CS155b: E-Commerce

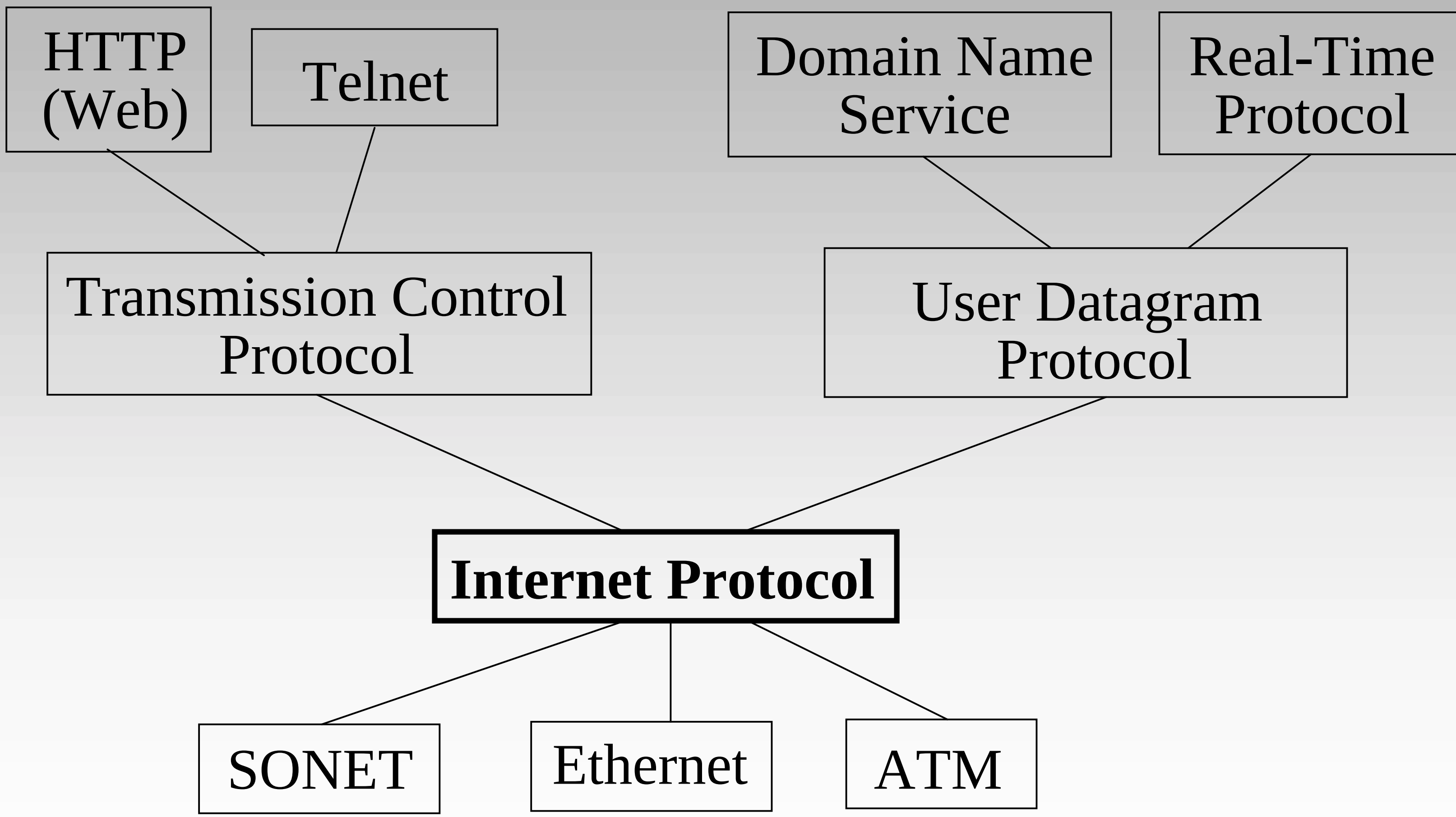
Lecture 4:   Jan 18, 2001

How Does the Internet Work? (continued)

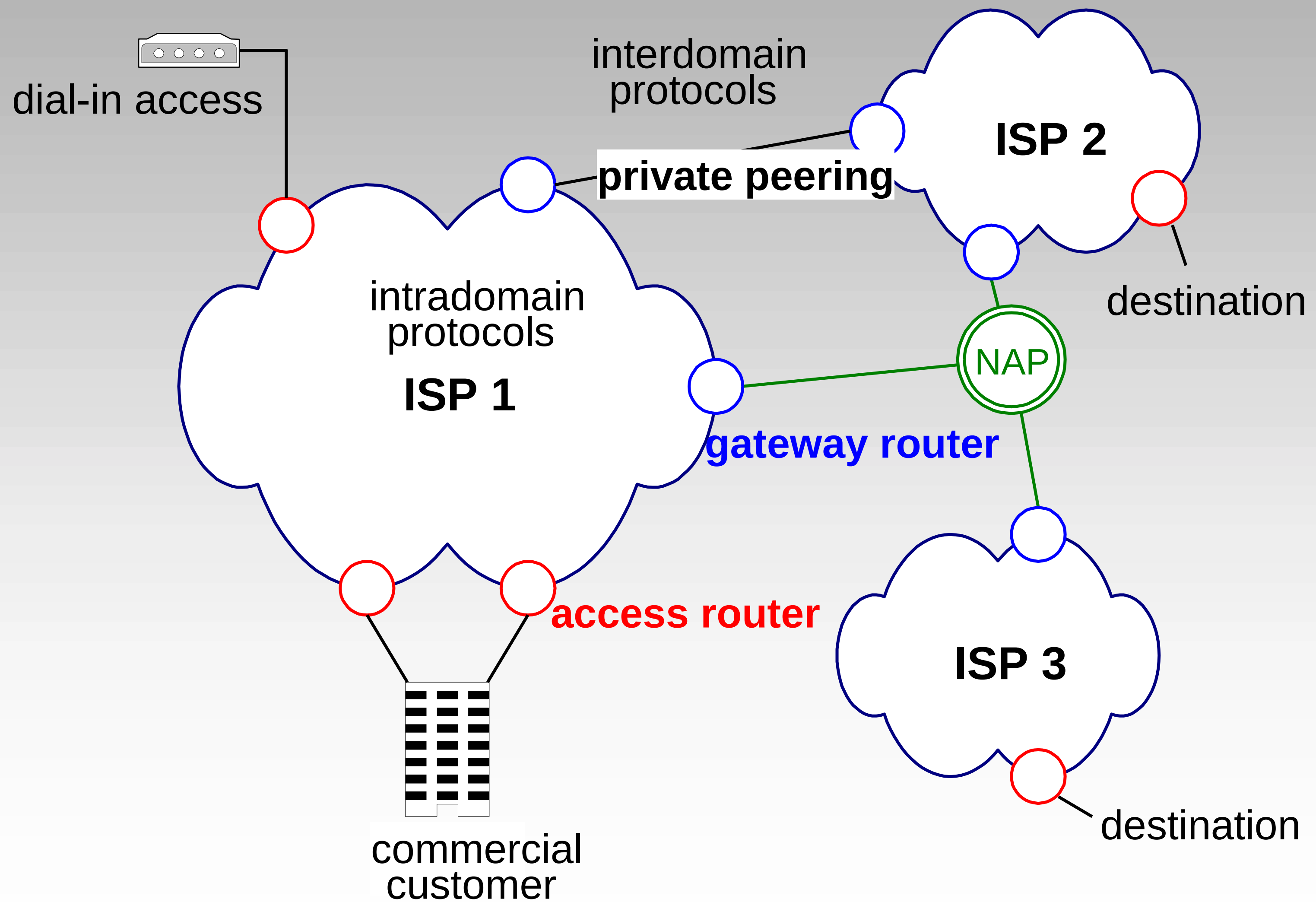
Acknowledgement: J. Rexford

and Lessons Learned From Netscape

Layering in the IP Protocols



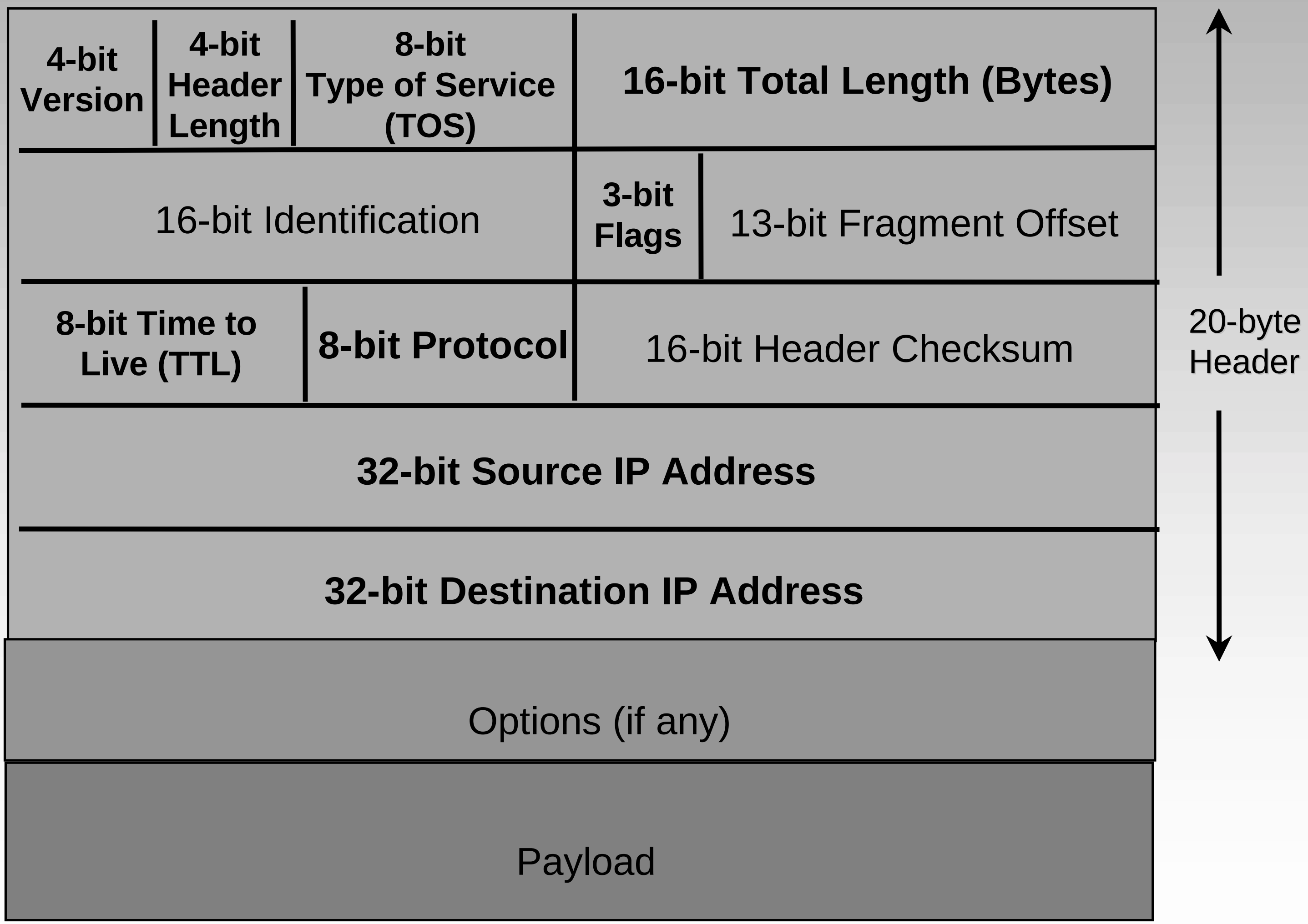
Internet Architecture



IP Connectionless Paradigm

- No error detection or correction for packet data
  - Higher-level protocol can provide error checking
- Successive packets may not follow the same path
  - Not a problem as long as packets reach the destination
- Packets can be delivered out-of-order
  - Receiver can put packets back in order (if necessary)
- Packets may be lost or arbitrarily delayed
  - Sender can send the packets again (if desired)
- No network congestion control (beyond “drop”)
  - Send can slow down in response to loss or delay

IP Packet Structure



Main IP Header Fields

- Version number (e.g., version 4, version 6)
- Header length (number of 4-byte words)
- Header checksum (error check on header)
- Source and destination IP addresses
- Upper-level protocol (e.g., TCP, UDP)
- Length in bytes (up to 65,535 bytes)
- IP options (security, routing, timestamping, etc.)

Time-to-Live Field

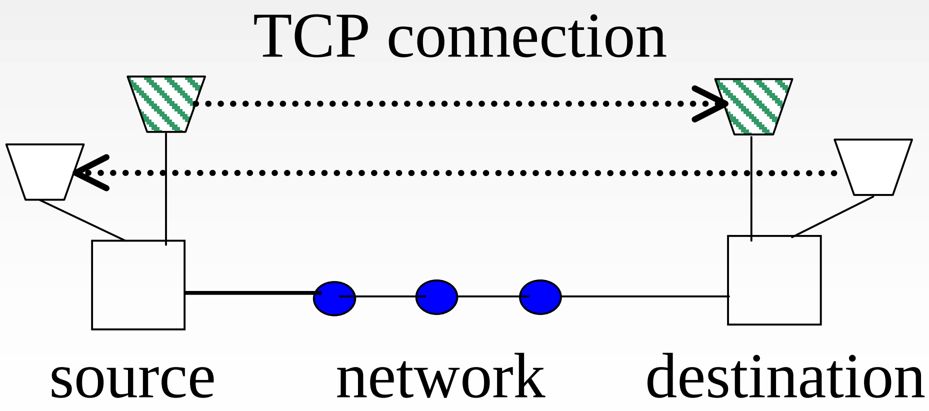
- Potential robustness problem
  - What happens if a packet gets stuck in a routing loop?
  - What happens if the packet arrives ***much*** later?
- Time-to-live field in packet header
  - TTL field decremented by each router on the path
  - Packet is discarded when TTL field reaches 0
  - Discard generates “timer expired” message to source
- Expiry message exploited in **traceroute** tool
  - Generate packets with TTL of i=1, 2, 3, 4, …
  - Extract router id from the “timer expired” message
  - Provides a way to gauge the path to destination

Type-of-Service Bits

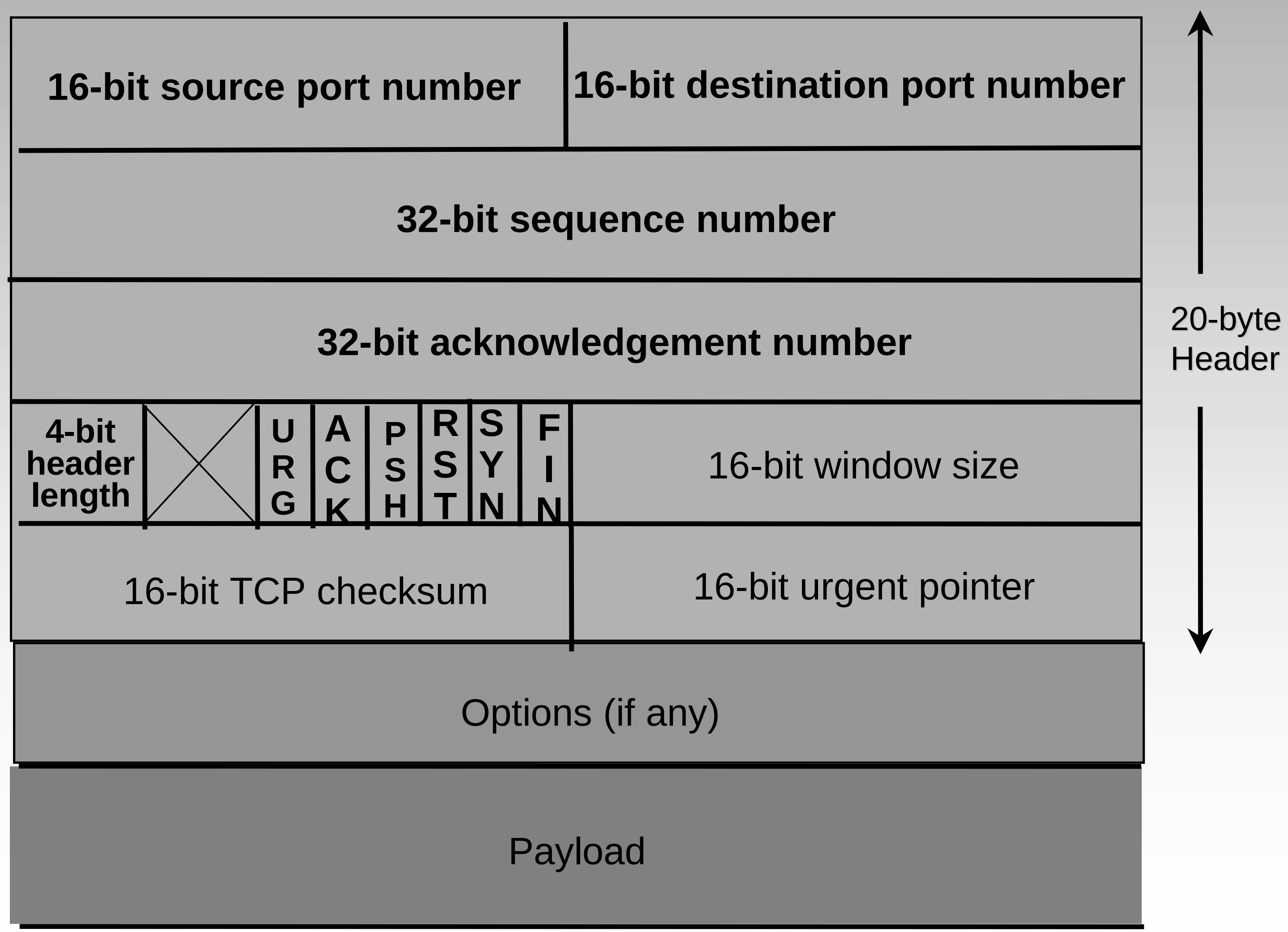
- Initially, envisioned for type-of-service routing
  - Low-delay, high-throughput, high-reliability, etc.
  - However, current IP routing protocols are static
  - And, most routers have first-in-first-out queuing
  - So, the ToS bits are ignored in most routers today
- Now, heated debate for differentiated services
  - ToS bits used to define a small number of classes
  - Affect router packet scheduling and buffering polices
  - Arguments about consistent meaning across networks

Transmission Control Protocol (TCP)

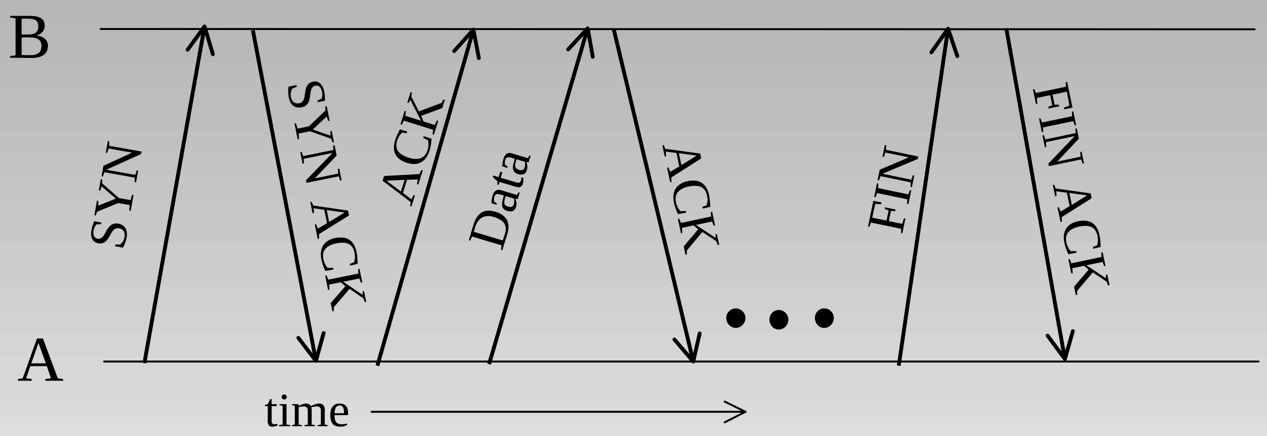
- Byte-stream socket abstraction for applications
- Retransmission of lost or corrupted packets
- Flow-control to respond to network congestion
- Simultaneous transmission in both directions
- Multiplexing of multiple logical connections



TCP Header


16-bit source port number
16-bit destination port number
32-bit sequence number
32-bit acknowledgement number
4-bit header length
URG
ACK
PSH
RST
SYN
FIN
16-bit window size
16-bit TCP checksum
16-bit urgent pointer
Options (if any)
Payload
20-byte Header

Establishing a TCP Connection



- Three-way handshake to establish connection
  - Host A sends a SYN (open) to the host B
  - Host B returns a SYN acknowledgement (ACK)
  - Host A sends an ACK to acknowledge the SYN ACK
- Closing the connection
  - Finish (FIN) to close and receive remaining bytes (and other host sends a FIN ACK to acknowledge)
  - Reset (RST) to close and not receive remaining bytes

Lost and Corrupted Packets

- Detecting corrupted and lost packets
  - Error detection via checksum on header and data
  - Sender sends packet, sets timeout, and waits for ACK
  - Receiver sends ACKs for received packets
- Retransmission from sender
  - Sender retransmits lost/corrupted packets
  - Receiver reassembles and reorders packets
  - Receiver discards corrupted and duplicated packets

Packet loss rates are high (e.g., 10%), causing significant delay (especially for short Web transfers)!

TCP Flow Control

- Packet loss used to indicate network congestion
  - Router drop packets when buffers are (nearly) full
  - Affected TCP connection reacts by backing-off
- Window-based flow control
  - Sender limits number of outstanding bytes
  - Sender reduces window size when packets are lost
  - Initial slow-start phase to learn a good window size
- TCP flow-control header fields
  - Window size (maximum # of outstanding bytes)
  - Sequence number (byte offset from starting #)
  - Acknowledgement number (cumulative bytes)

User Datagram Protocol (UDP)

- Some applications do not want or need TCP
  - Don’t need recovery from lost or corrupted packets
  - Don’t want flow control to respond to loss/congestion
- Amount of UDP packets is rapidly increasing
  - Commonly used for multimedia applications
  - UDP traffic interferes with TCP performance
  - But, many firewalls do not accept UDP packets
- Dealing with the growth in UDP traffic
  - Pressure for applications to apply flow control
  - Future routers may enforce “TCP-like” behavior
  - Need better mathematical models of TCP behavior

Classless Inter-Domain Routing (CIDR)

- IP addresses are all 32 bits in length
  - “Dotted-decimal” notation: 113.34.96.78
  - IP address has “network” part and “host” part
- Addresses used to have a natural network length
  - Class A: 8-bit network and 24-bit host part
  - Class B: 16-bit network and 16-bit host part
  - Class C: 24-bit network and 8-bit host part
- Now any division of the 32 bits is fine
  - Arbitrary division into prefix and mask
  - E.g.: 113.34.96.0/24 for mask of 255.255.255.0

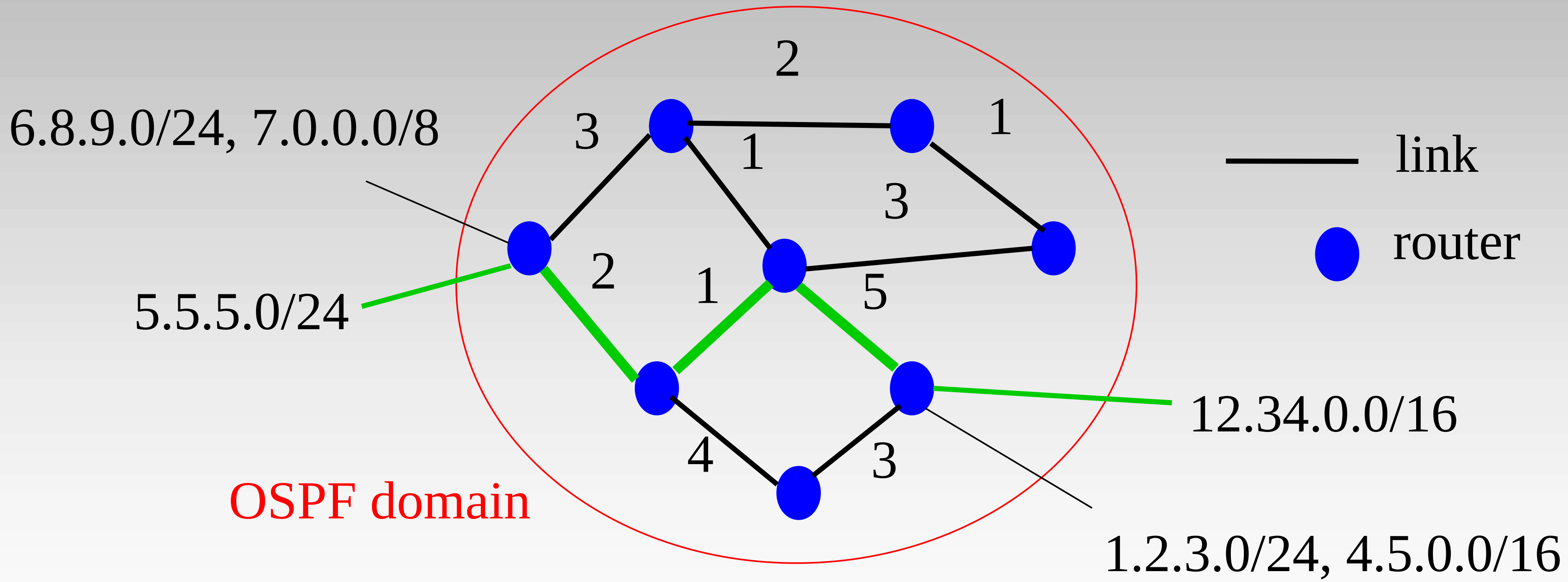
Getting an IP Packet From A to B

- Host must know at least three IP addresses
  - Host IP address (to use as its own source address)
  - Domain Name Service (to map names to addresses)
  - Default router to reach other hosts (e.g., gateway)
- Simple customer/company
  - Connected to a single service provider
  - Has just one router connecting to the provider
  - Has a set of IP addresses allocated in advance
  - Does not run an Internet routing protocol

Open Shortest-Path First (OSPF) Routing

- Network is a graph with routers and links
  - Each unidirectional link has a weight (1-63,535)
  - Shortest-path routes from sum of link weights
- Weights are assigned statically (configuration file)
  - Weights based on capacity, distance, and traffic
  - Flooding of info about weights and IP addresses
- Large networks can be divided in multiple domains

Example Network and Shortest Path



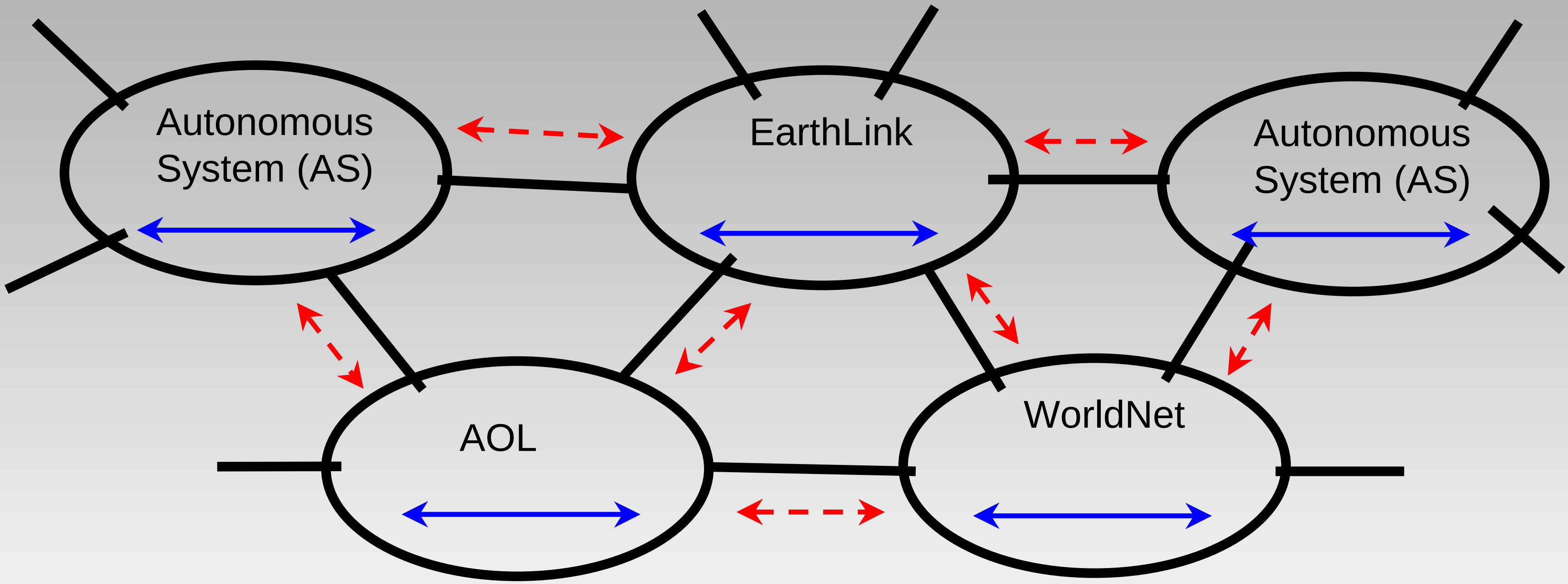
IP Routing in OSPF

- Each router has a complete view of the topology
  - Each router transmits information about its links
  - Reliable flooding to all routers in the domain
  - Updates periodically or on link failure/installation
- Each router computes shortest path(s)
  - Maintenance of a complete link-state database
  - Execution of Dijkstra's shortest-path algorithm
- Each router constructs a forwarding table
  - Forwarding table with next hop for each destination
  - Hop-by-hop routing independently by each router

Routing Software

- Routing protocol software
  - Checking connection with neighboring routers (“hello”)
  - Exchanging link-state information with other routers
  - Computing shortest paths and IP forwarding table
  - Handling of packets with IP options selected
  - Exchanging routing information between providers
- Router management and configuration
  - Configuration files to configure addresses, routing, etc.
  - Command-line interface to inspect/change configuration
  - Logging of statistics in management information base
  - More complex traffic measurement (e.g., NetFlow)

Connecting to Other Networks



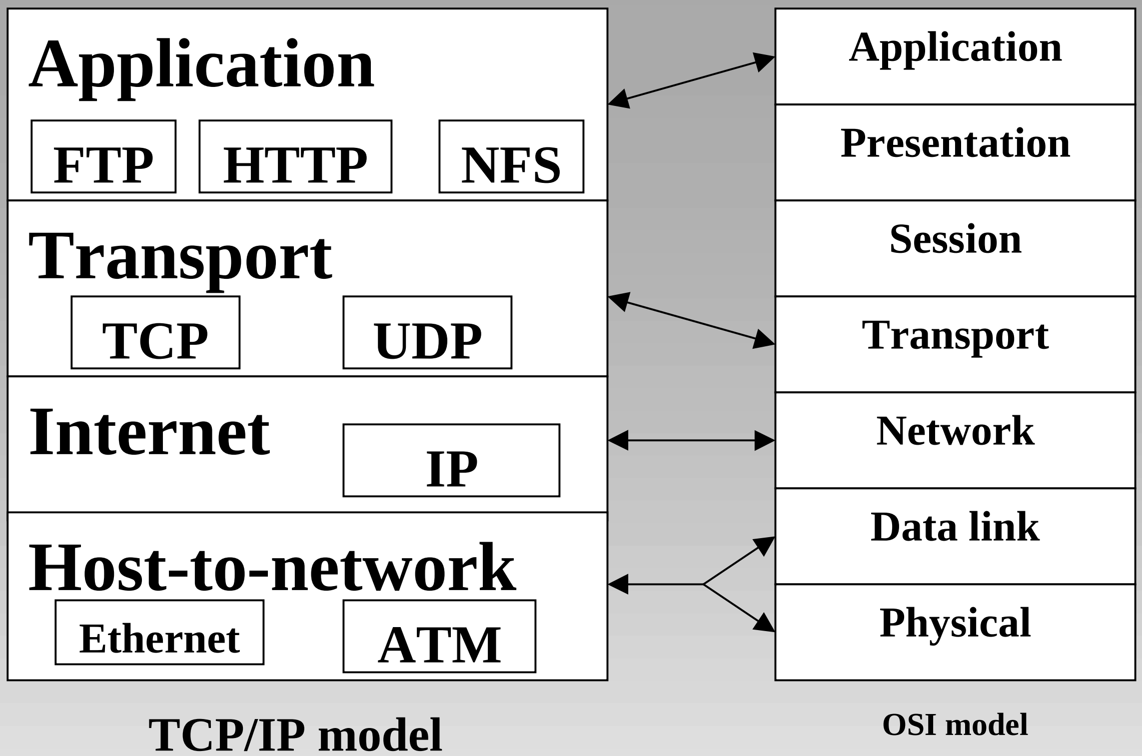
Autonomous System: A collection of IP subnets and routers under the same administrative authority.

Interior Routing Protocol (e.g., Open Shortest Path First)

Exterior Routing Protocol (e.g., Border Gateway Protocol)

Connecting With Our Neighbors

- Public peering
  - Network Access Points (e.g., MAE East, MAE West)
  - Public location for connecting routers
  - Routers exchange data and routing information
- Private peering
  - Private connections between two peers (e.g., MCI)
  - Private peers exchange direct traffic (no transit)
  - Private peers must exchange similar traffic volumes
- Transit networks
  - Provider pays another for transit service (e.g., BBN)
  - Improve performance and reach more addresses



HTTP

- Standard protocol for web transfer
- Request-response interaction
- Request methods: GET, HEAD, PUT, POST, DELETE, …
- Response: Status line + additional info (*e.g.*, a web page)

HTML

- The language in which web pages are written
- Contains formatting commands
- Tells browser what to display & how to display

<HEAD> Welcome to Yale </HEAD>

- The head of this page is “Welcome to Yale”

<B> Great News! </B>

- Set “**Great News!**” in boldface

<A HREF=”http://www.cs.yale.edu/index.html”>Yale Computer Science Department </A>

-A link pointing to the web page: “*http://www.cs.yale.edu/index.html*”

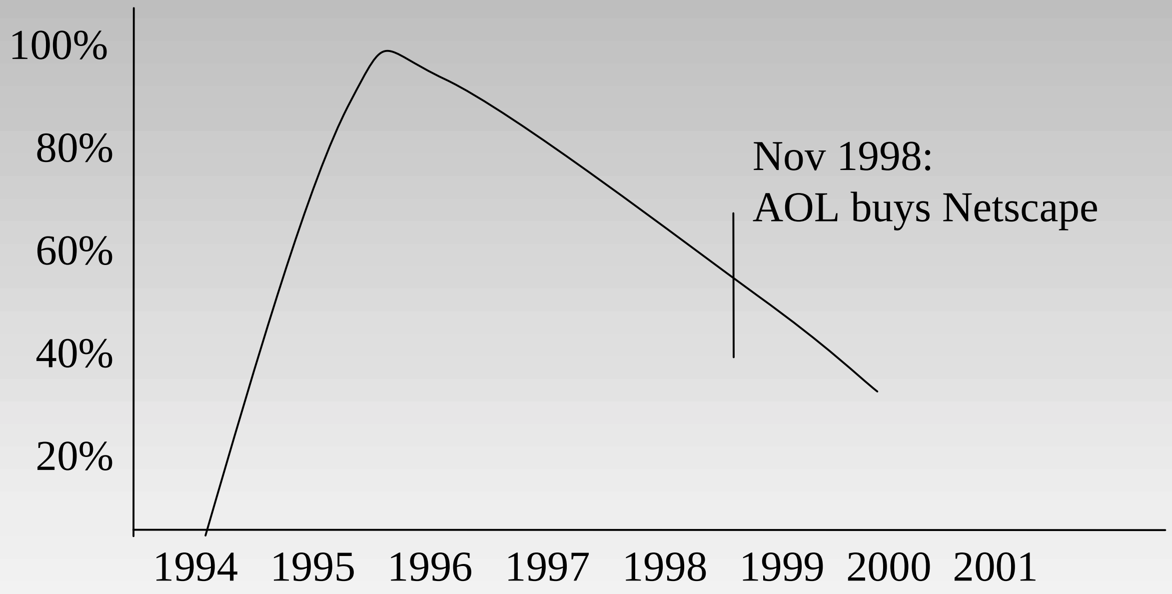
-with the text: “*Yale Computer Science Department*” displayed.

What does “*http://www.cs.yale.edu/index.html*” mean?

Protocol	**Host domain name**	Local file
http	www.cs.yale.edu	index.html

- **Late 1990:** WWW, HTTP, HTML, “Browser” invented by Tim Berners-Lee
- **Mid-1994:** Mosaic Communications founded (later renamed to Netscape Communications)
- **Summer of 1995:** Market share 80%+
- **August 1995:** Windows 95 released with Internet Explorer
- **January 1998:** Netscape announced that its browser would thereafter be **free;** the development of the browser would move to an **open-source** process

Estimated Market Share of Netscape



NOTE: data are from different sources and not exact

Perfectly Captures the *Essence* of Internet Business

- Enormous power of Internet architecture and ethos (*e.g.*, layering, "stupid network," open standards)
- <u>Must</u> bring new technology to market quickly to build market share
- Internet *is* the distribution channel
  - First via FTP, then via HTTP (using Netscape!)
  - Downloadable version available free <u>and</u> CD version sold

Uses Many "Internet Business Models"
(esp. those that involve making money by "giving away" an information product)

Complementary products (esp. server code)

- Bundling
  - Communicator includes browser, email tool, collaboration tool, calendar and scheduling tool, etc. One "learning curve," integration, compatibility, etc.
- Usage monitoring
  - Datamining, strategic alliances
  - "Installed base" ≠ "Active installed base"

Browser as “Soul of the Internet”

- “New layer” (Note Internet architectural triumph!)
- Portal business
  - Early “electronic marketplace”
  - Necessity of strategic alliances
  - “Positive transfers” to customers
- (Temporarily?) Killed R&D efforts in user interfaces

Pluses and Minuses of Network Effects

+ Initial "Metcalf's Law"- based boom

+ Initial boom <u>accelerated</u> by bundling, complementary products, etc.

- Market share ≠ lock in

  high market cap ≠ high switching costs

- Network effects strong for "browser" but weak for any particular browser

Exposed the True Nature of Microsoft

- 1995: Navigator released, MS rushes IE to market
- 1996: Version 3.0 of IE no longer technically inferior (“Openness” and standardization begets commoditization)
- MS exploits advantage with strategic allies (Windows!)
  - Contracts with ISPs to make IE the default
  - Incents OEMs not to load Netscape products
  - Exclusive access to premium content (from, *e.g.*, Star Trek)
- 1998: MS halts browser-based version of these “strategies” under DoJ scrutiny of its contracts with ISPs.

Internet-ERA Anti-Trust Questions are Still Open

- Can consumers benefit from full integration of browser and OS?
- How to prevent “pre-emptive strikes” on potential competitors in the Windows-monopoly universe?
  - (“post-desktop era” technical Solution?)
- Remember: DoJ case is <u>not</u> about protecting Netscape!