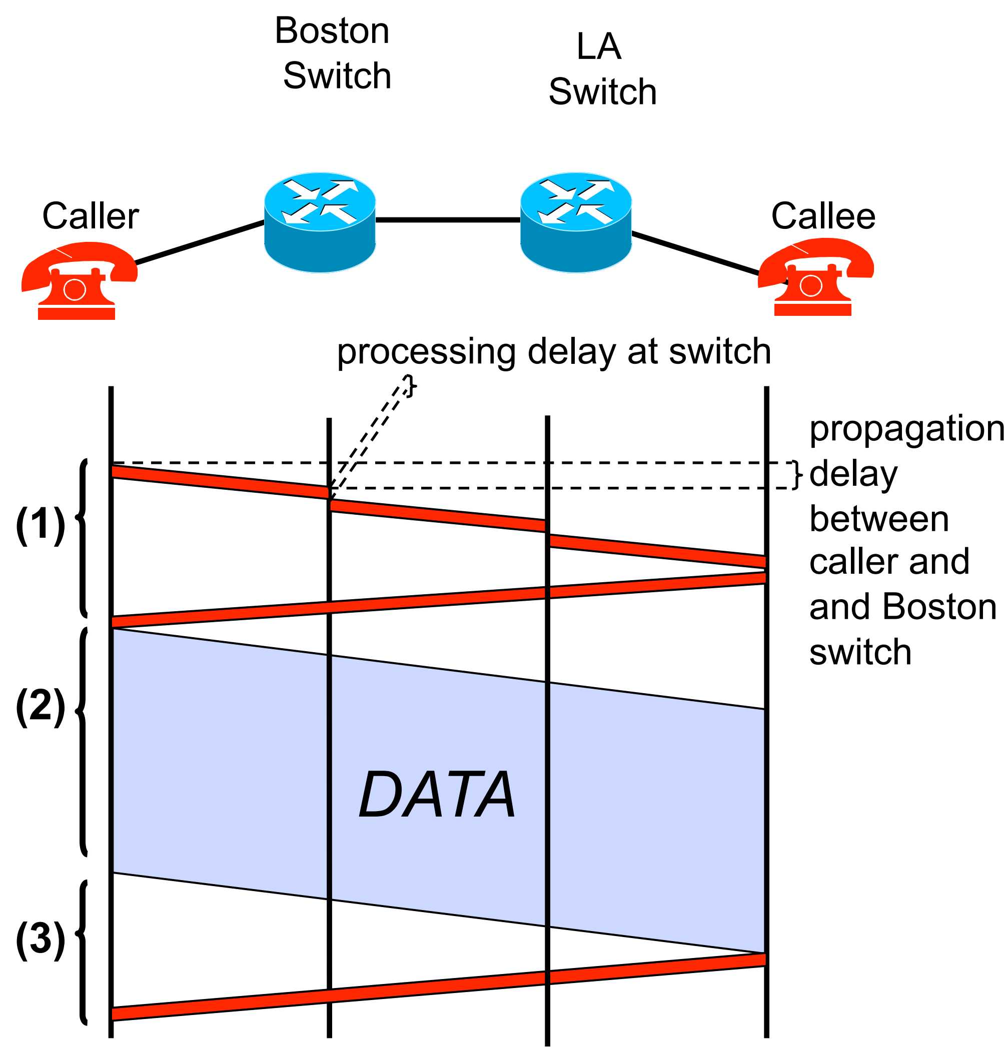
Circuit Switching

- It's the method used by the telephone network
- A call has three phases:

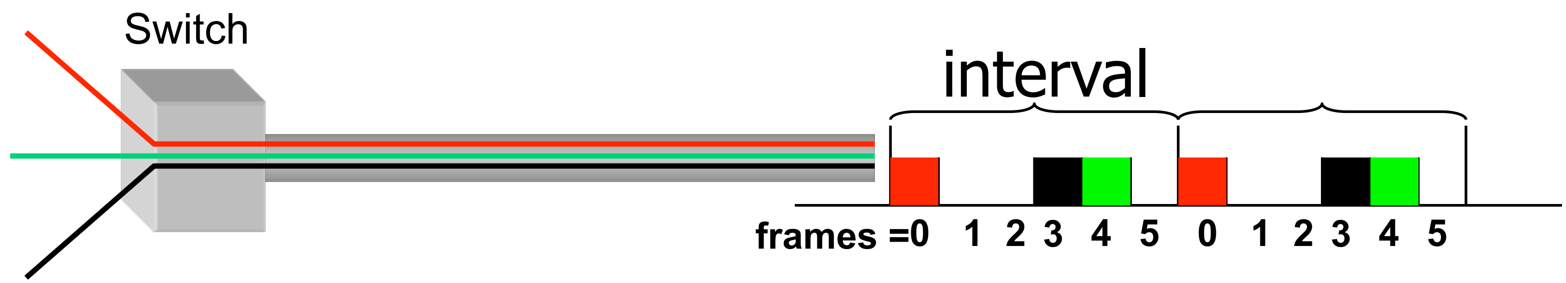
  Establish circuit from end-to-end ("dialing"),

  Communicate,

  Close circuit ("tear down").
- If circuit not available: "busy signal"



Isochronous Multiplexing/Demultiplexing



One way for sharing a link is TDM:

- A time interval is divided into *n* frames
- Each frame carries the data of a particular conversation
    - E.g., frame 0 belongs to the red conversation

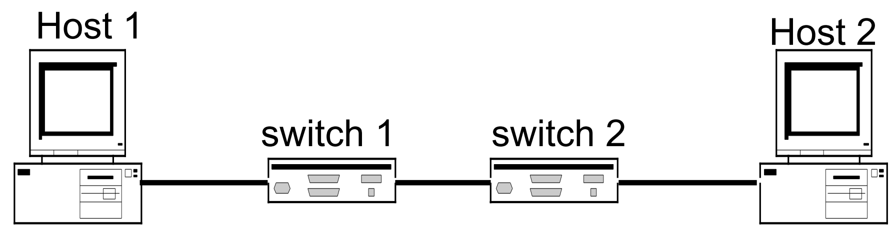
Circuit Switching

- Assume link capacity is C bits/sec
- Each communication requires R bits/sec
- #frames = C/R
- Maximum number of concurrent communications is C/R
- What happens if we have more than C/R communications?
- What happens if the a communication sends less/more than R bits/sec?

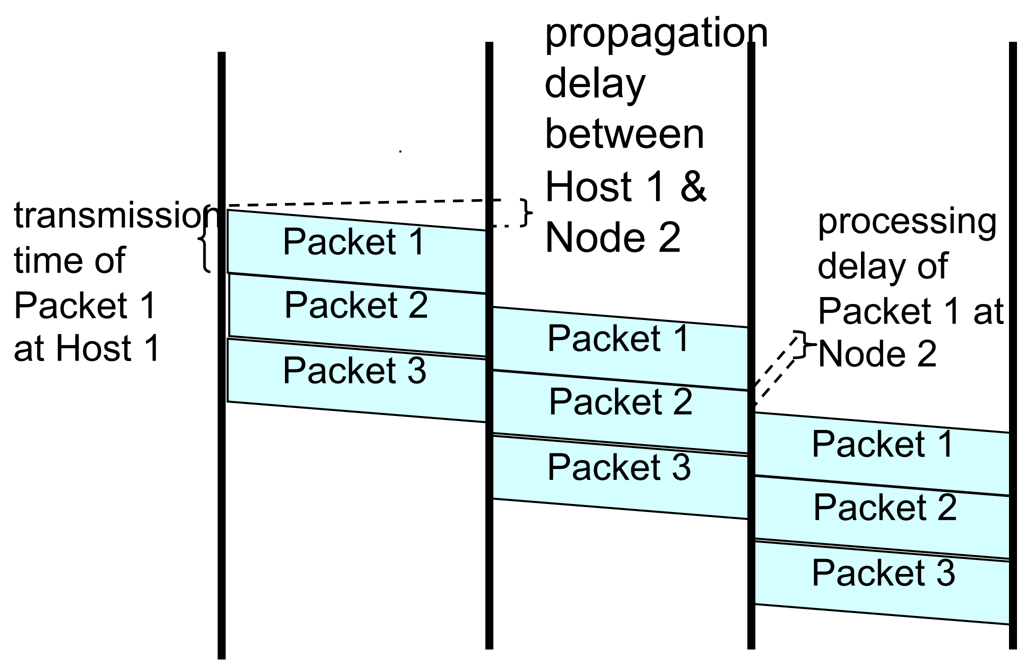
→ Design is unsuitable for bursty communications

Packet Switching

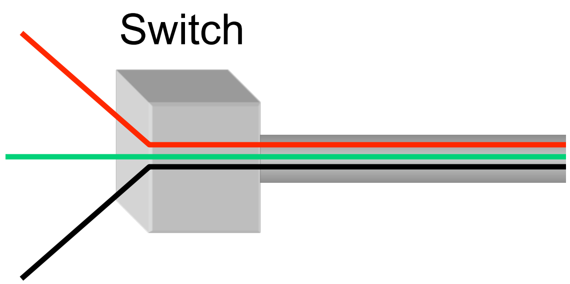
- Used in the Internet
- Data is sent in **Packets** (header contains control info, e.g., source and destination addresses)

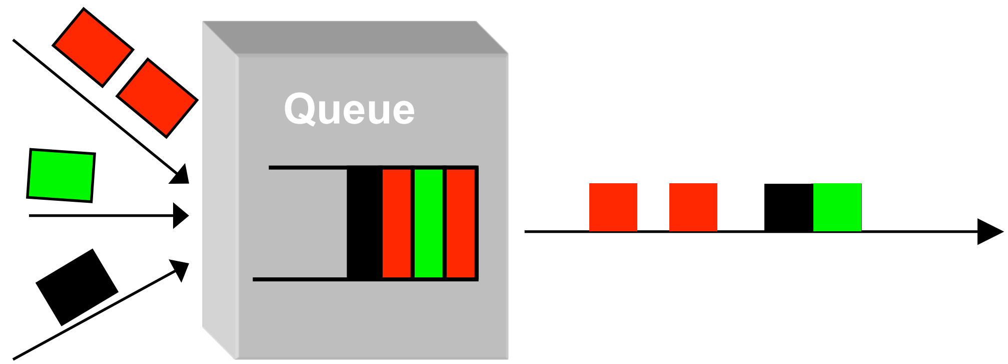


- Per-packet routing
- At each node the entire packet is received, buffered, and then forwarded)
- No capacity is allocated



Asynchronous Multiplexing/ Demultiplexing

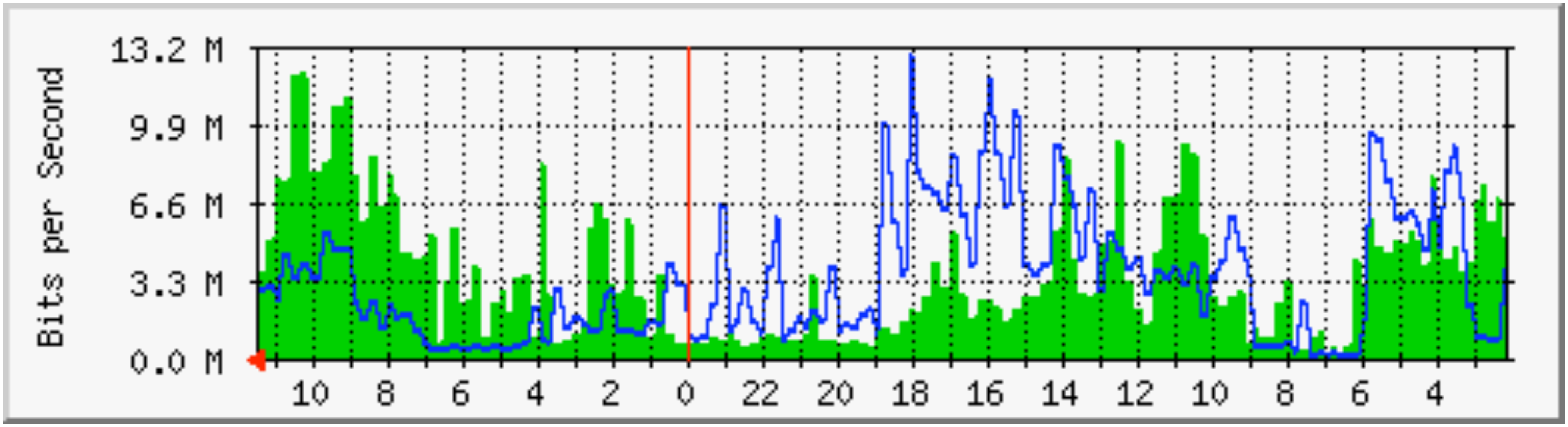




- Multiplex using a queue
  - Switch need memory/buffer
- Demultiplex using information in packet header
  - Header has destination
  - Switch has a forwarding table that contains information about which link to use to reach a destination

Aggregate Internet Traffic Smooths

5-min average traffic rate at an MIT-CSAIL router

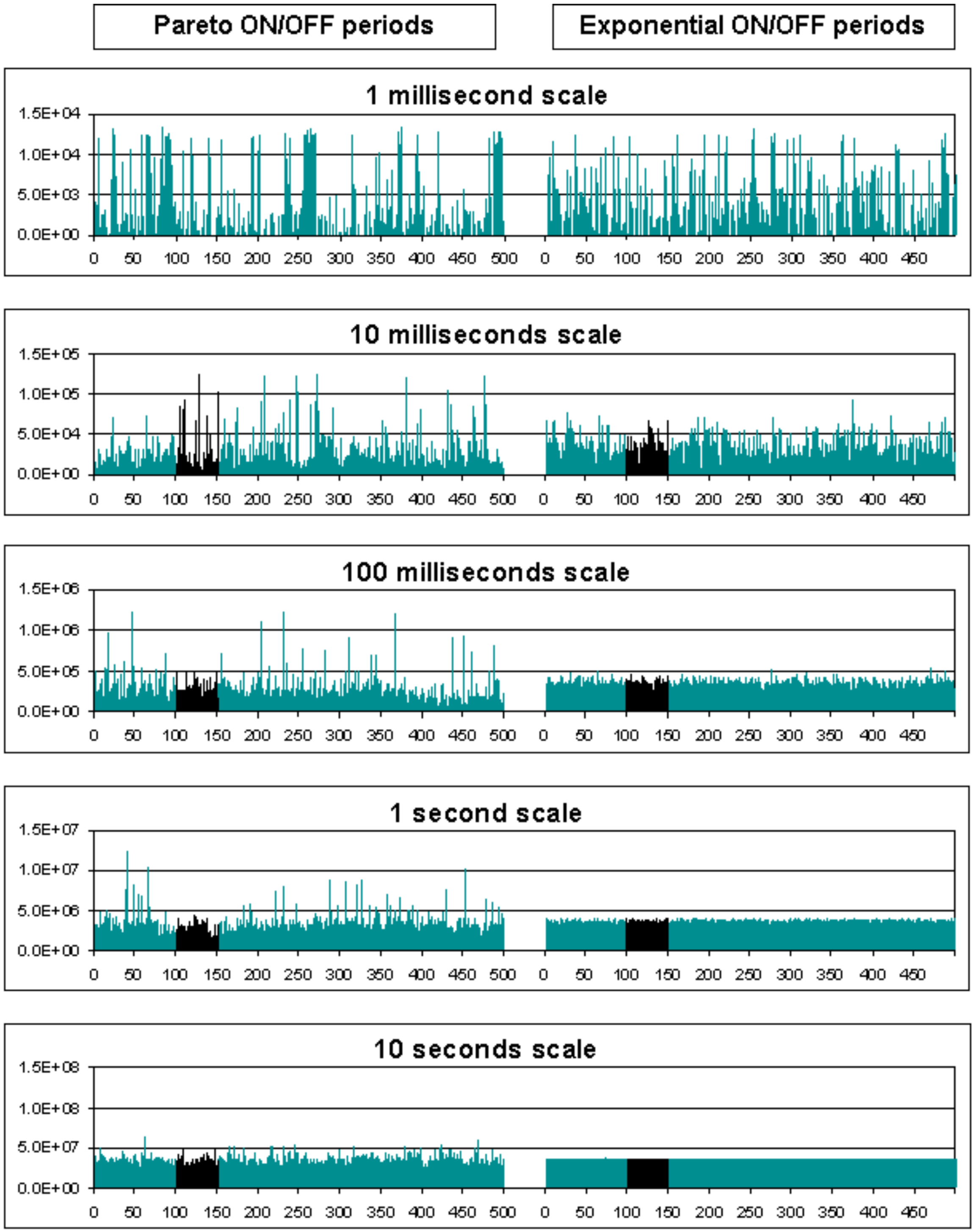


Max In:12.2Mb/s

Avg. In: 2.5Mb/s

Max Out: 12.8Mb/s

Avg. Out: 3.4 Mb/s



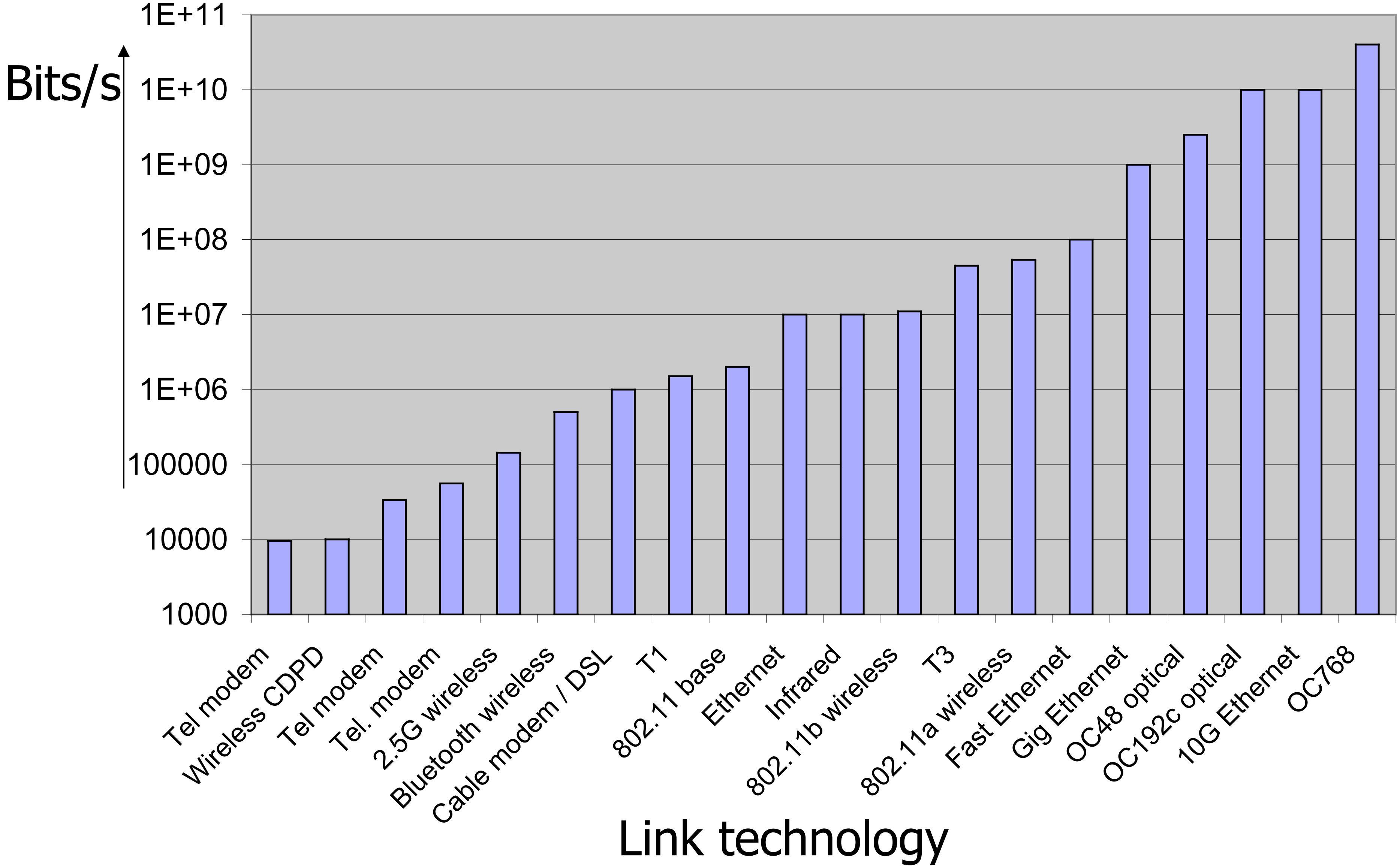
Statistical multiplexing

Best Effort

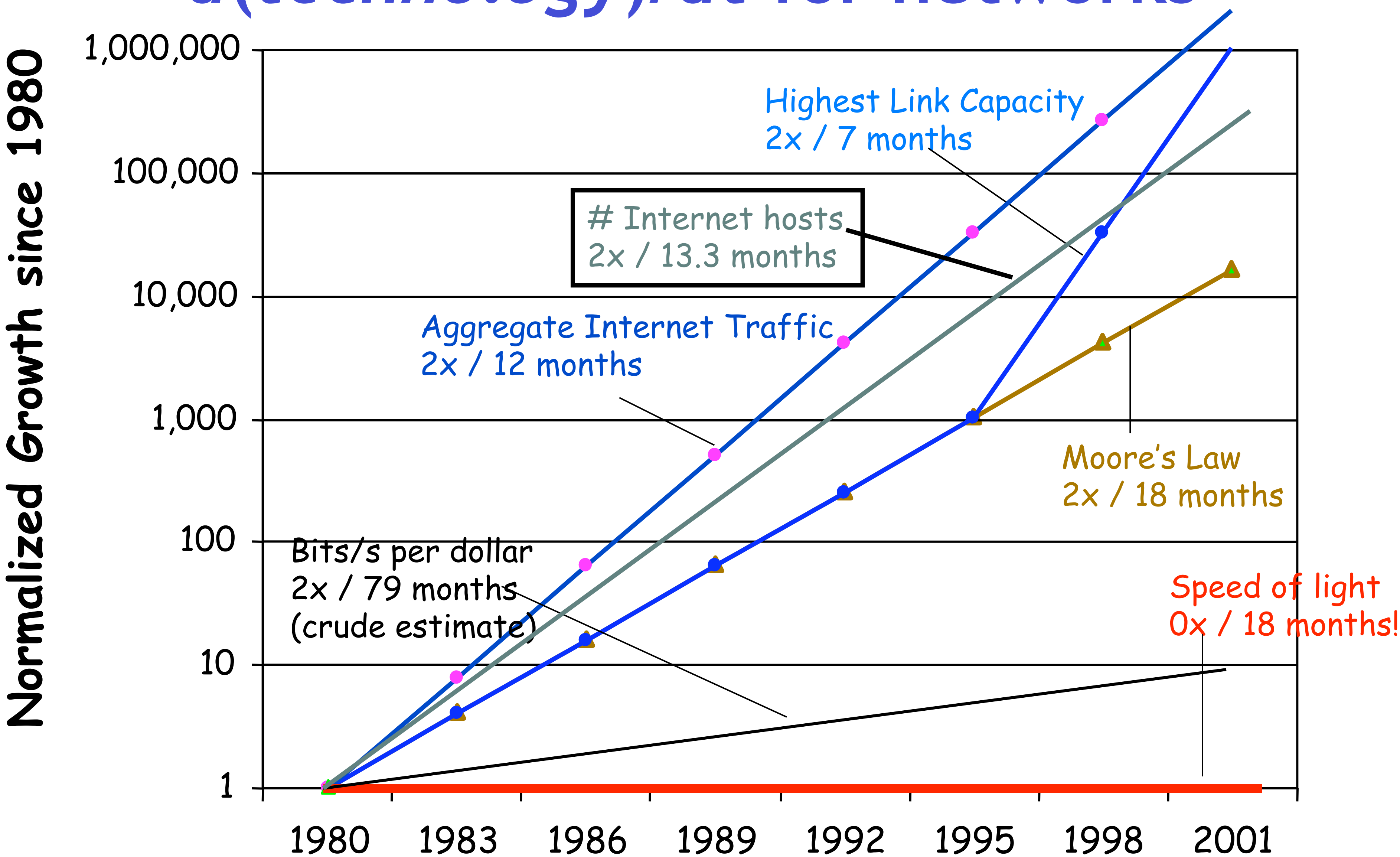
No Guarantees:

- Variable Delay (jitter)
- Variable rate
- Packet loss
- Duplicates
- Reordering

Networks are heterogeneous



d(technology)/dt for networks



Thanks to Nick Mckeown @ Stanford for some of these data points

Plan for studying network systems

Sharing and challenges	7.A	Ethernet
Layering	7.B+C	End-to-end
Routing	7.D	Internet routing
End-to-end reliability	7.E	Network file system
Congestion control	7.F	NATs