Overview: Networks

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'These notes were created by Prof. Walrand, F'02

Course Information

Instructors:
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Time/Place: Tu,Th 2:00-3:30 in 299 Cory

Home Page:
- http://www-inst.eecs.berkeley.edu/~ee228a

Topics

- Overview [1 week]
- Economics of Networks [4]
- 802.11 and Sensor Networks [4]
- Congestion Control [2.5]
- Traffic Models [2.5]
- Review [1]

Theoretical background
State of the art

Details

- Grading:
  - Class participation & presentations: 65%
  - Project: 35% - Original research on selected topic

- Material:
  - Lecture Slides and Notes
  - Research Papers

Overview

- Network Examples
- Network Components
- Internetworking
- Internet
- Other Networks
- Packets
- Transport
- Web Browsing
- Telephone Call
- Resource Sharing - Multiplexing
- Protocols
- IETF

Network Examples

Teledesic Communications Corporation - Fiber + Satellite

Network Map

[Image of a world map with network connections]
Network Examples

Global Crossing Corporation

Network Examples

KPNQWEST

Network Examples

Williams Communications

Network Examples

Palo Alto Network

Network Components

- **Link**: carry bits from one place to another (or maybe to many other places)
- **Switch/router**: move bits between links, forming internetwork
- **Host**: communication endpoint (workstation, PDA, cell phone, toaster, tank)

Network Components

- **Links**
  - Fibers
  - Cat5 Unshielded Twisted Pairs
  - Coaxial Cable
  - Wireless
Network Components

*Ethernet Network Interface Card*

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Network Components

*Ethernet*

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Network Components

**Link: Ethernet**

- Ethernet is a *broadcast-capable, multi-access* LAN

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Network Components

**Link: IEEE 802.11 WLAN**

- IEEE 802.11 WLAN is adaptation of Ethernet like protocol for wireless medium

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**IEEE 802.11 WLAN Products**

- **Access Points**
- **PC Cards**

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**3G UMTS Cellular Network**

*Convergence of Voice and Data*

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Network Components

- Telephone Switch
- Large Router

Network with Routers

LAN1 interconnected by routers

LAN1 - R1 - LAN2 - R2 - LAN3 - R3 - R4 - Internet

Internetworking

- Provides message delivery between multiple networks:
  - ISP 1
  - ISP 2
  - Subnet 1
  - Subnet 2

Example:
- Subnet 1 = network of LANs of previous slide
- ISP 1 = Sprint, ISP 2 = MCI
- Subnet 2 = UCB network

The Internet

- A global network of networks all using a common protocol (IP, the Internet Protocol)
- One focus of this class
- A challenge to understand:
  - large scale (10's of millions of users, 10's of thousands of networks)
  - heterogeneity, irregular topology, decentralized management

Scale of Internet

- Internet Domain Survey Host Count

Data from www.nw.com

Other Networks

- The Telephone Network
- Processor Interconnection Networks
- ATM Networks
- Cable-TV Networks
Packets

The switches (routers) have no memory of packets: scalability
The network is independent of the applications: flexibility
The packet formats and addresses are independent of the technology: extensibility

Web Browsing: top-down view

Example
Locating Resource: DNS
Connection
End-to-end
Packets
Bits
Points to remember

Web: Example

Click Link or URL
→ get content from local or remote computer
URL:
http://www.google.com/string
Specifies:
- Protocol: http
- Computer: www.google.com
- String: computer (server) selects contents based on string

Web: Locating Resource

www.google.com is the name of a computer
Network uses IP addresses
To find the IP address, the application uses a hierarchical directory service called the Domain Name System
Web: Connection

- The protocol (http) sets up a connection between the host and www.google.com to transfer the page.
- The connection transfers the page as a byte stream, without errors: pacing + error control.

Web: End-to-end

- The byte stream flows from end to end across many links and switches: routing (+ addressing).
- That stream is regulated and controlled by both ends: retransmission of erroneous or missing bytes; flow control.

Web: Packets

- The network transports bytes grouped into packets.
- The packets are “self-contained” and routers handle them one by one.
- The end hosts worry about errors and flow control:
  - Destination checks packet for errors (using error detection code CKS) and sends ACKs with sequence number #.
  - Source retransmits packets that were not ACKed and adjusts rate of transmissions.

Web: Bits

- Equipment in each node sends the packets as a string of bits.
- That equipment is not aware of the meaning of the bits.

Web: Points to remember

- Separation of tasks:
  - send bits on a link: transmitter/receiver (clock, modulation…)
  - send packet on each hop (framing, error detection…)
  - send packet end to end (addressing, routing)
  - pace transmissions (detect congestion)
  - retransmit erroneous or missing packets (acks, timeout)
  - find destination address from name (DNS)
- Scalability:
  - routers don’t know about connections
  - names and addresses are hierarchical.

Telephone Call

- Telephone Network
- Dialing a Number
- Setting up a Circuit
- Phone Conversation
- Releasing the Circuit
Telephone Network

Logic Diagram:

Dialing a Number

A Off-Hook
S1 Listens
A dials
S1 Registers

Setting Up a Circuit

Circuit = capacity to carry one phone call (shown by thin lines)
Circuit is allocated to the call between A and B
Circuits are not shared; they are dedicated.

Phone Conversation

Voice signals use the reserved circuits
Release Circuits

A or B goes Off-Hook
Circuits get released

Resource Sharing - Multiplexing

- Networks are shared resources
- Sharing via multiplexing
- Fundamental Question: how to achieve controlled sharing

Multiplexing

- Methods for sharing a communication channel
- Tradeoff between utilization and predictability
- Common Approaches:
  - TDM (time-division multiplexing)
  - Statistical Multiplexing

Time Division Multiplexing
(also called STDM - Synchronous Time Division Multiplexing)

Frame:
Time "slots" are reserved

bps = bits per second

Statistical Multiplexing

<table>
<thead>
<tr>
<th>n links</th>
<th>any rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplexer</td>
<td></td>
</tr>
<tr>
<td>1 link, any rate</td>
<td></td>
</tr>
</tbody>
</table>

Trace Excerpt:
Variable-sized "packets" of data are interleaved based on the statistics of the senders

Analysis of STDM/FDM

- TDM, FDM (frequency division multiplexing), and WDM (wavelength) may under-utilize channel with idle senders
- Applicable only to fixed numbers of flows
- Requires precise timer (or oscillator and guard bands for FDM)
- Resources are guaranteed
Analysis of Statistical Mux'ing

- Traffic is sent on demand, so channel is fully utilized if there is enough demand
- Any number of flows
- Need to control sharing:
  - packets are limited in size
  - prevents domination of single sender
- Resources are not guaranteed

Protocols

- Agreement dictating the form and function of data exchanged between two (or more) parties to effect a communication
- Two parts: syntax and semantics
  - syntax: where bits go
  - semantics: what they mean and what to do with them

Protocol Example

- Internet Protocol (IP)
  - if you can generate and understand IP, you can be on the Internet
  - media, OS, data rate independent
- TCP and HTTP
  - if you can do these, you are on the web

Protocol Standards

- New functions require new protocols
- Thus there are many (e.g. IP, TCP, UDP, HTTP, RIP, OSPF, IS-IS, SMTP, SNMP, Telnet, FTP, DNS, NNTP, NTP, BGP, PIM, DVMRP, ARP, NFS, ICMP, IGMP; IEEE802.x)
- Specifications do not change frequently
- Organizations: IETF, IEEE, ITU

The IETF

- Specifies Internet-related protocols
- Produces “RFCs” (www.rfc-editor.org)
- Quotation from IETF T-shirt:

  We reject kings, presidents and voting.
  We believe in rough consensus and running code.

  --- David Clark