Lecture 3
Protocol Stacks and Layering

Hui Zhang
School of Computer Science
Carnegie Mellon University

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What is a Communication Network? (from end-system point of view)

- Network offers a service: move information
  - » Bird, fire, messenger, truck, telegraph, telephone, Internet …
  - » Another example, transportation service: move objects
    - – Horse, train, truck, airplane ...
- What distinguish different types of networks?
  - » The services they provide
- What distinguish the services?
  - » Rich of the services
  - » Latency
  - » Bandwidth
  - » Loss rate
  - » Number of end systems
  - » Service interface
  - » Other details
    - – Reliability, unicast vs. multicast, real-time, message vs. byte …

What is a Communication Network? Infrastructure Centric View

- Electrons and photons as communication medium
- Links: fiber, copper, satellite, …
- Switches: electronic/optic, crossbar/Banyan
- Protocols: TCP/IP, ATM, MPLS, SONET, Ethernet, X.25, FrameRelay, AppleTalk, IPX, SNA
- Functionalities: routing, error control, flow control, congestion control, Quality of Service (QoS)
- Applications: telephony, FTP, WEB, X windows, ...

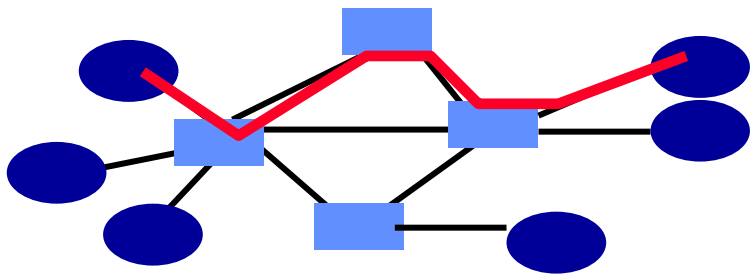
How to Draw a Network

Building block: The Links

- **Electrical questions**
  - » Voltage, frequency, …
  - » Wired or wireless?
- **Link-layer issues: How to send data?**
  - » When to talk – can everyone talk at once?
  - » What to say – low-level format?
  - » Stay tuned for lecture 5
- **Okay… what about more nodes?**

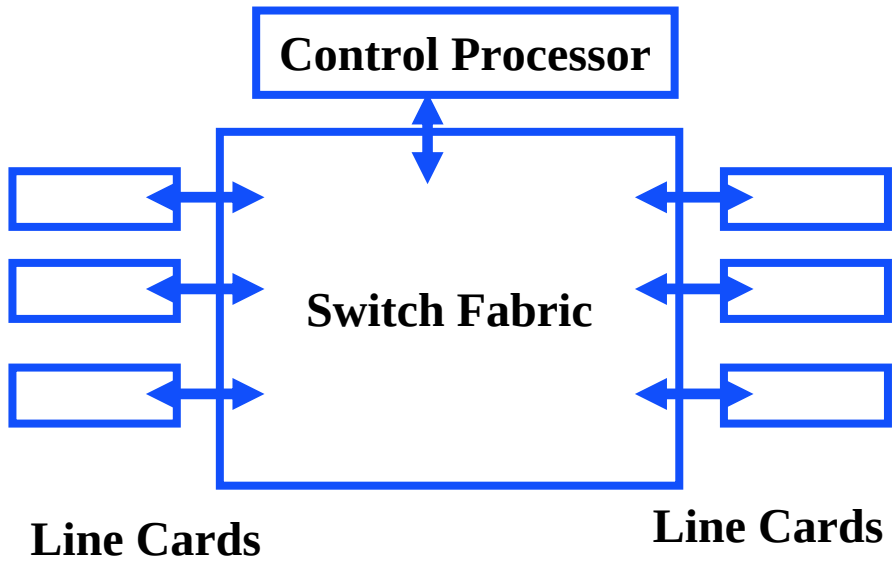
What Is In a Network?

- End system
- Switch (router)
  - » Access switch
  - » Core switch
- Access line: linking switch and end systems
- Trunk line
  - » Between switches
  - » Multiple connections simultaneously
    - – Multiplexing/demultiplexing



What Does Switch Do?

- **Multiplexing: multiple demands X use a shared resource Y**
  - » multiple voice circuits on a shared trunk link
  - » Multiple applications on top of a shared protocol stack
- **Switching**
  - » Packet switching
  - » Circuit switching
- **Tradeoffs?**

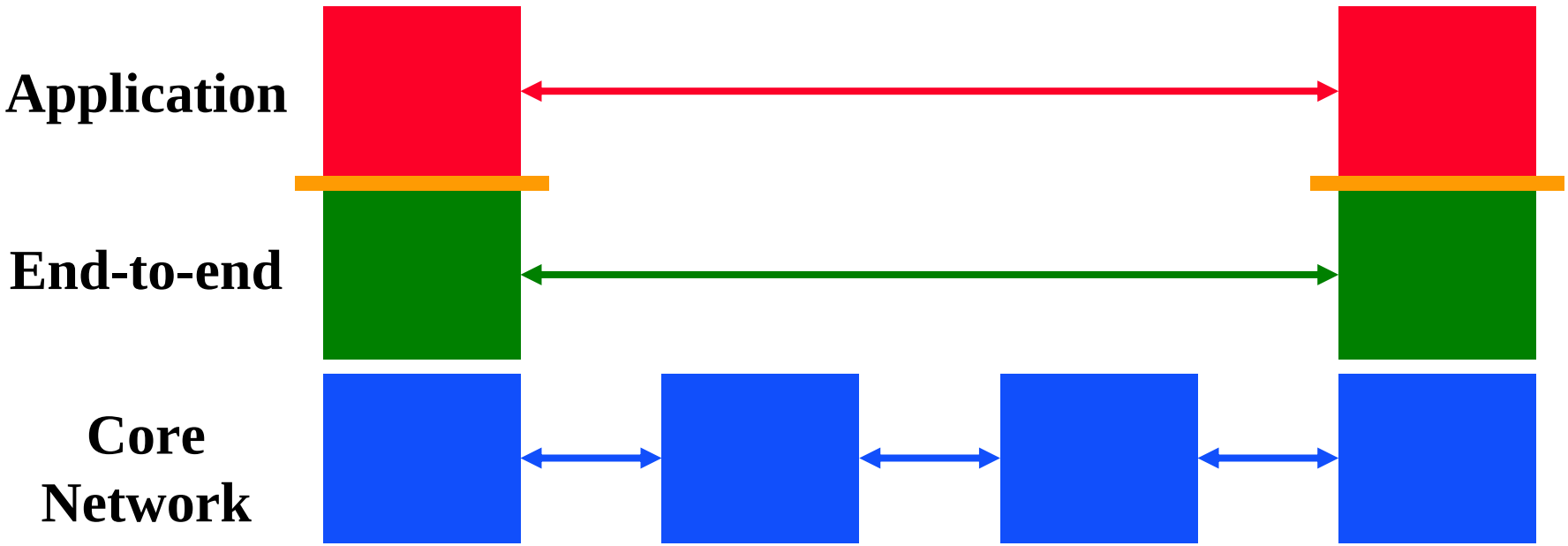


Packet vs. Circuit Switching

- **Packet-switching: Benefits**
  - » **Ability to exploit statistical multiplexing**
  - » **More efficient bandwidth usage**

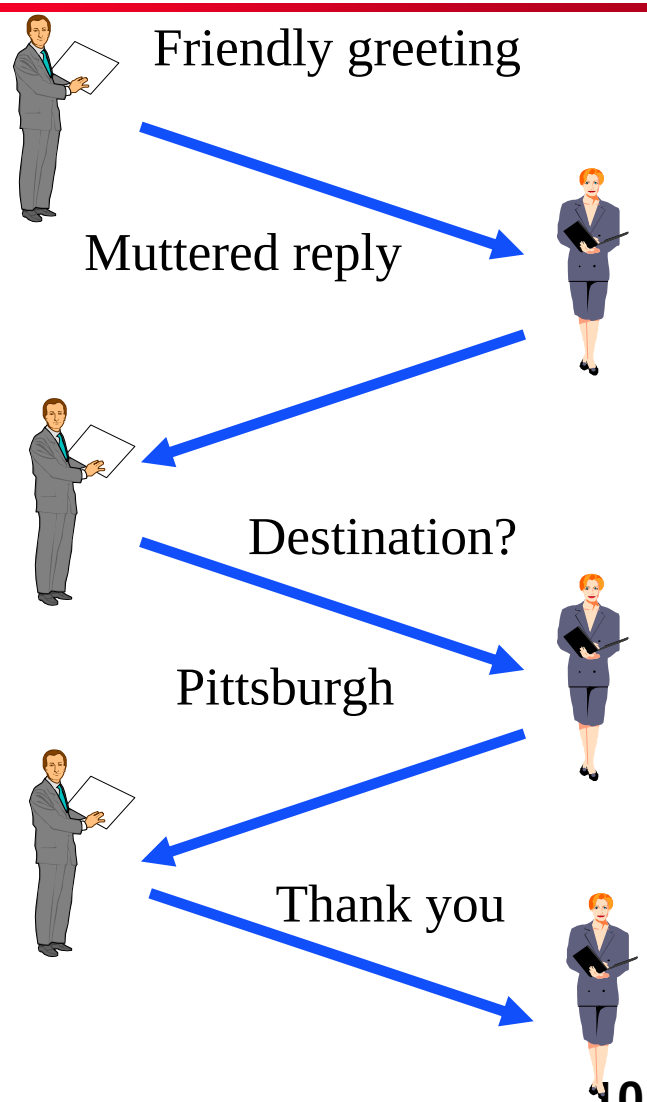
- **Packet switching: Concerns**
  - » **Needs to buffer and deal with congestion:**
  - » **More complex switches**
  - » **Harder to provide good network services (e.g., delay and bandwidth guarantees)**

Protocol and Service Interfaces



What is a Protocol

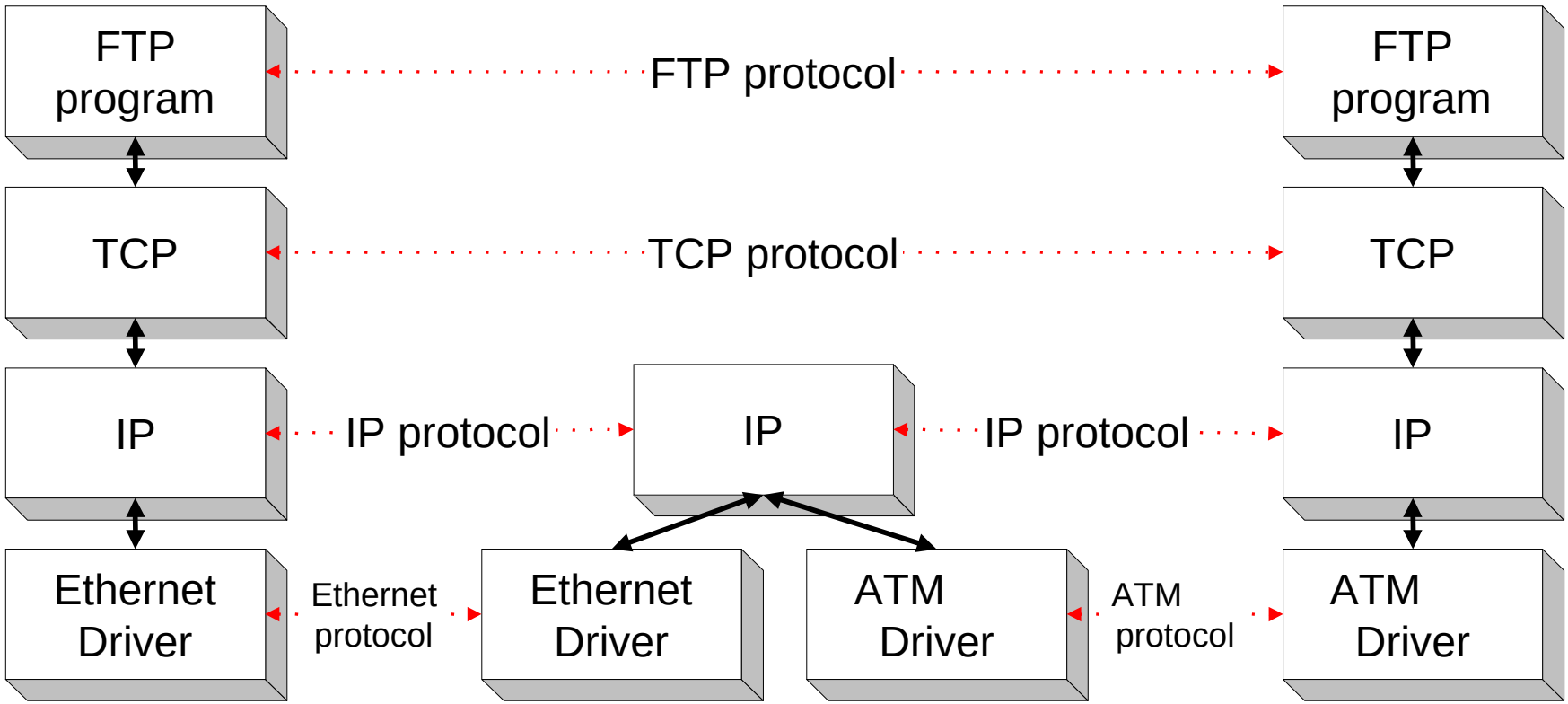
- **An agreement between parties on how communication should take place.**
- **Protocols may have to define many aspects of the communication.**
- **Syntax:**
  - » **Data encoding, language, etc.**
- **Semantics:**
  - » **Error handling, termination, ordering of requests, etc.**
- **Protocols at hardware, software, *all* levels!**
- **Example: Buying airline ticket by typing.**
- **Syntax: English, ascii, lines delimited by "\n"**



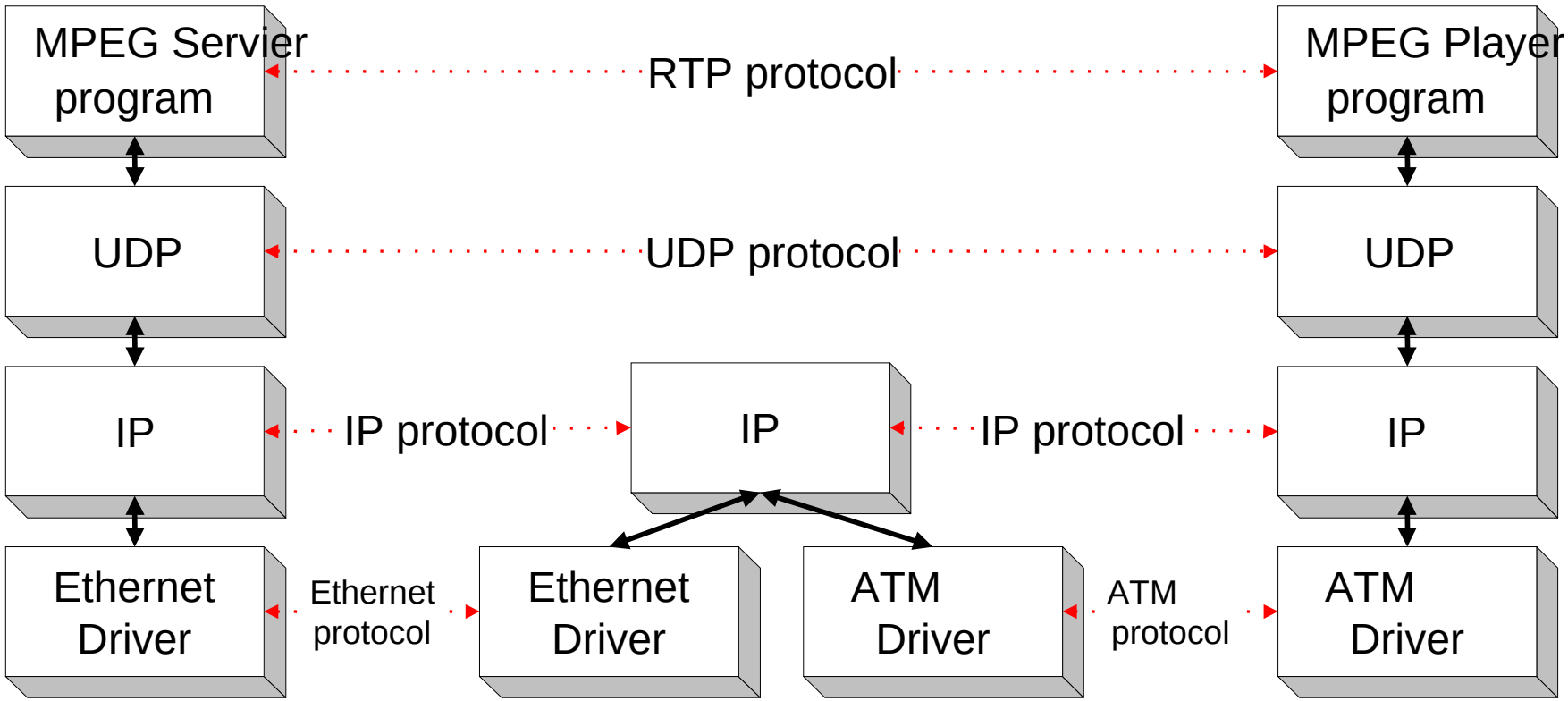
Interfaces

- **Each protocol offers an interface to its users, and expects one from the layers on which it builds**
  - **Syntax and semantics strike again**
    - **Data formats**
    - **Interface characteristics, e.g. IP service model**
- **Protocols build upon each other**
  - **Add value**
    - **E.g., a reliable protocol running on top of IP**
  - **Reuse**
    - **E.g., OS provides TCP, so apps don't have to rewrite**

Internet Protocol Architecture

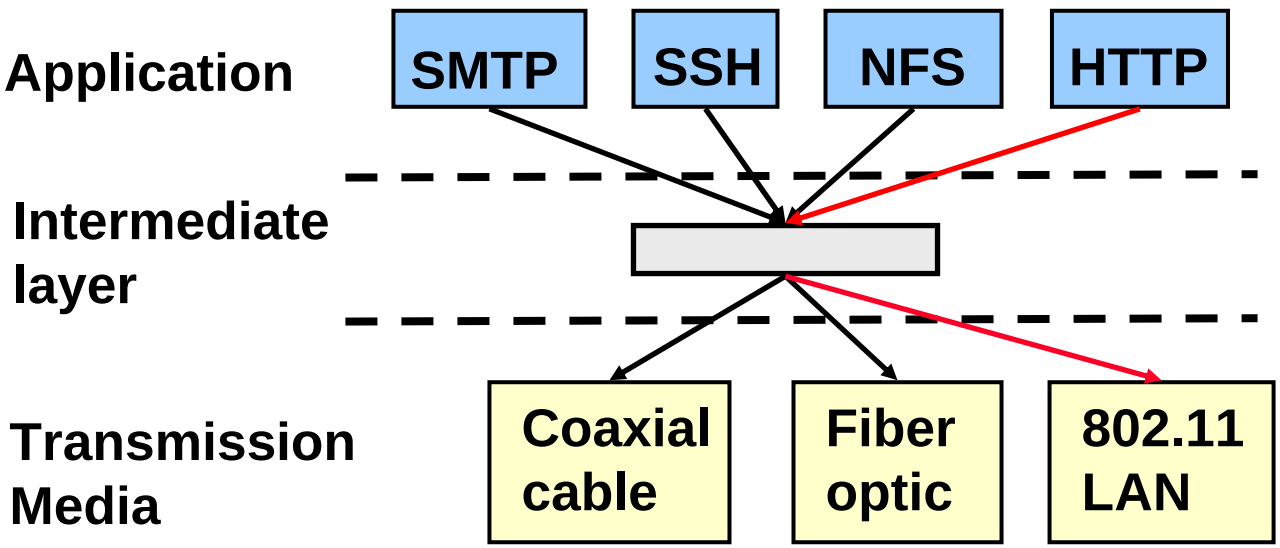


Internet Protocol Architecture



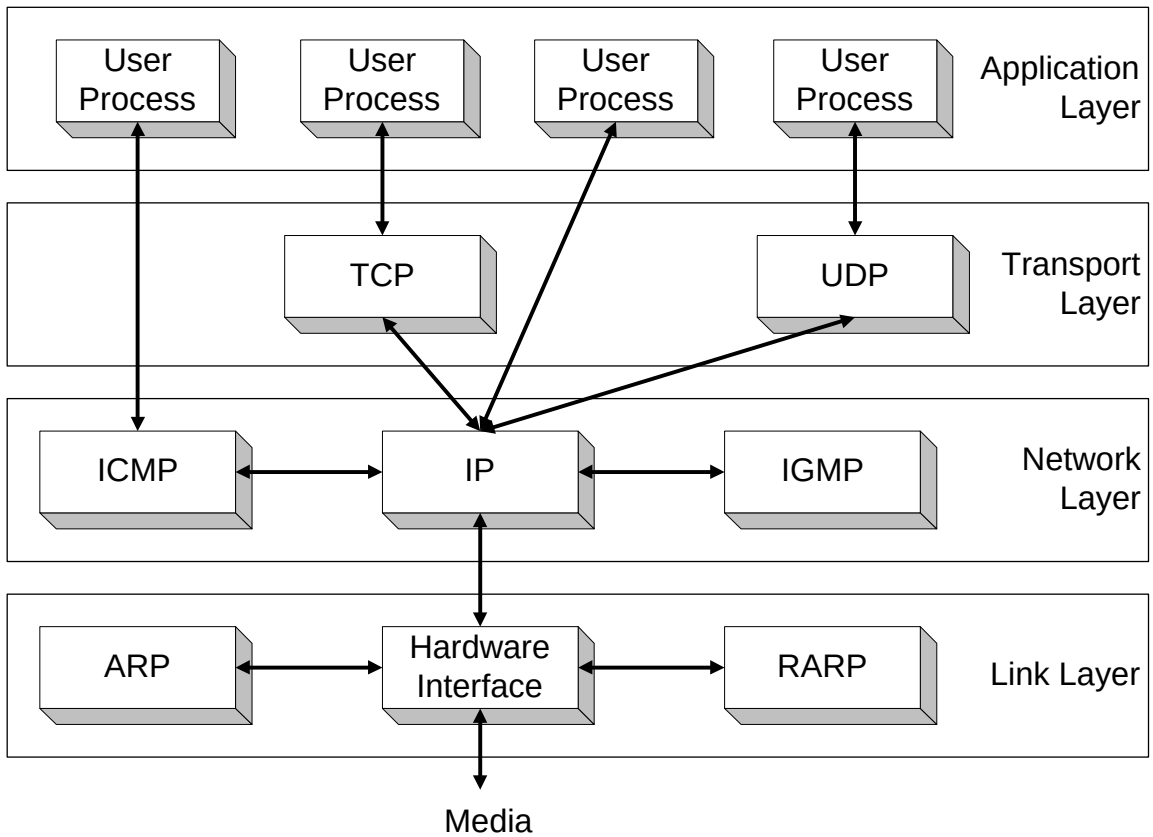
Power of Layering

- **Solution: Intermediate layer that provides a single abstraction for various network technologies**
  - » **O(1) work to add app/media**
  - » **variation on "add another level of indirection"**



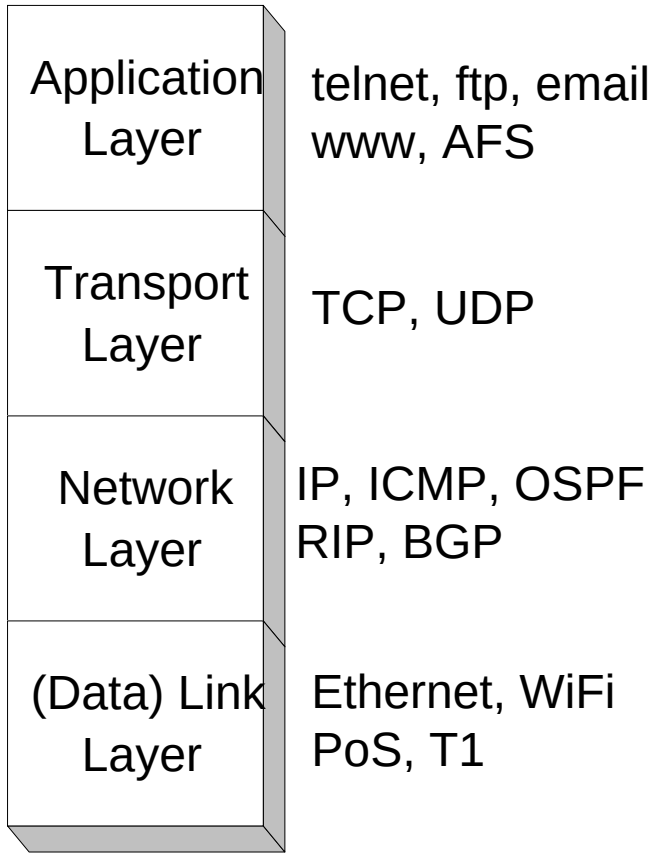
TCP/IP Protocol Suite

- **The complete TCP/IP protocol suite contains many protocols.**
- **Not even the following graph is a complete list.**



Application Layer

- **Service:** **Handles details of application programs.**
- **Functions:**

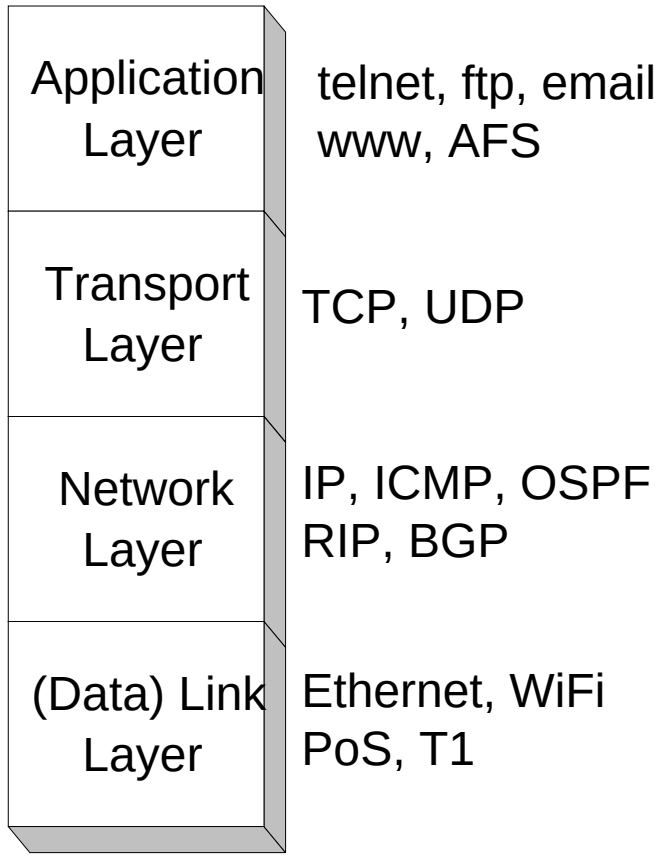


Transport Layer

- **Service:** **Controls delivery of data betweer**
- **Functions:** **Connection**

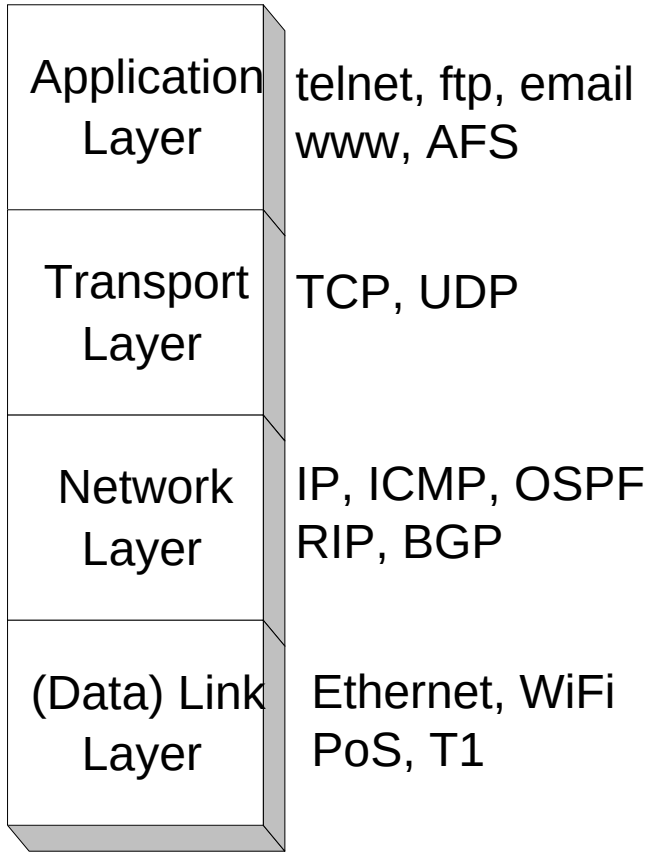
Establishment, Termination,

Error control, flow control.



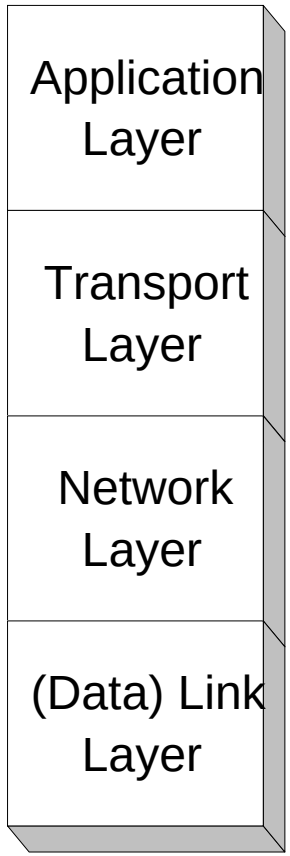
Network Layers

- **Service:** **Moves packets inside the network.**
- **Functions:** **Routing, addressing, switching, congestion control.**



Data Link Layer

- **Service:** **Transfer of frames over a link.**
- **Functions:** **Synchronization,**
  error control, flow control



telnet, ftp, email
www, AFS

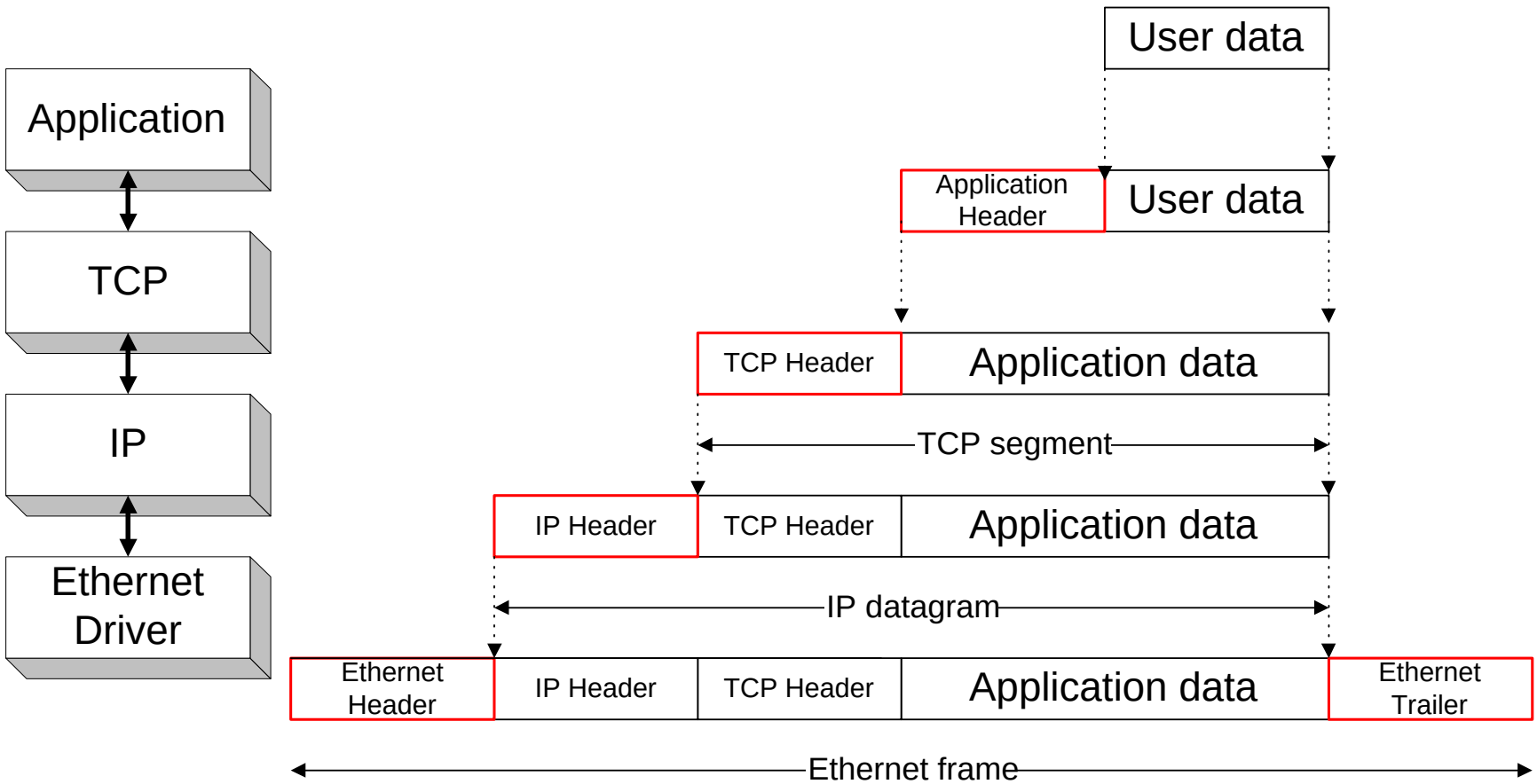
TCP, UDP

IP, ICMP, OSPF
RIP, BGP

Ethernet, WiFi
PoS, T1

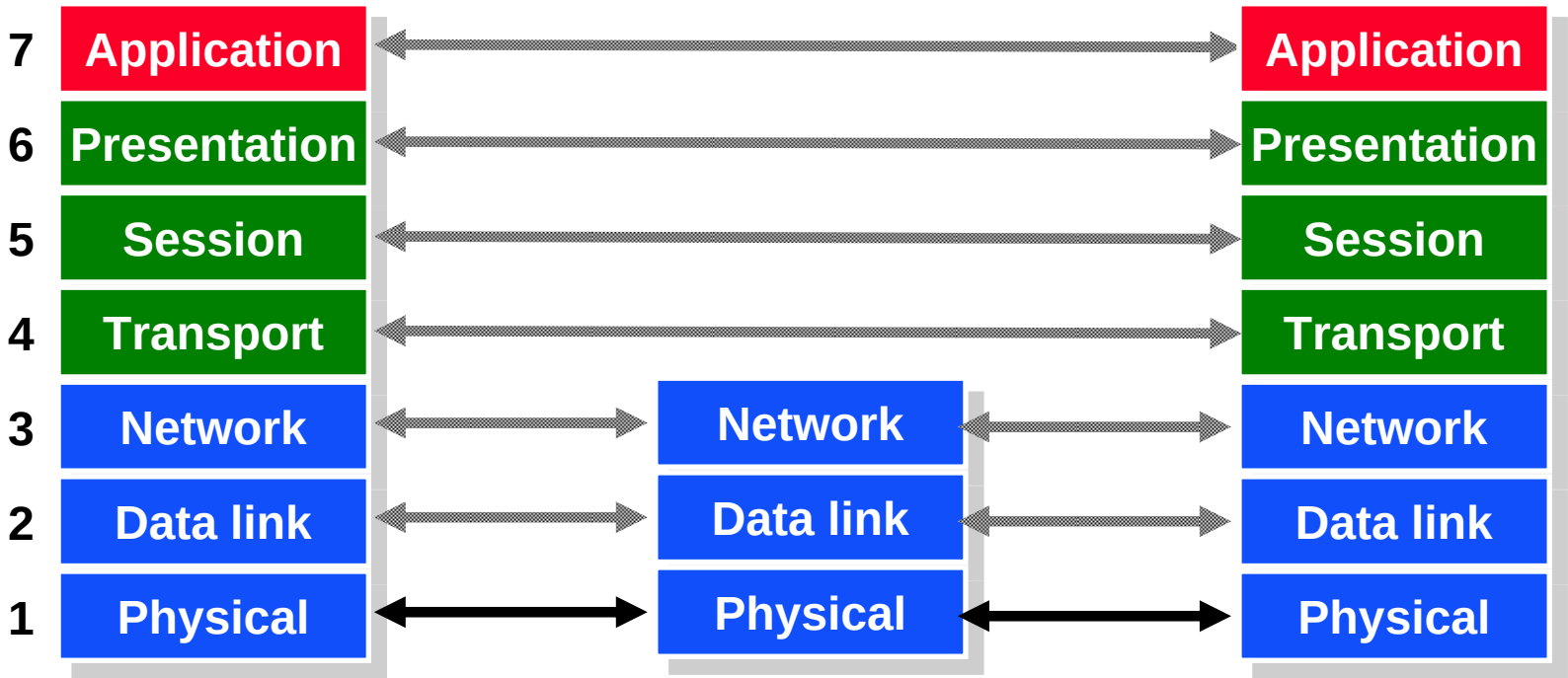
Encapsulation

- **As data is moving down the protocol stack, each protocol is adding layer-specific control information.**



A Finer Grain Layering Model

The Open Systems Interconnection (OSI) Model.

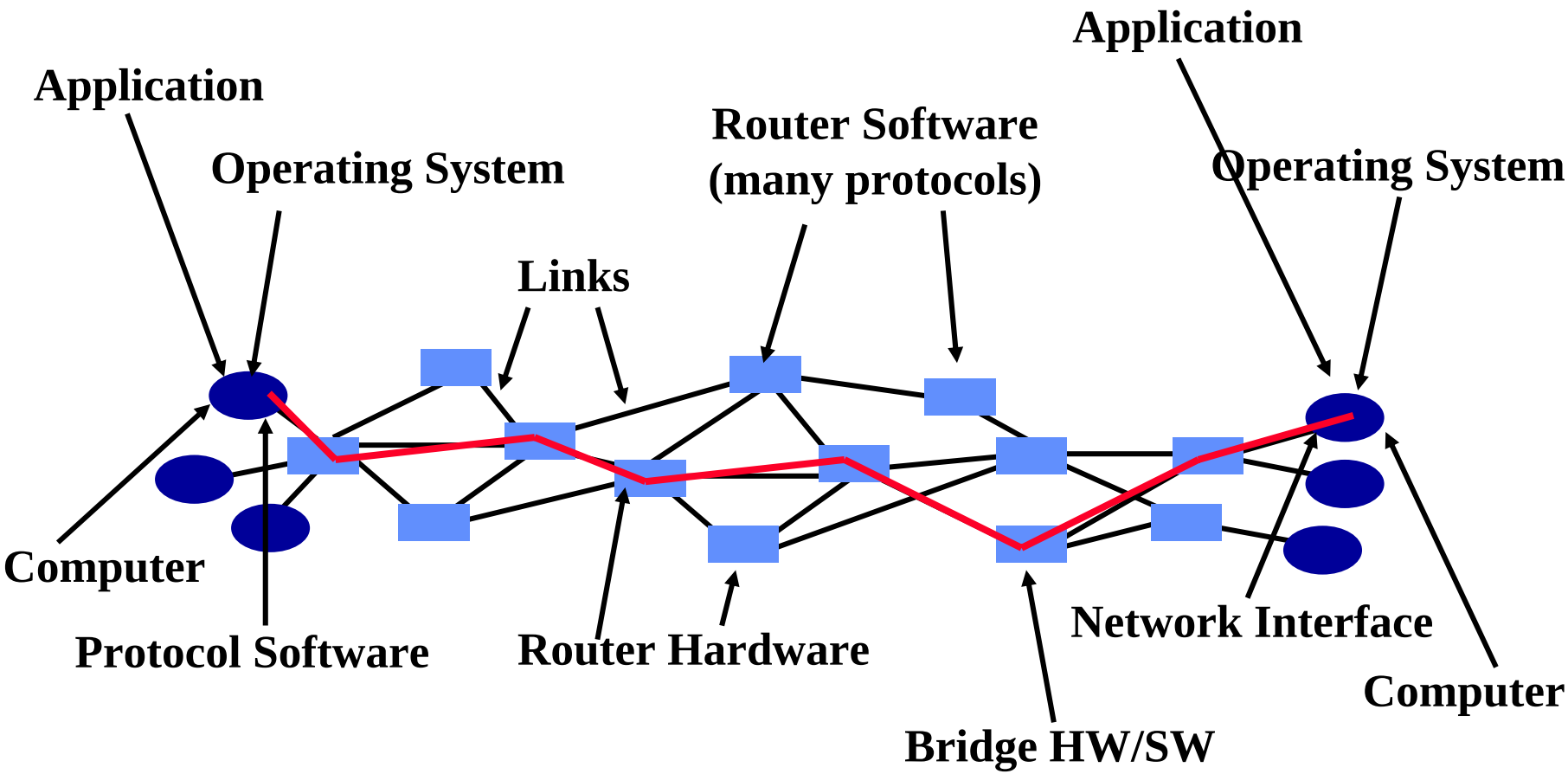


OSI Functions

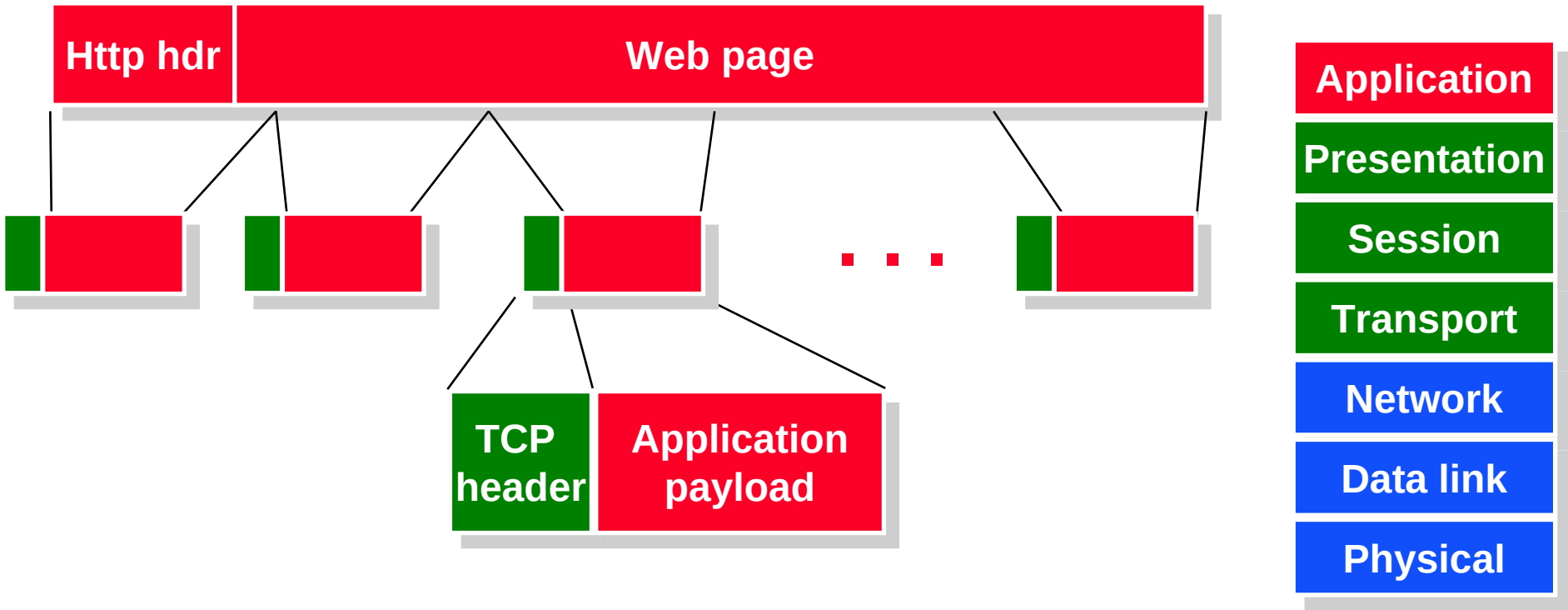
- (1) Physical: transmission of a bit stream.
- (2) Data link: flow control, framing, error detection.
- (3) Network: switching and routing.
- (4) Transport: reliable end to end delivery.
- (5) Session: managing logical connections.
- (6) Presentation: data transformations.
- (7) Application: specific uses, e.g. mail, file transfer, telnet, network management.

Multiplexing takes place in multiple layers

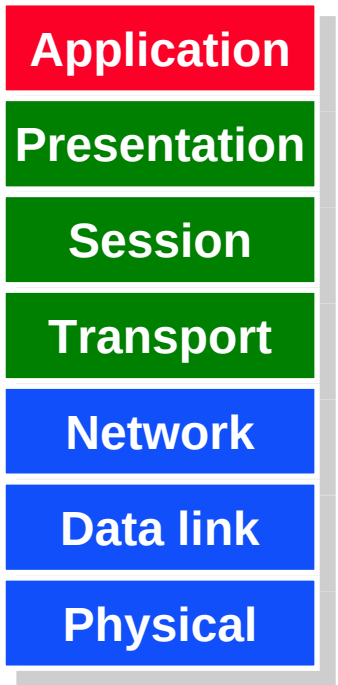
Which Protocols Are Implemented Where?

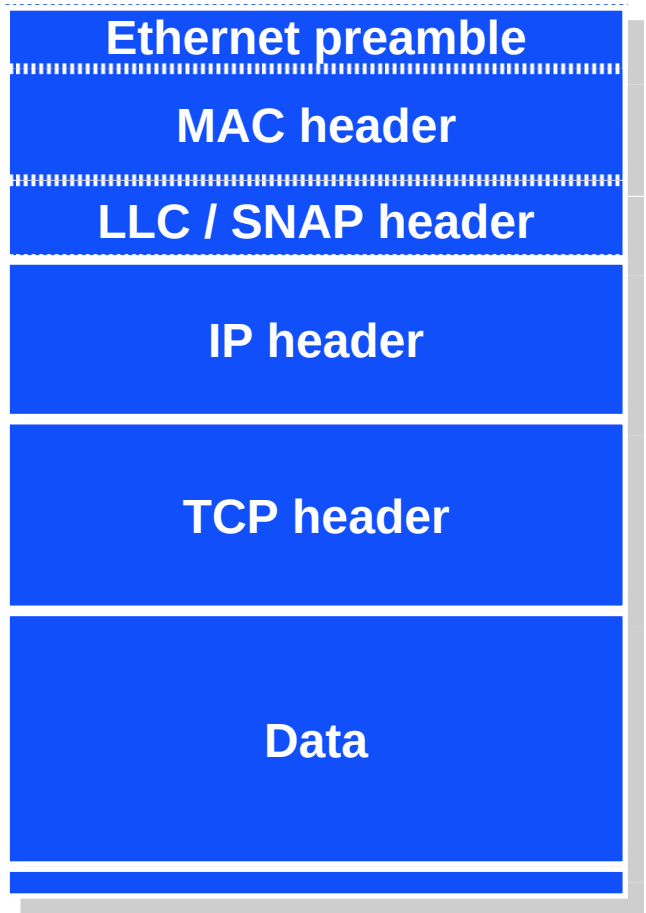


Example: Sending a Web Page



A TCP / IP / 802.3 Packet





Homework explores tradeoffs in header sizes, etc., with different applications

Limitations of the Layered Model

- **Some layers are not always cleanly separated.**
  - » **Inter-layer dependencies in implementations for performance reasons**
  - » **Some dependencies in the standards (header checksums)**
- **Higher layers not always well defined.**
  - » **Session, presentation, application layers**
- **Lower layers have “sublayers”.**
  - » **Usually very well defined (e.g., SONET protocol)**
- **Interfaces are not always well standardized.**
  - » **It would be hard to mix and match layers from independent implementations, e.g., windows network apps on unix (w/out compatability library)**
  - » **Many cross-layer assumptions, e.g. buffer management**

Standardization

- **Key to network interoperability.**
- **A priori standards.**
  - **Standards are defined first by a standards committee**
  - **Risk of defining standards that are untested or unnecessary**
  - **Standard may be available before there is serious use of the technology**
- **De facto standards.**
  - **Standards is based on an existing systems**
  - **Gives the company that developed the base system a big advantage**
  - **Often results in competing “standards” before the official standard is established**

Relevant Standardization Bodies

- **ITU-TS - Telecommunications Sector of the International Telecommunications Union.**
  - » **government representatives (PTTs/State Department)**
  - » **responsible for international “recommendations”**
- **T1 - telecom committee reporting to American National Standards Institute.**
  - » **T1/ANSI formulate US positions**
  - » **interpret/adapt ITU standards for US use, represents US in ISO**
- **IEEE - Institute of Electrical and Electronics Engineers.**
  - » **responsible for many physical layer and datalink layer standards**
- **ISO - International Standards Organization.**
  - » **covers a broad area**

The Internet Engineering Task Force

- **The Internet society.**
  - Oversees the operations of the Internet
- **Internet Engineering Task Force.**
  - decides what technology will be used in the Internet
  - based on working groups that focus on specific issues
  - encourages wide participation
- **Request for Comments.**
  - document that provides information or defines standard
  - requests feedback from the community
  - can be “promoted” to standard under certain conditions
    - consensus in the committee
    - interoperating implementations
  - Project 1 will look at the Internet Relay Chat (IRC) RFC

Higher Level Standards

- **Many session/application level operations are relevant to networks.**
  - » **encoding: MPEG, encryption, ...**
  - » **services: electronic mail, newsgroups, HTTP, ...**
  - » **electronic commerce, ...**
- **Standards are as important as for “lower-level” networks: interoperability.**
  - » **defined by some of the same bodies as the low-level standards, e.g. IETF**