CSC2209 Computer Networks

Network Architecture

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Outline

- Overview
  - Protocols and layering
  - Brief Internet tour
- E2E paper
- Internet design philosophy

Protocols and Layering

- We need abstractions to handle all this system complexity

A <u>protocol</u> is an agreement dictating the form and function of data exchanged between parties to effect communication

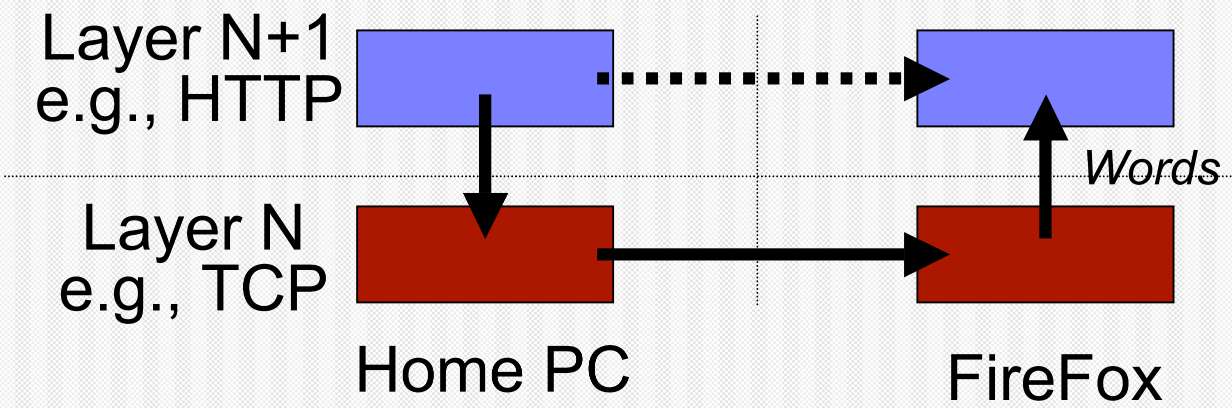
- Two parts:
  - Syntax: format -- where the bits go
  - Semantics: meaning -- what the words mean, what to do with them
- Examples:
  - Ordering food from a drive-through window
  - IP, the Internet protocol
  - TCP and HTTP, for the Web

Protocol Standards

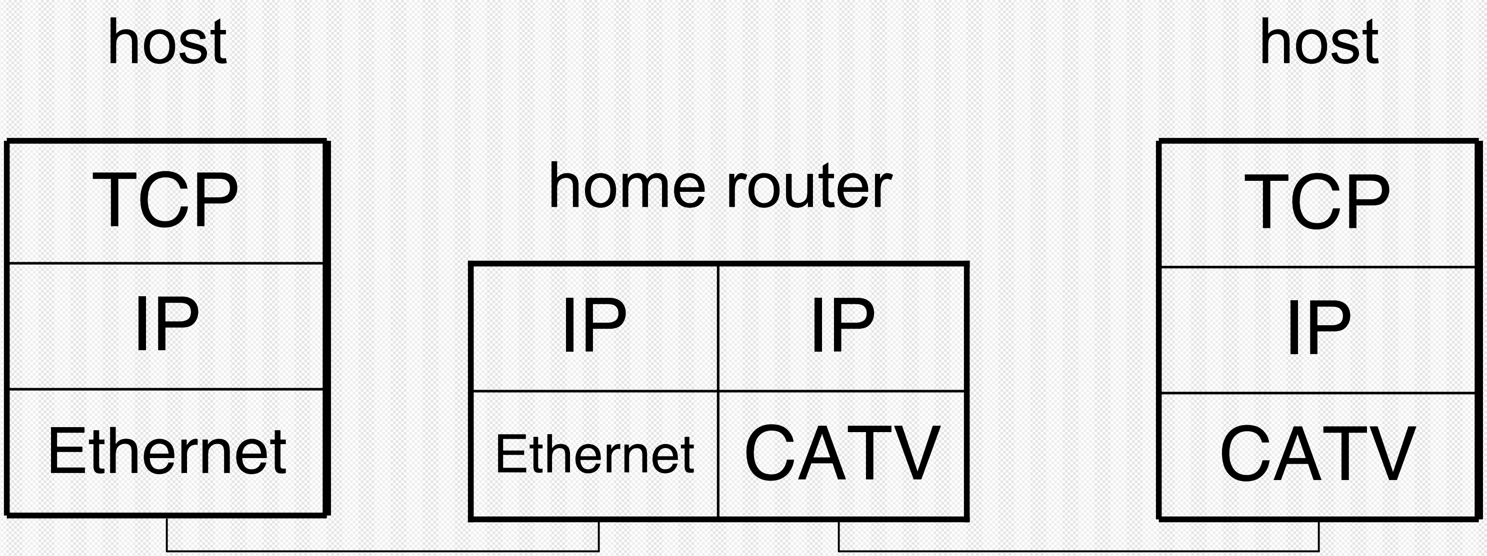
- Different functions require different protocols
- Thus there are many protocol standards
  - E.g., IP, TCP, UDP, HTTP, DNS, FTP, SMTP, NNTP, ARP, Ethernet/802.3, 802.11, RIP, OPSF, 802.1D, NFS, ICMP, IGMP, DVMRP, IPSEC, PIM-SM, BGP
- Organizations: IETF, IEEE, ITU
- IETF (www.ietf.org) specifies Internet-related protocols
  - RFCs (Requests for Comments)
  - "We reject kings, presidents and voting. We believe in rough consensus and running code.", Dave Clark.

Layering and Protocol Stacks

- Layering is how we combine protocols
  - Higher level protocols build on services provided by lower levels
  - Peer layers communicate with each other

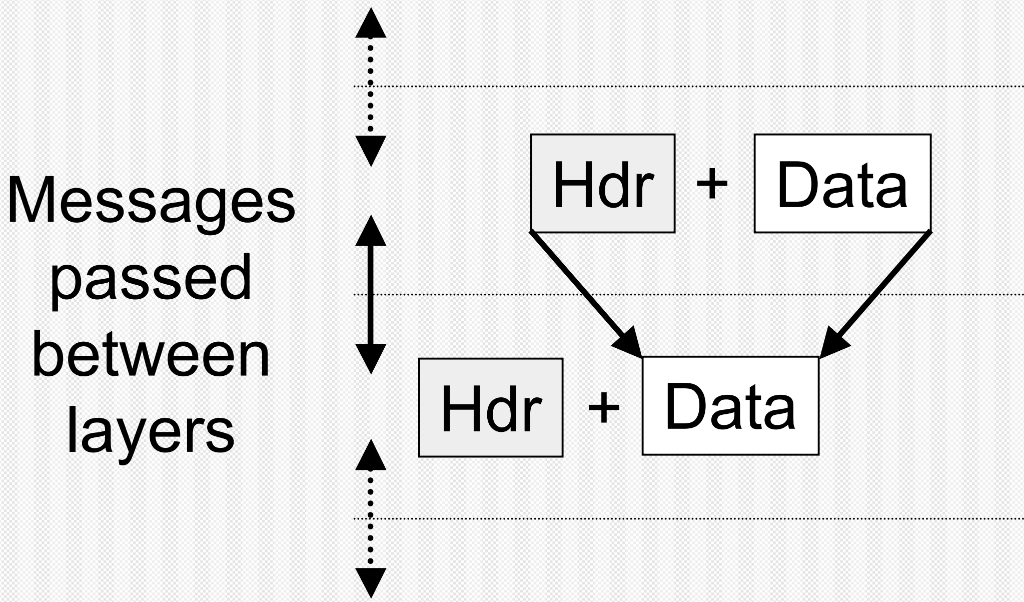


Example – Layering at work



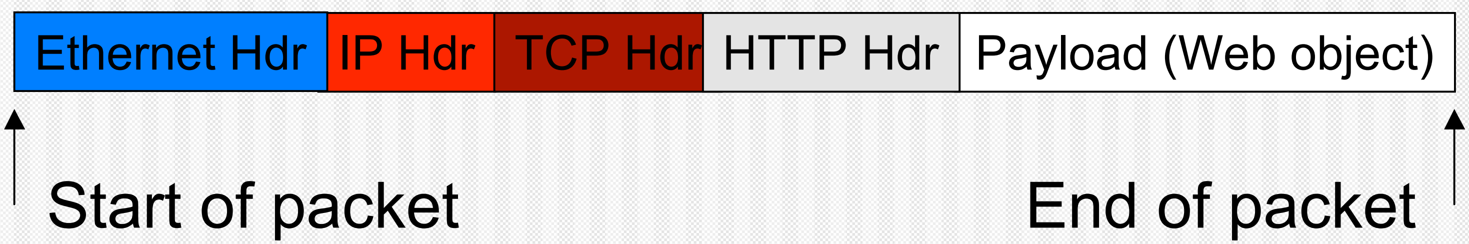
Layering Mechanics

- Encapsulation and de(en)capsulation



A Packet on the Wire

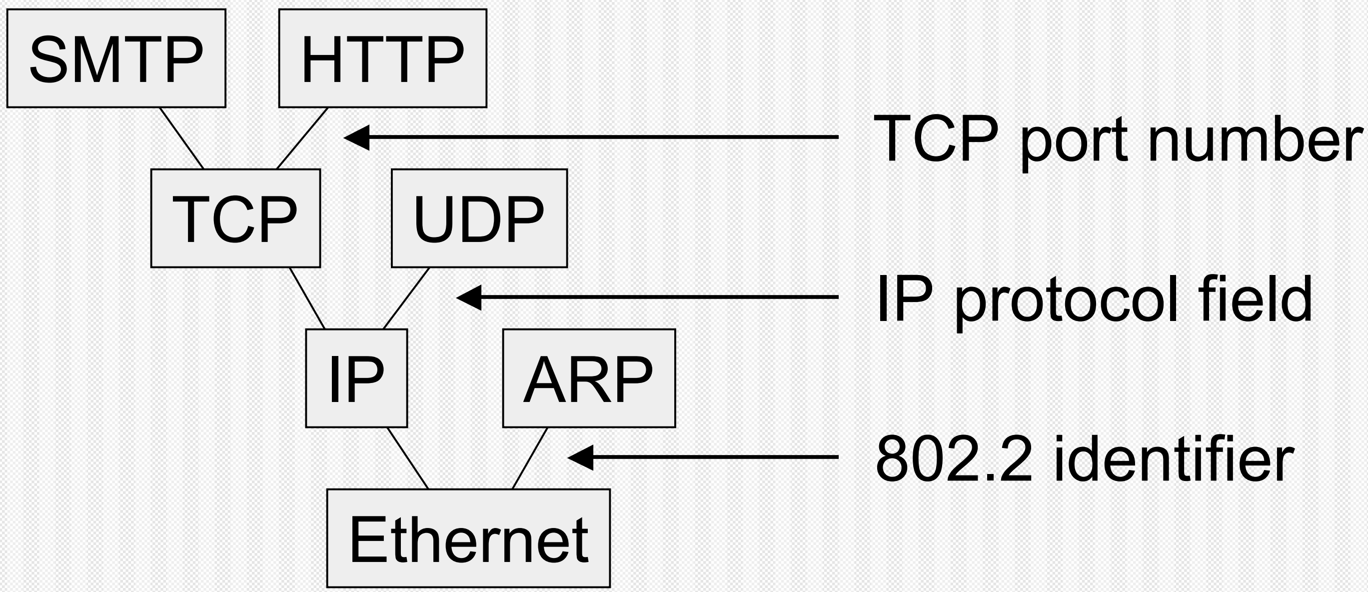
- Starts looking like an onion!



- This isn't entirely accurate
  - ignores segmentation and reassembly, Ethernet trailers, etc.
- But you can see that layering adds overhead

More Layering Mechanics

- Multiplexing and demultiplexing in a protocol graph



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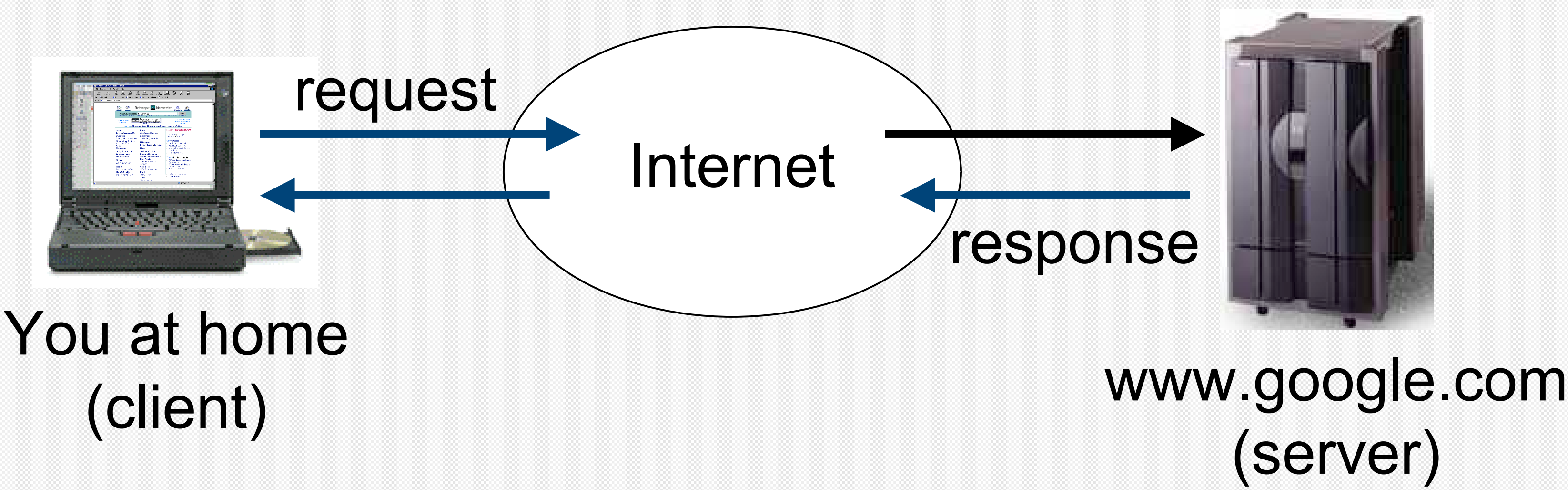
A Brief Tour of the Internet

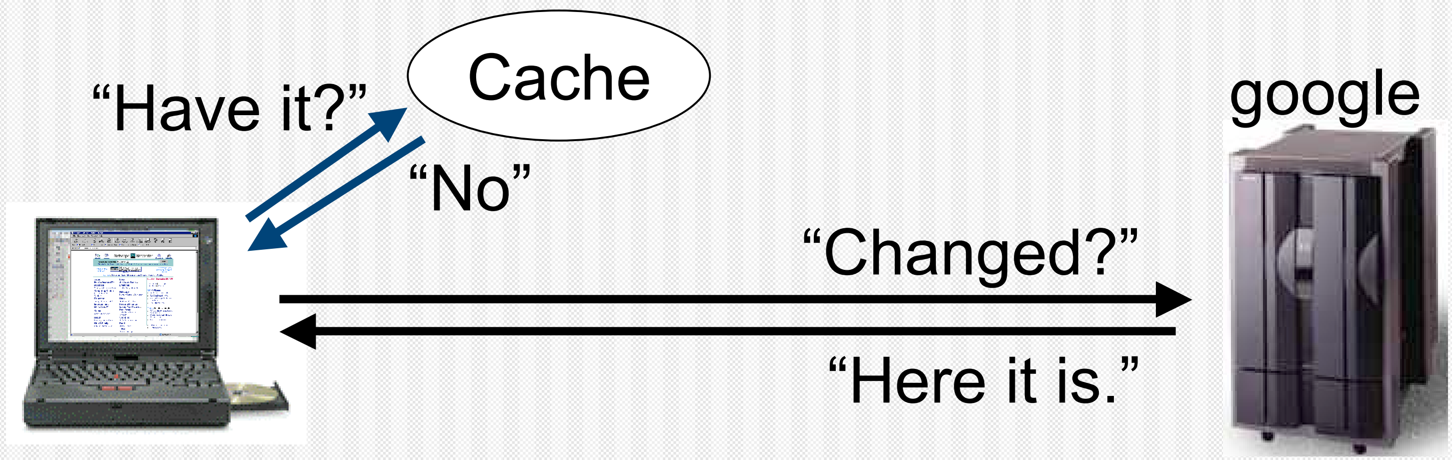
- What happens when you "click" on a web link?



- This is the view from 10,000 ft …

9,000 ft: Scalability

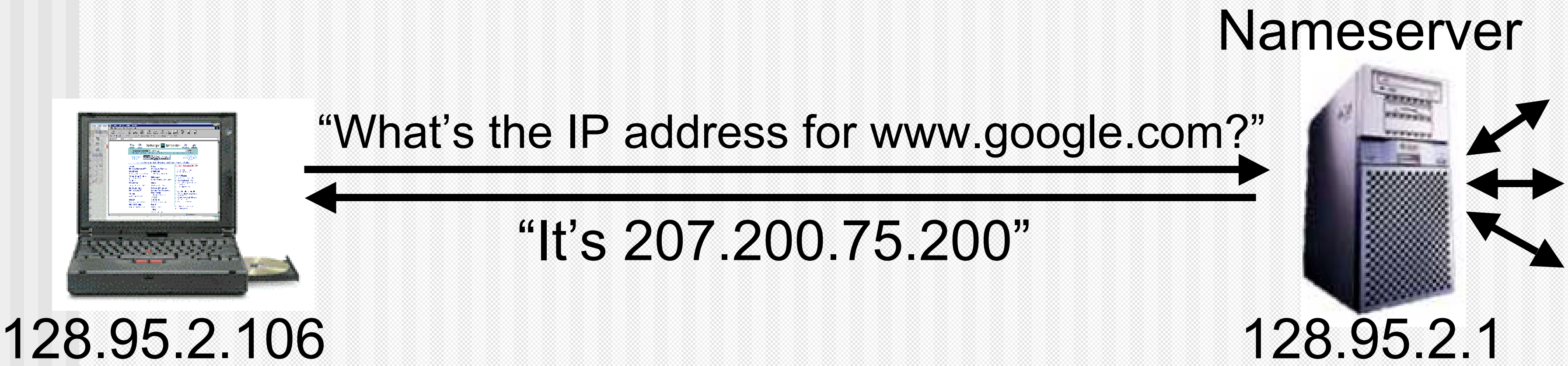
- Caching improves scalability



- We cut down on transfers:
  - Check cache (local or proxy) for a copy
  - Check with server for a new version

8,000 ft: Naming (DNS)

- Map domain names to IP network addresses



- All messages are sent using IP addresses
  - So we have to translate names to addresses first
  - But we cache translations to avoid doing it next time (why?)

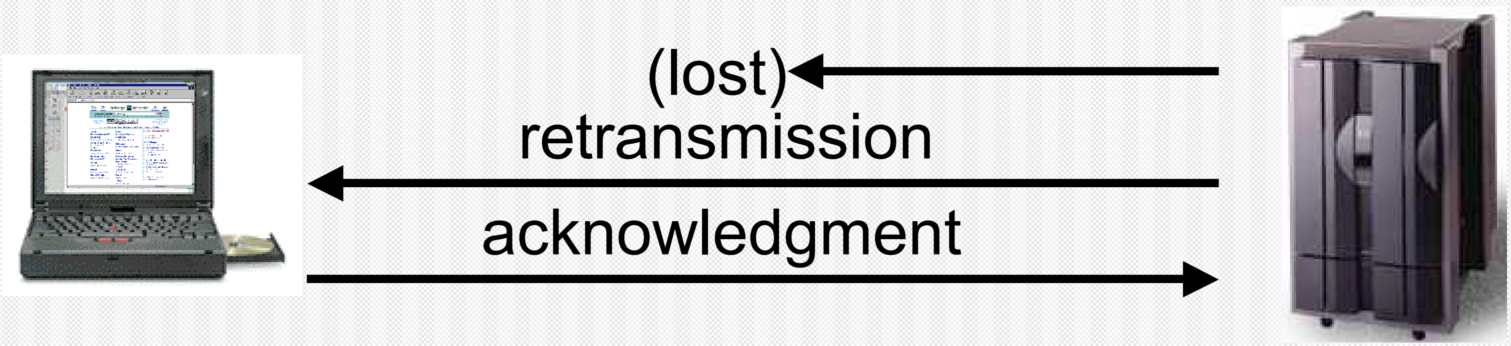
7,000 ft: Sessions (HTTP)

- A single web page can be multiple “objects”

- Fetch each “object”
  - either sequentially or in parallel

6,000 ft: Reliability (TCP)

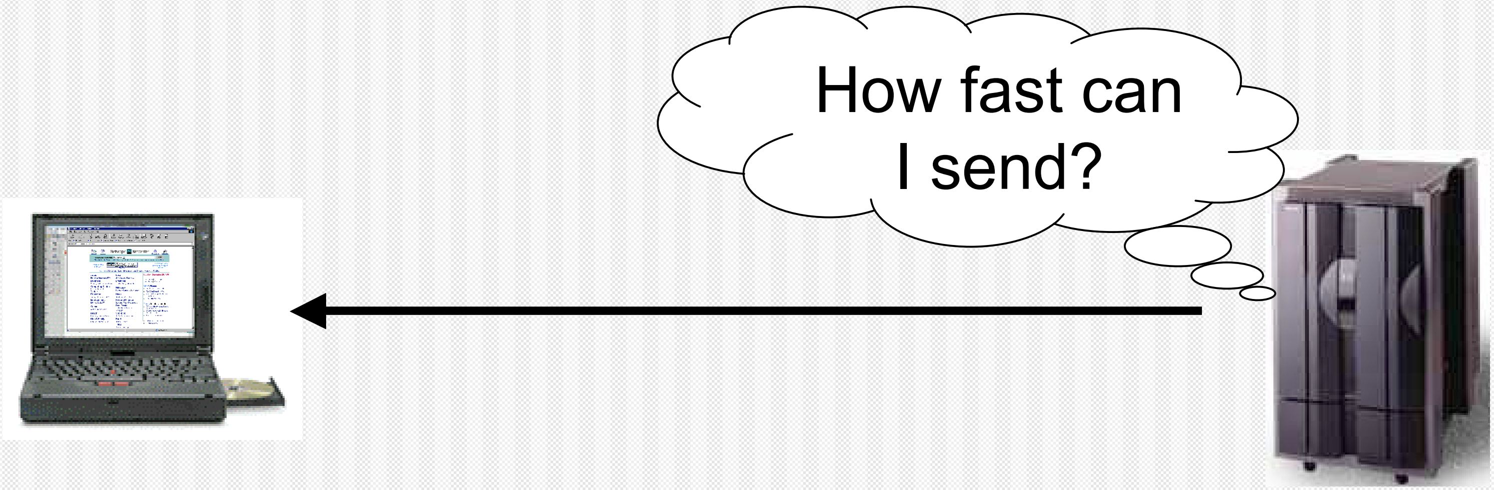
- Messages can get lost



- We acknowledge successful receipt and detect and retransmit lost messages (e.g., timeouts)

5,000 ft: Congestion (TCP)

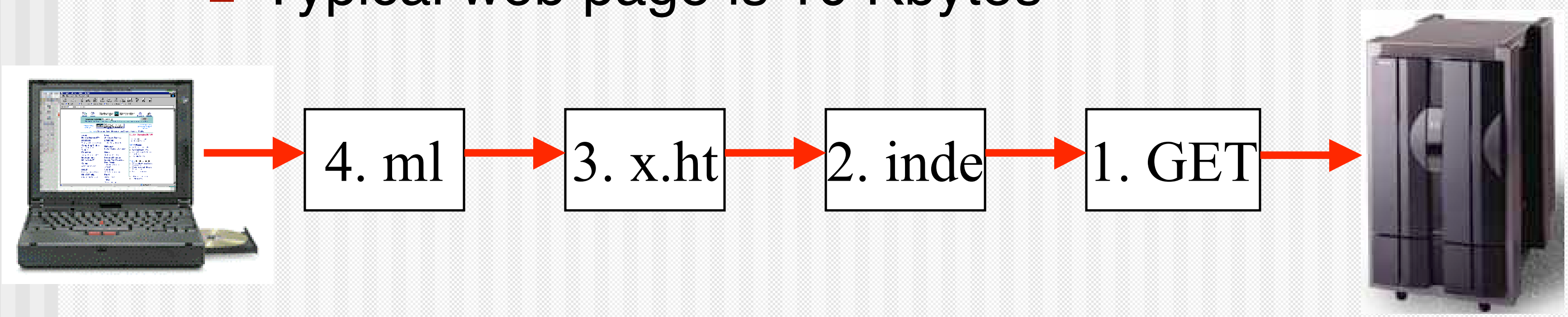
- Need to allocate bandwidth between users



- Senders balance available and required bandwidths by probing network path and observing the response

4,000 ft: Packets (TCP/IP)

- Long messages are broken into packets
  - Maximum Ethernet packet is 1.5 Kbytes
  - Typical web page is 10 Kbytes

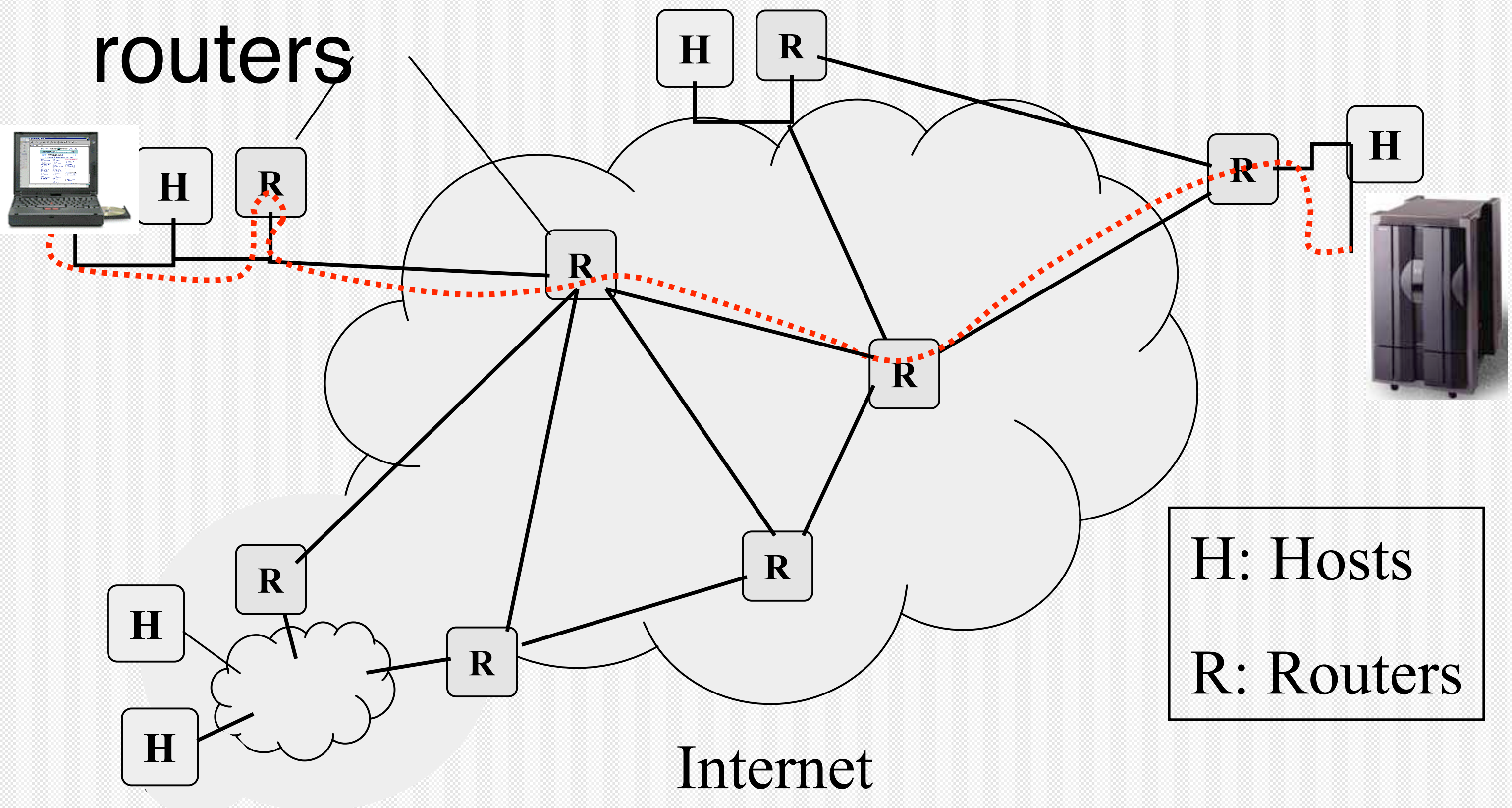


GET index.html

- Number the segments for reassembly

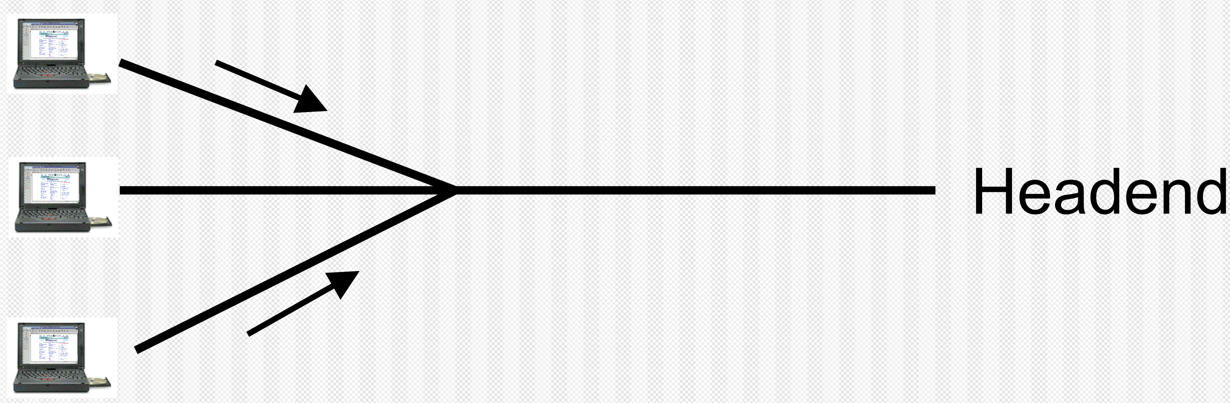
3,000 ft: Routing (IP)

- Packets are directed through many routers



2,000 ft: Multi-access (e.g., Cable)

- May need to share links with other senders



- Poll headend to receive a timeslot to send upstream
  - Headend controls all downstream transmissions
  - A lower level of addressing (than IP addresses) is used … why?

1,000 ft: Framing/Modulation

- Protect, delimit and modulate payload as signal

Sync / Unique	Header	Payload w/ error correcting code

- E.g, for cable, take payload, add error protection (Reed-Solomon), header and framing, then turn into a signal
  - Modulate data to assigned channel and time (upstream)
  - Downstream, 6 MHz (~30 Mbps), Upstream ~2 MHz (~3 Mbps)

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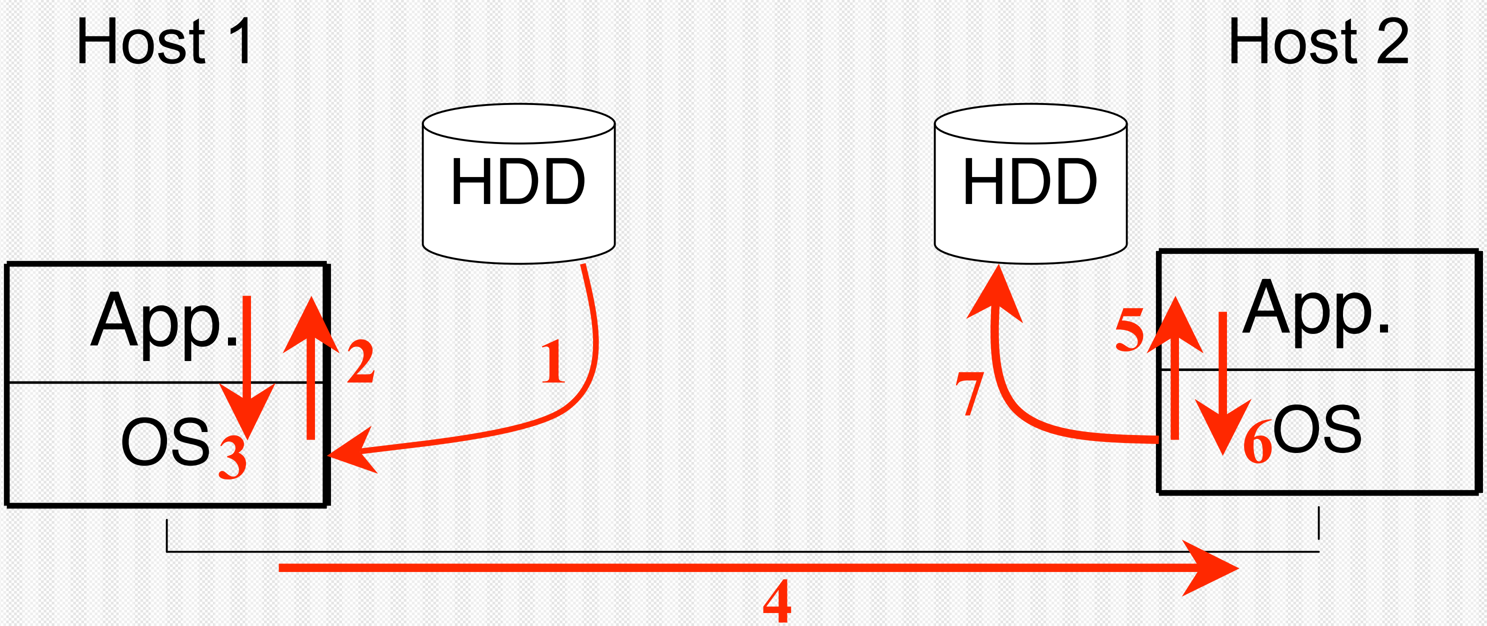
End-to-End Principle

- Question: where should functionality be placed in the network?
- The argument:
  - 1. Functionality should be implemented at a lower level iff it can be implemented **correctly** and **completely**
  - 2. Incomplete functionality could be implemented at a lower level for performance

Example – File transfer



If not done E2E, checks must be done at every single step

Performance Optimizations

- Functionality at lower layer can enhance performance
  - Could come in very useful
- E.g. path with 15 hops
  - Prob of packet loss is 0.0001% per hop
    - Prob of e2e loss is 0.0015%
  - Prob of packet loss is 1% per hop
    - Prob of e2e loss is 14%

Optimization Trade-Off

- Higher layers have semantic information about the data
  - HTML text bits more important than IMG in the presence of massive loss
- Lower layers are “closer” to the data
  - They are the ones dealing with loss, bandwidth issues, corruption, etc…
- This trade-off is one of the main driving factors behind networking research

Additional Examples

- Networking
  - Reordering
  - Retransmission
  - Supressing duplicate messages
- Security
  - WEP

E2E Final Thoughts

- What's the consensus?
- Do these violate E2E?
  - Proxy caches
  - NATs

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Design Philosophy of DARPA

- Context:
  - Multiple research and military networks
  - How can we connect them?
  - Before LANs existed

Main Internet Goal

- Multiplexed utilization of existing interconnected networks
  - i.e., functionality
- Minimal assumptions underlying networks
  - No support for broadcast, multicast, real-time
- Packet switched, store-and-forward
- “Gateways” interconnect networks

This is a hard problem

- Main reason: heterogeneity
  - Addressing: each network different addressing scheme
  - Bandwidth: dialups to dedicated links
  - Latency: seconds to nanoseconds
  - Packet size
  - Loss rates
  - Service guarantees

IP: Common Substrate

- Convert all formats to IP
  - IP over everything
- Alternative?

Secondary Goals

- Survivability in the face of failure
- Support for multiples types of service
- Support for a variety of networks
- Distributed management of resources
- Cost effectiveness
- Easy addition of new hosts
- Accounting of resource usage

Survivability Implications

- No hard-state in the middle
  - Routers are stateless
  - Endpoints responsible for failure recovery\
    - "fate-sharing"
- Host machines are trusted
  - Must implement protocols correctly
  - Easy to be malicious
- Problems:
  - Hard to detect cause of failures
  - Hard to prevent hosts from becoming malicious
    - Much more complex functionality than routers

Types of Service

- Common denominator: IP
- Reliable delivery TCP
- Unreliable delivery UDP
- Real-time delivery: ???
- Multicast: ???
- Broadcast: ???

Network Variety

- Internet successful in part due to so little assumptions of the underlying network
  - Topology: point-to-point, bus, ring, radio
  - Characteristics: dial-up, fiber, etc…
- Does not mean IP is efficient:
  - ATM uses 53 byte cells, poor fragmentation for IP packets

Other Goals

- Distributed management
  - Different parts of network owned, controlled, and managed by different entities
  - Hard to get consensus
  - What does optimize mean in this context?
- Cost-effective
  - Routers are cheap compared to POTS
  - Efficient bandwidth use
  - But much more unreliable than POTS switches

Other Goals (2)

- Attachment costs
  - Success if you look at costs per user (millions of users)
  - Misbehaving hosts due to bugs
    - Think Wal-Mart vs. Harrods
- Accountability
  - Who pays for all of this
  - What is the economic model
  - Hot religious debate

Questions

- Did the Internet realized its vision?
- What is different about the Internet today?
- What are the limitations of Internet design

- The Internet has evolved very much like a research project:
  - Many iterations, trial-and-error

Summary

- Layering: key technique for managing complexity in systems
- Key question:
  - Where to put functionality
- E2E: put functionality at the highest level where service is provided
  - Use lower-levels for optimizations
  - Trade-offs btw. complexity and performance
- Internet design points
  - Internetworking: minimal assumptions about networks
  - Fate-sharing: smart hosts, dumb core
  - All higher services built on top of IP

Next class

- Papers review
  - *Measured Ethernet: Myths and Relity.* Boggs, Mogul, and Kent. Sigcomm 88.
  - *Revised ARPANET routing metric.* Khanna and Zinky. Sigcomm '89.
- Reviews due at 11am