High Performance Communication Networks

Introduction, Part I
Part I: Introduction

Chapter goal:
- get context, overview, “feel” of networking
- more depth, detail later in course
- approach:
  - descriptive
  - use Internet as example

Overview:
- what’s the Internet
- what’s a protocol?
- network edge
- network core
- access net, physical media
- performance: loss, delay
- protocol layers, service models
- backbones, NAPs, ISPs
- history
- ATM network
What’s the Internet: “nuts and bolts” view

- millions of connected computing devices: hosts, end-systems
  - PC’s, workstations, servers
  - PDA’s, phones, toasters
  running network apps
- communication links
  - fiber, copper, radio, satellite
- routers: forward packets (chunks) of data through network
What’s the Internet: “nuts and bolts” view

- **protocols**: control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, FTP, PPP

- **Internet**: “network of networks”
  - loosely hierarchical
  - public Internet versus private intranet

- **Internet standards**
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force
What’s the Internet: a service view

- communication infrastructure enables distributed applications:
  - WWW, email, games, databases, e-commerce, voting,
  - more?
- communication services provided:
  - connectionless
  - connection-oriented
What’s a protocol?

human protocols:
• “what’s the time?”
• “I have a question”
• introductions

... specific msgs sent
... specific actions taken when msgs received, or other events

network protocols:
• machines rather than humans
• all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt
What’s a protocol?

a human protocol and a computer network protocol:

Q: Other human protocol?

Excuse me!

Yes?

Got the time?

2:00

TCP connection request.

TCP connection reply.

Get http://ece.iisc.ernet.in/~bgbala/gce

<file>
A closer look at network structure:

- network edge: applications and hosts
- network core:
  - routers
  - network of networks
- access networks, physical media: communication links
The network edge:

• **end systems (hosts):**
  - run application programs
  - e.g., WWW, email
  - at “edge of network”

• **client/server model**
  - client host requests, receives service from server
  - e.g., WWW client (browser)/server; email client/server

• **peer-peer model:**
  - host interaction symmetric
  - e.g.: teleconferencing
**Goal**: data transfer between end sys.
- **handshaking**: setup (prepare for) data transfer ahead of time
  - Hello, hello back human protocol
  - *set up “state”* in two communicating hosts
- TCP - Transmission Control Protocol
  - Internet’s connection-oriented service

**TCP service** [RFC 793]
- **reliable, in-order byte-stream data transfer**
  - loss: acknowledgements and retransmissions
- **flow control**:
  - sender won’t overwhelm receiver
- **congestion control**:
  - senders “slow down sending rate” when network congested
Network edge: connectionless service

**Goal:** data transfer between end systems
- same as before!

**UDP** - User Datagram Protocol [RFC 768]: Internet’s connectionless service
- unreliable data transfer
- no flow control
- no congestion control

**App’s using TCP:**
- HTTP (WWW), FTP (file transfer), Telnet (remote login), SMTP (email)

**App’s using UDP:**
- streaming media, teleconferencing, Internet telephony
The Network Core

- mesh of interconnected routers
- **the fundamental question**: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete “chunks”
Network Core: Circuit Switching

End-end resources reserved for “call”
- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required
Network Core: Circuit Switching

network resources (e.g., bandwidth) divided into “pieces”
• pieces allocated to calls
• resource piece *idle* if not used by owning call (*no sharing*)
• dividing link bandwidth into “pieces”
  • frequency division
  • time division
Network Core: Packet Switching

each end-end data stream divided into *packets*

- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*,

Bandwidth division into “pieces”
Dedicated allocation
Resource reservation

resource contention:
- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - transmit over link
  - wait turn at next link
Packet-switching versus circuit switching: human restaurant analogy

- other human analogies?
Network Core: Packet Switching

Packet-switching: store and forward behavior
Packet switching versus circuit switching

Packet switching allows more users to use network!

- 1 Mbit link
- each user:
  - 100Kbps when “active”
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - with 35 users, probability > 10 active less than .004

N users

1 Mbps link
Packet switching versus circuit switching

Is packet switching a “slam dunk winner?”

• Great for bursty data
  • resource sharing
  • no call setup

• Excessive congestion: packet delay and loss
  • protocols needed for reliable data transfer, congestion control

• Q: How to provide circuit-like behavior?
  • bandwidth guarantees needed for audio/video apps
  still an unsolved problem (chapter 6)
Packet-switched networks: routing

- **Goal:** move packets among routers from source to destination
  - we’ll study several path selection algorithms (chapter 4)
- **datagram network:**
  - *destination address* determines next hop
  - routes may change during session
  - analogy: driving, asking directions
- **virtual circuit network:**
  - each packet carries tag (virtual circuit ID), tag determines next hop
  - fixed path determined at *call setup time*, remains fixed thru call
  - routers maintain per-call state
Access networks and physical media

Q: How to connect end systems to edge router?

• residential access nets
• institutional access networks (school, company)
• mobile access networks

Keep in mind:

• bandwidth (bits per second) of access network?
• shared or dedicated?
Residential access: point to point access

- **Dialup via modem**
  - up to 56Kbps direct access to router (conceptually)
- **ISDN:** integrated services digital network: 128Kbps all-digital connect to router
- **ADSL:** asymmetric digital subscriber line
  - up to 1 Mbps home-to-router
  - up to 8 Mbps router-to-home
Residential access: cable modems

- **HFC:** hybrid fiber coax
  - asymmetric: up to 10 Mbps upstream, 1 Mbps downstream
- **network:** network of cable and fiber attaches homes to ISP router
  - shared access to router among home
  - issues: congestion, dimensioning
- deployment: available via cable companies, e.g., MediaOne
Institutional access: local area networks

- company/univ local area network (LAN) connects end system to edge router
- Ethernet:
  - shared or dedicated cable connects end system and router
  - 10 Mbs, 100Mbps, Gigabit Ethernet
- deployment: institutions, home LANs soon
- LANs: chapter 5
Wireless access networks

- shared wireless access network connects end system to router
- wireless LANs:
  - radio spectrum replaces wire
  - e.g., Lucent Wavelan 10 Mbps
- wider-area wireless access
  - CDPD: wireless access to ISP router via cellular network
Physical Media

- **physical link:** transmitted data bit propagates across link

- **guided media:**
  - signals propagate in solid media: copper, fiber

- **unguided media:**
  - signals propagate freely e.g., radio

Twisted Pair (TP)

- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps ethernet
  - Category 5 TP:
Physical Media: coax, fiber

Coaxial cable:
- wire (signal carrier) within a wire (shield)
  - baseband: single channel on cable
  - broadband: multiple channel on cable
- bidirectional
- common use in 10Mbs Ethernet

Fiber optic cable:
- glass fiber carrying light pulses
- high-speed operation:
  - 100Mbps Ethernet
  - high-speed point-to-point transmission (e.g., 5 Gbps)
- low error rate
Physical media: radio

- signal carried in electromagnetic spectrum
- no physical “wire”
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:
- microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., waveLAN)
  - 2Mbps, 11Mbps
- wide-area (e.g., cellular)
  - e.g. CDPD, 10’s Kbps
- satellite
  - up to 50Mbps channel (or multiple smaller channels)
  - 270 Msec end-end delay
  - geosynchronous versus LEOS