EECS 489
Computer Networks

Winter 2023

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Material with thanks to Aditya Akella, Sugih Jamin, Philip Levis, Sylvia Ratnasamy, Peter Steenkiste, and many other colleagues.

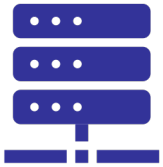
Agenda

- How is communication organized?

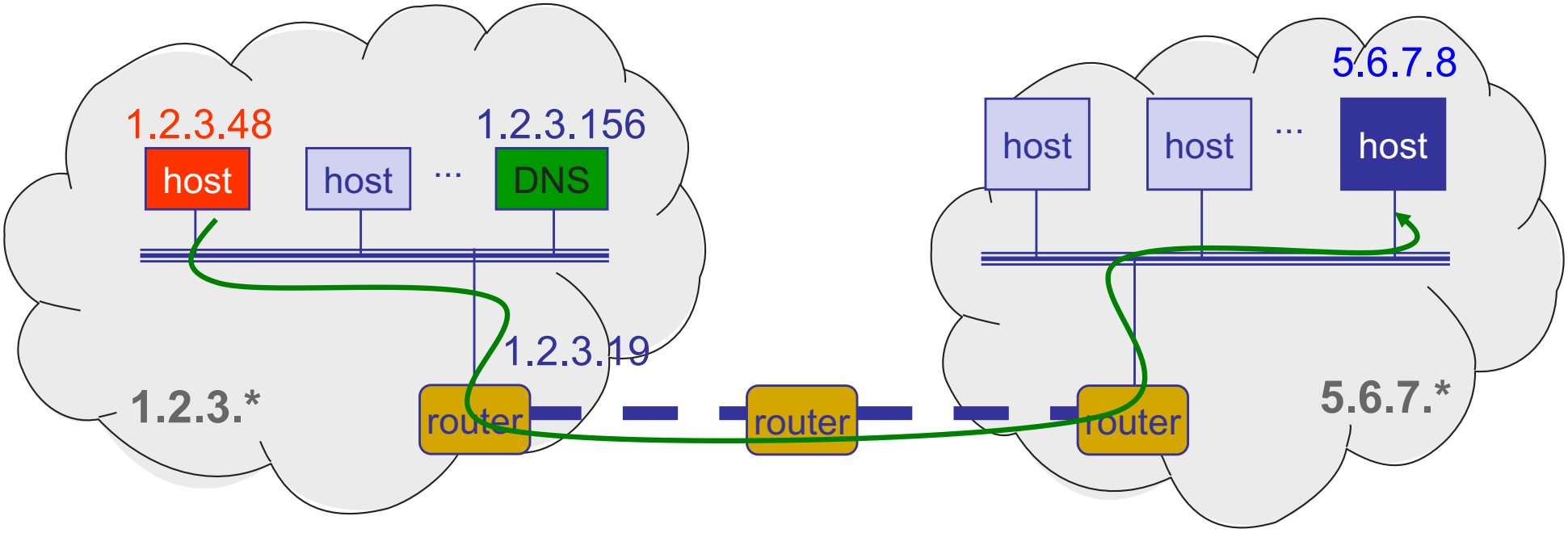
What we want

http://123.xyz

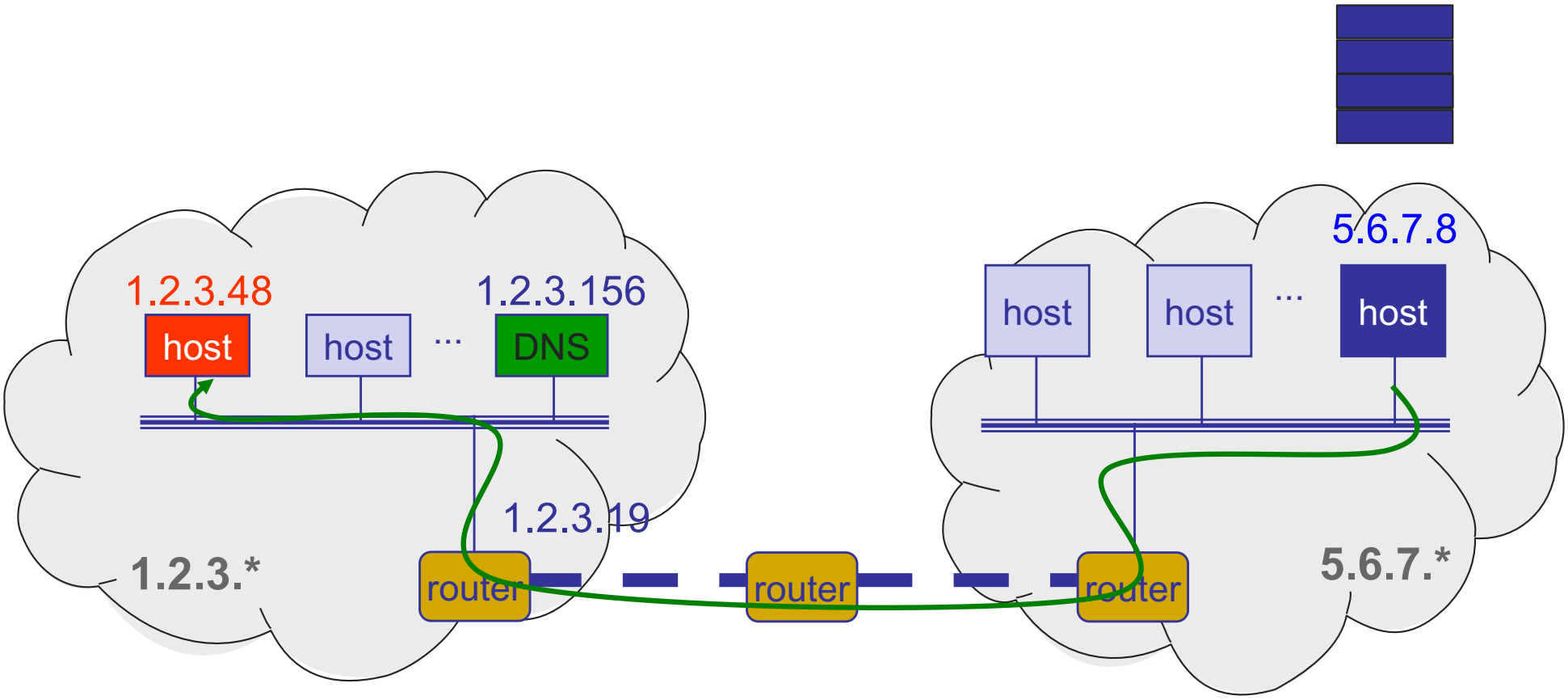
123.xyz server



(Some of) What happens…

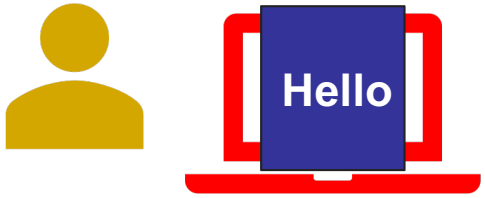


(More of) What happens

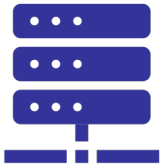


What we get

http://123.xyz



123.xyz server



Inspiration…

- CEO A writes letter to CEO B

Dear John,

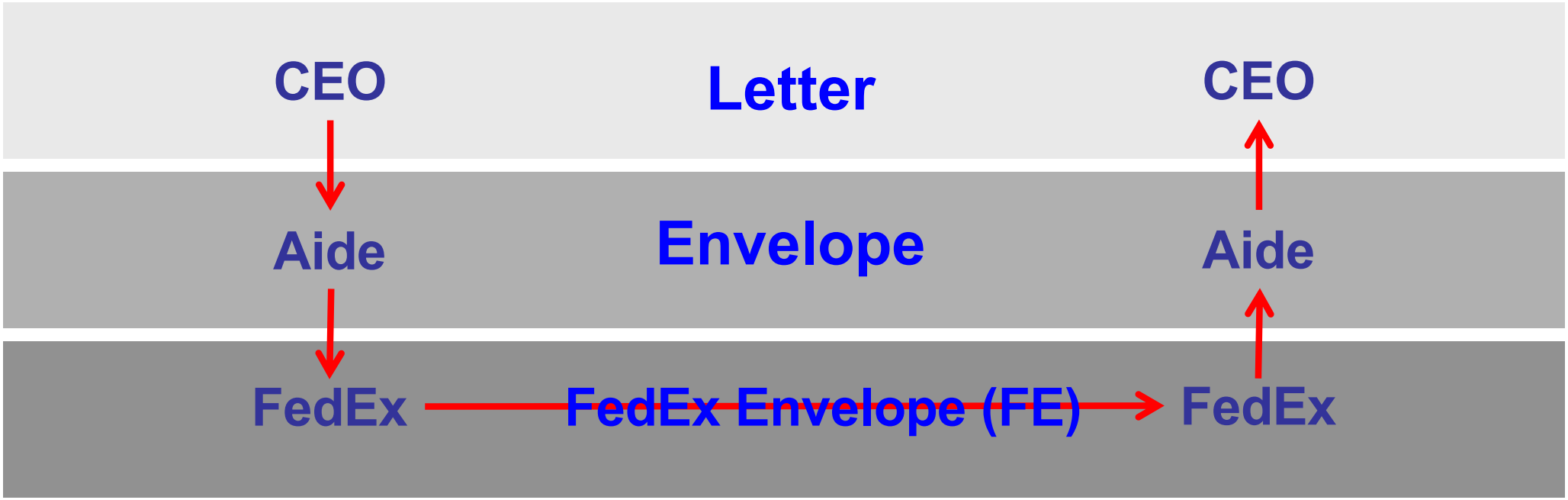
Your days are numbered.

--Pat

Inspiration…

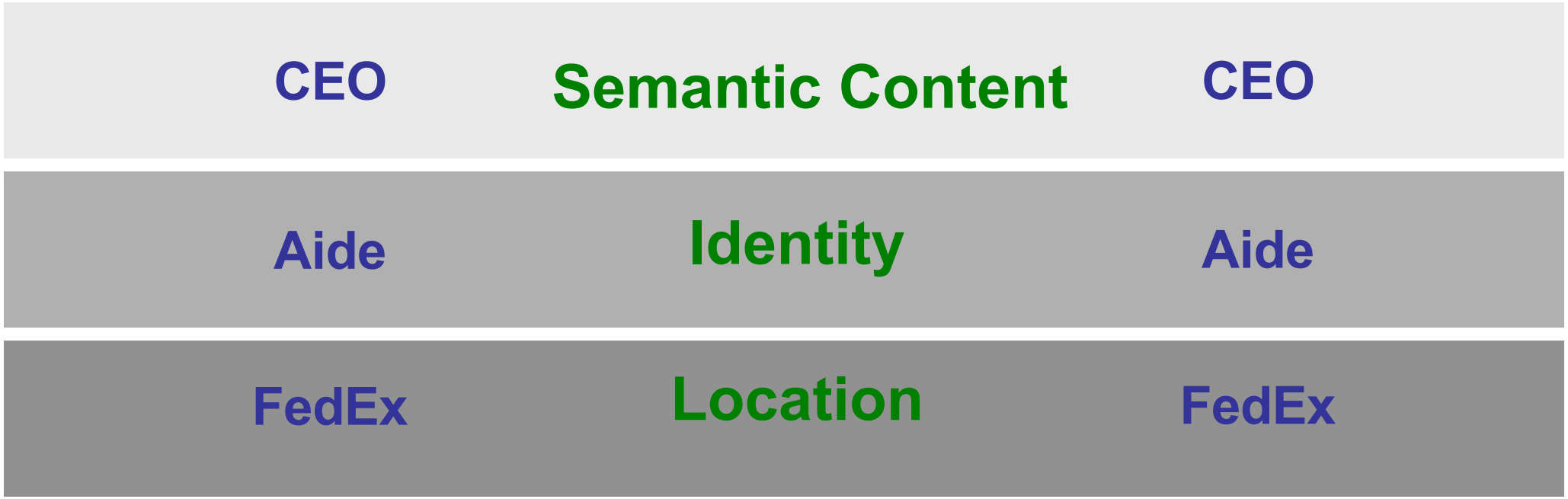
- CEO A writes letter to CEO B
  - Folds letter and hands it to administrative aide
- Aide:
  - Puts letter in envelope with CEO B's full name
  - Takes to FedEx
- FedEx Office
  - Puts letter in larger envelope
  - Puts name and street address on FedEx envelope
  - Puts package on FedEx delivery truck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



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

in built on

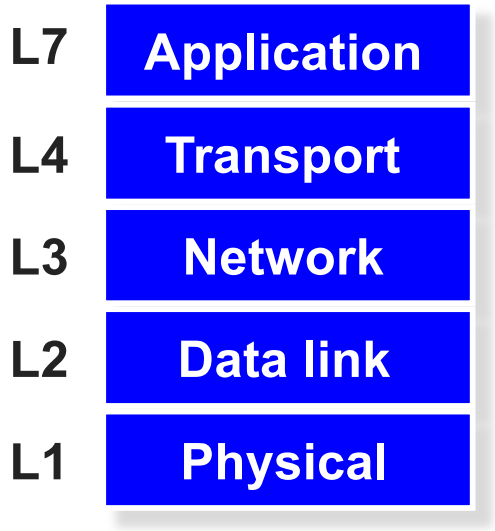
Best-effort global packet delivery

in built on

Best-effort local packet delivery

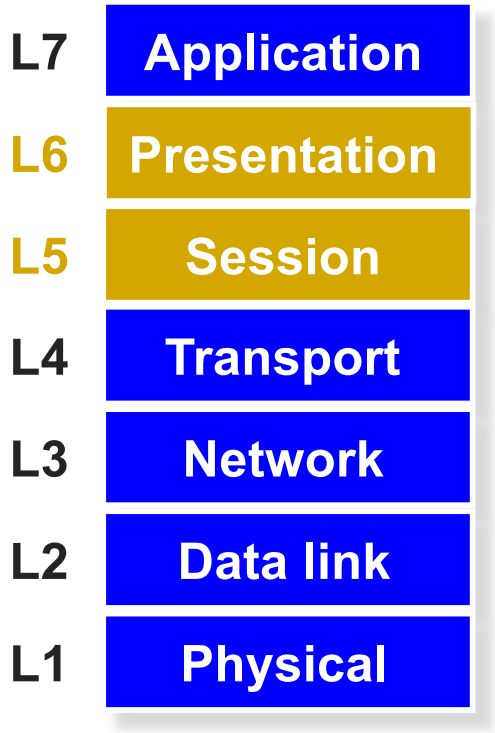
in built on

Physical transfer of bits



OSI layers

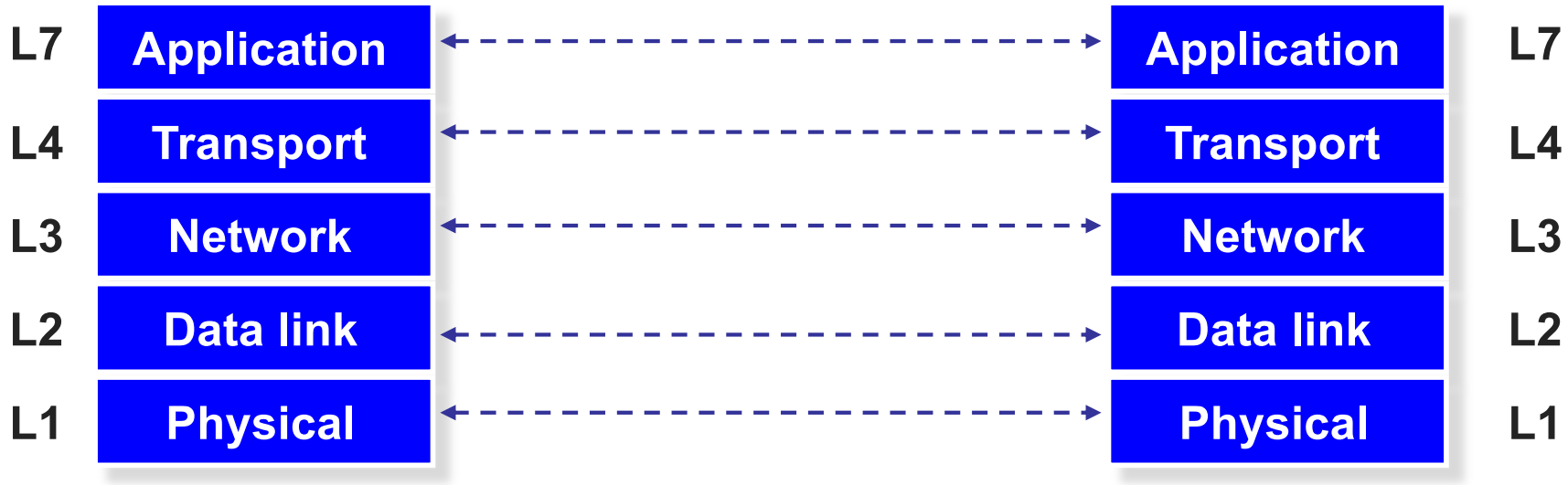
- OSI stands for Open Systems Interconnection model
  - Developed by the ISO
- Session and presentation layers are often implemented as part of the application layer



Layers

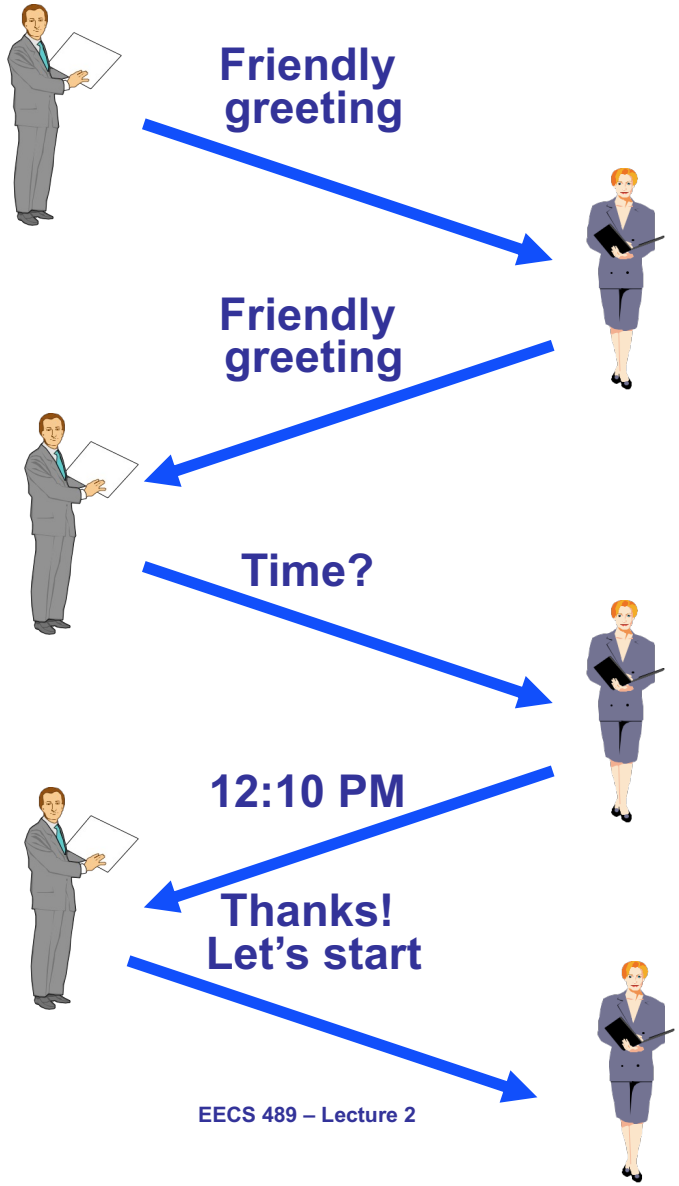
- Layer: a part of a system with well-defined interfaces to other parts
- One layer interacts only with layer above and layer below
- Two layers interact only through the interface between them

Layers and protocols



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

What is a Protocol?



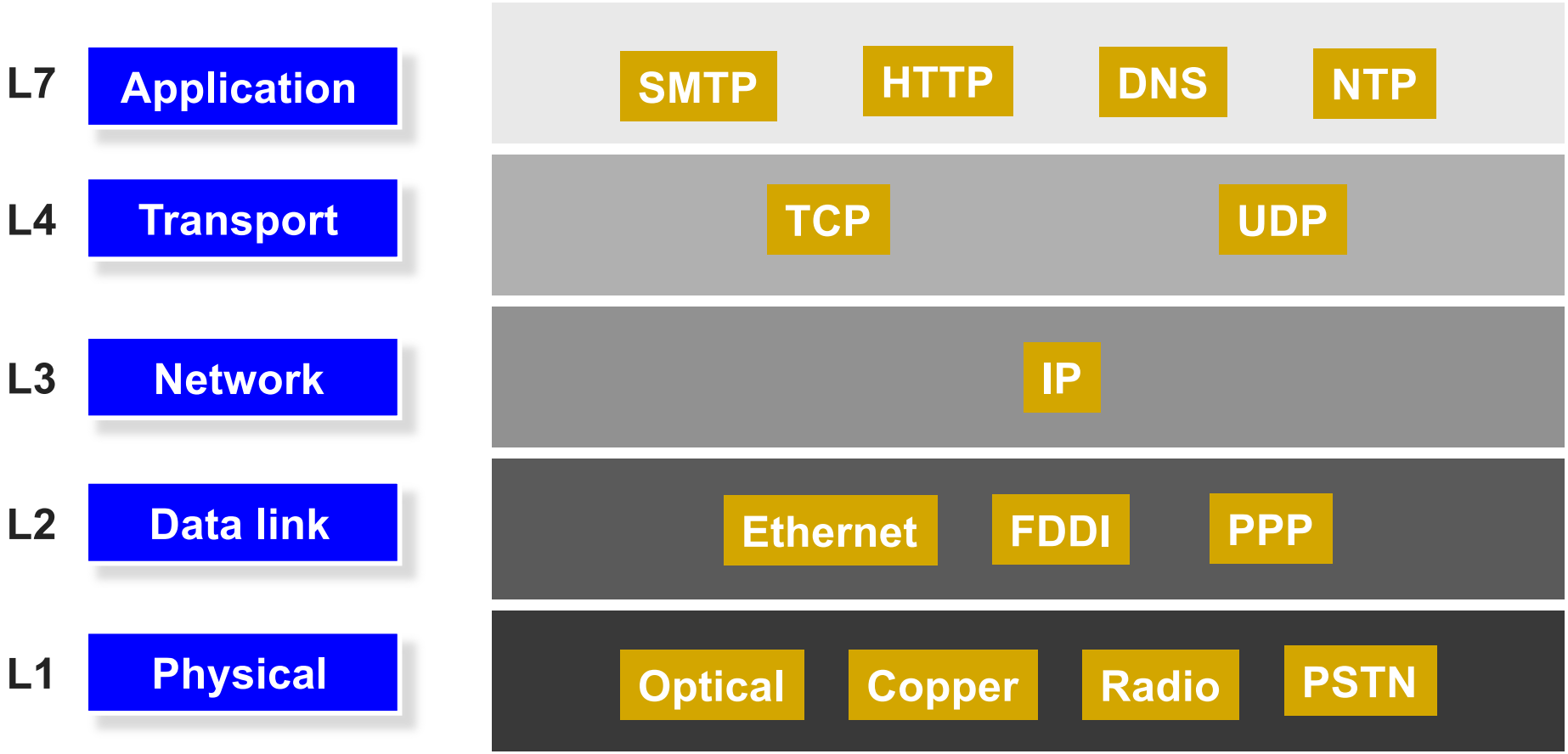
What is a Protocol?

- An agreement between parties (in the same later) 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”

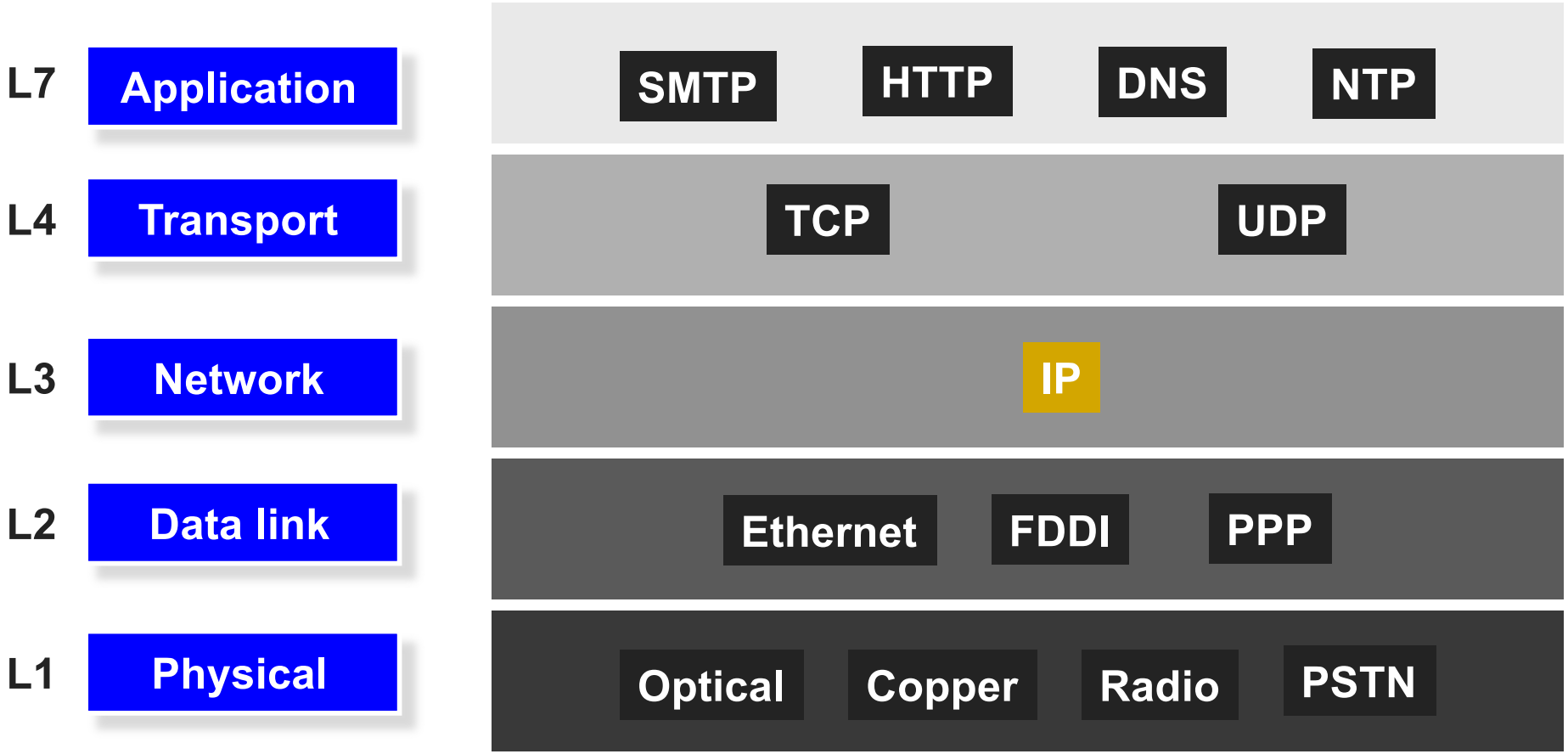
What is a Protocol?

- 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

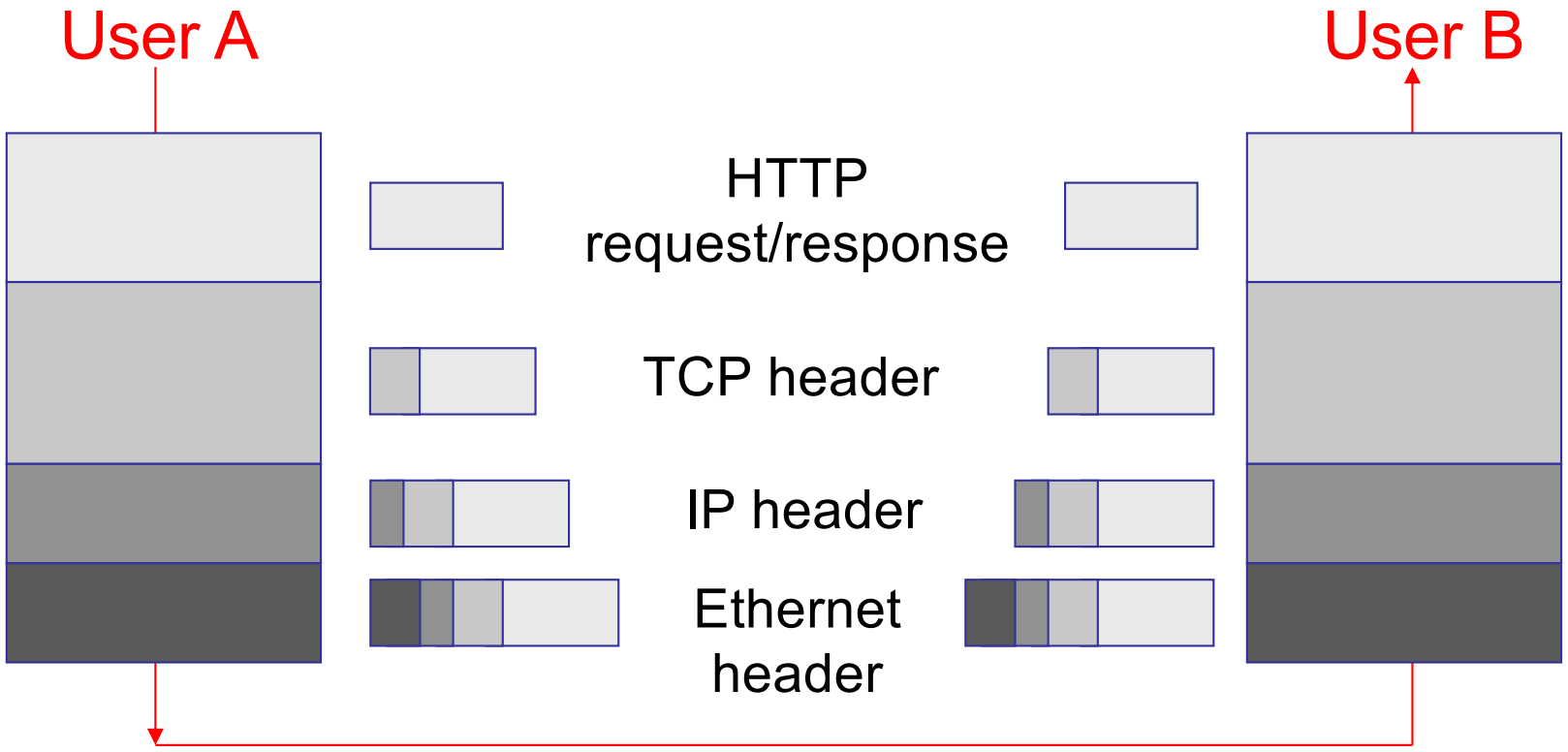
Protocols at different layers



ONE network layer protocol



Layer encapsulation: Protocol headers



5-MINUTE BREAK!

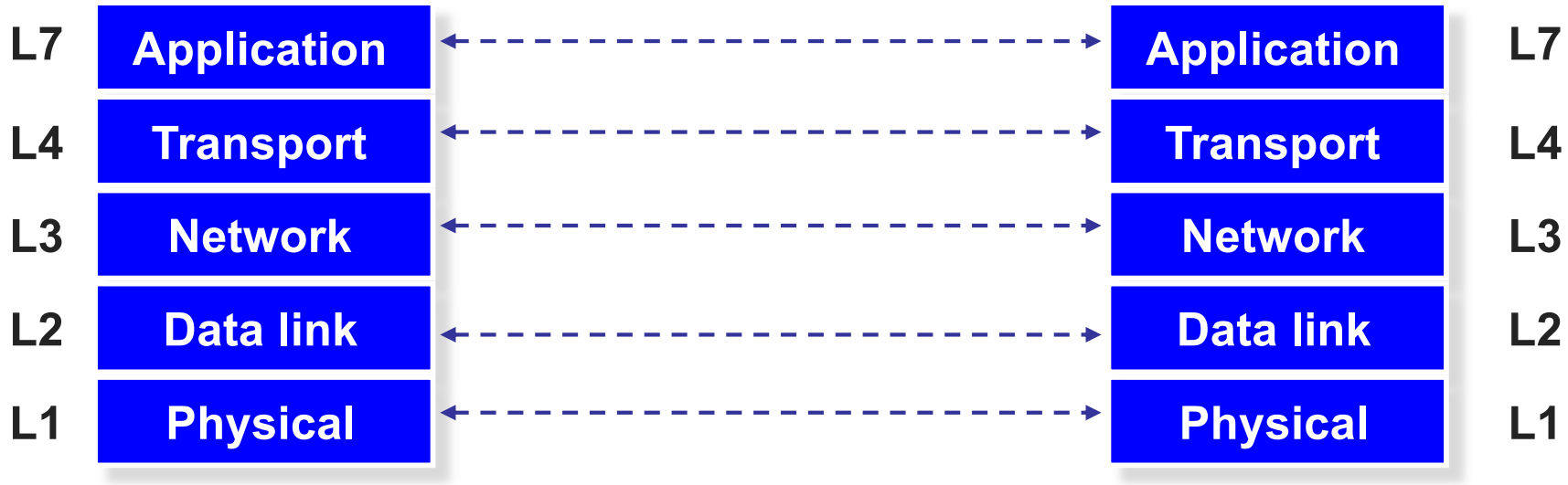
Announcements

- Assignment 1 is out!
  - Due Jan 25, 2023
- Register your github username
  - Link in A1 spec

Three steps

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

What gets implemented where?



What gets implemented at the end systems?

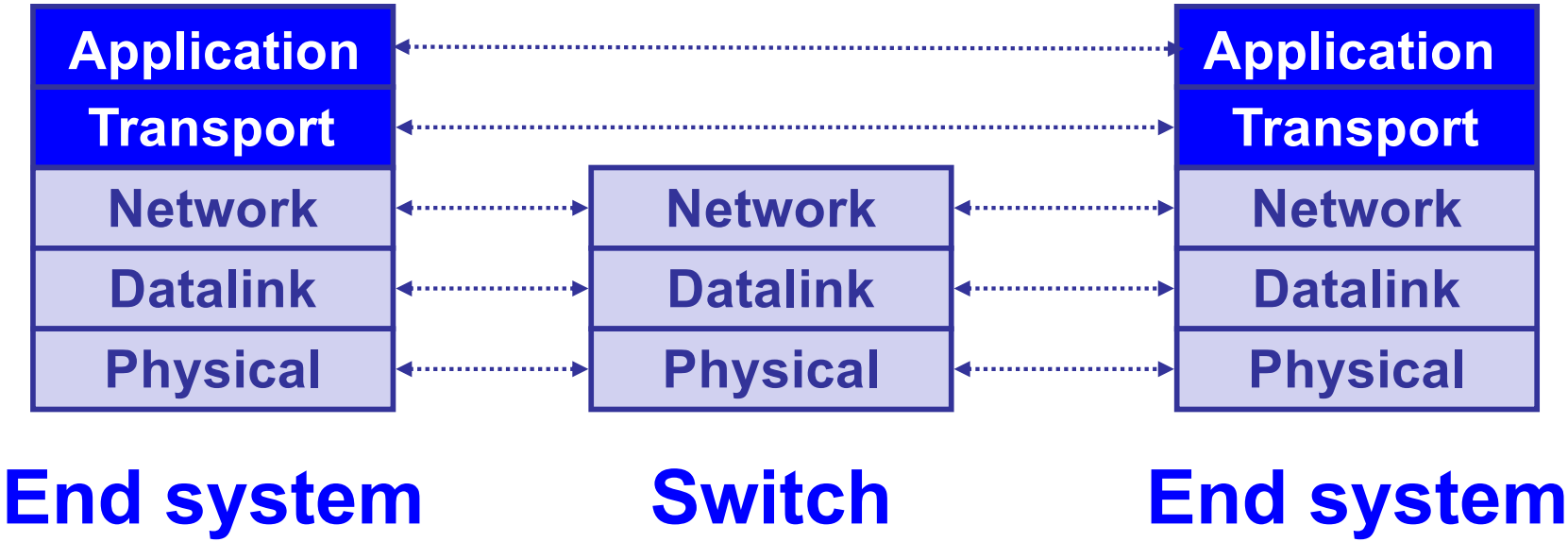
- Bits arrive on wire, must make it up to application
- Therefore, all layers must exist at host!

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) not supported

Simple Diagram

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



A closer look: End system

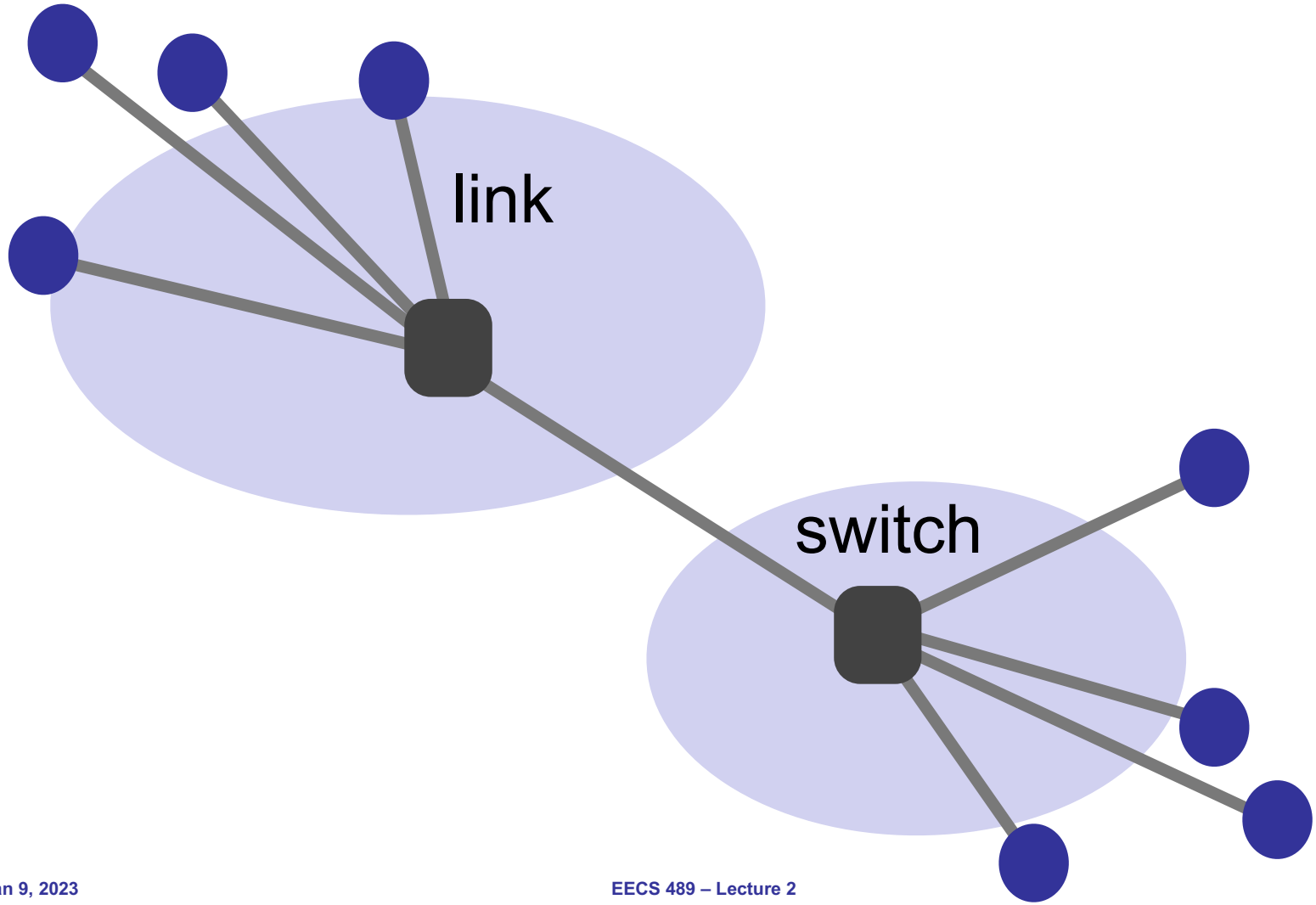
- Application
  - Web server, browser, mail, game
- Transport and network layer
  - typically part of the operating system
- Datalink and physical layer
  - hardware/firmware/drivers

What gets implemented in the network?

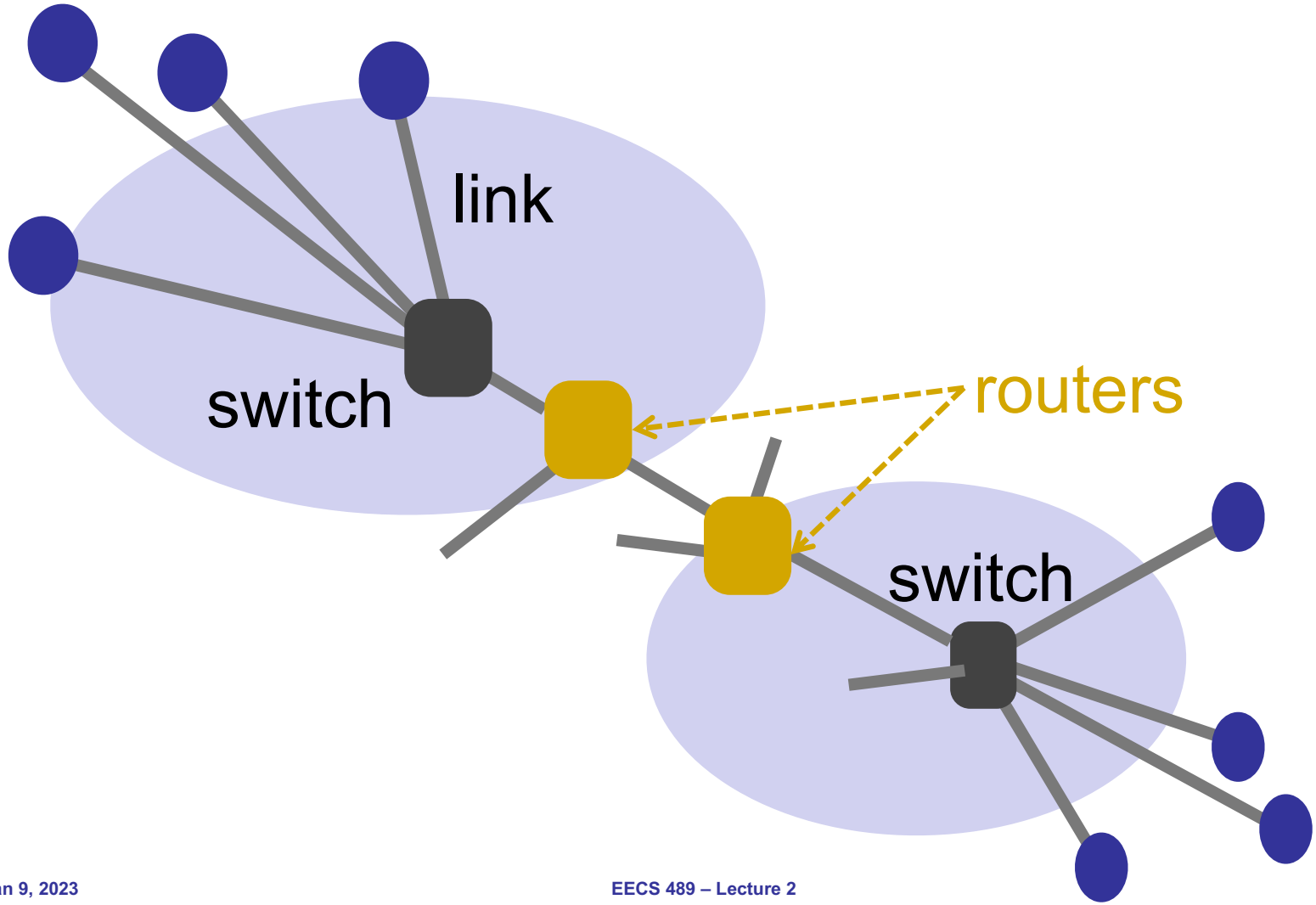
- Bits arrive on wire → physical layer (L1)
- Packets must be delivered across links and local networks → datalink layer (L2)
- Packets must be delivered between networks for global delivery → network layer (L3)

- 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



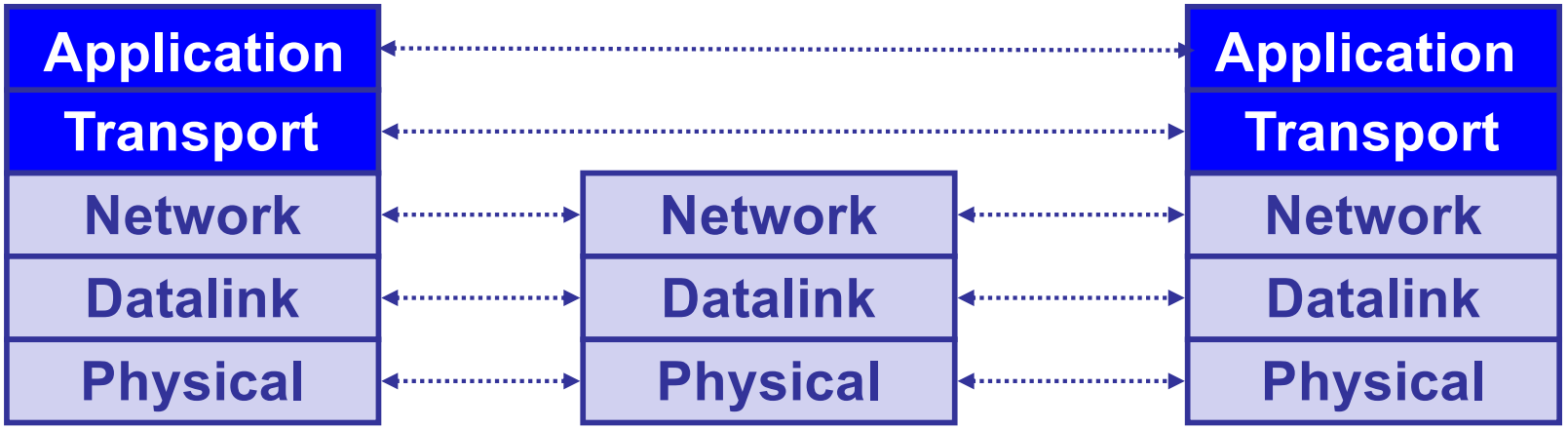
Switches vs. Routers

- 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

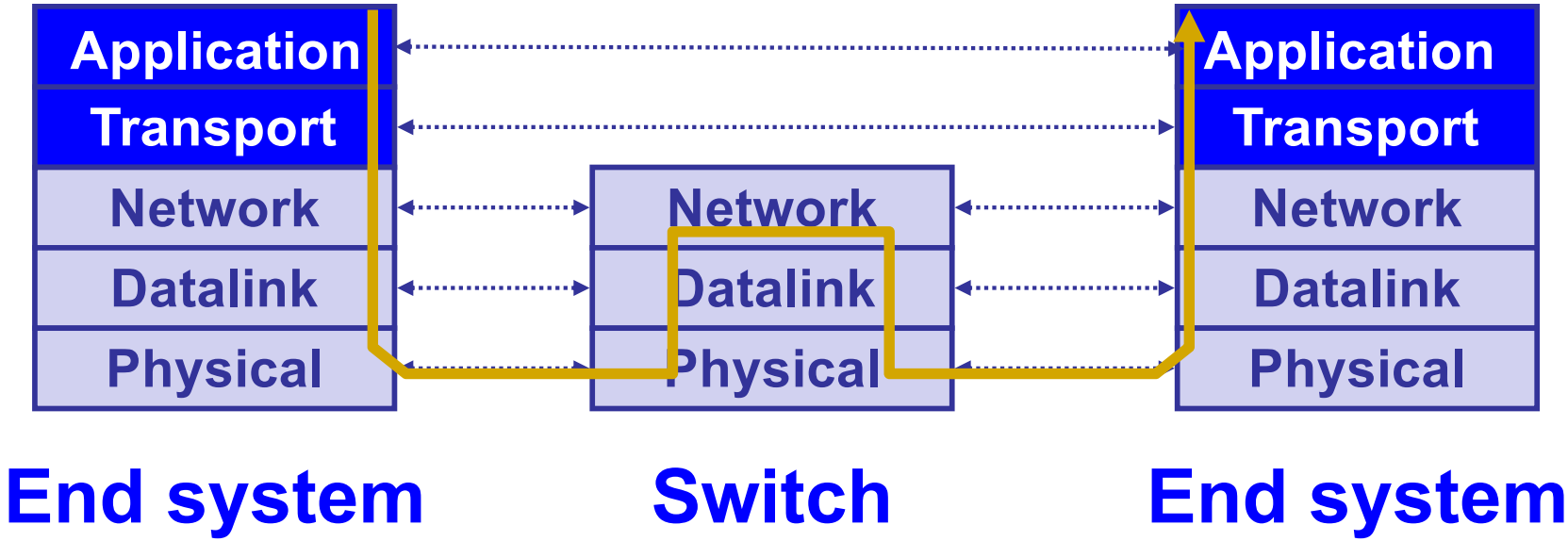
Logical communication

- A layer interact with its peers corresponding layer

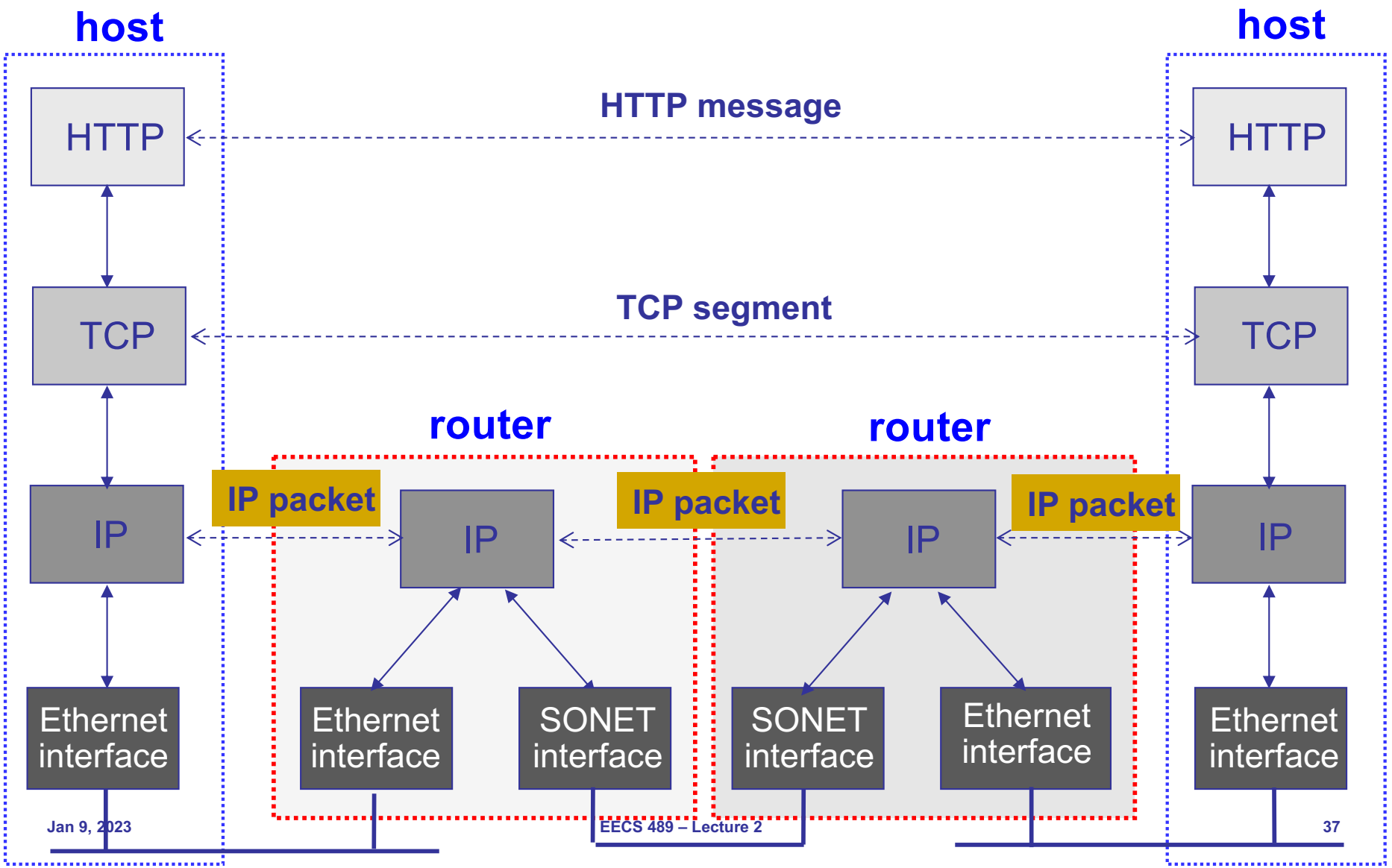


Physical communication

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



A protocol-centric diagram



Pros and cons of layering

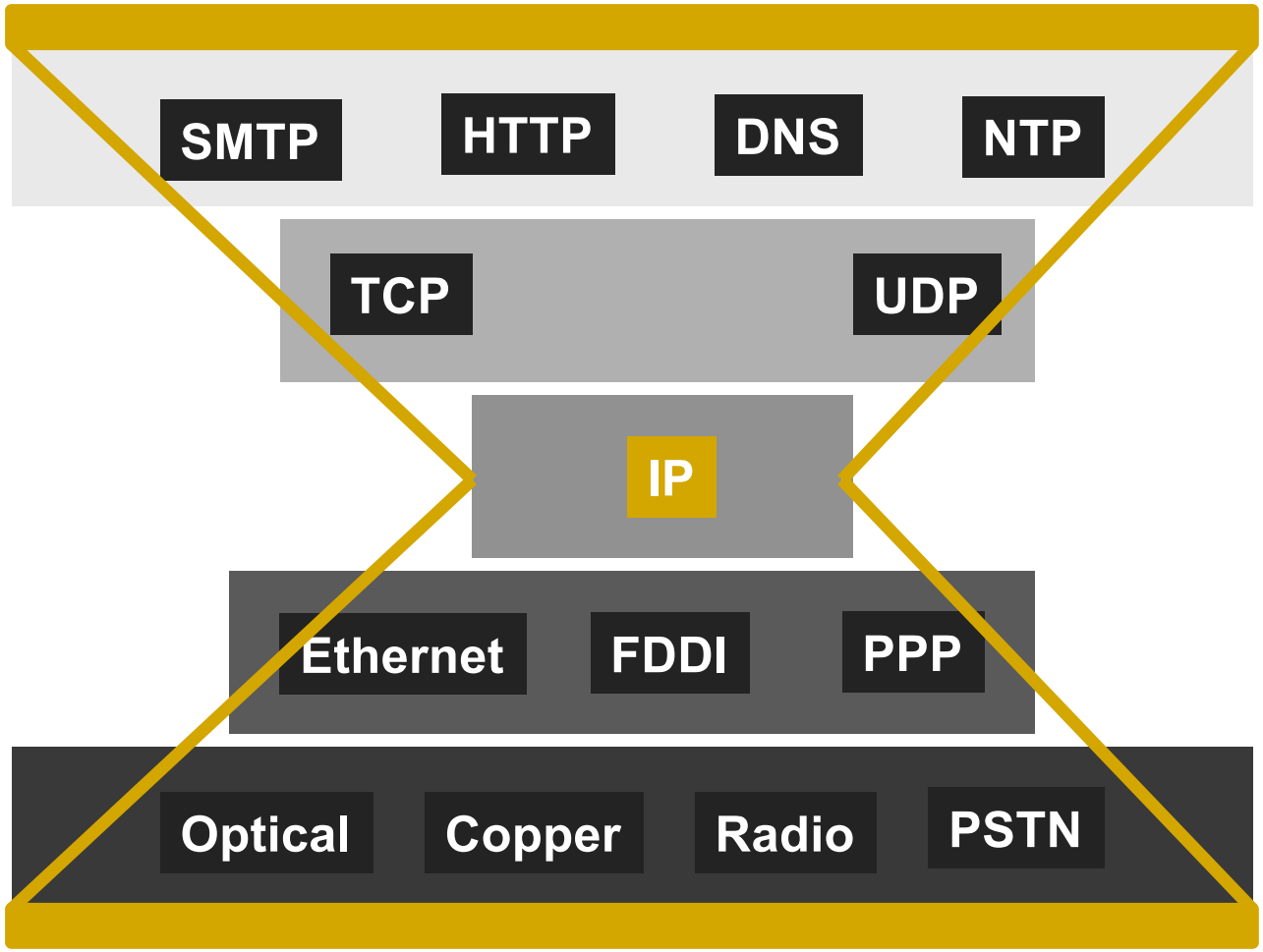
Why layers?

- 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

Summary

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