Computer Networks and Mobile Systems

Shyam Gollakota

The Internet of Things

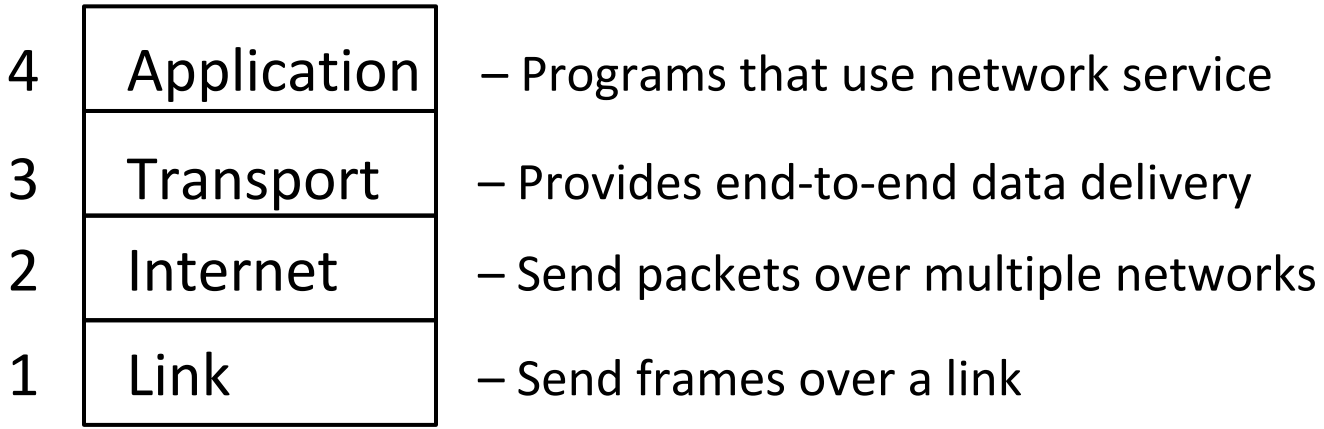
"The internet's next big frontier"

- BBC 1/7/2013

- A look at how the Internet is becoming immersed in the physical world, not just communications
  - Backscatter and sensing

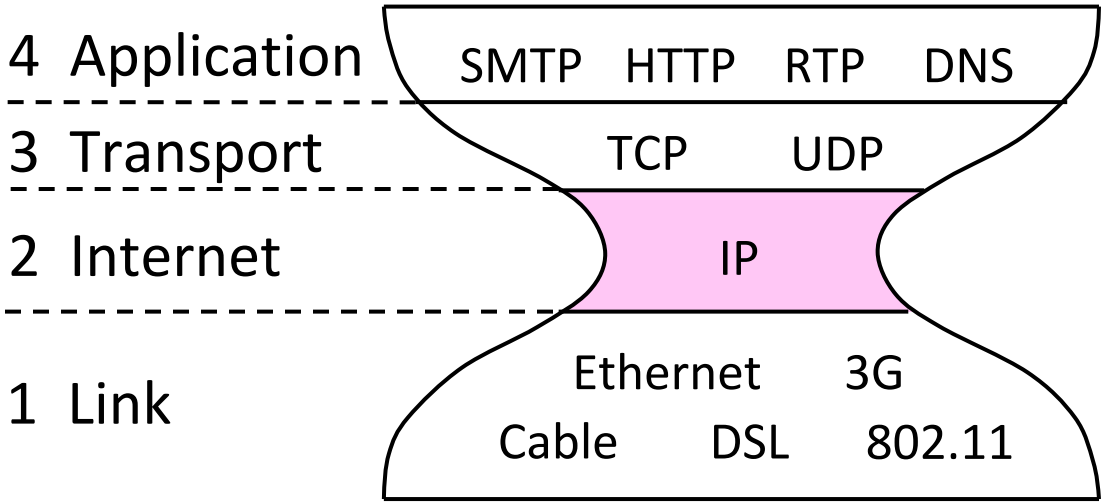
Internet Reference Model

- A four layer model based on experience; omits some OSI layers and uses IP as the network layer.



Internet Reference Model (3)

- IP is the “narrow waist” of the Internet
  - Supports many different links below and apps above



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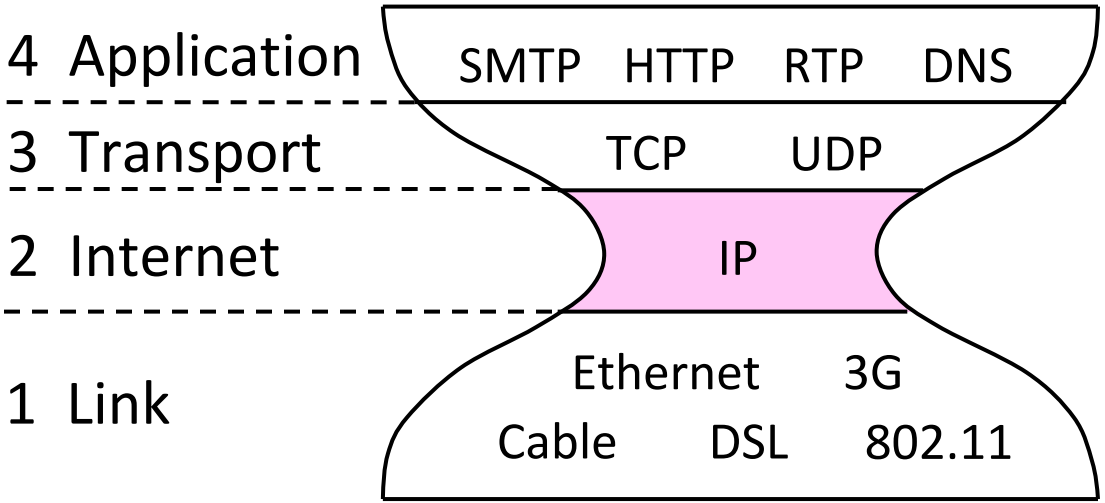

Cover Cutting Edge Research

- PHY Layer: Backscatter, IOT
- Internet: Data Center, SDN
- Transport: DCTCP, Multipath-TCP
- Applications: Localization, Gesture recognition, SPDY, mobile system design, gaming design

Class Structure

- Go over each of the layer
- Go over the required background
- Read the latest papers on each topic

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- Go over each of the layer
- Go over the required background
- Read the latest papers on each topic
  - Questions to be answered before each class
  - We will cover 2-3 papers

Evaluation

- Project 1,2,3 (10%,10%, 10%)
  - Create a communication system between two phones (Jan 31st)
  - Program a raspberry pi (Feb 10th)
  - Perform gesture recognition on smartphone (Feb 20th)
- Project 4 (40%)
  - Define and execute a research project (groups of 2)
- Paper presentations (30%)

Course Webpage

Cs.washington.edu/561

Cover Cutting Edge Research

- Phy Layer: Backscatter, passive-wifi
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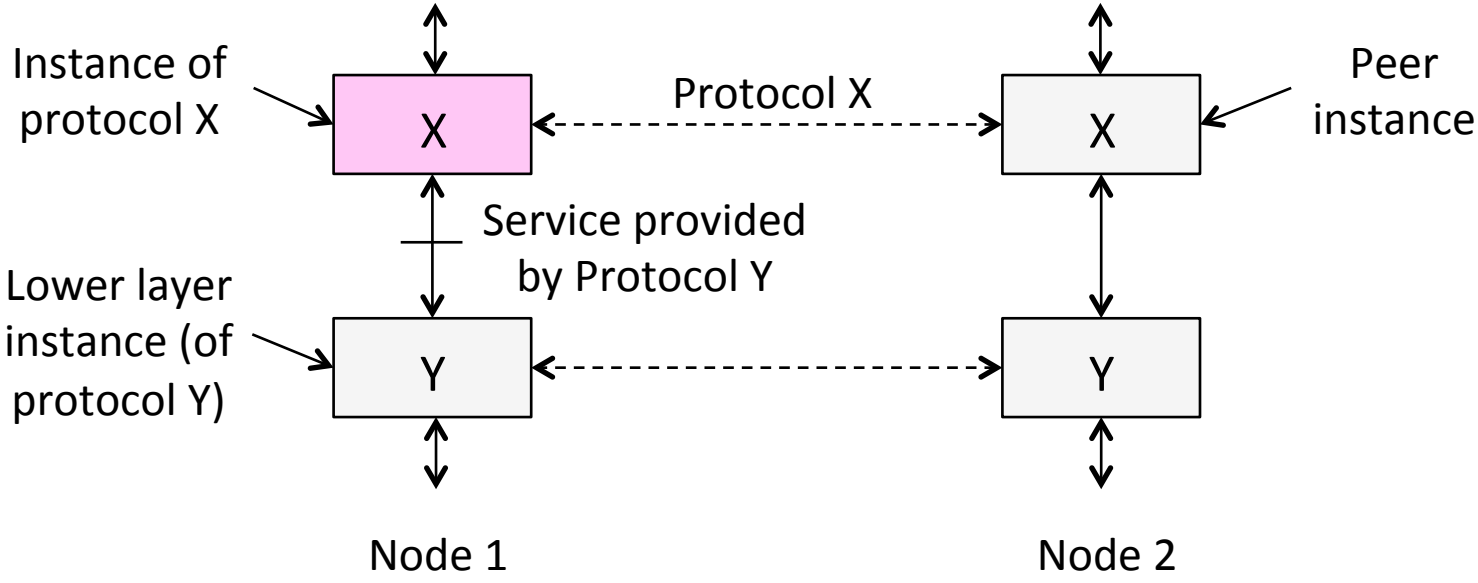
Protocols and Layers

- Protocols and layering is the main structuring method used to divide up network functionality
  - Each instance of a protocol talks virtually to its peer using the protocol
  - Each instance of a protocol uses only the services of the lower layer

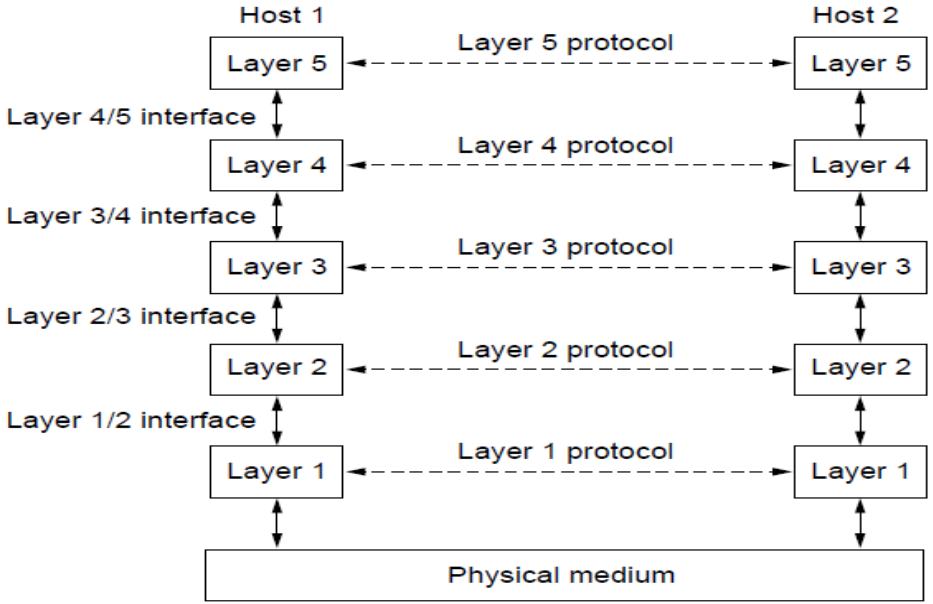
Protocols and Layers (3)

- Protocols are horizontal, layers are vertical



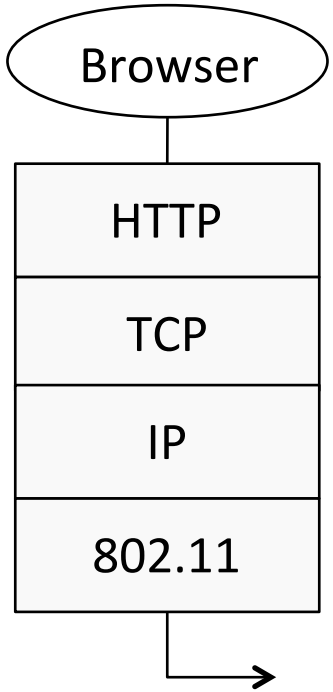
Protocols and Layers (4)

- Set of protocols in use is called a protocol stack



Protocols and Layers (6)

- Protocols you've probably heard of:
  - TCP, IP, 802.11, Ethernet, HTTP, SSL, DNS, … and many more
- An example protocol stack
  - Used by a web browser on a host that is wirelessly connected to the Internet

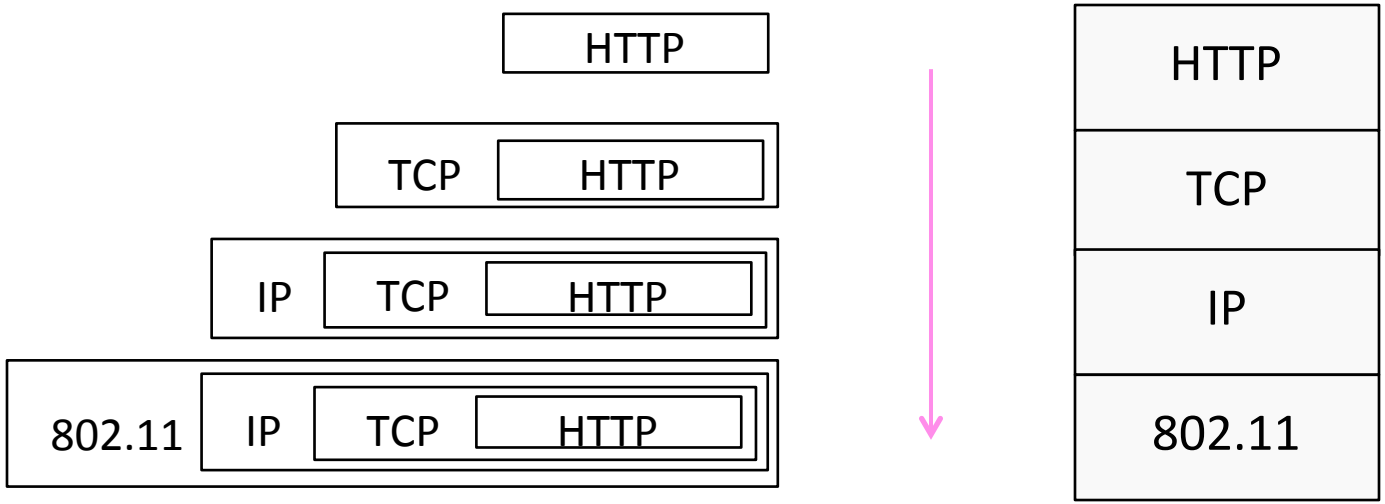


Encapsulation

- Encapsulation is the mechanism used to effect protocol layering
  - Lower layer wraps higher layer content, adding its own information to make a new message for delivery
  - Like sending a letter in an envelope; postal service doesn't look inside

Encapsulation (3)

- Message “on the wire” begins to look like an onion
  - Lower layers are outermost



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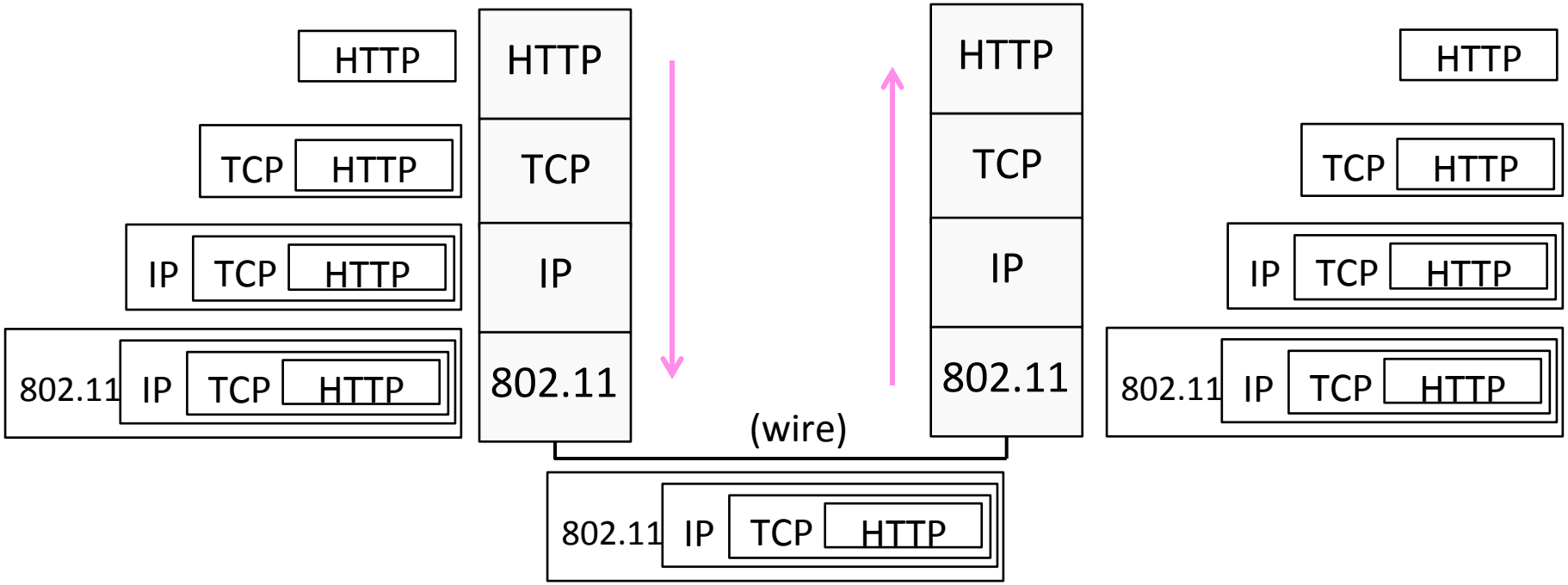
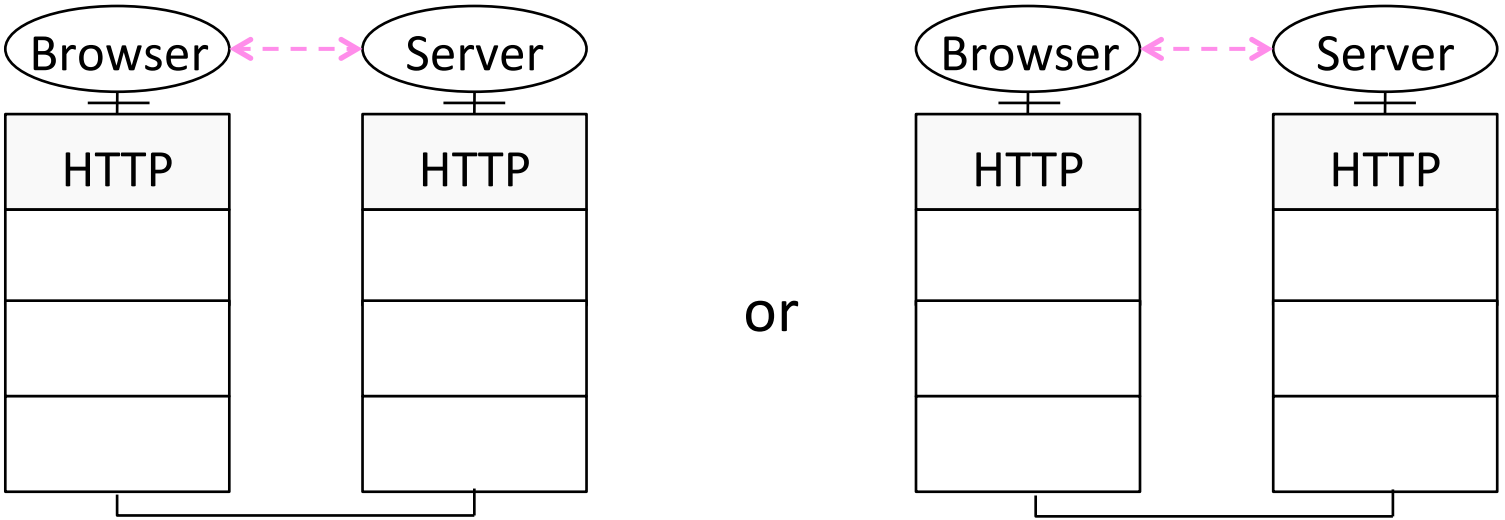


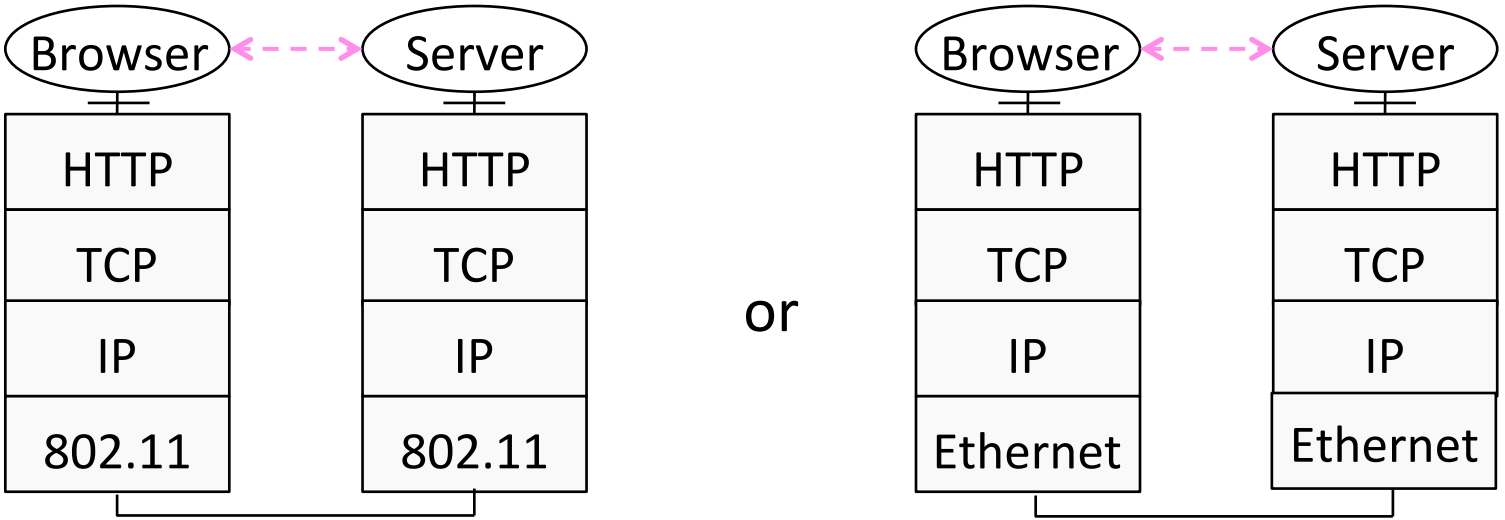
Advantage of Layering

- Information hiding and reuse



Advantage of Layering (2)

- Information hiding and reuse



Advantage of Layering (3)

- Using information hiding to connect different systems

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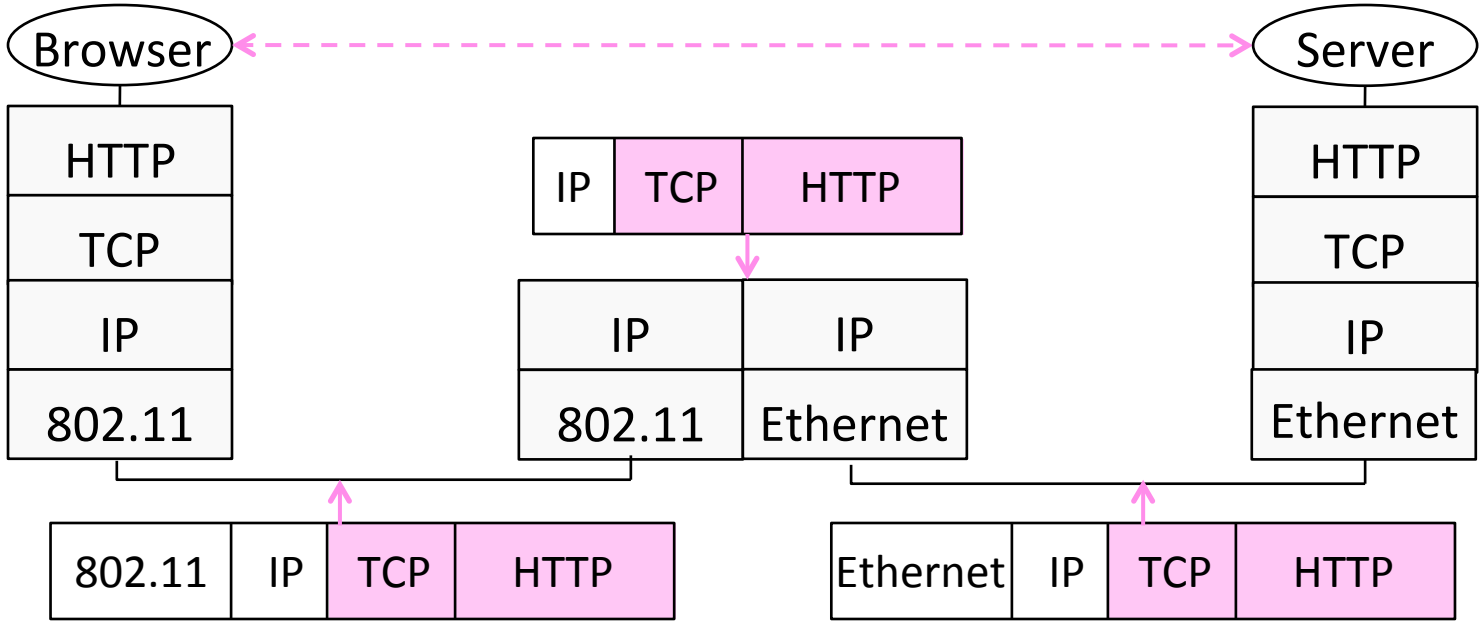

Disadvantage of Layering

- ??

Internet Reference Model

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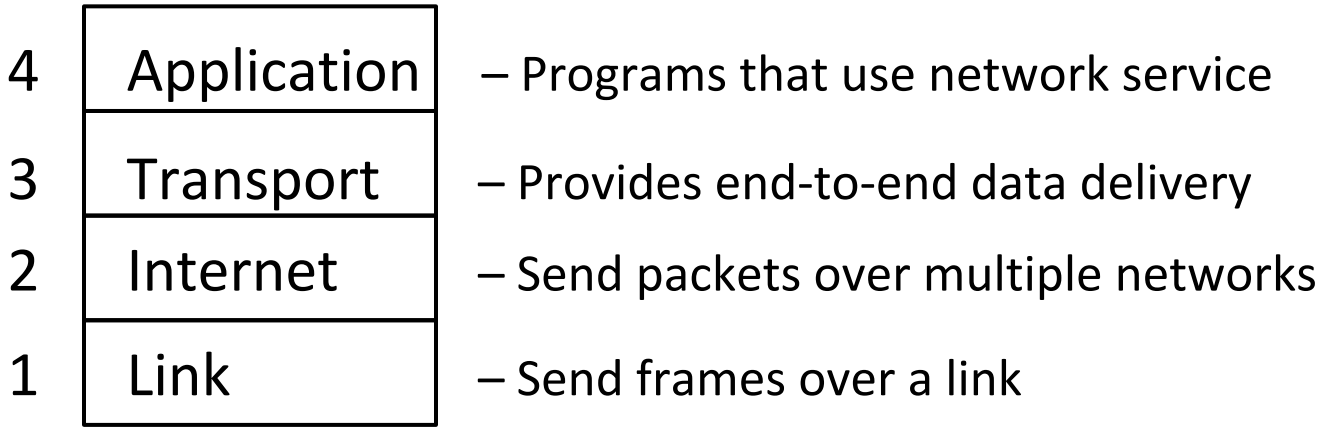

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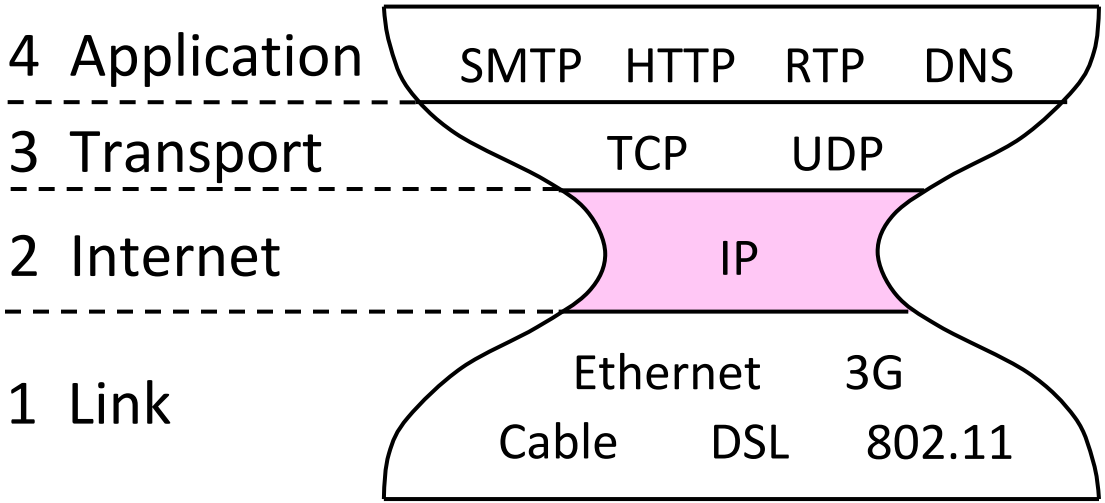
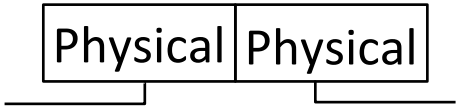


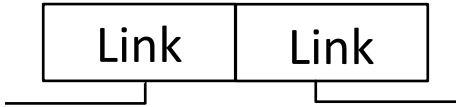
Layer-based Names (2)

- For devices in the network:

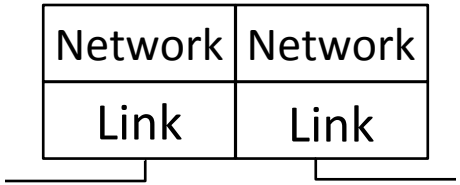
Repeater (or hub)



Switch (or bridge)



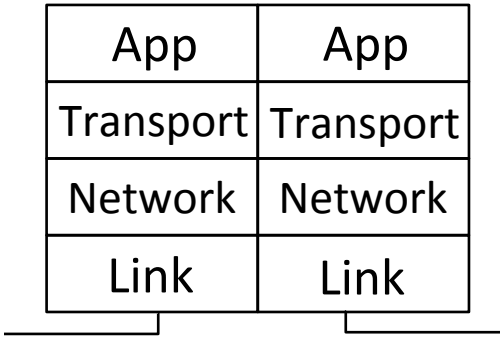
Router



Layer-based Names (3)

- For devices in the network:

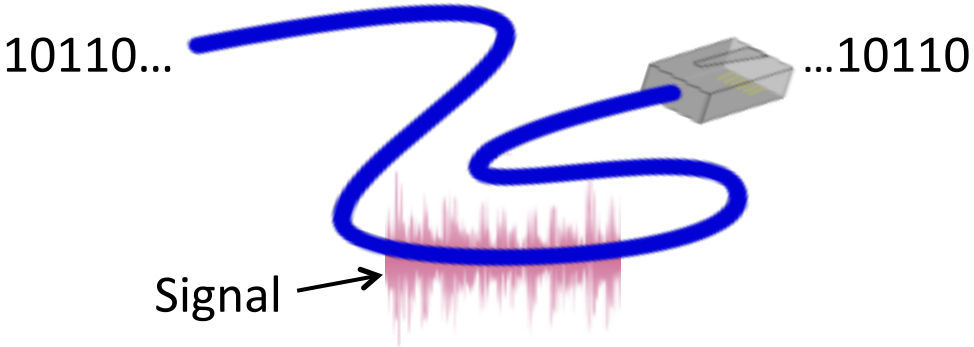
Proxy or middlebox or gateway



But they all look like this!

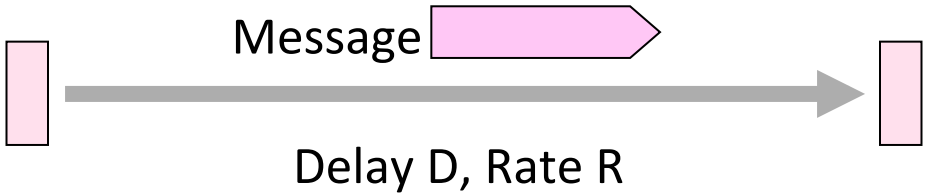
Scope of the Physical Layer

- Concerns how signals are used to transfer message bits over a link
  - Wires etc. carry analog signals
  - We want to send digital bits



Simple Link Model

- We'll end with an abstraction of a physical channel
  - Rate (or bandwidth, capacity, speed) in bits/second
  - Delay in seconds, related to length



- Other important properties:
  - Whether the channel is broadcast, and its error rate

Message Latency

- Latency is the delay to send a message over a link
  - Transmission delay: time to put M-bit message “on the wire”
  - Propagation delay: time for bits to propagate across the wire
  - Combining the two terms we have:

Message Latency (2)

- Latency is the delay to send a message over a link
  - Transmission delay: time to put M-bit message "on the wire"

    T-delay = M (bits) / Rate (bits/sec) = M/R seconds

  - Propagation delay: time for bits to propagate across the wire

    P-delay = Length / speed of signals = Length / ⅔c = D seconds

  - Combining the two terms we have: L = M/R + D

Metric Units

- The main prefixes we use:

Prefix	Exp.	prefix	exp.
K(ilo)	10^3	m(illi)	10^{-3}
M(ega)	10^6	μ(micro)	10^{-6}
G(iga)	10^9	n(ano)	10^{-9}

- Use powers of 10 for rates, 2 for storage
  - 1 Mbps = 1,000,000 bps, 1 KB = 2^{10} bytes
- "B" is for bytes, "b" is for bits

Latency Examples (2)

- "Dialup" with a telephone modem:

  D = 5 ms, R = 56 kbps, M = 1250 bytes

  L = 5 ms + (1250x8)/(56 x 10^3) sec = 184 ms!

- Broadband cross-country link:

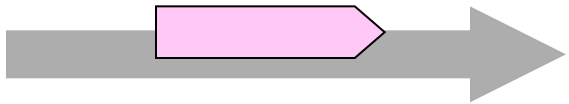
  D = 50 ms, R = 10 Mbps, M = 1250 bytes

  L = 50 ms + (1250x8) / (10 x 10^6) sec = 51 ms

- A long link or a slow rate means high latency
  - Often, one delay component dominates

Bandwidth-Delay Product

- Messages take space on the wire!



- The amount of data in flight is the <u>bandwidth-delay (BD) product</u>

$$BD = R \times D$$

  - Measure in bits, or in messages
  - Small for LANs, big for “long fat” pipes

Bandwidth-Delay Example (2)

- Fiber at home, cross-country

  R=40 Mbps, D=50 ms

  BD = $40 \times 10^{6} \times 50 \times 10^{-3}$ bits

  = 2000 Kbit

  = 250 KB

- That's quite a lot of data "in the network"!