Protocols and Layering

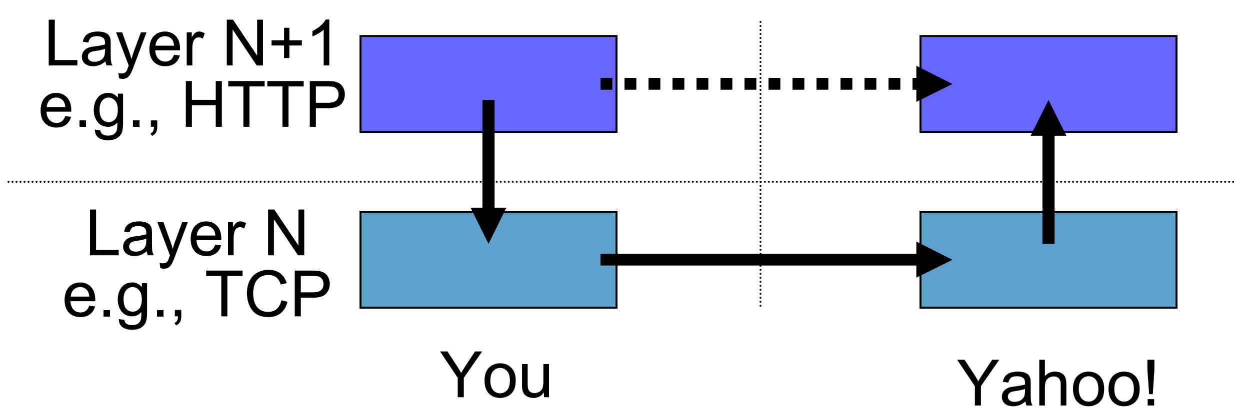
- We need abstractions to handle all this system complexity

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:
  - IP, the Internet protocol; TCP and HTTP, for the Web
  - You can make up your own

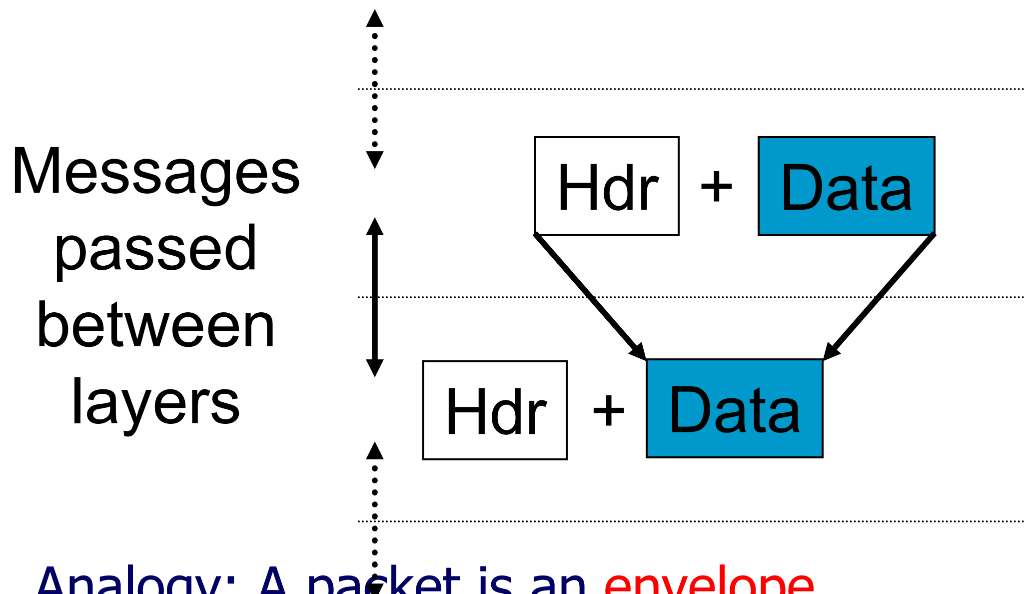
Layering and Protocol Stacks

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



Layering Mechanics

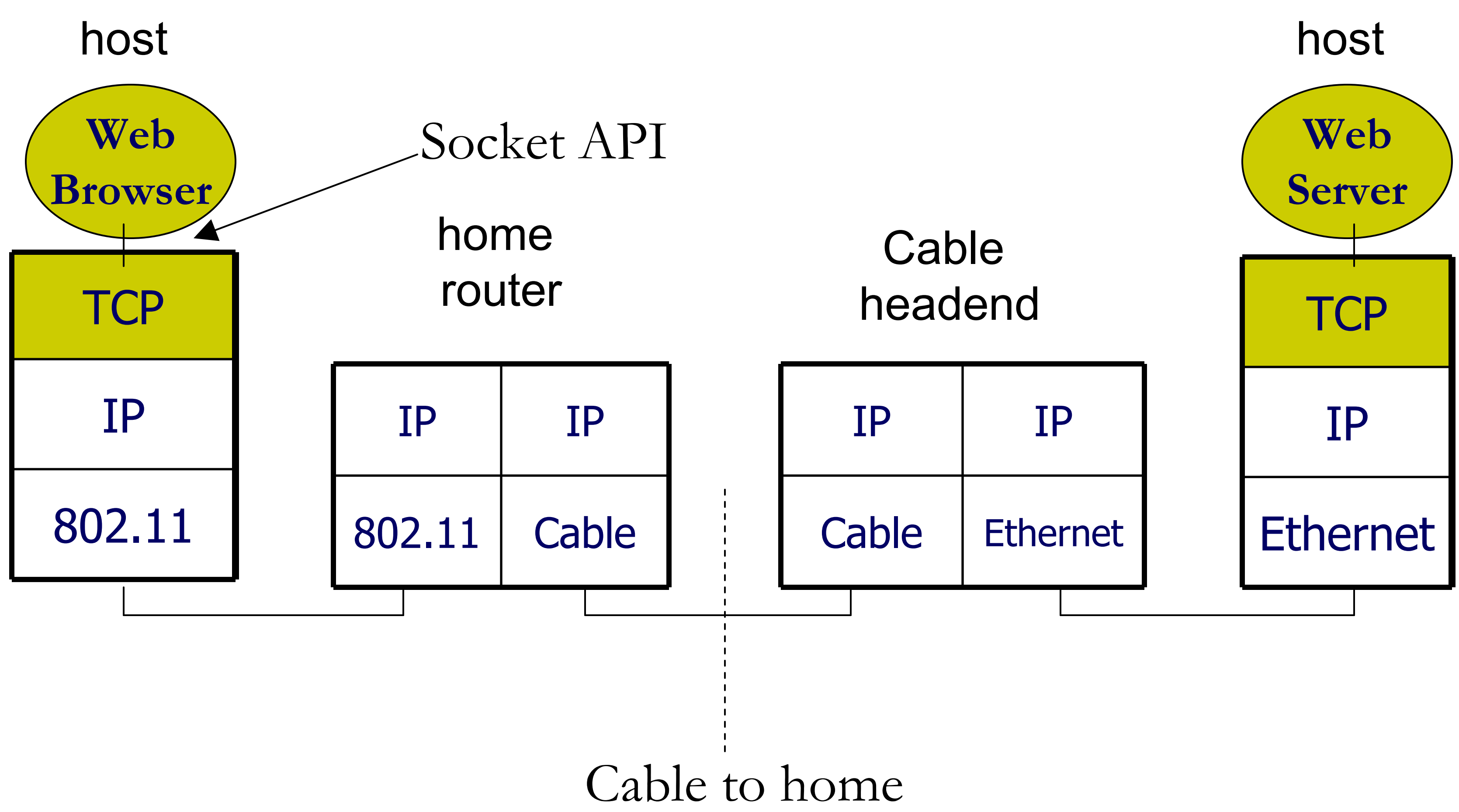
- Encapsulation and de(en)capsulation



Analogy: A packet is an envelope.

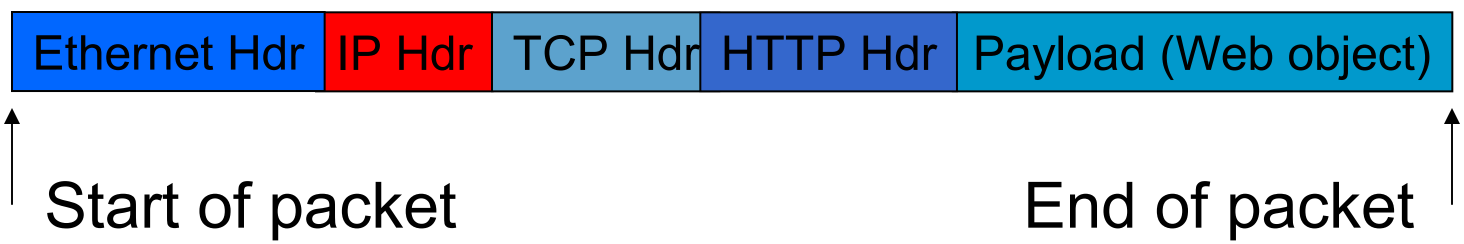
- What's written on the outside is the header
- What's contained on the inside is the payload
- The payload may, itself, be another envelope
- Each layer understands (and acts on) the writing on the outside, but doesn't understand what it contains – just delivers it.

Example – Layering at work



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
  - one protocol’s header is another protocol’s data

What's Inside a Packet (detailed view)

Ethernet Header:	FROM=00:30:65:0a:ea:62, TO=00:30:64:9a:11:22, SIZE=200,…
IP Header:	FROM=128.95.1.32, TO=28.2.5.1, SIZE=200-SIZEOF(Ehdr)
TCP Header:	FROM=Port 5000, TO=Port 80, Byte#=23, SIZE=200-SIZEOF(Ehdr)-SIZEOF(IPHdr)
HTTP Hdr:	HTTP v.1.0, Internet Explorer v5.1,…
Good Stuff	GET http://www.google.com

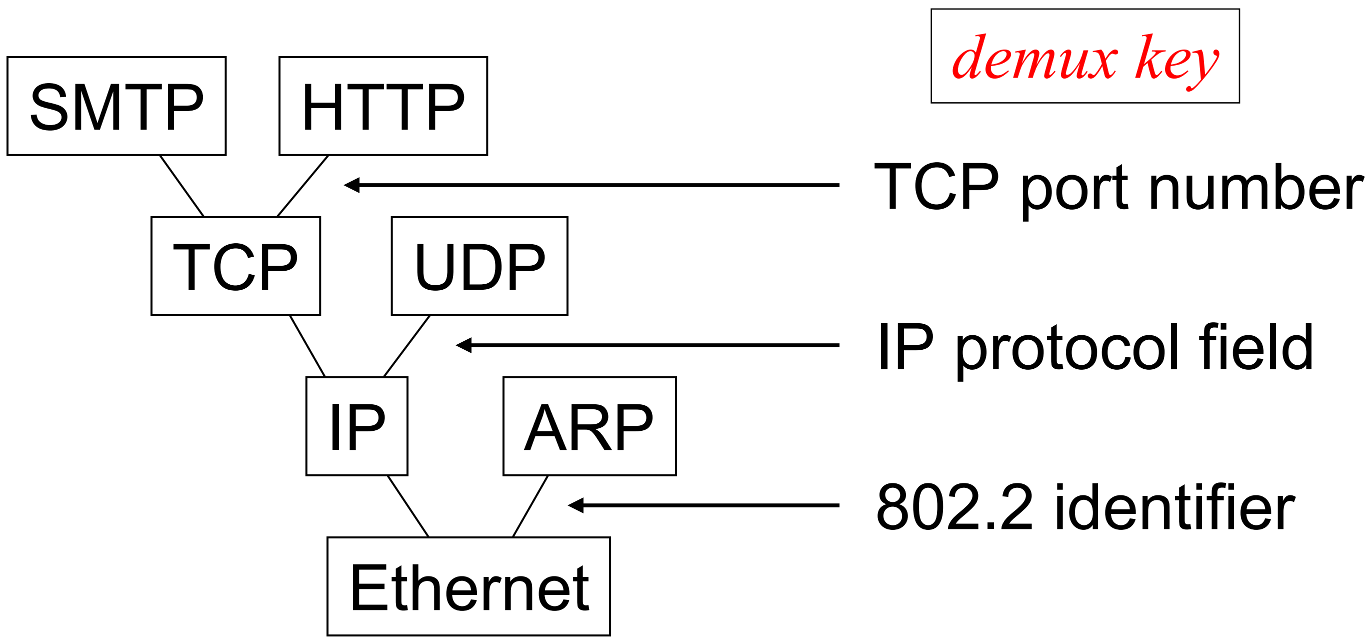
Top (start)

Bottom (end)

Read rows
Left to Right

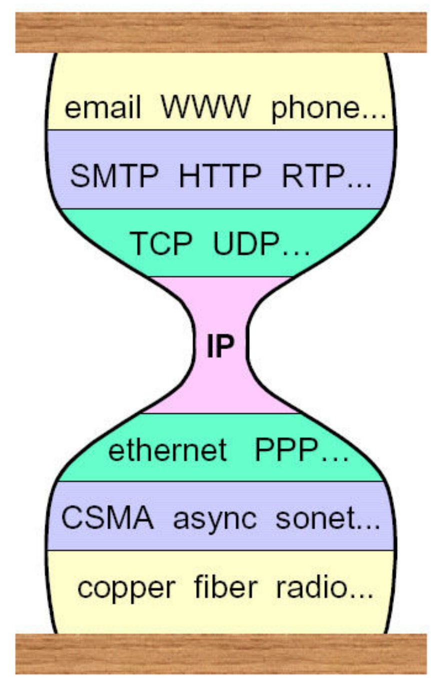
More Layering Mechanics

- Multiplexing and demultiplexing in a protocol graph



Internet Protocol Framework

Model	Protocols
Application	Many (HTTP,SMTP)
Transport	TCP / UDP
Network	IP
Link	Many (Ethernet, ...)



The “narrow waist”

OSI "Seven Layer" Reference Model

Application
Presentation
Session
Transport
Network
Link
Physical

Their functions:

- Up to the application
- Encode/decode messages
- Manage connections
- Reliability, congestion control
- Routing
- Framing, multiple access
- Symbol coding, modulation

Protocol Standards

- Different functions require different protocols
- A "standard" protocol is one that has been carefully specified so that different implementations can interoperate.
  - Standardized: screws, batteries
  - Not standardized: Appliances, furniture
- 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.

What goes in a standard?

- Is it, e.g., for 802.11:
  - A) The messages exchanged and their meaning
  - B) The services that the higher layer can invoke
  - C) What you need to know to implement it well
  - D) All of the above.

Key Design Question
What functionality goes in which layer?

- The "End to End Argument" (Reed, Saltzer, Clark, 1984):

  Functionality should be implemented at a lower layer only if it can be correctly and completely implemented. (Sometimes an incomplete implementation can be useful as a performance optimization.)

- Example: reliability needs to be done by the endpoints for correctness; add it over individual links just to help performance

- Tends to push functions to the endpoints, which has aided the extensibility of the Internet.

Pros of the End-to-End principle

- Fosters innovation by *anyone* without being a “big player”
  - The middle of the network is (historically) hard to change

- Don’t impose functionality on applications that don’t need it
  - E.g., VoIP doesn’t *want* reliability inside the network

- Favors simplicity. Complex middle = complex interface.
  - Can improve robustness
  - Plus many complicated things fail ..

Cons of the End-to-End principle

- Doesn't work well with security, e.g., firewalls
  - Articulated in a time when we trusted each other ☺
- End-points are also hard to change *en masse*
  - New versions of TCP can't "just be deployed"
  - Leads to middleboxes in the Internet
- Loss of efficiency or duplication of effort if taken literally
  - Just relax a bit …