1 # EECS 122, Lecture 3

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2 ## Channel Capacity

- Some number of symbols per second (baud rate). Each symbol does not necessarily correspond to a bit.
- Nyquist: symbol rate = 2H sym/sec
  - H bandwidth
- Shannon: data rate = H log (1+S/N) b/s
  - S is signal power, N is noise power

3 ## Some Comm Theory

- So, with Nyquist, we cannot hope to send *binary* data even over a noiseless 3-kHz channel at more than 6000 b/sec:
  - 2H = 2(3000) = 6000 b/sec
- With Shannon, bit rate over an analog phone line is limited to about 30kb/s [assuming 30dB S/N ratio]:
  - Hlog(1+S/N) = 3000log(1 + 1000) = 30kb/s

4 ## Transmission Time

5 ## Latency

- Slower channels "stretch out" bits in time:
  - a bit on a 1Mb/s link is 1 µsec wide
  - a bit on a 10Mb/s link is 0.1 µsec wide
- Total Latency = tx time + queue
  - transmit time = { last slide }
  - queue delay = { depends! }

6 ## Low Speed Links

- Small R -> large Tx Time (M/R)
- Ex: Dialup (D = 10ms, R = 56Kb/s)
  - Tx Time = .010 + ((1024x8)/(56x1024)) = 0.153 sec = 153 msec (1KB msg@56Kb/s)

7 ## High Speed Links

- Large R -> small Tx Time (M/R)
- Ex: OC-3 (D = 10ms, R = 155Mb/s)
  - Tx Time = .010 + ((1024x8)/(155x1024x1024)) = 0.01005 sec = 10.05 ms (D >> M/R)

8 ## Total (one way) Latency

- Propagation Delay (D) = *distance/speed-of-light*
- Transmission delay = (M / R)
- Queueing delay (Q) (using statistical multiplexing) depends on utilization
- Total Latency = D + (M/R) + Q

9 Beware of Overheads

10 Measuring Latencies (1)

11 Measuring Latencies (2)

12 Measuring Latencies (3)

13 What Happens on the Web?

- Click on a link (http://foo.bar.com/xx)
- Conversion from name to address
- Open connection to remote machine
- Pass arguments to process
- Retrieve contents from server
- Display locally

14 So, What does this Require?

- Name mapping service (DNS)
- Addressing/routing (IP)
- Reliable delivery (TCP)
- Representation of content (HTTP)
- Local display (application)

15 Naming Computers

- Need a way to locate services; easier for humans than numbers
- Flat Name Space:
  - every computer has unstructured name
  - must coordinate not to stomp on eachother
  - examples: *ucbvax*, *sdcsvax*, *sri-nic*
  - didn't scale very well

16 Hierarchical Naming

- First real growth problem of Internet
  - rule of thumb: things break if they grow 2 orders of magnitude (5-7 years in today's Internet!)
  - Common Idea: **hierarchies scale well**
- Divide up space into "Domains"
  - examples: EDU, COM, MIL, ORG, NET
  - (ISO3166-based): FI, JP, DK, US, ..

17 Benefits of Naming Hierarchy

- much better scaling
- decentralized administration
- redundant databases
- recursive, can subdivide each subdivision

18 URLs: New Names

– popularized by web browsers
– *proto*://*host-name*:*port*/*arg1*/*arg2*/*arg3*/...
– http://www.cs.berkeley.edu/~kfall
– gopher://gopher.colorado.edu
– ftp://ftp.microsoft.com
– telnet://blueskies.sprl.umich.edu:3000

19 A Problem with HTTP

- In version 1.0 of HTTP, the host name is not passed to the web server
- What about "web hosting" multiple sites?
- Utilizes more IP addresses than necessary!

20 IP (v4) Addresses

- Every interface has at least 1 IP address
- IP addresses are 32-bit numbers (4.3 billion of them!)
- Divided into parts: (network prefix, host number)
- Classical structure use net/subnet/host partitioning where hosts on same subnet share net and subnet number

21 Expressing Addresses

- 4 decimal numbers, called "dotted quad"
- Each (decimal) number is one byte
- Example: 128.32.25.12
- Can generally be used in place of names
- Classically, parts of "Classes"

22 IP Address Classes (historical)

23 Special IP Addresses

24 Example Assignments

25 Subnet Addressing

- Historical, but terminology is consistent and still used
- Allows one site to have multiple *subnetworks* of their main network. Practical result: multiple segments.
- Subnetting scheme is a **local** decision
- Requires a "subnet mask"

26 Subnet Structure

- Idea is to steal host bits and use them for numbering subnets
- Rest of Internet only sees classes (or their aggregates--- later)
- Mask indicates which bits are network/subnet part, and which are host part

27 Subnet Example

- 128.32.25.12 is a "Class B" address
- 16 bits of network, 16 bits of host

- So, need 10 bits to indicate subnet
- Use a *subnet mask* of (16+10=26) bits

28 Subnet Example (cont)

- 26 bit mask: 0xffffffc0 or simply "/26"
- So, 128.32.25.12/26 is:
  - 10000000 00100000 00011001 00001100

    & 11111111 11111111 11111111 11000000
    - Subnet 100 of net 128.32, host 12

29 Subnet Partitioning (ex cont)

- 128.32.0.0/26 gives 2^(26-16) = 1024 subnets of 2^(32-26)-2 = 62 hosts each
- First usable address: 128.32.0.1 (see RFC1812, page 48)
- Last usable address: 128.32.255.254
- Any address with all "1" bits in host part is a (*subnet*) *broadcast*

30 Subnet Partitioning (ex cont)

- 128.32.25.12/26 is:
  - 10000000 00100000 00011001 00001100
- 128.32.0.65/26 is:
  - 10000000 00100000 00000000 01000001
- 128.32.255.190/26 is:
  - 10000000 00100000 11111111 10111110

31 Common Subnet?

- Is 128.32.25.12 and 128.32.25.85 on the same subnet using a /26 mask?
- 128.32.25.12 is:
  - 10000000 00100000 00011001 00001100
- 128.32.25.85 is:
  - 10000000 00100000 00011001 01010101
- Prefixes differ, so *not on same subnet* (need router to reach)

32 Classless Inter-domain Routing (CIDR)

- About 1993, remove strict classes from architecture
- Generalized notion of "network prefix"
- Requires "longest prefix" match routing
- Subsumes and generalizes subnetting
- (will discuss when we cover IP routing)