Introduction
(CSE 473S, Fall 2007)

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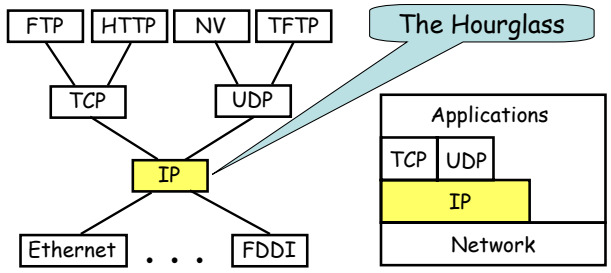
General Information

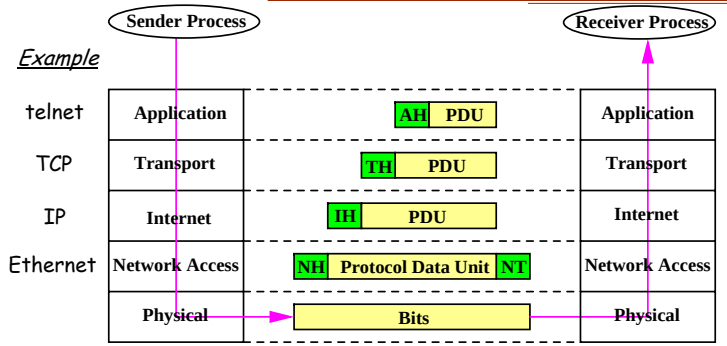
- http://www.arl.wustl.edu/~gorinsky(Follow link)
  - »Syllabus, latest handouts, etc.
- TA: Shobana Padmanabhan (sp3@arl.wustl.edu)
- Textbook
  - »Kurose and Ross, ***Computer Networking, 4th edition***
- Other Books
  - »Donahoo and Calvert, ***TCP/IP Sockets in C***
  - »Stevens, Unix Network Programming
  - »Stevens, TCP/IP Illustrated, Volume 1: The Protocols
  - »Tannenbaum, Computer Networks
- Internet
  - »www.ietf.org: Internet Engineering Task Force
    - Look for link to RFCs (Request For Comments)

THE Internet Architecture



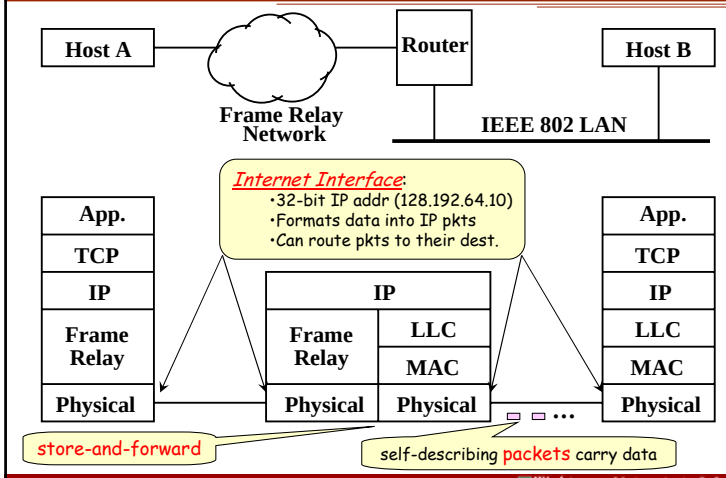
- *An Internet*: A network of heterogeneous networks
- *THE (Global) Internet* is an internet that uses IP
- Goals: Universal connectivity/Uniform access

Internet Protocol Layers



- The layers form a *protocol stack*
  - »Services at 1 level depend on lower layer services

Internetworking Overview



Equations Can Be Dangerous

- Propagation Delay
  d.prop = D/c' where c' = 2/3 c
- End-to-End Delay
  d.e2e = H (d.queue + d.trans + d.prop + d.x)
  - » d.queue: queueing delay
  - » d.trans = L/R: transmission delay where
    - L is pkt size, and R is transmission rate
  - » d.prop: propagation delay
  - » d.x: extra delay (e.g., processing)
  - » H: number of hops
- Work Conservation $\sum_{i=1}^{N}$ p.i d.i = Constant
  - » p.i: probability of type i pkt
  - » d.i: average delay of a type i pkt

understanding is not just remembering !!!

Networking Core

- Applications
  - » possibilities???
- Protocols
  - » resource discovery
  - » pkt delivery (best-effort, guaranteed service)
- Fundamental constants, technology limits, etc.
- Distributed algorithms
  - » asynchronous, geographically separated ends
  - » sometimes long-running
- Network physics
  - » Laws of pkt motion
- Technology
  - » now . . . tomorrow

What ?
How ?
Why ?
Why not ?

Blank

Lectures

- Elaborate on reading
- Address potential difficulties
- Deeper understanding
- Build your confidence
- Additional examples

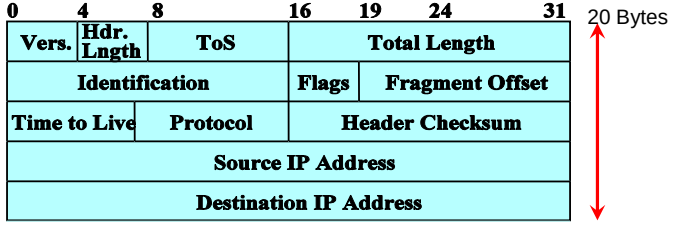
The End

Basic Internet Technology

- Packets
  - » Packets carry information and are self-describing
  - » A packet has 2 parts:
    - A *header* (metadata (information about the payload))
    - A *payload* (information content)
- Store-And-Forward Technology
  - » The packet header
    - Allows a packet to be stored at a router for eventual delivery
    - The packet can be released when convenient
  - » Direct analogy with the post office system
  - » Less expensive to operate than the telephone network

IP Service Model

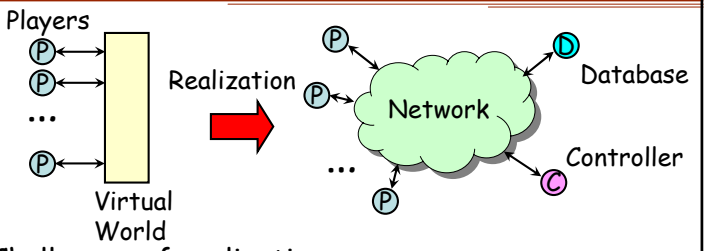
- Datagram (Connectionless) data delivery model
  - » *Best-Effort*: No guarantee of datagram delivery
    - Unreliable, Unordered delivery; Duplicate datagram service
    - Simplifies job of routers
    - End-systems provide reliable, ordered delivery
  - » *Connectionless*: No connection setup phase
    - Datagram has self-describing header



Topics

- Internet Protocol (IP)
  - » Architecture, protocol layers and services
  - » LAN routing
  - » Internet routing
  - » Bit train speed and Bandwidth-Delay product
- User Datagram Protocol (UDP)
  - » Features
- Transmission Control Protocol (TCP)
  - » Features
  - » Congestion control
- Communication Structures

Multiplayer Computer Game



- Challenges of realization
  - » Provide enough *consistency* between player views
    - Absolute consistency means all nodes see the same shared state
  - » Provide enough *responsiveness* to make the game interesting
    - Responsiveness inversely related to the state update time (delay)
  - » The two are interrelated

Internets And The Internet

- THE (Global) Internet
  - » An internet that uses IP
  - » Organized into a multilevel hierarchy
- An Internet: A network of heterogeneous networks
- An Internet-Capable Host
  - » Has a 32-bit IP address
    - e.g., 128.192.64.10, 0x80C0400A
  - » Formats data into IP packets
  - » Knows how to route packets to their destination
- Goals of Internetworking
  - » Universal connectivity
  - » Uniform access (hide hardware/software heterogeneity)

Resource Limitations

- Perfect World: Instantaneous shared state update
- Network Bandwidth
  - » *Transmission capacity* of communication lines (e.g., Mbps)
  - » Inherent overhead of the transport protocol
    - Especially when many players are involved
- Network Latency (Delay)
  - » *Length of time* for a message to travel from one process to another
    - Coast-to-coast speed-of-light propagation delay is about 40 msec
  - » Most demanding games: 0.1 to 1 sec is tolerable
- Network Traffic Processing at Host
  - » Bottleneck is *memory access time* !!!
  - » *Receiver livelock* must be avoided

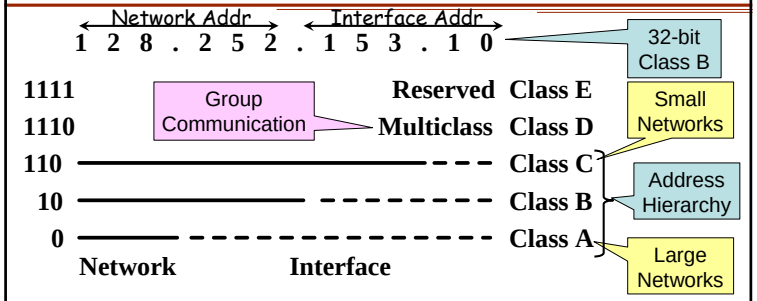
Internet Protocol Layers

- Physical
  - » Interface between data transmission device and medium
- Network
  - » Accessing and routing across the same network
  - » Exchange data between endsystem and network
  - » Endsystem addressing
- Internet (IP)
  - » Routing between different networks
  - » Endsystem addressing that hides network heterogeneity
- Transport (UDP, TCP)
  - » Process addressing (Port number)
  - » Reliable, ordered delivery
- Application

Current Internet

- *Decentralized control*: Multiple admin domains
  - » Requires manual intervention and frequent monitoring
- Independent *Autonomous Systems* (ASs)
  - » Each AS decides its own policies about routing packets
  - » Policies driven by contracts and use directives
- Class B Address Exhaustion
  - » Core routers: 1000s of Class C networks
  - » CIDR developed to mitigate problem
- Core Routing Table Explosion
  - » Core routers: 80,000-140,000 routes
  - » Consumes memory for table entries and auxilliary data
- Core Routers Advertise Routes To Networks

IPv4 Addressing



- A unique address for each active interface
  - » A central authority allocates blocks of IP addresses to organizations
- Address hierarchy reduces routing table size