Internet Programming & Protocols CS594

Lecture 1

Goals & objectives

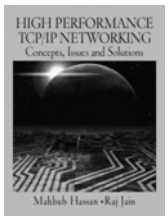
What's a network

Physical layer

Internet history

Internet Programming & Protocols

- Instructor: Tom Dunigan (*dunigan@cs.utk.edu*)
  - Office hours: after class or by appointment (Claxton C222)
- Teaching assistant: Kent Galbraith (*galbraith@cs.utk.edu*)
- Meet Claxton C206 Tu/Th 9:40-10:55
- Text:

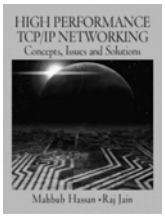


Objectives

- Writing internet software (TCP and UDP)
- Understanding Internet protocols
- Measuring, diagnosing, understanding network performance
- Simulating network performance
- Optimizing TCP performance
- Becoming a network wizard

Course work

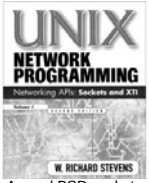
- Textbook readings
- Lectures
- Programming and simulation (ns) assignments
- Reading key papers
- Midterm & final (open-book)



Prerequisites

- Tattoo
- Comfortable with UNIX, C, and makefiles
- CS 360 or equivalent smarts
- CS account (access to Linux boxes)
- Familiar with BSD socket library
- tcpdump/ethereal access (personal machine?)

Kurose/Ross good network overview (fig's)



A good BSD socket resource

Concepts

- Packet-switched networks
- Layers and encapsulation
- Discrete event simulation
- Unreliable datagrams
- Reliable streams
- Performance measurement
- Bandwidth estimation

Plan of attack

- Network overview
- BSD sockets and UDP
- TCP sockets
- TCP protocol
- Network simulation (ns)
- TCP accelerants
- TCP implementations

Network tools

•ping/traceroute

•tcpdump/ethereal

•ns

•iperf/netperf/ttcp

•netstat/ifconfig/tcptrace

"Tell me and I forget. Show me and I remember. Involve me and I understand."
-- Chinese proverb

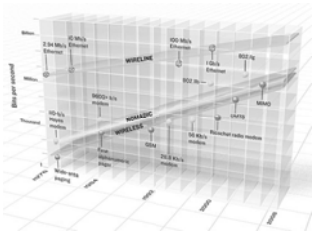
Class resources on the web

- Class page
  - Lectures (pdf) and required readings
  - Assignments
  - Policy on collaboration etc.
- Resource page
- Network papers
- ~dunigan/ipp05/
  - Code snippets
  - ns scripts etc.
  - bin/ handy executables

What's a network

- media
- protocols
- service

Internet DECnet SNA FDDI uunet AOL ATM ISDN IEEE 802.11 wireless NSFnet Bitnet Fidonet ARPAnet MILNET VPN PPP intranet LAN VLAN WAN…



Selection criteria:

- speed
- connectivity
- cost
- community of interest
- portability
- availability/survivability

Net history

'57 ARPA
'69 ARPAnet bomb proof (packet switched)
'75 DECnet
'76 Ethernet
'77 UNIX PDP-11
'78 UUCP PCs
'79 USENET (home 300 bps), XMODEM, BBS
'80 BITNET (PCs)
'81 CSNET
'82 BSD 4.1c TCP/IP, FidoNet
'84 ORNL-MILNET (9.6Kbs), Ether, IBM SNA
'85 Sun workstations, sniffer
'86 NSFNET (home 1200 bps)
'87 UT-ORNL (56Kbs)
'88 ORNL-MILNET (56Kbs) (home 2400)
'89 ORNL-UT T1 (1.5Mbs), IRC
'90 ORNL (T1 ESnet) home(9600bps)
'91 ORNL FDDI
'92 MBONE (multicast video/audio)
'93 ORNL ATM home(ISDN 128Kbs) WWW
'94 ESnet/ORNL T3 (45Mbs)
'96 ORNL/UT ATM (155 Mbs), broadband
'98 ESnet/ORNL OC12 (622), wireless, home(broadband, 3 mbs)
'02 Internet2/ORNL OC192 (10gig)

Proprietary networks ('70s and '80s)

IBM

- big iron servers, dumb remotes
- not peer-to-peer (originally)
- look like a reader/punch/3270
- SNA (7 layers)

Digital Equipment Corp. (DEC)

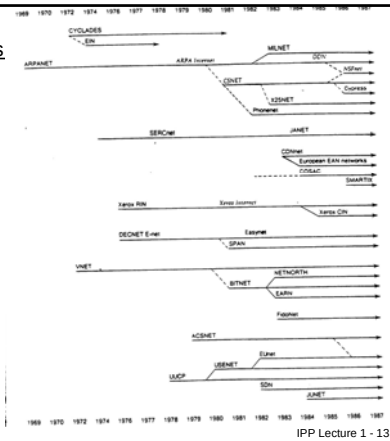
- scientific labs, PDP-11s
- point-to-point
- then Ethernet, wide-area (HEPnet)

Others: XNS/Netware, Apollo, Prime, Appletalk

DARPA/Internet protocols

- ARPAnet '69
- packet-switched, survivable
- experimental, universities
- UNIX BSD 4.1 (free) included TCP/IP, sockets, '83
- non-proprietary
- loosely administered

Notable networks



OSI

Open Systems Interconnection -- '83

- designed network
- seven layers
- services/interfaces/protocols
- bigger addresses
- international standard (ISO) -- not proprietary
- IBM, European phone companies
- in '89, all government procurements required OSI

OSI failed ...

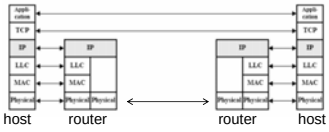
Q: *What do you get when you cross a mobster with an international standard?*

A: *Someone who makes you an offer you can't understand.*

- design by committee, 3' of paper
- flawed and complex
- initial implementation slow
- initially, connection-based
- "not invented here"
- TCP/IP was spreading (free)

layers

- OSI's main contribution
- each layer offers a service to the layer above
- hides details from higher layer
- details of lower level can change
- well-defined interfaces between layers
- protocol is the interface between the same layer on two machines
- encapsulation -- each layer may add an envelope

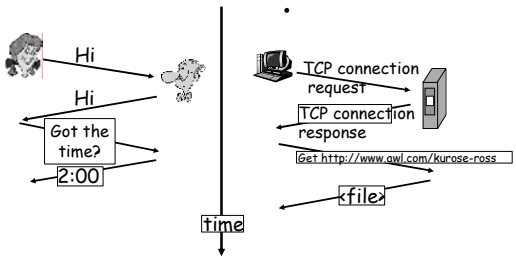


protocol

- For people, a recipe or a set of procedures, e.g.
  - Buy airline ticket
  - Check in luggage
  - Board plane
  - Retrieve luggage
- Network protocol
  - Format of messages
  - Action required upon receiving a given message type
  - There are application layer protocols (what to "say" to request a file transfer)
  - There are transport layer protocols (TCP)
  - There are link layer protocols (Ethernet)

What's a protocol?

a human protocol and a computer network protocol:

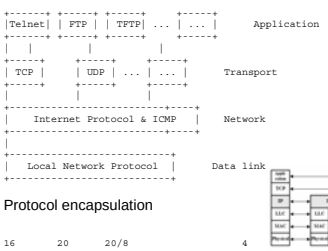


OSI reference model

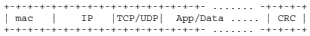
- physical -- bit stream (wire, optical, wireless)
- data link -- packets on the link (FDDI, ethernet, token ring)
- network -- connects links, routers (IP)
- transport -- reliable stream (TCP, UDP)
- session -- more reliable (SSL)
- presentation -- canonical form (API, data conversion)
- application -- mail, telnet, http, ssh, etc.

Layers/encapsulation

Protocol Relationships



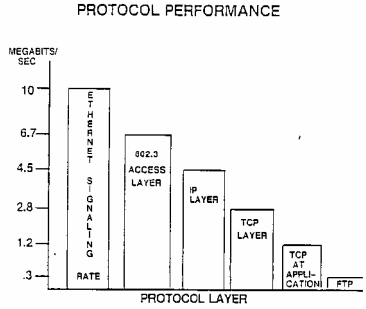
Protocol encapsulation



Data is carried in packets. Packets are intermixed.

Does laying affect performance?

•Extra bits for headers, delay in adding/stripping headers



Not quite this bad, but you get the idea.

Physical layer – media & speeds

speeds	
10 Gbps	10 GigE, optical carriers OC192
1 Gbs	GigE
155 Mbs	OC3 optical carrier
100 Mbs	FDDI (100 Mbs), Ethernet, ATM
45 Mbs	T3
16 Mbs	token ring
10 Mbs	Ethernet (10 Mbs)
1.5 Mbs	DSL, T1
64 Kbs	ISDN voice
10 Kbs	modem (9.6 Kbs)
300 bps	acoustic coupler modem
100 bps	human data rate (read/talk/type)

Media

Copper

Fiber/optical

Radio frequency

802.11

microwave

satellite

infrared

bluetooth

Network peformance

- Bandwidth
  - Capacity vs available
- Latency
  - Transmission delay (interface putting bits onto media)
  - Propagation delay (distance/speed-of-light)
  - Queuing delays
  - OS delays (encapsulation: application, TCP, IP, Ethernet)
- Other factors affecting performance:
  - Jitter
  - Errors (packet loss)
  - Protocol specs
  - Protocol bugs
  - Implementation limits
  - Application delays

what this course is about!

Latency applet

Transfer times				
Material	bytes	@2400	@T1	@1Gbs
page	2400	8s	.01s	1x10**-5s
report	7x10**4	4m	.4s	3x10**-4s
book	7x10**5	40m	4s	.003s
dictionary	6x10**7	2.3d	5.3m	.3 s
Encyclo.	2x10**8	5d	12h	.6 s
OR lib	7x10**10	7.4y	4d	5.5m
UT lib	7x10**11	74y	43d	55m
lib. Cong.	2x10**13	1900y	3y	23h

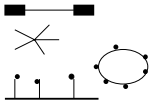
Speed of light

- Physical limits of latency
- Speed of light: 186,000 miles/sec 300,000 km/sec
  - Only 200,000 km/sec in glass fiber
  - Travels 'bout 11 inches in a nanosecond
- Circumference of earth: 40,000 km
  - Round-trip time (RTT) 'bout 200 ms
  - UT to Russia RTT 'bout 166 ms (ping)
  - UT to California RTT 'bout 65 ms

- Satellite RTT 'bout 250 ms
- Do I do a calculation on my computer, or send it across the net to a supercomputer?

Network topology

- point-to-point
- star
- ring
- bus (Ethernet)
- tree
- forest

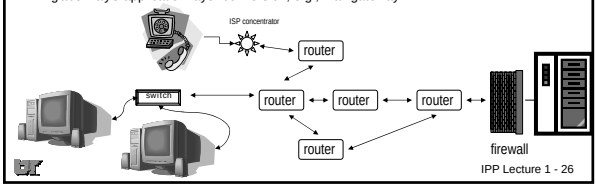


The Internet is a network of networks, connecting rings, Ethernets, etc.

interconnects

- modem voice/data
- repeaters signal regeneration (data)
- hubs/switches filter (data/link)
- bridges/concentrators/access point filter, store & forward, media interconnect, modem pools
- routers/NAT network-layer routing/ address mapping
- firewall gateway/routers
- gateways application-layer conversion, e.g., mail gateway

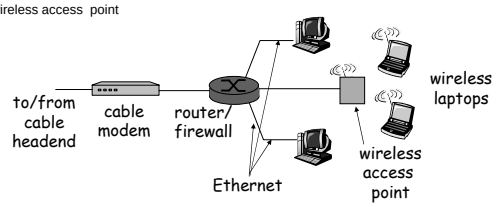
Out the interface, through the hub, over the bridge, off the router... nothing but net.



Home networks

Typical home network components:

- DSL or cable modem
- router/firewall/NAT
- Ethernet
- wireless access point



End-to-end connections

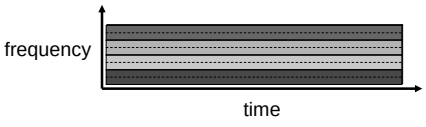
- Circuit-switched
  - Like telephone, call setup required
  - Circuit guarantees "bandwidth" (limited number of circuits, "busy")
  - Share resources (wire/bandwidth) with
    - Time-division multiplexing
    - Frequency-division multiplexing
  - if user is "idle", resource is wasted (reserved)
  - Good for video/audio(voice)
- Packet-switched
  - Data is broken into packets, each carrying addressing info
  - Packet gets full-bandwidth
  - Packets compete for bandwidth (statistical multiplexing)
  - More robust, packets can bypass broken link, but packets can be lost ☹
  - Hard to do video/audio

Circuit Switching: FDM and TDM

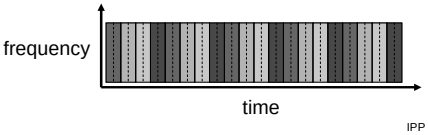
FDM

Example:

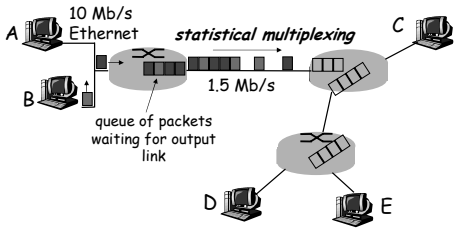
4 users



TDM



Packet Switching: Statistical Multiplexing



Sequence of A & B packets does not have fixed pattern,

shared on demand → ***statistical multiplexing***.

TDM: each host gets same slot in revolving TDM frame.

Next time ...

- Ethernet and IP

Assignment 1 is due next week!