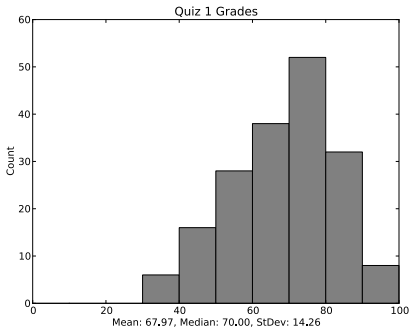
Quiz 1 histogram



L10: Network Systems

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http://web.mit.edu/6.033

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

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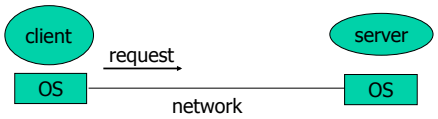
What have you seen so far?

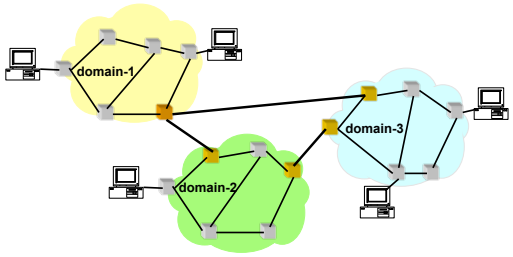
Systems	Complexity Modularity Dtechnology/dt	Hierarchy Therac-25
Client/service design	Enforced modularity	X windows
Naming systems	Gluing systems	File system name space/DNS
Operating systems	Client/service with in a computer	Eraser and Unix
Performance	Coping with bottlenecks	MapReduce

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

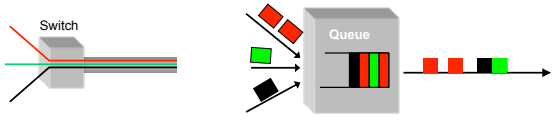
Today's topic: problems and approach

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

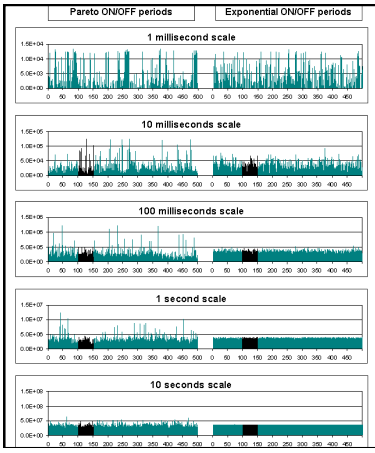
Design challenge: what does the network do and what do hosts do?

- Internet: best-effort

Asynchronous Multiplexing/ Demultiplexing

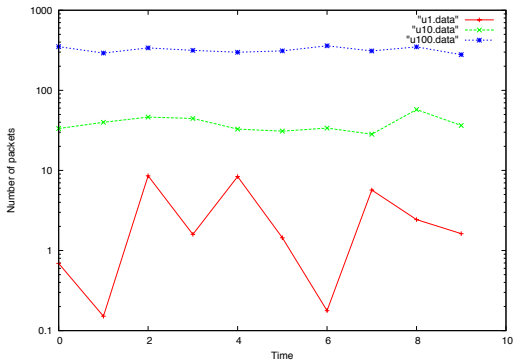


- Multiplex using a queue
  - Switch need memory/buffer
- Demultiplex using information in packet header
  - Header has destination
  - Switch has a forwarding table that contains information about which link to use to reach a destination



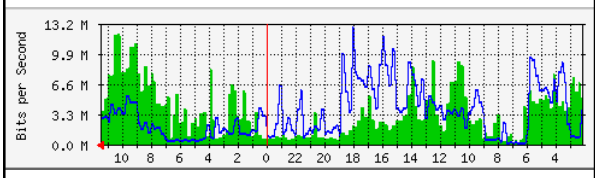
Queue length

Statistical multiplexing



Aggregate Internet Traffic Smooths

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

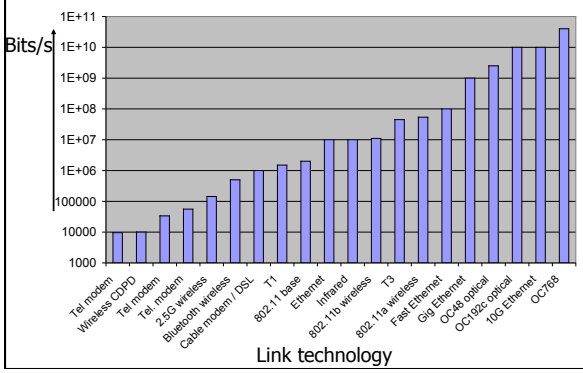


Max In:12.2Mb/s Avg. In: 2.5Mb/s

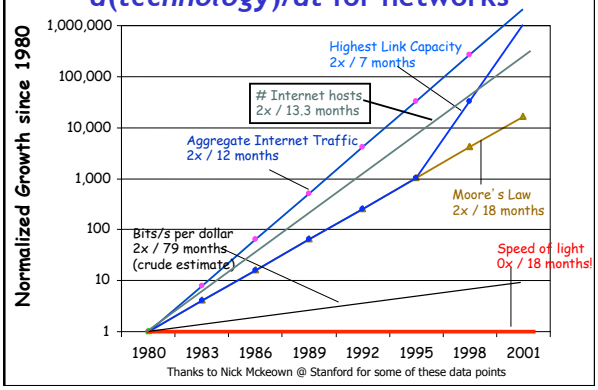
Max Out: 12.8Mb/s Avg. Out: 3.4 Mb/s

https://mrtg.mit.edu/mrtg/dmz-rtr-1-ospf.16.html

Networks are heterogeneous



d(technology)/dt for networks



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

Internet: Best Effort

No Guarantees:

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

End hosts implement everything else