Internet:
The Technology Behind the Hype

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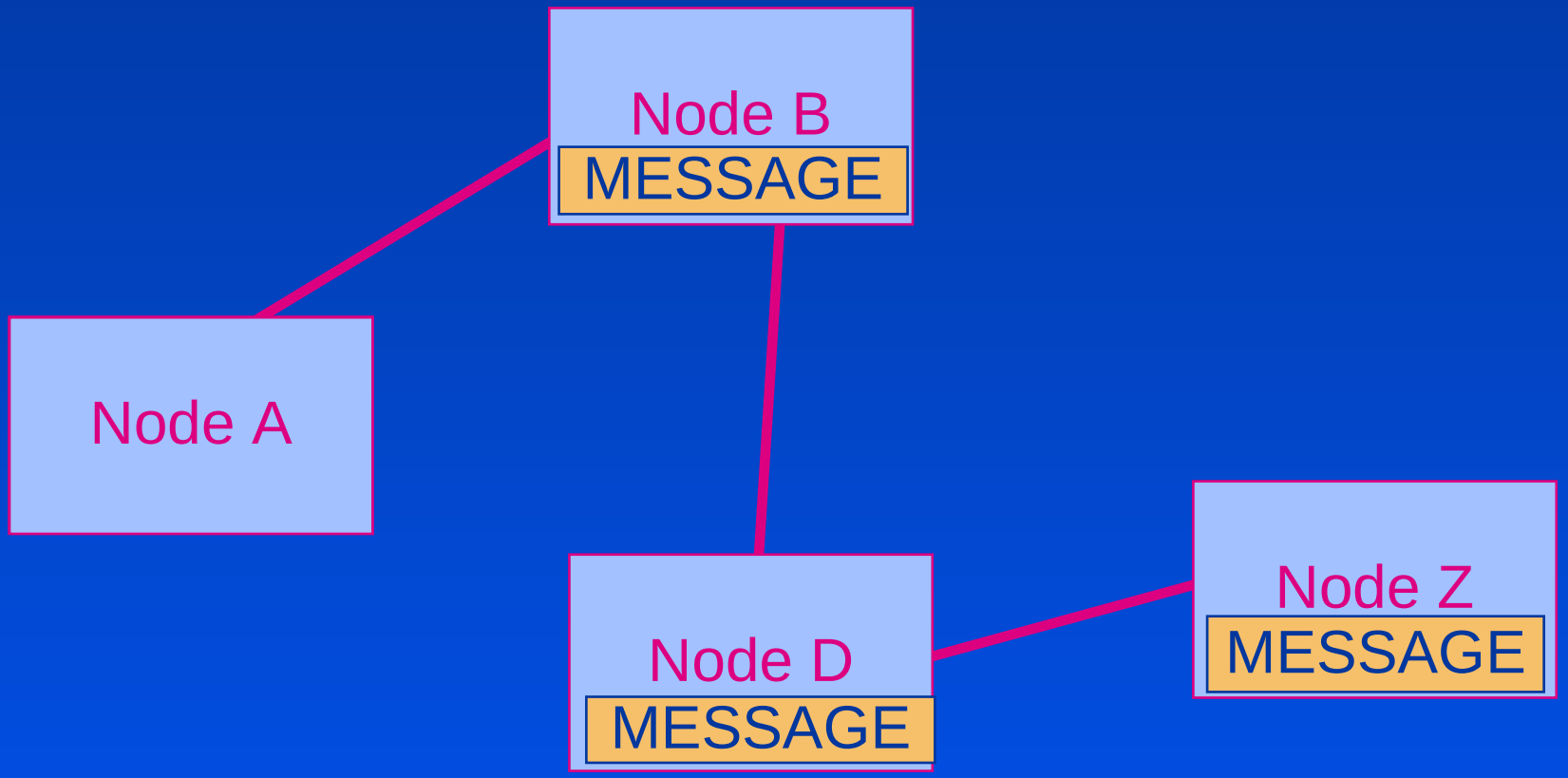
Packet Switching



Packet Switching

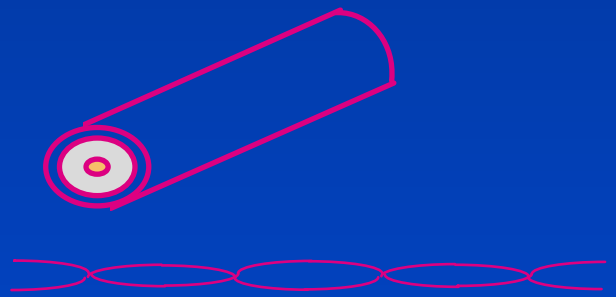
- Divide Information into small units
  - there is a maximum size to a packet
  - there may also be a **minimum** size too
- Send each packet separately
  - if one packet is lost, the rest may get through
- Packets may travel several hops
- Store-and-Forward
  - each node copy the packet to memory
  - forwards it to the next location

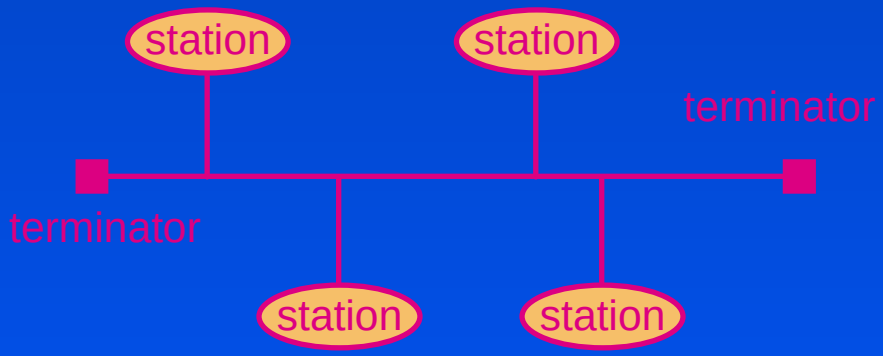
Wide Area Network: ARPANET

- First “public” wide area network
- Ideas Pioneered
  - packet switching
  - internetworking: radio, wire, satellite
  - build it before you standardize it!
- Dates: 1969-1987
- How to get connect:
  - have a DOD Arpa Contract
- Technology
  - 56 kbps dedicated links
  - custom built network switches (called IMPs)

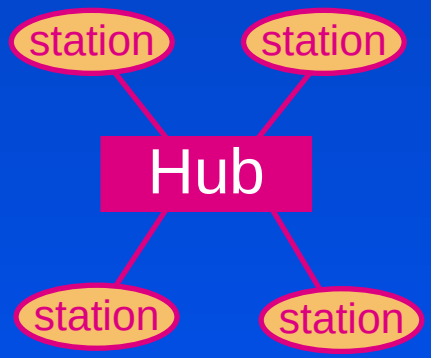
Local Area Networks: Ethernet

- Physical Media
  - 50 ohm coax cable
  - twisted pair wires
- rates
  - 10's to 100's Mbps





Coax Based Ethernet



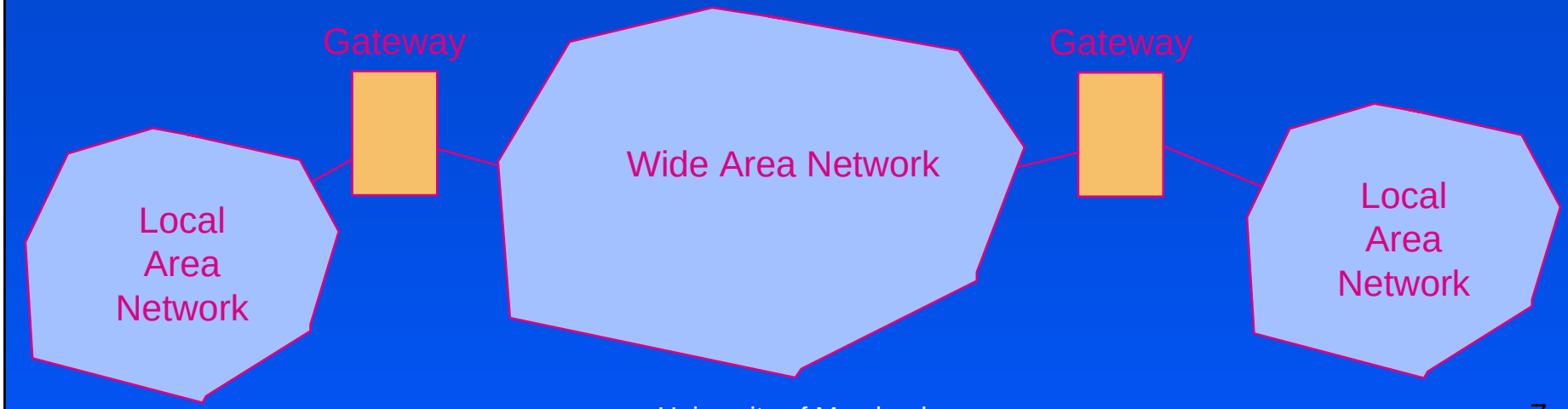
Hub Based Ethernet

Ethernet Operation

- Stations
  - independent stations each sending packets
  - station may not send another frame until the first is sent
- Single Channel: Shared by all Stations
- Carrier Sense
  - stations can tell if channel is in use before sending
  - stations must wait to know if channel was in use
- Collisions: two stations try to send at once
  - neither transmission succeeds
  - exponential backoff
    - after first collision, wait either 0 or 1 slot times
    - after second, wait either 0, 1, 2, or 3 slot times
    - limited to 1023 slots and 16 collisions

Internetworking

- Connect Several Networks Together
- each network has own rules for link layers
  - max packet size
  - broadcast vs. point-to-point link
- Provide global (end-to-end) transmission
  - end-points (addresses for each host)
  - protocol to get information between hosts



NSFNet

- First general “public” wide area network
- Ideas Pioneered
  - wide area networking for the masses
  - backbone wide area network connecting regional nets
- Dates: 1984-1995
- How to get connected:
  - be an academic site and join a regional network
- Technology
  - 448kbps - 45 Mbps
  - general purpose workstations as routers

Internet

- Ideas Pioneered
  - multi-vendor public networks
  - if you build it they will come!
- Dates: 1983- (TCP/IP protocol first used)
- How to get connected:
  - stop by the mall
  - call 1-800...
- Technology
  - 9.6kbps to OC-48 (2 Gbps)
    - soon higher AND lower speeds will be supported
  - custom routers from many vendors
  - general computers for some routing

Basic Issues In Building A Network

- Rules for data transmission (Protocol)
  - full vs. half duplex
  - error control (detection, correction, etc.)
  - flow control (rate matching)
  - message order (is arrival the same order as sent?)
- Abstractions for communications
  - end points for communication
    - switches, nodes, processes, threads in a process
    - how are these end points named (addresses)?
  - service providers and service users
- Service Primitives
  - request, indication, response, confirm

Protocols are divided into layers

ISO - 7 layers

- Application
- Presentation
- Session
- Transport
- Network
- Link
- Physical

TCP/IP - four layers

- Application
- Transport/session/present (TCP)
- Network (IP)
- Link

- Old Saying: If you know what you are doing, four layers is enough; if you don't seven won't help.

Application

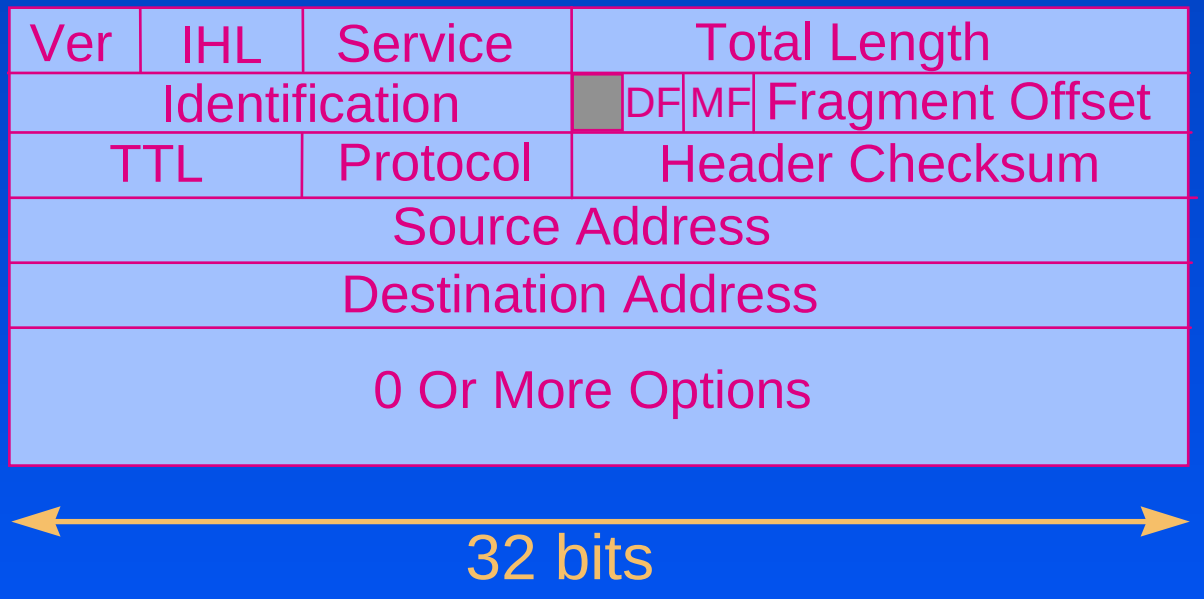
- Goal: common types of exchanges standardized
- Sample Issues:
  - when sending email, what demarks the subject field
  - how to represent cursor movement in a terminal
- Examples:
  - Simple Mail Transport Protocol (SMTP)
  - File Transfer Protocol (FTP)
  - Hyper-Text Transport Protocol (HTTP)
  - Simple Network Management Protocol (SNMP)
  - Network Time Protocol (NTP)
  - Net News Transport Protocol (NNTP)
  - X (X Window Protocol)

TCP/IP

- IP - Internet Protocol
  - Network level protocol
  - 32 bit address (e.g., 128.8.131.1)
- TCP - Transmission Control Protocol
  - reliable byte stream between end-points
  - Ports indicate endpoint (within host) of communication
- UDP - User Datagram Protocol
  - unreliable packet service
  - really just a thin layer over raw IP
- ICMP - Internet Control Message Protocol
  - used to run network
  - ICMP ECHO - ping packets

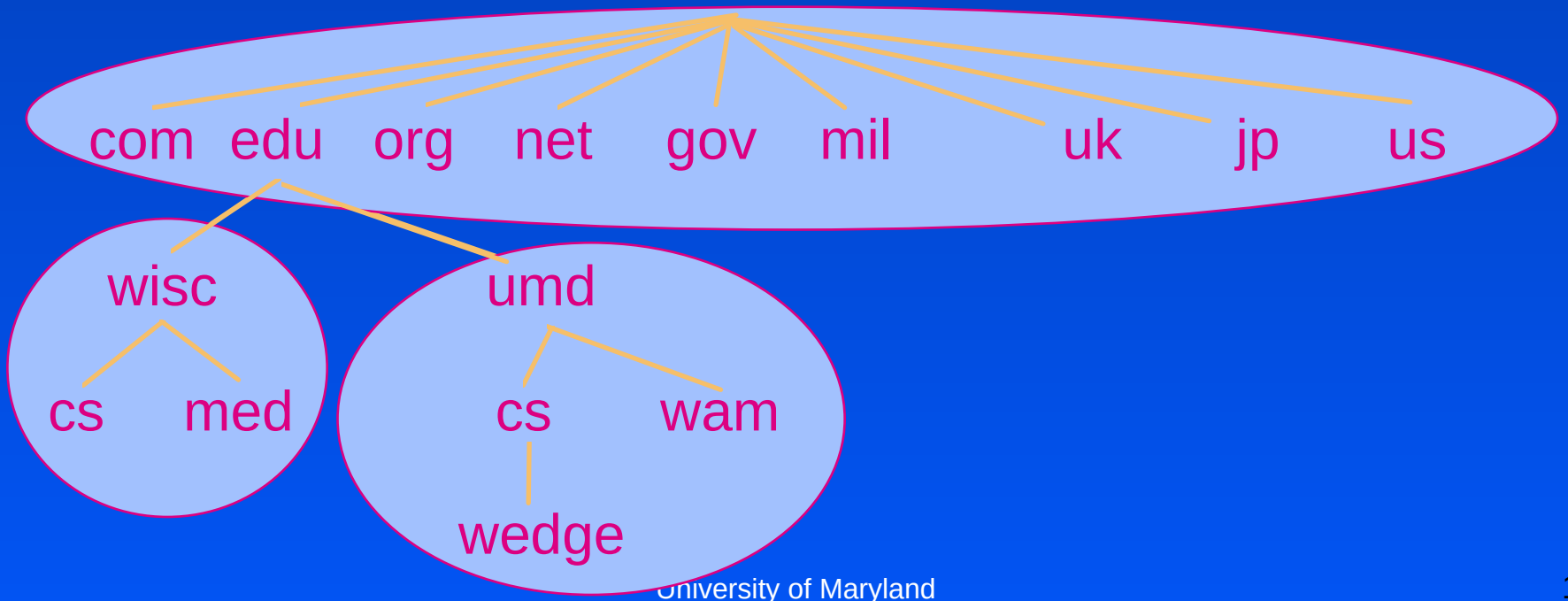
IP Packets

- Address is Complete Address
- Version is the first nibble
- Time to Live Field
- Supports fragmentation



Naming Hosts In the Internet

- Originally used a single file
  - all hosts had line line with name and IP Address
- Domain Naming System (DNS)
  - introduced in 1986
  - tree based structure to names



Routing

- How to get From Node “A” to “B”
  - selecting among multiple alternative paths
    - implies knowledge of the network topology
  - balance utilization of the links
    - spread load among different routes
- Goals of A Routing Algorithm
  - Correctness: packets get where they are supposed
  - Simplicity: easy to implement correctly
  - Robustness: failures still permit communication
  - Stability
  - Fairness
  - Optimality

Distance Vector Routing

- AKA Bellman-Ford or Ford-Fulkerson
  - original ARPANET routing algorithm
  - early versions of IPX and DECnet used it too
- Each router keeps an entry for all other routers
  - outbound link to use to that router
  - metric (hops, etc.) to that router
  - routers also must know “distance” to each neighbor
- Each router exchanges data with neighbors
  - Routers then update their table based on the new info
- Problems:
  - fast response to good news
  - slow response to bad news
    - takes max hops rounds to learn of a downed host
    - known as count-to-infinity problem

Link State Routing

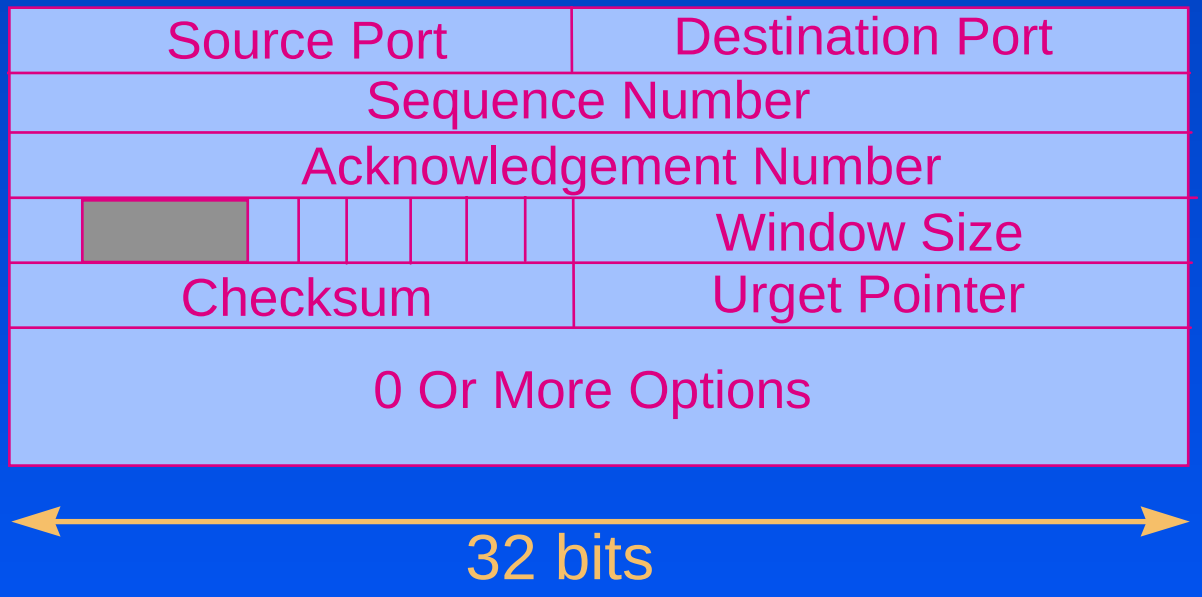
- Used on the ARPANET after 1979
- Each Router:
  - computes metric to neighbors
  - sends to **every** other router
  - computes the shortest path based on received data
- Distributing Info to other routers
  - each router may have a different view of the topology
  - simple idea: use flooding
  - refinements
    - use age sequence number to damp old packets
    - use acks to permit reliable delivery of routing info

TCP

- Provides error free end-to-end delivery of data
  - in-order delivery over unreliable network layer
- Issues:
  - checking packet integrity
    - error detecting and correcting codes
  - re-transmission of lost of corrupt packets
    - when data is received, acknowledge it
    - if the data is not received in time t, resend it
  - connection establishment and management
  - addresses
    - need to define a host plus process
    - typical abstraction is <host, port>
  - congestion control
    - sometimes too many people want to use the network

TCP Packets

- Permits acks to be piggy packed
- Sequence number is in bytes
- Urgent data can be sent
- Also used for connection establishment



TCP Congestion Control

- Detecting Congestion
  - In general it is difficult
  - But, consider why a packet might be dropped
    - link error - but links are very reliable now
    - buffer overflow --> congestion
  - Use timeouts as an estimate of congestion
- Dealing with Congestion
  - limit transmissions to network capasity
  - learn capasity during operation
    - increasing the outstanding traffic
    - when traffic gets loss, drop back sending
  - clasic feedback system

What the Future May Hold

- ATM
  - small fixed sized packets
    - permits fluid models for traffic
  - link speeds of 155Mps to over 2 Gbps
  - good support for multi-media applications
    - can negotiate stable bandwidth
- Everything Has A Network Address
  - every home
  - all appliances
  - light switches
- Network PC
  - no stable storage of it own
  - cheaper?

Future Challenges

- IP Address Exhaustion
  - 32 bits are not well used and will run out
  - will need bigger addresses
- Flat rate (non-usage based) Pricing
  - OK as long as everyone uses same, constant BW
    - every user is a modem
  - no, if want to vary rates
    - have different peak, mean bandwidth
- Name Space Contention
  - how to accommodate similar names
  - possible solution?: multiple top level hierarchies

Fundamental Challenge: Latency

- It is not going to get much better
  - current round time time to west coast 90msec
  - minimum possible:
    - speed of light is 186,282 miles/second
    - distance is 2440 miles (4880 round trip)
    - absolute best possible is 25 msec
    - This is only a factor of four **ever!**
- Implications
  - only 40 round trips/second
  - must design protocols to tolerate latency

Conclusions

- The Internet today is really 30 years old
  - started in the 1960s
  - TCP/IP has been in use for almost 15 years
- Bandwidth is growing rapidly
  - no real limits in sight
- Latency will not change much
  - at most a factor of 3 ever (cross country)