15-744: Computer Networking

L-1 Intro to Computer Networks

Short Diagnostic Quiz

- Problem
  - Different undergraduate backgrounds
- Objective
  - Gauge relative skill level
- Time
  - 15 minutes

Outline

- Administrivia
- Whirlwind tour of networking

Who's Who?

- Professor: Srinivasan Seshan
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- Course info
  - http://www.cs.cmu.edu/~srini/15-744/S02/

Objectives

- Understand the state-of-the-art in network protocols, architectures and applications
- Understand how networking research is done
- How is class different from undergraduate networking (15-441)
  - Training network programmers vs. training network researchers

Web Page

- Check regularly!!
- Course schedule
- Reading list
- Lecture notes
- Announcements
- Assignments
- Project ideas
- Exams
- Student list

Course Materials

- Research papers
  - Links to ps or pdf on Web page
  - Combination of classic and recent work
  - ~40 papers
  - Optional readings
- Recommended textbook
  - For students not familiar with networking
  - Peterson & Davie 2nd edition
  - 2 copies on reserve

Grading

- Homework assignments (20%)
  - Problem sets
  - Hands-on assignments
- Class participation (10%)
  - Pop quizzes
- 2 person project (30%)
- Midterm exam (20%)
- Final exam (not cumulative) (20%)

Outline

- Administrivia
- Whirlwind tour of networking

What is the Objective of Networking?

- Communication between applications on different computers
- Must understand application needs/demands
  - Traffic data rate
  - Traffic pattern (bursty or constant bit rate)
  - Traffic target (multipoint or single destination, mobile or fixed)
  - Delay sensitivity
  - Loss sensitivity

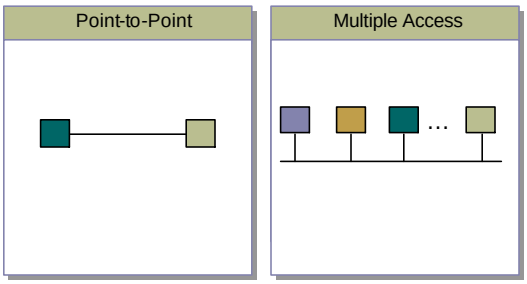
Four Steps to Networking

- Communicating across a link
- Connecting together multiple links (internetworking)
- Finding and routing data to nodes on internetwork
- Matching application requirements

A First Step

- Creating a link between nodes
- Link: path followed by bits
  - Wired or wireless
  - Broadcast or point-to-point (or both)
- Node: any device connected to a link

Types of Links

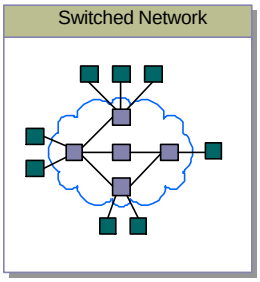


Packet Transmission Modes

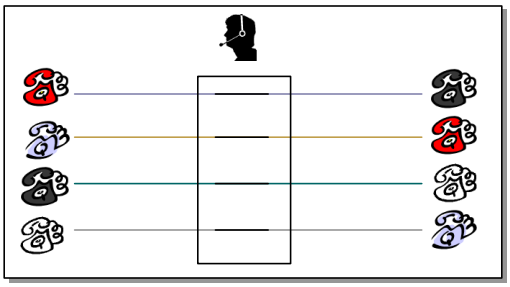
- Unicast
  - Transmission to single specific receiver
- Broadcast
  - Transmission to all network nodes
- Multicast
  - Transmission to specific subset of nodes
- Anycast
  - Transmission to one of a specific subset of nodes

What are Switched Networks?

- Switch: moves bits between links
  - Packet switching
  - Circuit switching

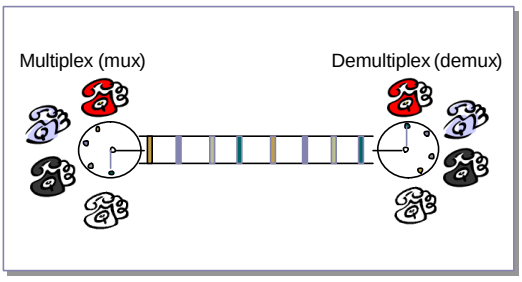


Back in the Old Days…

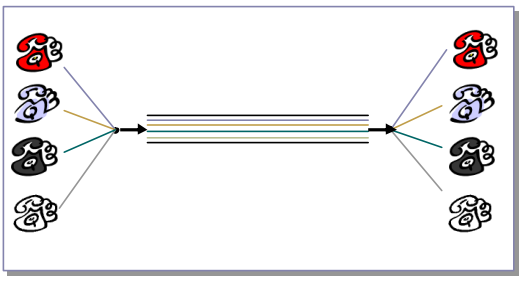


Then Came TDM…

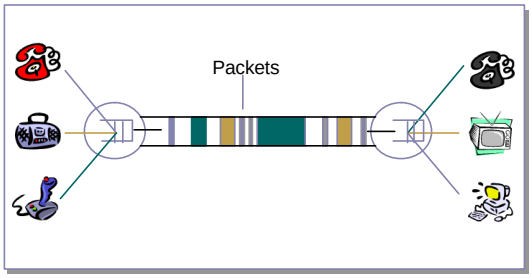
- Synchronous time division multiplexing



TDM Logical Network View



Packet Switching (Internet)



Packet Switching

- Interleave packets from different sources
- Efficient: resources used on demand
  - Statistical multiplexing
- General
  - Multiple types of applications
- Accommodates bursty traffic
  - Addition of queues

Statistical Multiplexing Gain

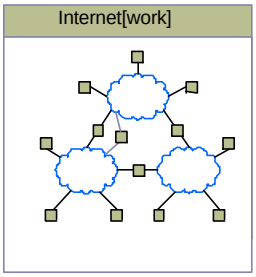
- 1 Mbps link; users require 0.1 Mbps when transmitting; users active only 10% of the time
- Circuit switching: can support 10 users
- Packet switching: with 35 users, probability that >=10 are transmitting at the same time < 0.0017

Characteristics of Packet Switching

- Store and forward
  - Packets are self contained units
  - Can use alternate paths - reordering
- Contention
  - Congestion
  - Delay

Second Step: Internet[work]

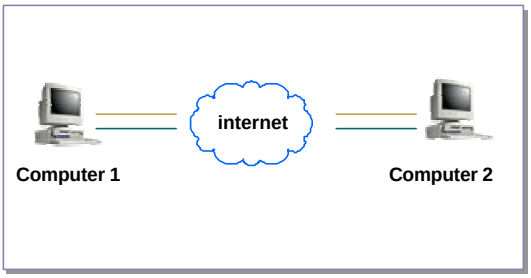
- A collection of interconnected networks
- Host: network endpoints (computer, PDA, light switch, …)
- Router: node that connects networks
- Internet vs. internet



Challenge

- Many differences between networks
  - Address formats
  - Performance – bandwidth/latency
  - Packet size
  - Loss rate/pattern/handling
  - Routing
- How to translate between various network technologies

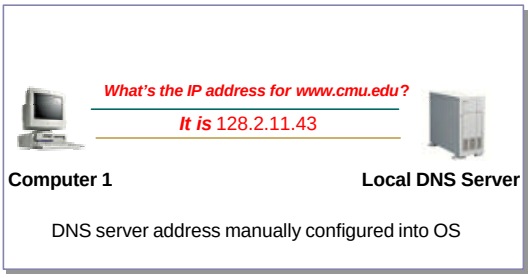
Third Step: How To Find Nodes?



Naming

- Humans use readable host names
  - E.g. www.cmu.edu
  - Globally unique (can correspond to multiple hosts)
- Naming system translates to physical address
  - E.g. DNS translates name to IP Address (e.g. 128.2.11.43)
  - Address reflects location in network

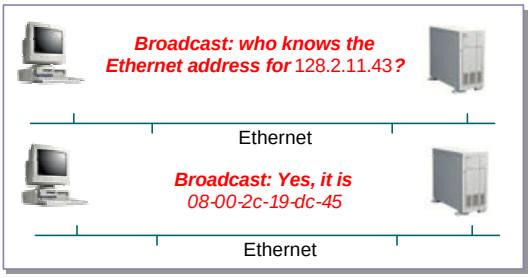
Domain Name System



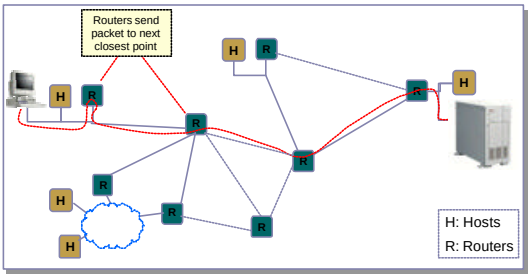
Packet Routing/Delivery

- Each network technology has different local delivery methods
- Address resolution provides delivery information within network
  - E.g., ARP maps IP addresses to Ethernet addresses
  - Local, works only on a particular network
- Routing protocol provides path through an internetwork

Network:Address Resolution Protocol



Internetwork: Datagram Routing



Routing

- Forwarding tables at each router populated by routing protocols.
- Original Internet: manually updated
- Routing protocols update tables based on "cost"
  - Exchange tables with neighbors or everyone
  - Use neighbor leading to shortest path

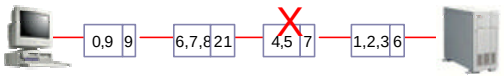
Fourth Step: Application Demands

- Reliability
  - Corruption
  - Lost packets
- Flow and congestion control
- Fragmentation
- In-order delivery
- Etc…

What if the Data gets Corrupted?

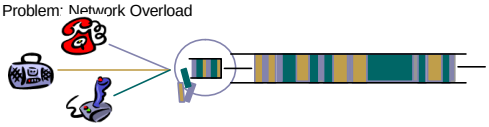
Problem: Data Corruption

Solution: Add a *checksum*



What if Network is Overloaded?

Problem: Network Overload



Solution: Buffering and Congestion Control

- Short bursts: buffer
- What if buffer overflows?
  - Packets dropped
  - Sender adjusts rate until load = resources
- Called "congestion control"

What if the Data gets Lost?

Problem: Lost Data

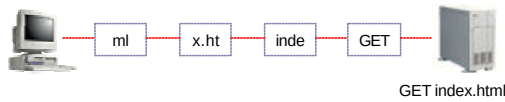
Solution: Timeout and Retransmit

What if the Data Doesn't Fit?

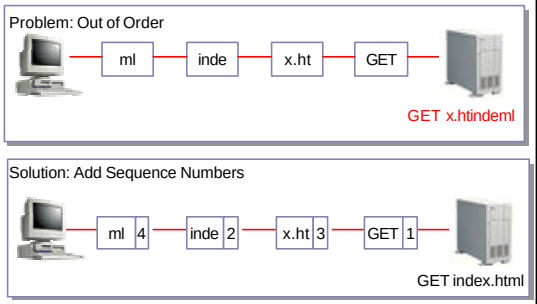
Problem: Packet size

- On Ethernet, max IP packet is 1.5kbytes
- Typical web page is 10kbytes

Solution: Fragment data across packets



What if the Data is Out of Order?

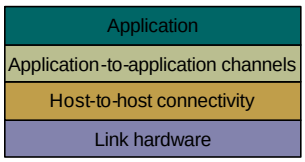


Network Functionality Summary

- Link
- Multiplexing
- Routing
- Addressing/naming (locating peers)
- Reliability
- Flow control
- Fragmentation
- Etc….

What is Layering?

- Modular approach to network functionality
- Example:



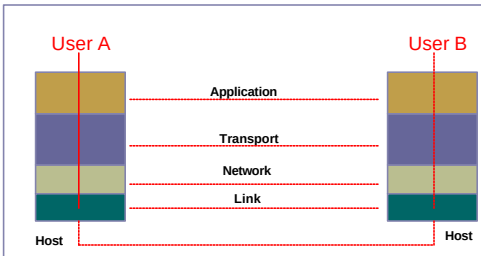
Protocols

- Module in layered structure
- Set of rules governing communication between network elements (applications, hosts, routers)
- Protocols define:
  - Interface to higher layers (API)
  - Interface to peer
    - Format and order of messages
    - Actions taken on receipt of a message

Layering Characteristics

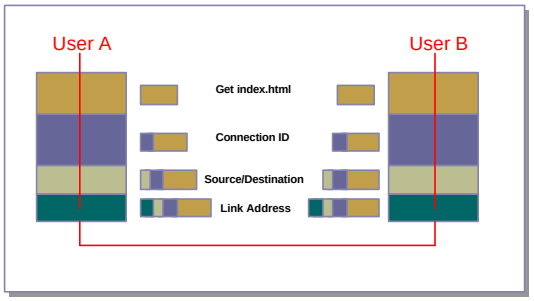
- Each layer relies on services from layer below and exports services to layer above
- Interface defines interaction
- Hides implementation - layers can change without disturbing other layers (black box)

Layering



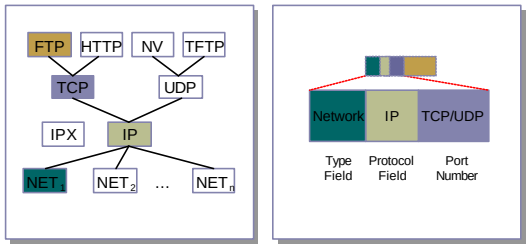
Layering: technique to simplify complex systems

Layer Encapsulation



Protocol Demultiplexing

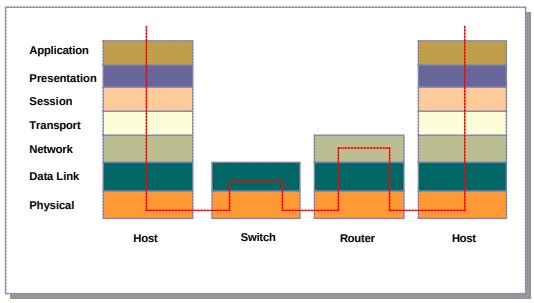
- Multiple choices at each layer



E.g.: OSI Model: 7 Protocol Layers

- Physical: how to transmit bits
- Data link: how to transmit frames
- Network: how to route packets
- Transport: how to send packets end2end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

OSI Layers and Locations



Example: Transport Layer

- First end-to-end layer
- End-to-end state
- May provide reliability, flow and congestion control

Example: Network Layer

- Point-to-point communication
- Network and host addressing
- Routing

Is Layering Harmful?

- Sometimes..
  - Layer N may duplicate lower level functionality (e.g., error recovery)
  - Layers may need same info (timestamp, MTU)
  - Strict adherence to layering may hurt performance

Class Coverage

- No coverage of physical and data link layer
  - Students expected to know this
- Focus on network to application layer
- We will deal with:
  - Protocol rules and algorithms
  - Investigate protocol trade-offs
  - Why this way and not another?

Lecture Topics

Traditional

- Layering
- Internet architecture
- Routing (IP)
- Transport (TCP)
- Queue management (FQ, RED)
- Naming (DNS)

Recent Topics

- Multicast
- Mobility
- Active networks
- QOS
- Security
- Network measurement
- Overlay networks
- P2P applications

Next Lecture: Design Considerations

- How to determine split of functionality
  - Across protocol layers
  - Across network nodes
- Assigned Reading
  - [SRC84] End-to-end Arguments in System Design
  - [Cla88] Design Philosophy of the DARPA Internet Protocols