EN.601.414/614 Computer Networks

Protocol Layering

Xin Jin

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https://github.com/xinjin/course-net

Agenda

- **How is communication organized?**

Inspiration…

- **CEO A writes letter to CEO B**

Dear John,

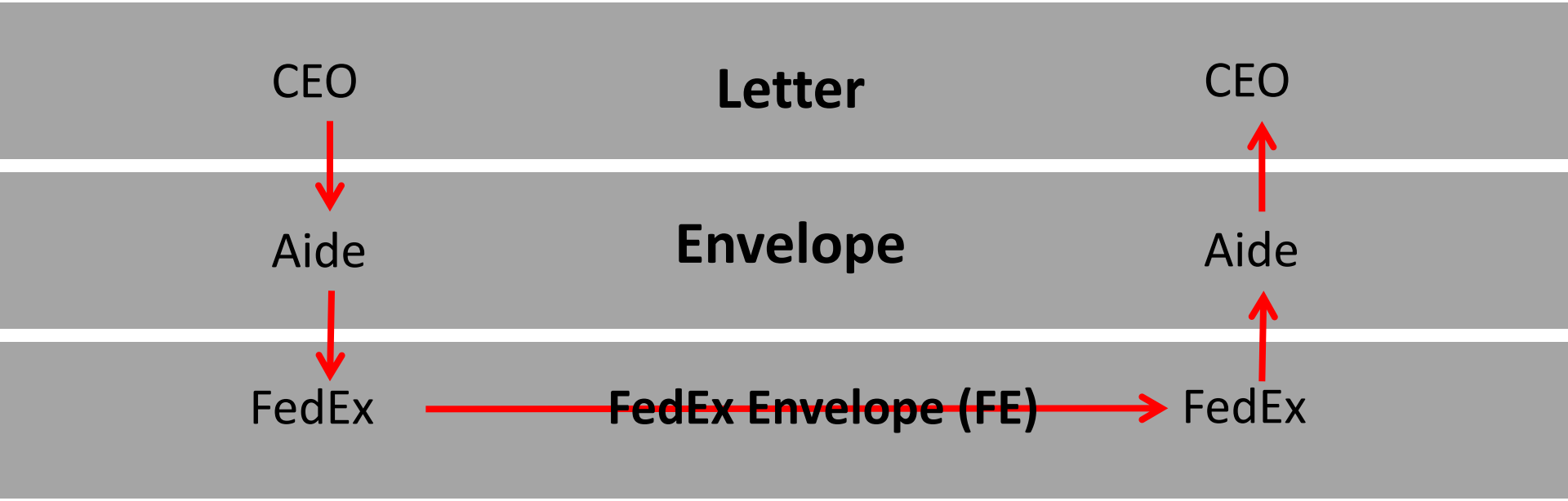
Your days are numbered.

--Pat

Inspiration…

- **CEO A writes letter to CEO B**
  - Folds letter and hands it to administrative aide
- **Aide:**
  - Puts letter in envelope with CEO B's full name
  - Takes to FedEx
- **FedEx Office**
  - Puts letter in larger envelope
  - Puts name and street address on FedEx envelope
  - Puts package on FedEx delivery truck
- **FedEx delivers to other company**

The path of the letter



The path of the letter

- “Peers” in same layer understand each other
- No one else needs to
- Lowest level has most packaging

CEO	**Semantic Content**	CEO
Aide	**Identity**	Aide
FedEx	**Location**	FedEx

Three steps

- Decompose the problem into tasks
- Organize these tasks
- Assign tasks to entities (who does what)

Back to the Internet: Decomposition

Applications

in built on

Reliable or unreliable transport

in built on

Best-effort *global* packet delivery

in built on

Best-effort *local* packet delivery

in built on

Physical transfer of bits

Communication organization

Applications

in built on

Reliable or unreliable transport

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Best-effort *global* packet delivery

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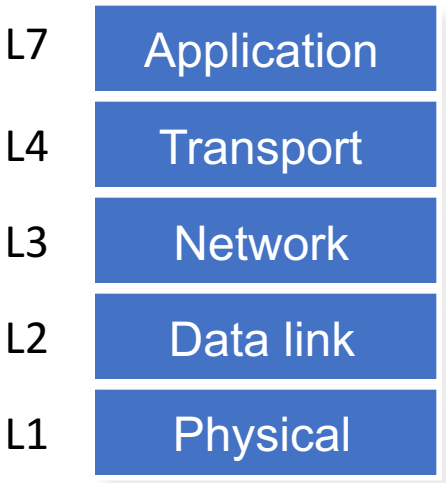
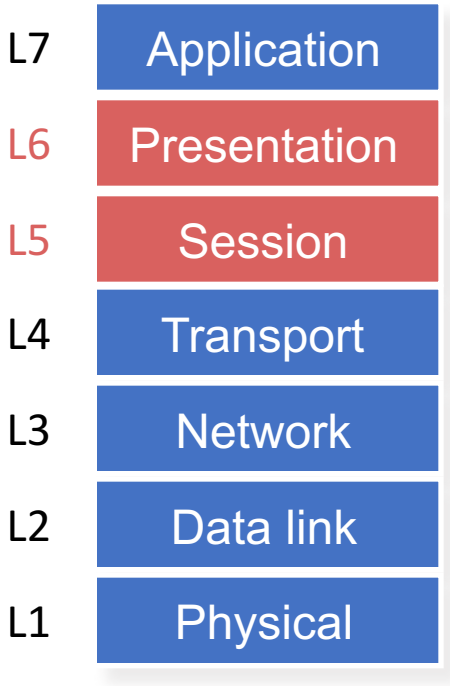
Physical transfer of bits



OSI layers

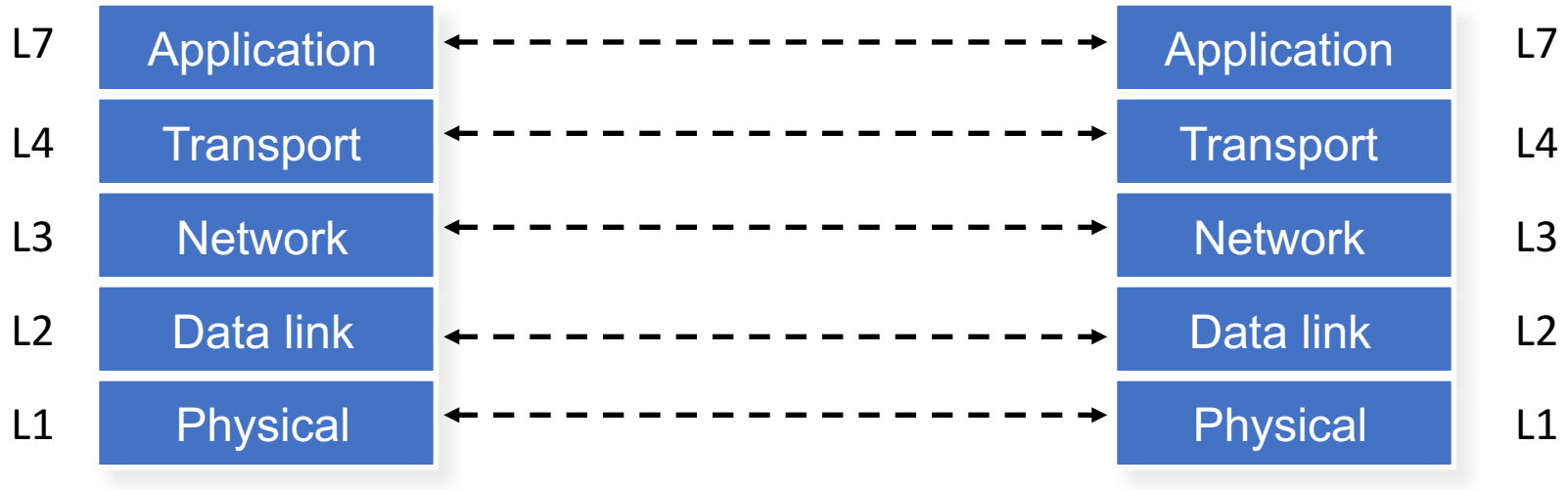
- **OSI stands for Open Systems Interconnection model**
  - ➢Developed by the ISO
- **Session and presentation layers are often implemented as part of the application layer**



Layers

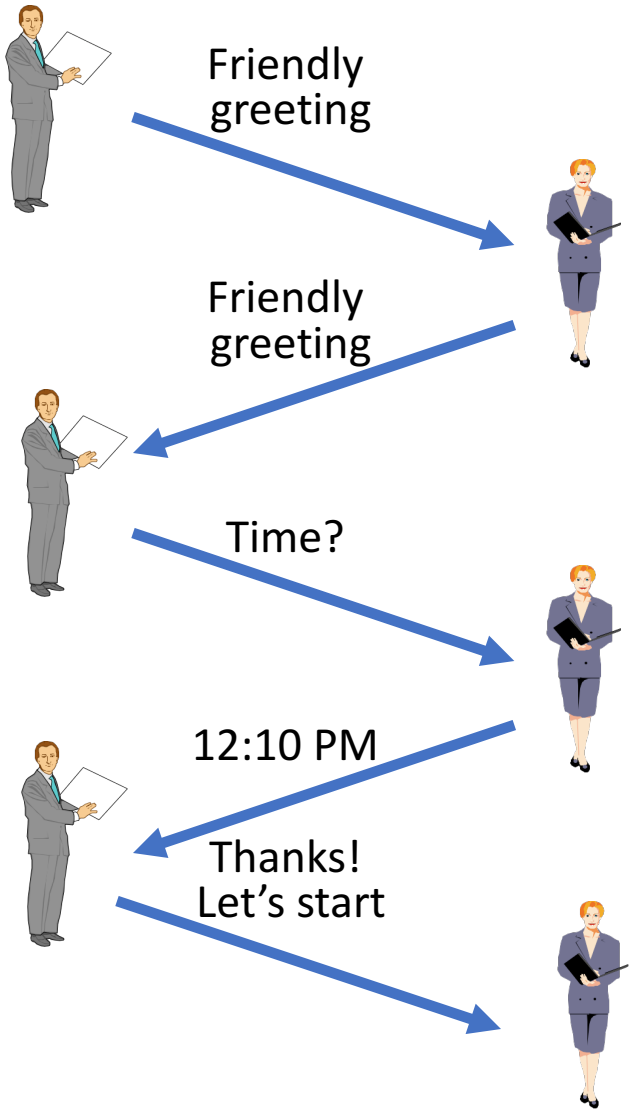
- Layer: a part of a system with well-defined interfaces to other parts
- One layer interacts only with layer above and layer below
- Two layers interact only through the interface between them

Layers and protocols



- **Communication between peer layers on different systems is defined by protocols**

What is a Protocol?



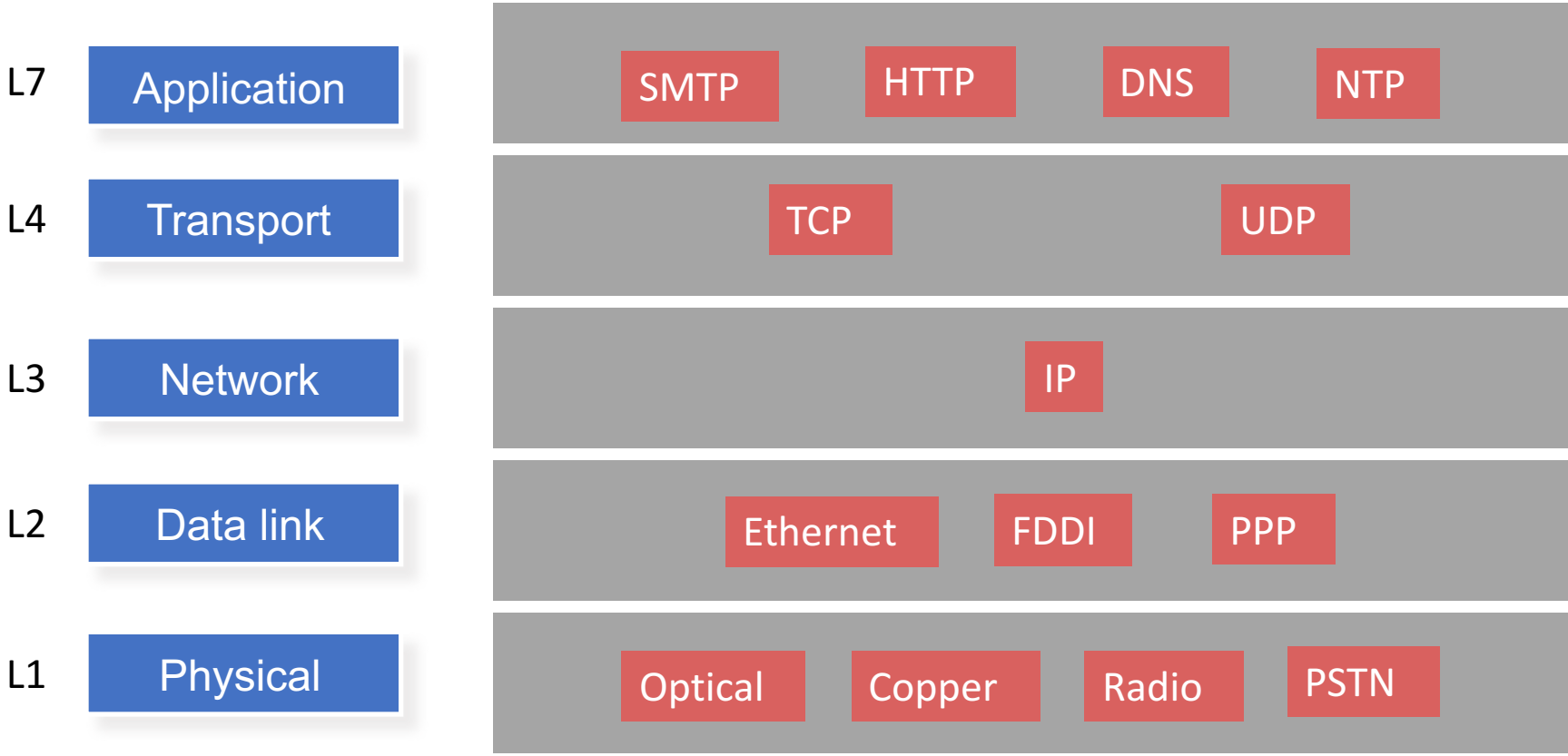
What is a Protocol?

- **An agreement between parties (in the same layer) on how to communicate**
- **Defines the syntax of communication**
  - Header → instructions on how to process payload
  - Each protocol defines the format of its headers
    - e.g., “the first 32 bits carry the destination address”

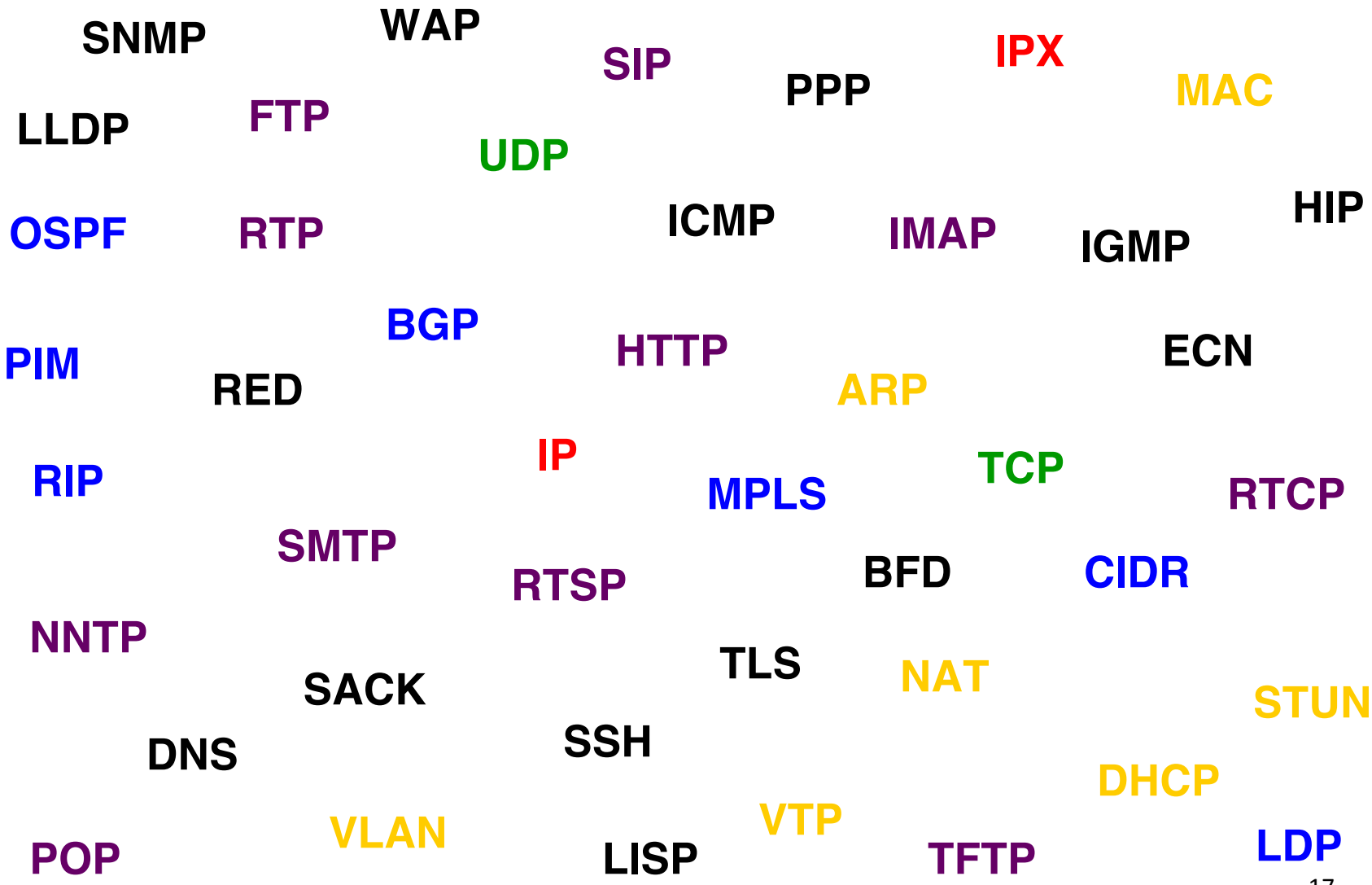
What is a Protocol?

- **An agreement between parties on how to communicate**
- **Defines the syntax of communication**
- **And semantics**
  - "First a hello, then a request…"
  - We will study many protocols later in the semester
- **Protocols exist at many levels, hardware, and software**
  - Defined by standards bodies like IETF, IEEE, ITU

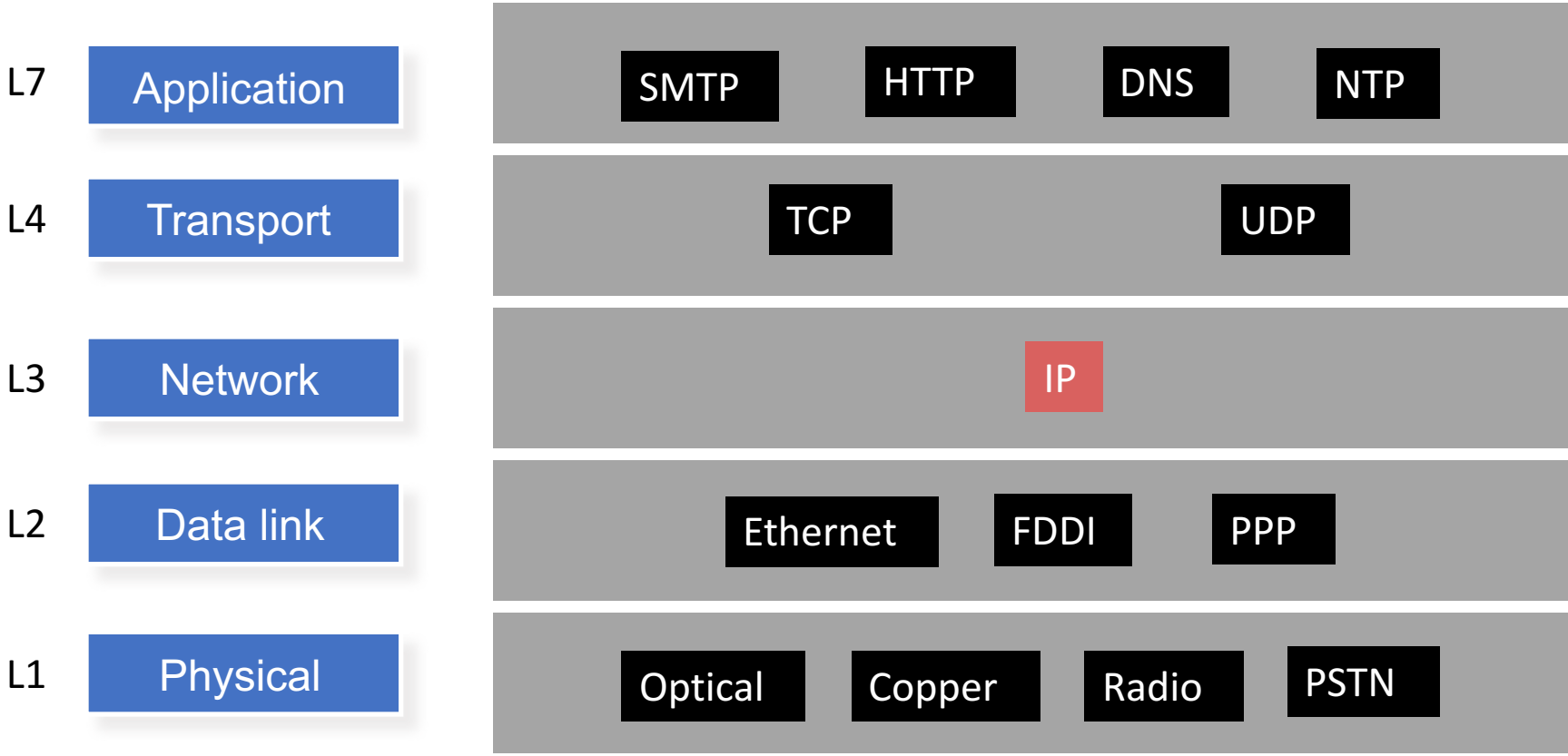
Protocols at different layers



A Plethora of Protocol Acronyms



ONE network layer protocol

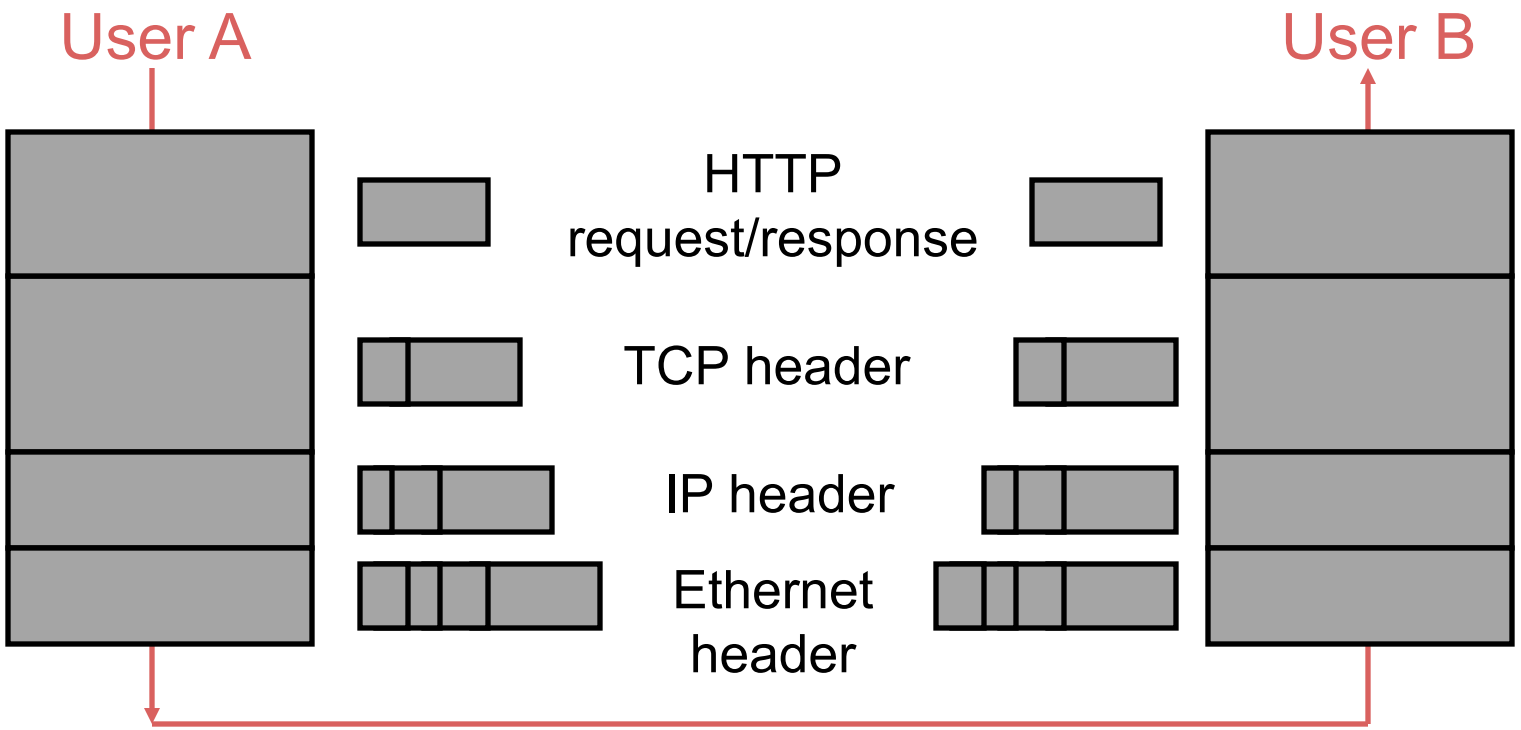


What do students say about this course?

- “In the computer networks class, I fell asleep at the start of the semester when the IP header was on the screen, and woke up at the end of the semester with the TCP header on the screen.”

- “Network class final: ARP, DHCP, ICMP, IGMP, IP, TCP, UDP.”

Layer encapsulation: Protocol headers



Three steps

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- Organize these tasks
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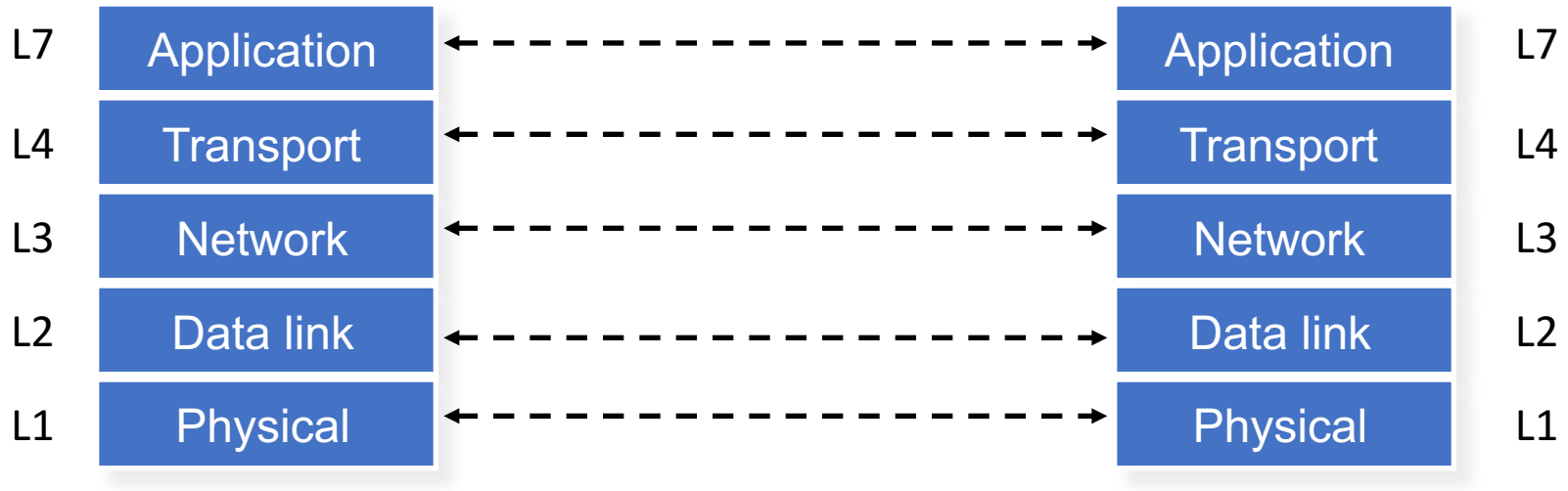
What get's implemented where?



What gets implemented at the end systems?

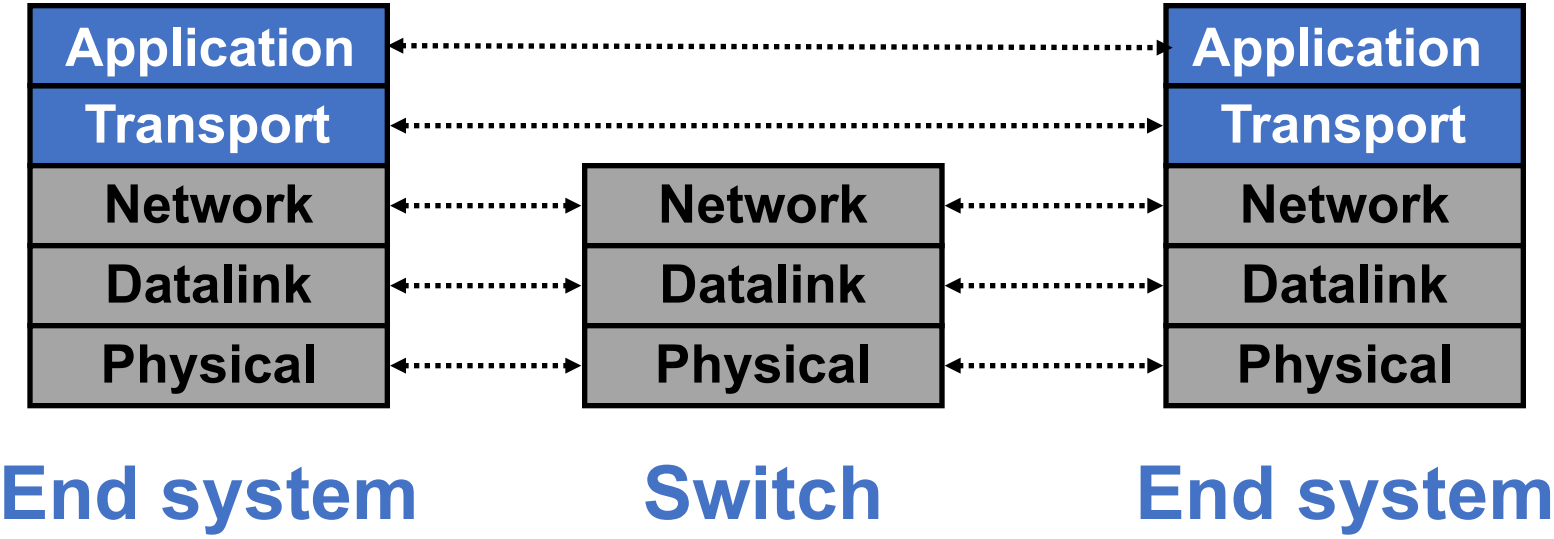
- Bits arrive on wire, must make it up to application
- Therefore, all layers must exist at host!

What gets implemented in the network?

- Bits arrive on wire → physical layer (L1)
- Packets must be delivered across links and local networks → datalink layer (L2)
- Packets must be delivered between networks for global delivery → network layer (L3)
- The network does not support reliable delivery
  - Transport layer (and above) at end systems supports

Simple Diagram

- Lower three layers implemented everywhere
- Top two layers implemented only at hosts



A closer look: End system

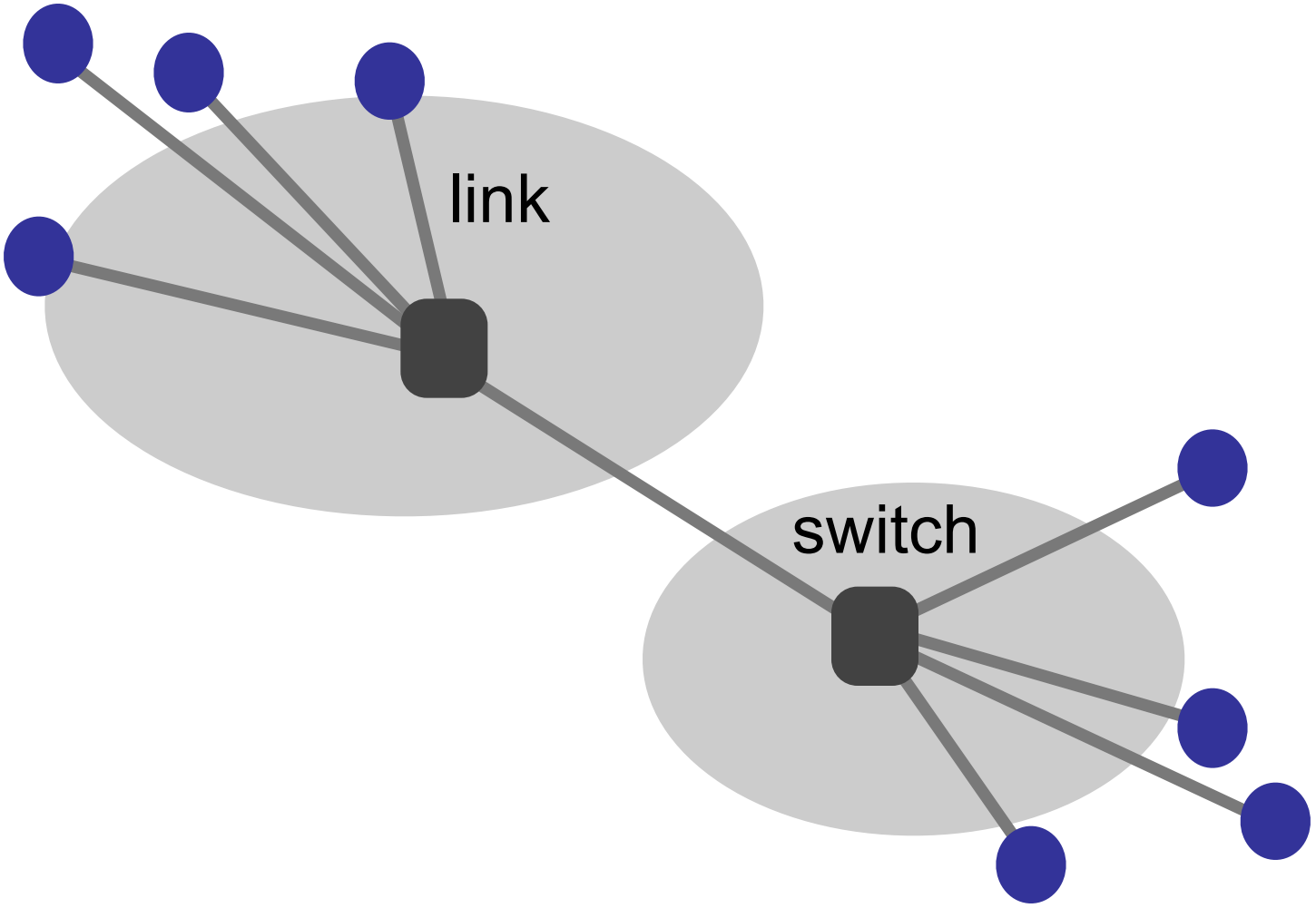
- **Application**
  - Web server, browser, mail, game
- **Transport and network layer**
  - typically part of the operating system
- **Datalink and physical layer**
  - hardware/firmware/drivers

What gets implemented in the network?

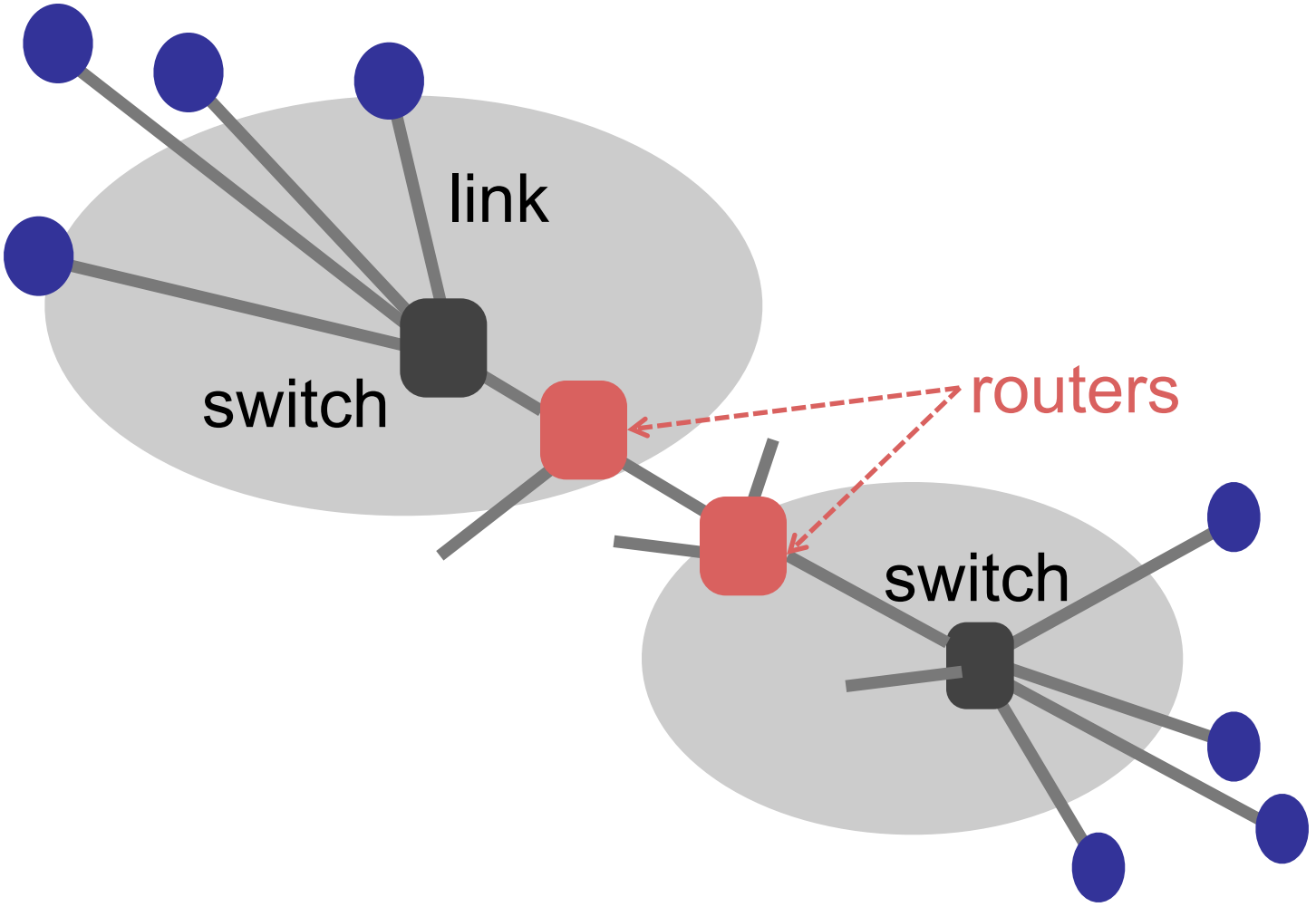
- Bits arrive on wire → physical layer (L1)
- Packets must be delivered across links and local networks → datalink layer (L2)
- Packets must be delivered between networks for global delivery → network layer (L3)

- Switches implement only physical and datalink layers (L1, L2)
- Routers implement the network layer too (L1, L2, L3)

A closer look at the network



A closer look at the network



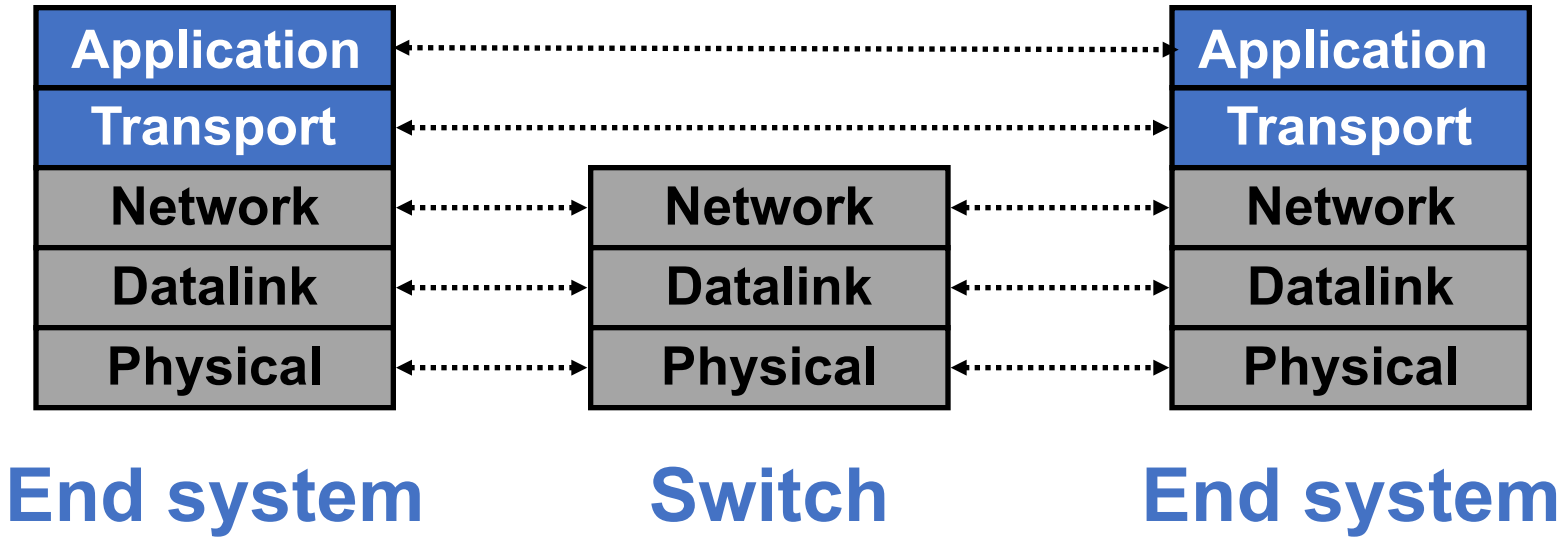
Switches vs. Routers

- **Switches do what routers do but don't participate in global delivery, just local delivery**
  - Switches only need to support L1, L2
  - Routers support L1-L3

- **Won't focus on the router/switch distinction**
  - Almost all boxes support network layer these days

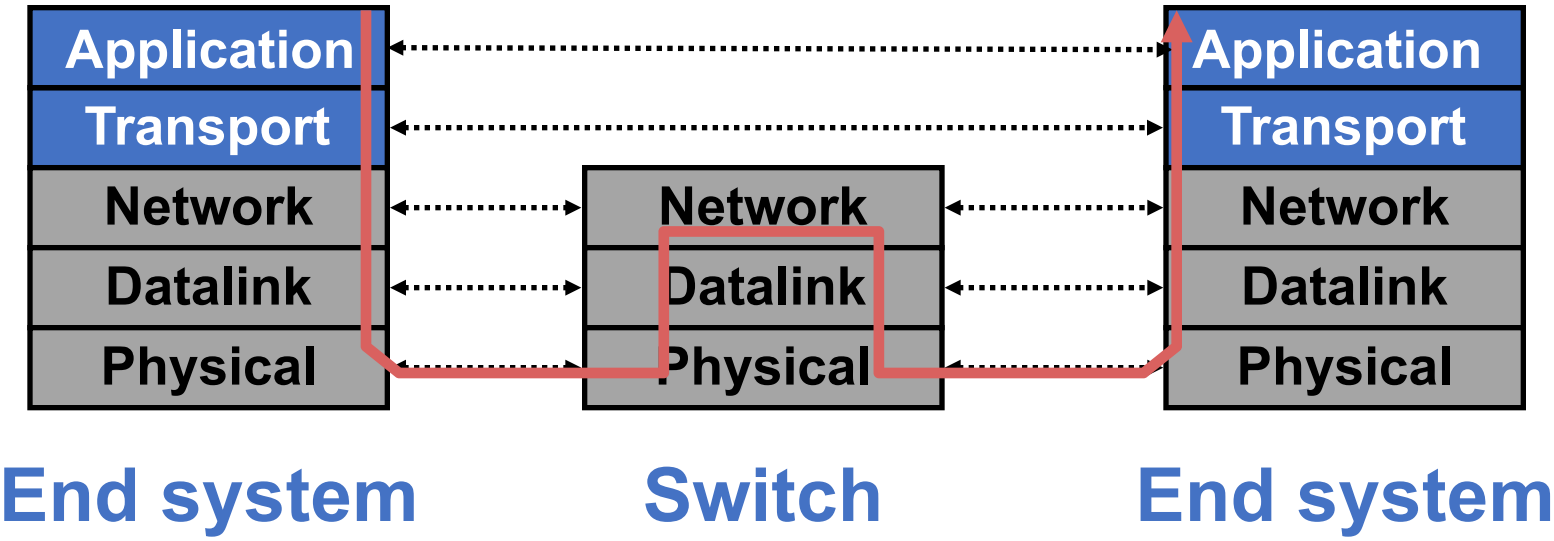
Logical communication

- **A layer interact with its peers corresponding layer**

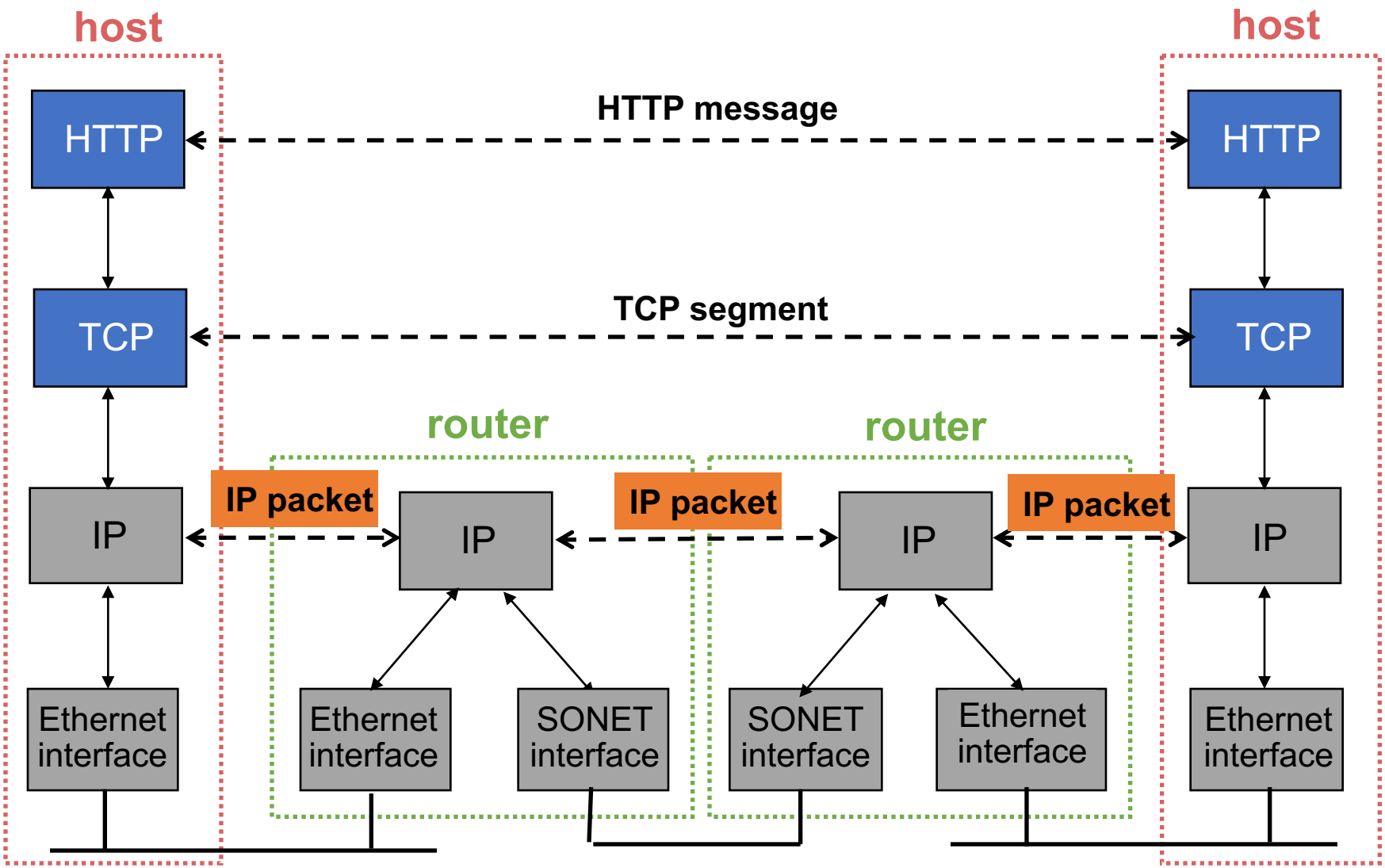


Physical communication

- **Communication goes down to physical network**
- **Then up to relevant layer**



A protocol-centric diagram



Pros and cons of layering

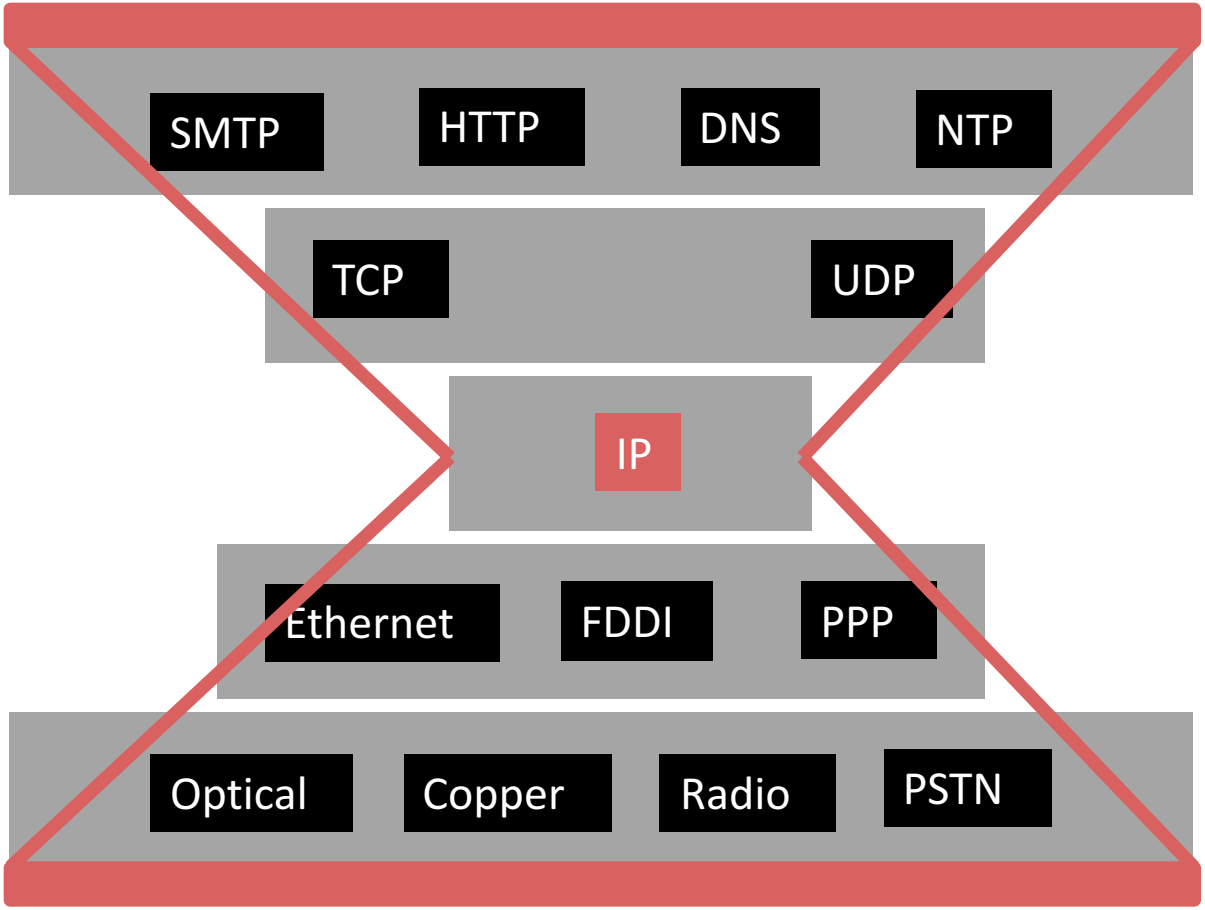
Why layers?

- Reduce complexity
- Improve flexibility

Why not?

- Higher overheads
- Cross-layer information often useful

IP is the narrow waist of the layering hourglass



Implications of hourglass

- **Single network-layer protocol (IP)**
- **Allows arbitrary networks to interoperate**
  - Any network that supports IP can exchange packets
- **Decouples applications from low-level networking technologies**
  - Applications function on all networks
- **Supports simultaneous innovations above and below IP**
- **But changing IP itself is hard (e.g., IPv4 → IPv6)**

Placing network functionality

- **End-to-end arguments by Saltzer, Reed, and Clark**
  - Dumb network and smart end systems
  - Functions that can be *completely* and *correctly* implemented *only* with the knowledge of application end host, should not be pushed into the network
  - Sometimes necessary to break this for performance and policy optimizations
  - Fate sharing: fail together or don't fail at all

Assignment 1

- **Socket Programming**
  - Socket: communication endpoint at the end hosts
  - Provide an application interface to exchange data between processes.
- **Server side**
  - socket() → bind() → listen() → accept() → recv() → close()
- **Client side**
  - socket() → connect() → send() → close()

Summary

- **Layering is a good way to organize networks**
- **Unified Internet layer decouples applications from networks**
- **E2E argument encourages us to keep IP simple**

- **Assignment 1 is out**

Thanks!
Q&A