EECS 122, Lecture 3

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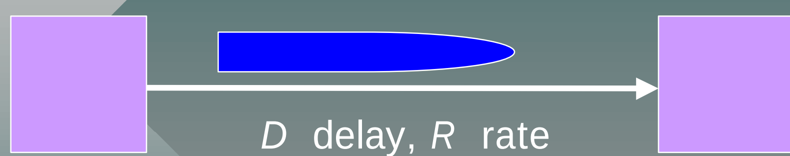
Channel Capacity

- 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

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

Transmission Time

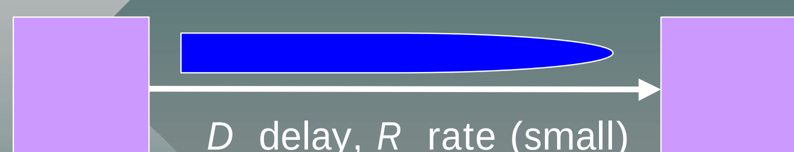


- Trans delay = (M bits) / (R b/s) = M/R sec
- Prop delay = D sec
- **Tx Time = D + M/R sec**

Latency

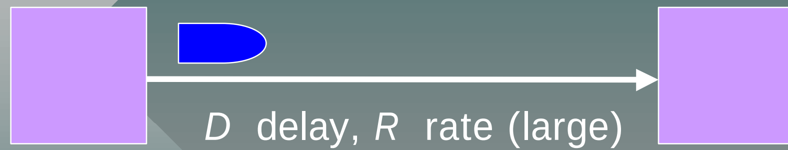
- Slower channels "stretch out" bits in time:
  - a bit on a 1Mb/s link is 1 μsec wide
  - a bit on a 10Mb/s link is 0.1 μsec wide
- Total Latency = tx time + queue
  - transmit time = { last slide }
  - queue delay = { depends! }

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)

High Speed Links

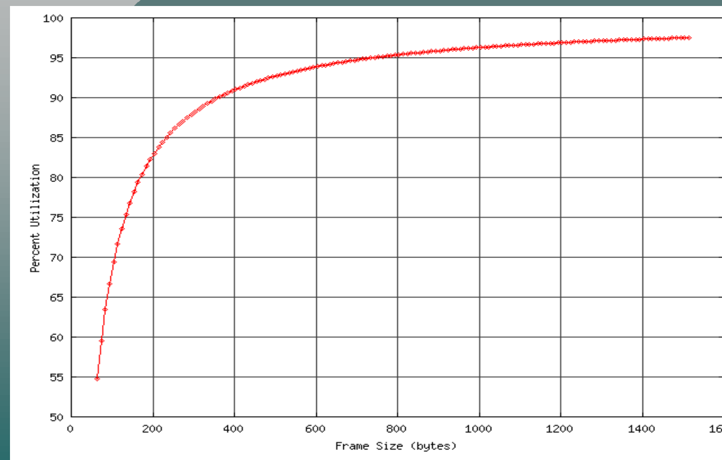


- Large R -> small Tx Time (M/R)
- Ex: OC-3 (D = 10ms, R = 155Mb/s)
  - Tx Time = .010 + ((1024x8)/(155x1024x1024)) = 0.01005 sec = 10.05 ms (D >> M/R)

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

Beware of Overheads



Measuring Latencies (1)

```
prompt> ping localhost
ping localhost (127.0.0.1) from default, 56 data bytes, 0 iter
64 bytes from 127.0.0.1 to 127.0.0.1: icmp_seq=1. 0.855 ms,
64 bytes from 127.0.0.1 to 127.0.0.1: icmp_seq=2. 0.482 ms,
64 bytes from 127.0.0.1 to 127.0.0.1: icmp_seq=3. 0.62 ms,
64 bytes from 127.0.0.1 to 127.0.0.1: icmp_seq=4. 0.595 ms,
----localhost:default PING Statistics----
--- 4 packets transmitted, 4 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 0.482/0.637/0.855


prompt> ping cs.ucla.edu
ping cs.ucla.edu (131.179.128.13) from default, 56 data bytes, 0 iter
64 bytes from 131.179.128.13 to 131.243.1.20: icmp_seq=1. 23.858 ms,
64 bytes from 131.179.128.13 to 131.243.1.20: icmp_seq=2. 22.244 ms,
64 bytes from 131.179.128.13 to 131.243.1.20: icmp_seq=3. 23.658 ms,
64 bytes from 131.179.128.13 to 131.243.1.20: icmp_seq=4. 21.153 ms,
----cs.ucla.edu:default PING Statistics----
--- 4 packets transmitted, 4 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 21.153/22.728/23.858
```

Measuring Latencies (2)

```
prompt> date
Wed Feb 12 01:08:55 PST 1997
prompt> ping -n 5 cs.cmu.edu
ping cs.cmu.edu (128.2.222.173) from default, 56 data bytes, 5 iter
64 bytes from 128.2.222.173 to 131.243.1.20: icmp_seq=1. 112.809 ms,
64 bytes from 128.2.222.173 to 131.243.1.20: icmp_seq=2. 112.621 ms,
64 bytes from 128.2.222.173 to 131.243.1.20: icmp_seq=3. 111.503 ms,
64 bytes from 128.2.222.173 to 131.243.1.20: icmp_seq=4. 113.707 ms,
64 bytes from 128.2.222.173 to 131.243.1.20: icmp_seq=5. 111.924 ms,
----cs.cmu.edu:default PING Statistics----
--- 5 packets transmitted, 5 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 111.503/112.512/113.707

prompt> ping -n 10 www.ucl.ac.uk
ping rs6-svr-8.ucl-0.bcc.ac.uk (144.82.100.19) from default, 56 data bytes, 10 i
ter
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=1. 261.023 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=2. 252.449 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=3. 231.537 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=4. 255.727 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=5. 1358.58 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=6. 1269.01 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=7. 575.574 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=8. 270.217 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=9. 219.999 ms,
64 bytes from 144.82.100.19 to 131.243.1.20: icmp_seq=10. 264.128 ms,
----rs6-svr-8.ucl-0.bcc.ac.uk:default PING Statistics----
--- 10 packets transmitted, 10 packets received, 0% packet loss
round-trip (ms)  min/avg/max = 219.999/495.823/1358.58
```

Measuring Latencies (3)

```
prompt> ping -n 10 rena.dit.co.jp
ping rena.dit.co.jp (133.156.1.1) from default, 56 data bytes, 10 iter
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=1. 689.198 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=2. 441.927 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=3. 311.559 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=4. 193.169 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=6. 182.508 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=7. 410.274 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=8. 236.438 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=9. 186.925 ms,
64 bytes from 133.156.1.1 to 131.243.1.20: icmp_seq=10. 195.303 ms,
----rena.dit.co.jp:default PING Statistics----
--- 10 packets transmitted, 9 packets received, 10% packet loss
round-trip (ms)  min/avg/max = 182.508/316.366/689.198


prompt> ping -n 20 saathi.ncst.ernet.in
ping saathi.ncst.ernet.in (144.16.1.2) from default, 56 data bytes, 20 iter
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=1. 2626.31 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=4. 2555.89 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=6. 3207.09 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=8. 3994.32 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=13. 2592.44 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=14. 2603.16 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=18. 2590.9 ms,
64 bytes from 144.16.1.2 to 131.243.1.20: icmp_seq=20. 2562.72 ms,
----saathi.ncst.ernet.in:default PING Statistics----
--- 20 packets transmitted, 8 packets received, 60% packet loss
round-trip (ms)  min/avg/max = 2555.89/2841.6/3994.32
```

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

So, What does this Require?

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

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

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, ..

Benefits of Naming Hierarchy

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

URLs: New Names

- Relatively New Name Format on Internet
  - 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

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!

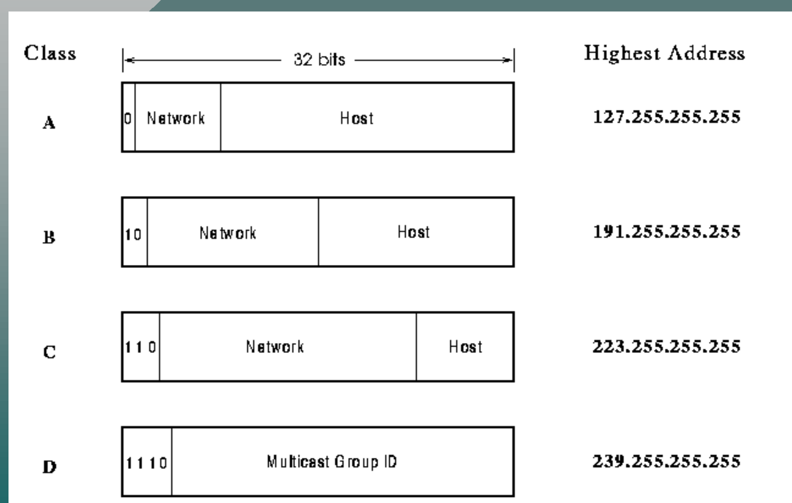
IP (v4) Addresses

- 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

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"

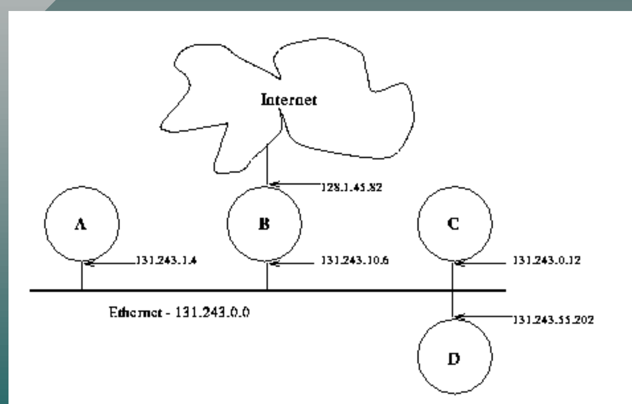
IP Address Classes (historical)



Special IP Addresses

32 bits	Use
all zero	This host (during boot) Default route (in tables)
all one	Local net broadcast
Network | all one	Directed broadcast
0 1 1 1 1 1 1 1 | Not 0, often 1	Loopback

Example Assignments



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"

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

Subnet Example

- 128.32.25.12 is a "Class B" address
- 16 bits of network, 16 bits of host
- Locally, want a thousand "subnets"
- So, need 10 bits to indicate subnet
- Use a *subnet mask* of (16+10=26) bits

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

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*

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

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)

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)