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

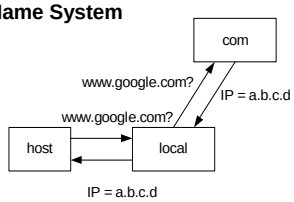
Specifies

- Protocol: http
- Computer: www.google.com
- String

Computer (server) selects contents based on string

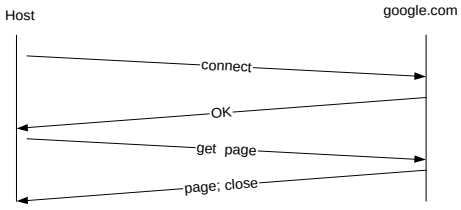
Locating Resource

- 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**



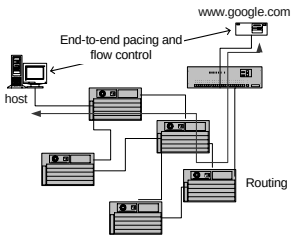
Connection

- 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**



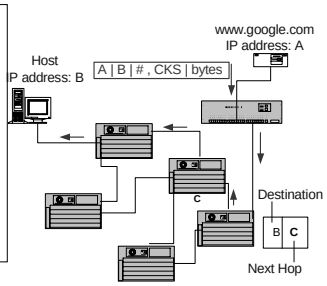
End-to-end

- 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**



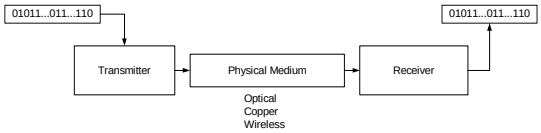
Packets

- 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

Telephone Network

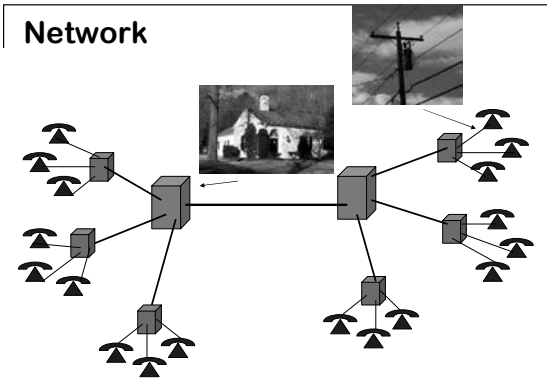
- Switches
- Network
- Logic Diagram

Switches

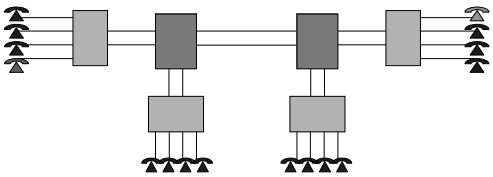
5ESS (Lucent)

DMS100 (Nortel)

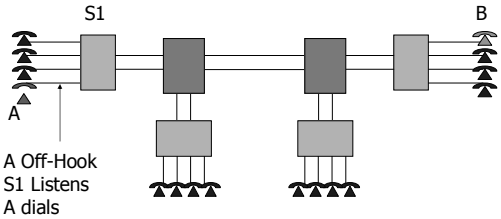
Network



Logic Diagram

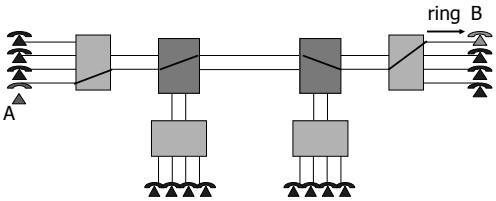


Dialing a Number



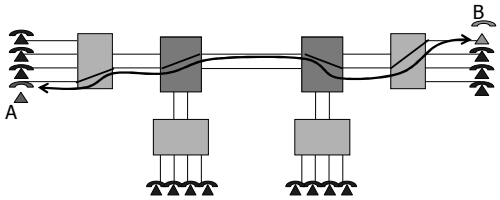
A Off-Hook
S1 Listens
A dials
S1 Registers

Setting Up a Circuit



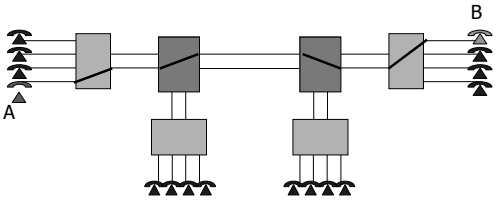
Circuit = capacity to carry one phone call (shown by thin lines)
Circuit is allocated to the call between A and B
Circuits are not shared; they are dedicated.

Phone Conversation



Voice signals use the reserved circuits

Release Circuits



A or B goes Off-Hook
Circuits get released

Multiplexing

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

Overview

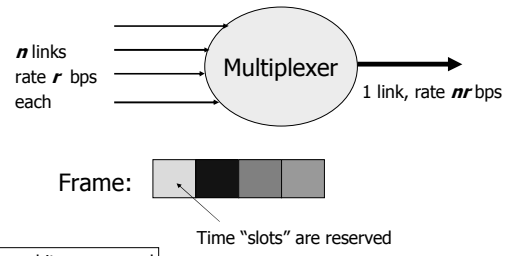
- Networks are *shared resources*
- Sharing via *multiplexing*
- Fundamental Question:

  how to achieve controlled sharing

Operations

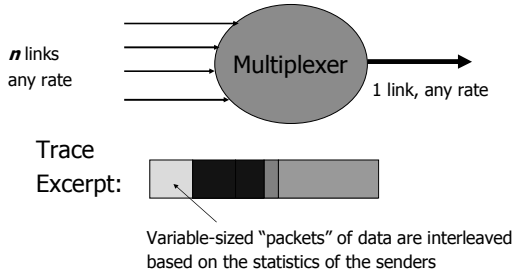
- Methods for sharing a communication channel
- Tradeoff between utilization and predictability
- Common Approaches:
  - TDM (time-division multiplexing)
  - Statistical Multiplexing

Time Division Multiplexing



bps = bits per second

Statistical Multiplexing



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

Protocols

- Definition
- Examples
- Standards

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

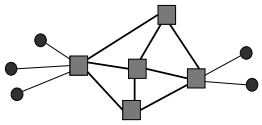
- Specifies Internet-related protocols
- Produces “RFCs” (www.rfc-editor.org)
- Quotation from IETF T-shirt:

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, …