Applications/Design

- Web Browsing
- Telephone Call
- Multiplexing
- Protocols
- IETF
- Summary

Web Browsing

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

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

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

Connection

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

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
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.

Bits

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

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

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

Switches

- SESS (Lucent)
- DMS100 (Nortel)
### 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
Multiplexing

- Overview
- Operations
- TDM/FDM
- Statistical Multiplexing
- Analysis of TDM/FDM
- Analysis of Statistical Multiplexing

Overview

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

Operations

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

Time Division Multiplexing

- $n$ links
- rate $r$ bps each
- 1 link, rate $nr$ bps
- Frame: Time "slots" are reserved
- bps = bits per second

Statistical Multiplexing

- $n$ links
- any rate
- 1 link, any rate
- Trace Excerpt:
  - Variable-sized "packets" of data are interleaved based on the statistics of the senders

Analysis of TDM/FDM

- The rate of the outgoing link must be at least equal to the sum of the rates of the incoming links
- Consequently, that outgoing link may be under-utilized if the incoming links are not constantly busy
- FDM (frequency division multiplexing) divides the outgoing link into separate frequency bands instead of time slots
- WDM (wavelength) separates outgoing signals by sending them on different wavelengths
- These schemes are applicable only to fixed numbers of flows
- Requires precise timer (or oscillator and guard bands for FDM)
- Resources are guaranteed
Analysis of SM

- The rate of the outgoing link must exceed the sum of the average rates of the incoming packet streams.
- Traffic is sent on demand, so channel is fully utilized if there is traffic to send.
- Any number of flows.
- Need to control sharing:
  - packets are limited in size.
  - prevents domination of single sender.
- Resources are not guaranteed.

Definition

- 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.

Examples

- 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.

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).
- 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
Summary

- Network Structure:

  ➔ Finding Destination: Directory Service
  ➔ Regulating Flows of Packets: E2E Transport
  ➔ Finding a path to destination: Routing
  ➔ Switching: Circuits (telephone) or Packets (Internet)
  ➔ Sharing a link = Multiplexing: TDM (telephone) or SM (Internet)
  ➔ Framing packets inside bit stream: Link
  ➔ Transmitting bits

- Protocols, Standards, IEEE, IETF, ...