CSE/EE 461
Protocols and Layering

Protocols

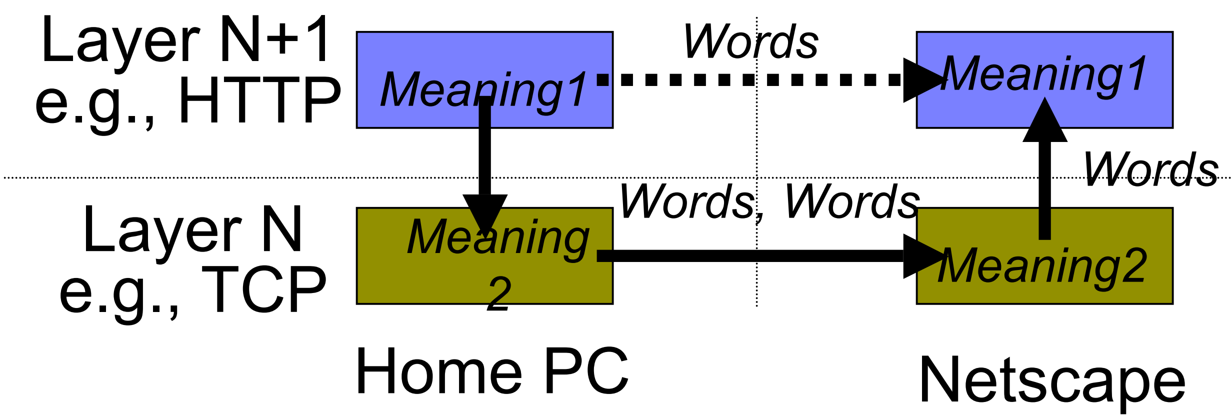
- We need abstractions to handle communication system complexity
- *A protocol is an agreement dictating the form and function of data exchanged between parties to affect communication*
- Two parts:
  - Syntax: Words.
    - where the bits go
  - Semantics:Meaning
    - what the words mean, what to do with them
- Examples:
  - Ordering pizza
  - International relations
  - IP, the Internet protocol
  - TCP and HTTP, for the Web

Protocol Standards

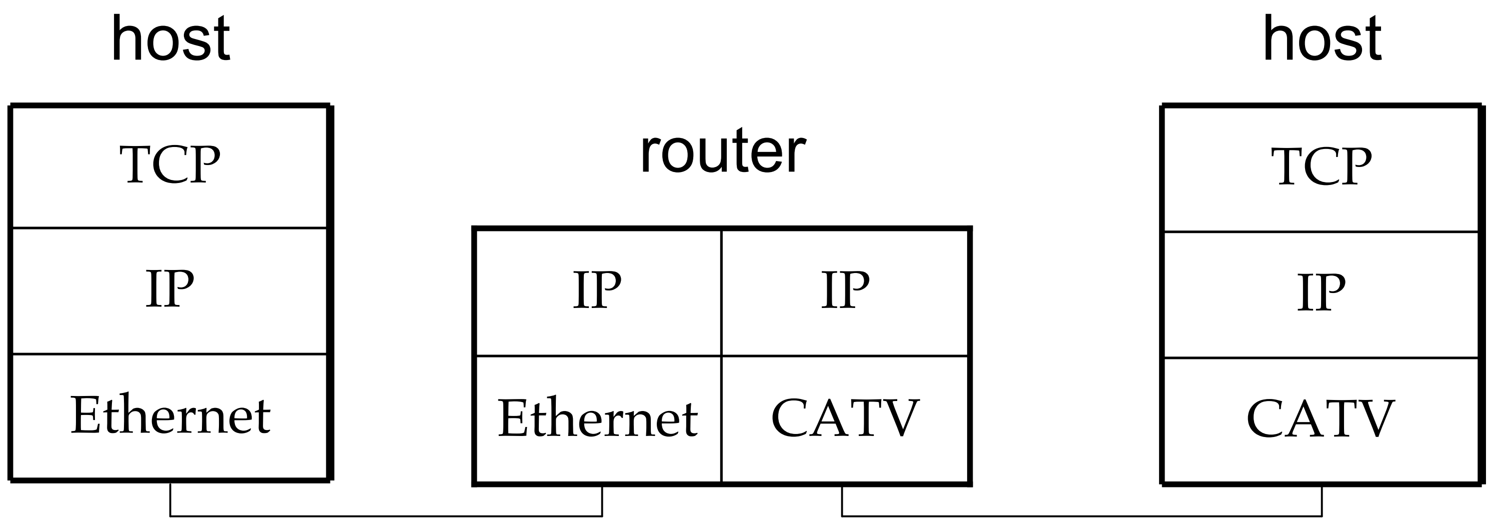
- Different functions require different protocols
- Thus there are many protocol standards
  – E.g., IP, TCP, UDP, HTTP, DNS, FTP, SMTP, NNTP, ARP, Ethernet/802.3, 802.11, RIP, OPSF, 802.1D, NFS, ICMP, IGMP, DVMRP, IPSEC, PIM-SM, BGP, …
- Organizations: IETF, IEEE, ITU
- IETF (www.ietf.org) specifies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

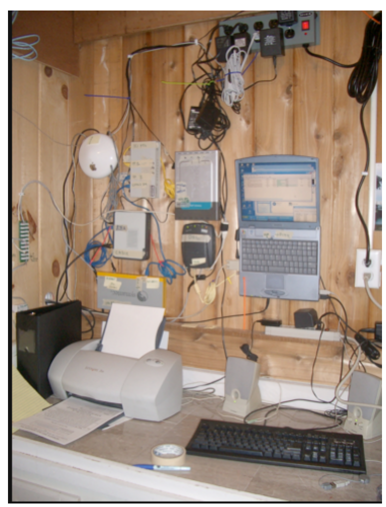
Layering and Protocol Stacks

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



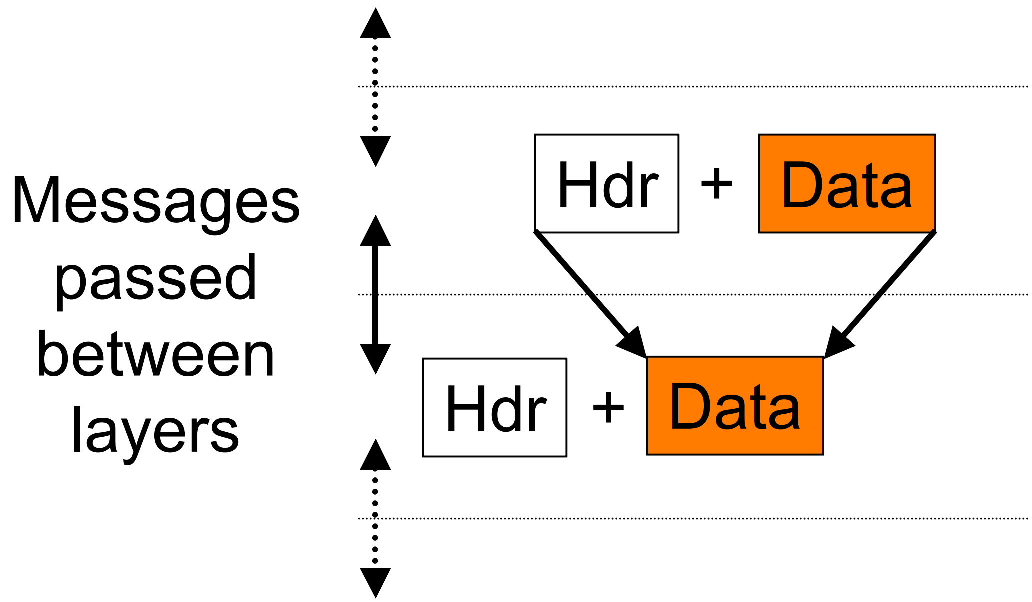
Example – Layering at work





Layering Mechanics

- Encapsulation and deencapsulation



Speaking Abstractly

- Suppose you have something to express
- Must have an utterance (**message**)
  - Must choose a language (**protocol**) with which to utter
  - Must identify a person (**destination**) to whom to utter
  - Must identify self (**source**) in order to receive a response
  - Must include some control information “outside” the utterance
- Use the PROTOCOL to emit the MESSAGE from the SOURCE to the DESTINATION with the CONTROL information
- All the way down

Abstract Send

- Think “M”, S and D.
- Call Protocol P with Message M to be sent from endpoint S to endpoint D
  - P_down(S, D, M)
- Protocol P adds header information to M
  - H = [S, D, C, P]
    - P is the type of protocol; used on delivery
    - S,D endpoints
    - C is control information.
      - S,D influence
  - M’ = [H,M]
- Protocol P invokes a new protocol P’ that can be used to communicate with P
  - P’_down(S’, D’, M’)
    - With endpoints S’= “this” end of P’, D’=“that” end of P’
- Continue until call chain terminates
  - Including just “dropping the message”

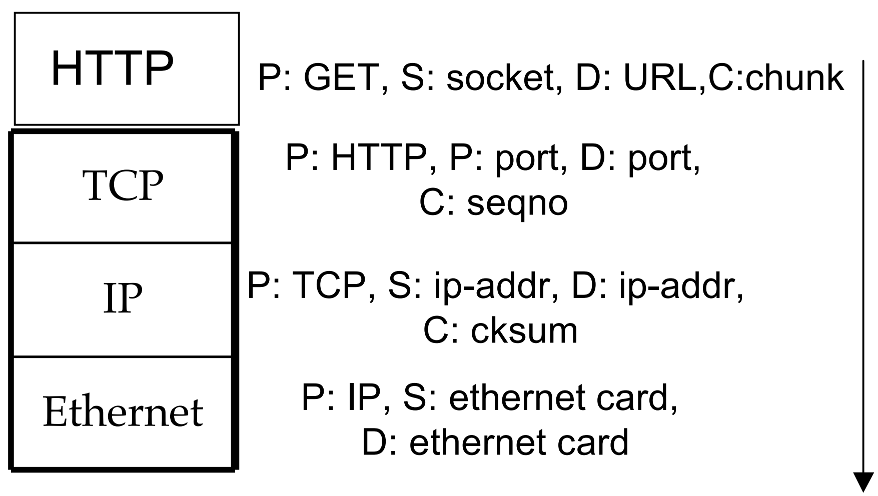
Abstract Deliver

- P_up is a request from a lower level protocol to deliver a message using protocol P
- P_up(M′)
  - M′ = [H, M]
  - Extract H = [S, D, C, P′]
  - Process C accordingly (S, D are important here)
  - Invoke (Choose_P_up(P′))(M)
- Type identifier for P allows multiple protocols to “ride on top” of
    - Choose P_up method based on type of next level up protocol.

For example

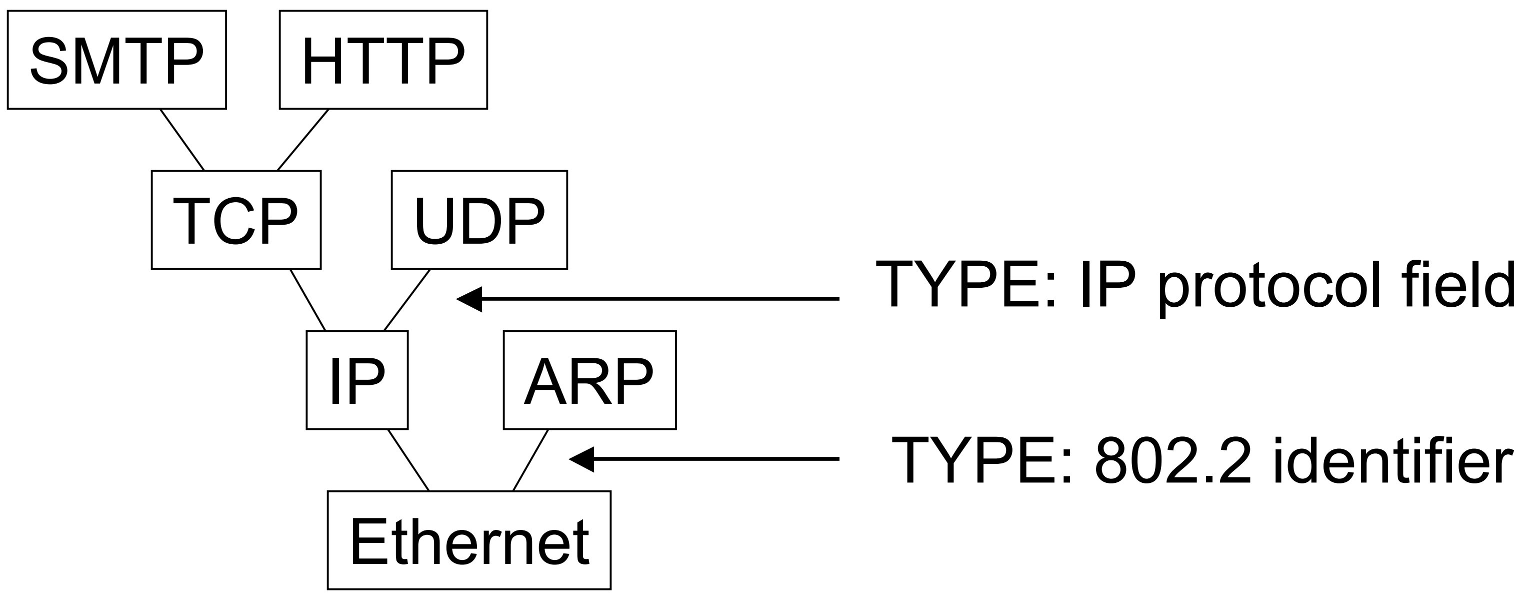
- Sample chains
  - HTTP->TCP->IP->ETHERNET
  - DNS->UDP->IP->FIBER

Type information (P) allows for lower level to “route” to higher level, e.g. lower level delivery reads a field written by a higher level send.



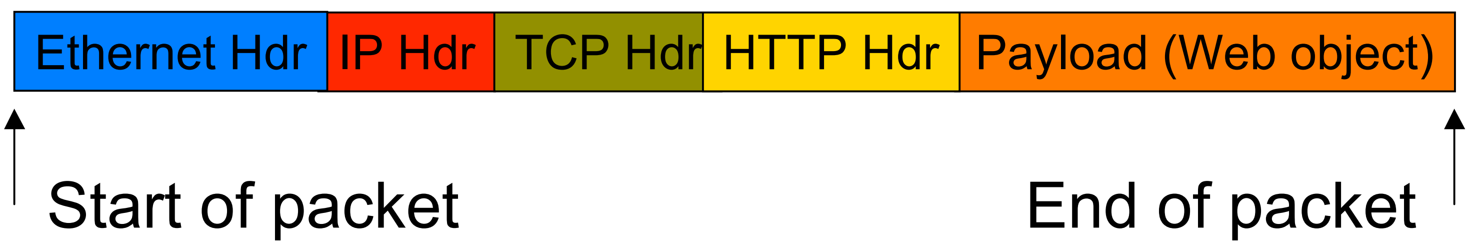
Protocol Graphs

- Multiplexing and demultiplexing in a protocol graph

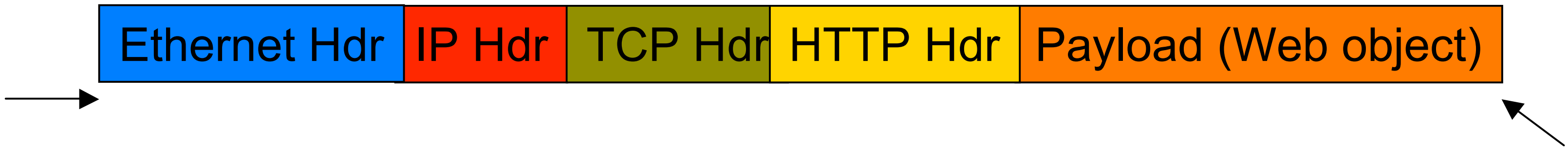


A Packet on the Wire

- Starts looking like an onion!

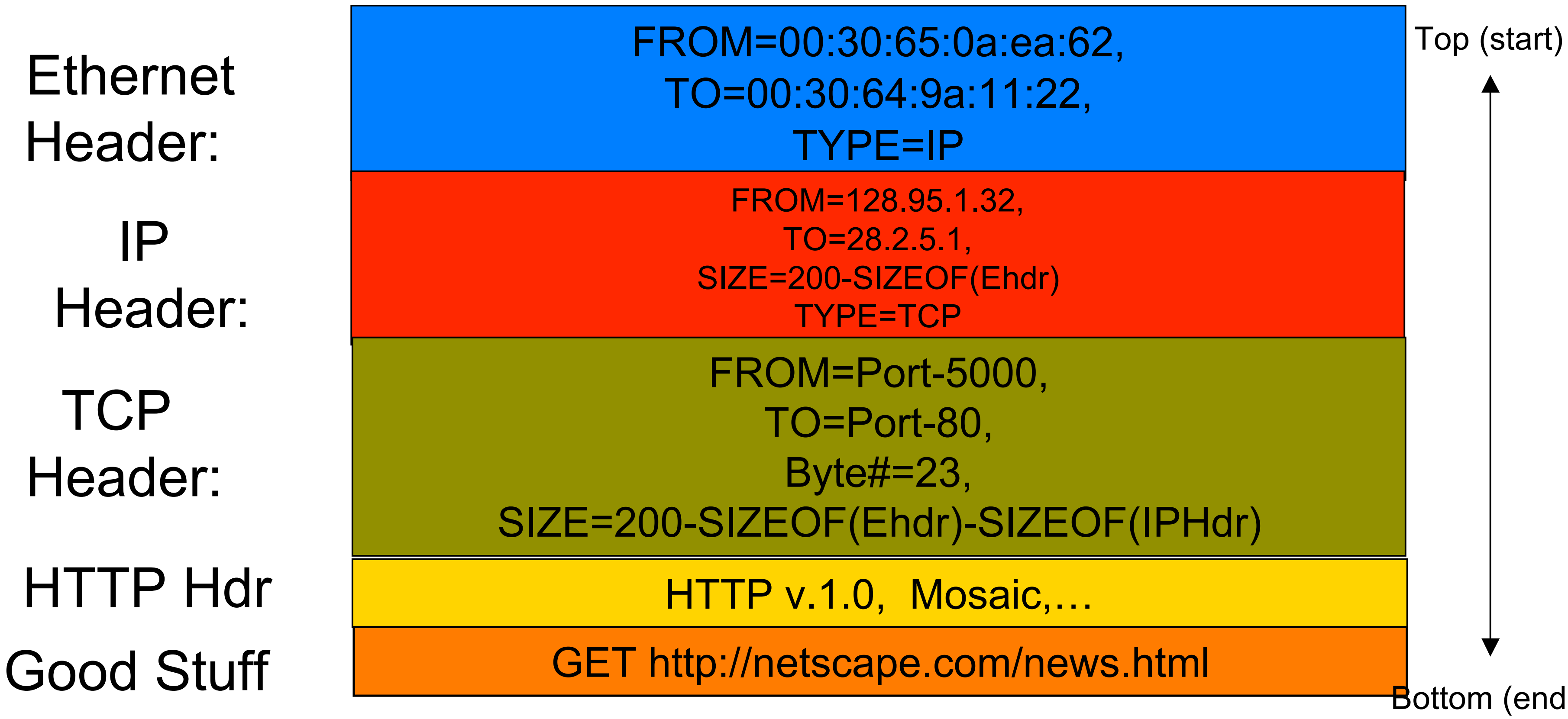


- This isn't entirely accurate
  - ignores segmentation and reassembly, Ethernet trailers, etc.



What’s Inside a Packet

Last byte



A Protocol is an ENCAPSULATION.

One protocol’s *payload* may be another encapsulated protocol.

Deliver vs. Receive

- Networks deliver messages asynchronously
- When a message arrives, some program must service it
  - Interrupt handler
    - Synchronous with message delivery
  - OS Protocol
    - Asynchronous with message delivery
  - Application protocol
    - Asynchronous with message delivery
- Buffering is used to store messages between when they are delivered and when they are received (read) by an OS protocol or an Application protocol
  - Eg, recvfrom can block
    - Blocks if message has not yet arrived.
    - Does not block if message has already arrived and has been buffered by OS

OSI/Internet Protocol Stacks

Key Question: What functionality goes in which protocol?

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.)*
- Tends to push functions to the endpoints, which has aided the transparency and extensibility of the Internet.

OSI "Seven Layer" Reference Model

- Seven Layers:

Application
Presentation
Session
Transport
Network
Link
Physical

Their functions:

- Your call
- Encode/decode messages
- Manage connections
- Reliability, congestion control
- Routing
- Framing, multiple access
- Symbol coding, modulation

Internet Protocol Framework

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

Key Concepts

- Protocol layers are the modularity that is used in networks to handle complexity
- Structure of a protocol layer is well-defined
- The Internet/OSI models give us a roadmap of what kind of function belongs at what layer