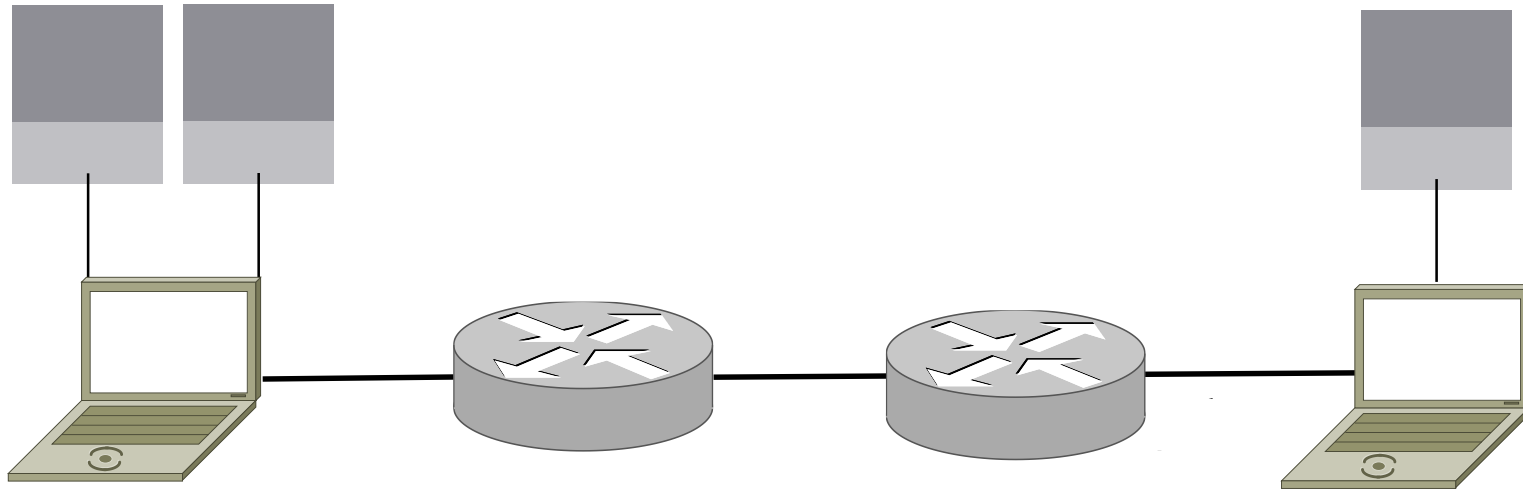
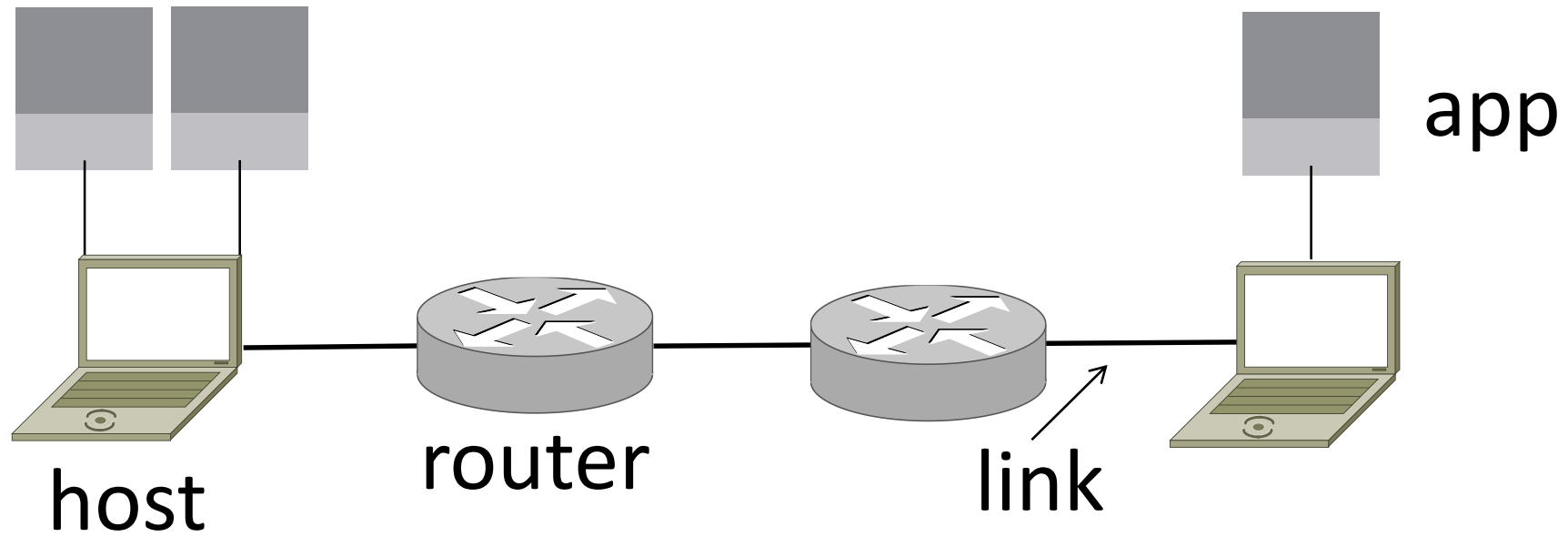


Network Components

Parts of a Network



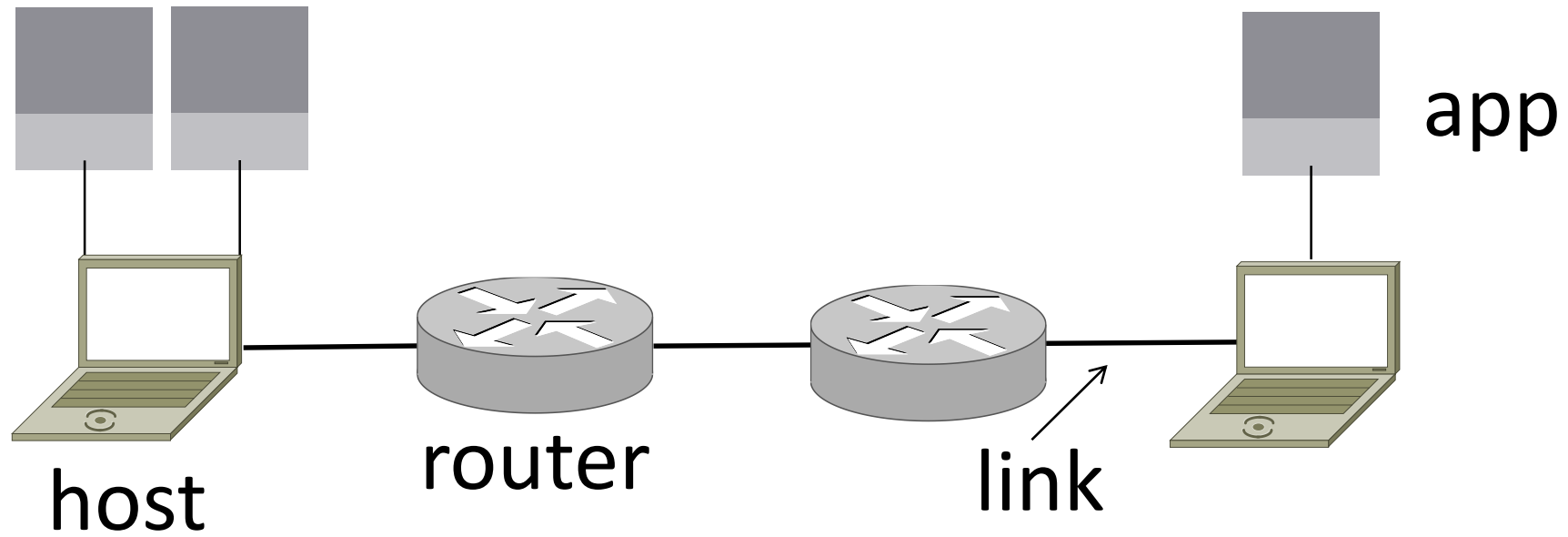
Parts of a Network



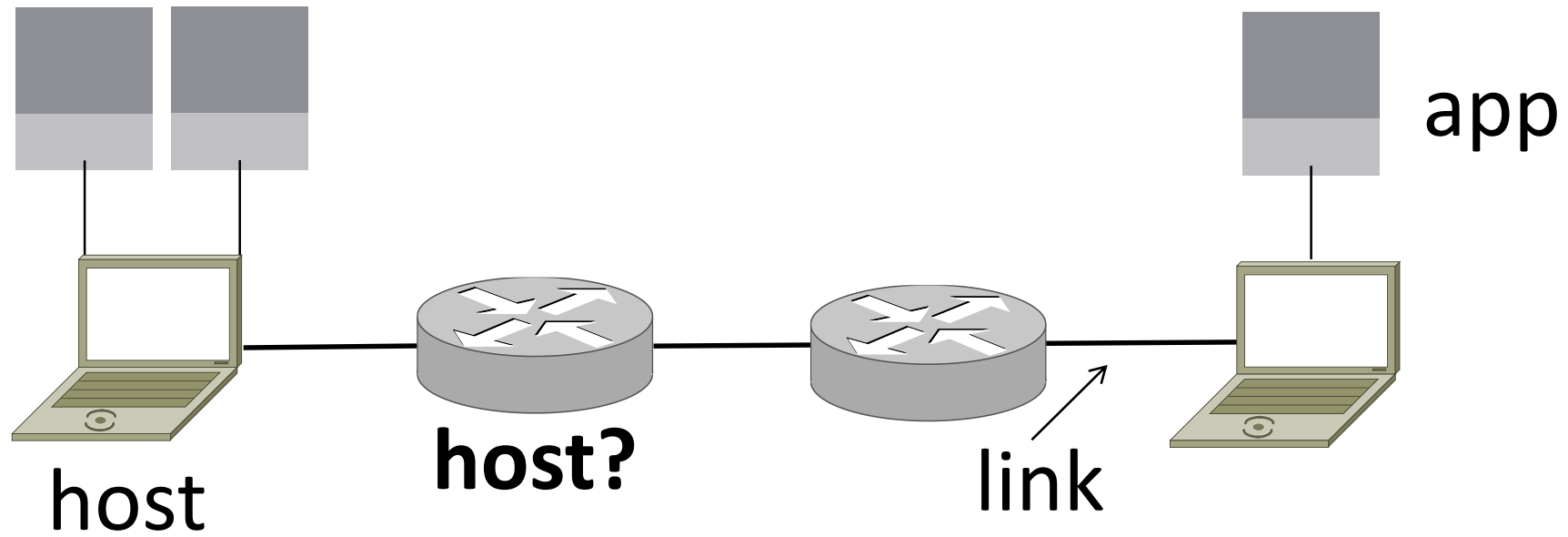
Component Names

| Component | Function | Example |
|--|-------------------------------|-------------------------------|
| <u>Application</u> , or app, user | Uses the network | Skype, iTunes, Amazon |
| <u>Host</u> , or end-system, edge device, node, source, sink | Supports apps | Laptop, mobile, desktop |
| <u>Router</u> , or switch, node, hub, intermediate system | Relays messages between links | Access point, cable/DSL modem |
| <u>Link</u> , or channel | Connects nodes | Wires, wireless |

Parts of a Network



Parts of a Network

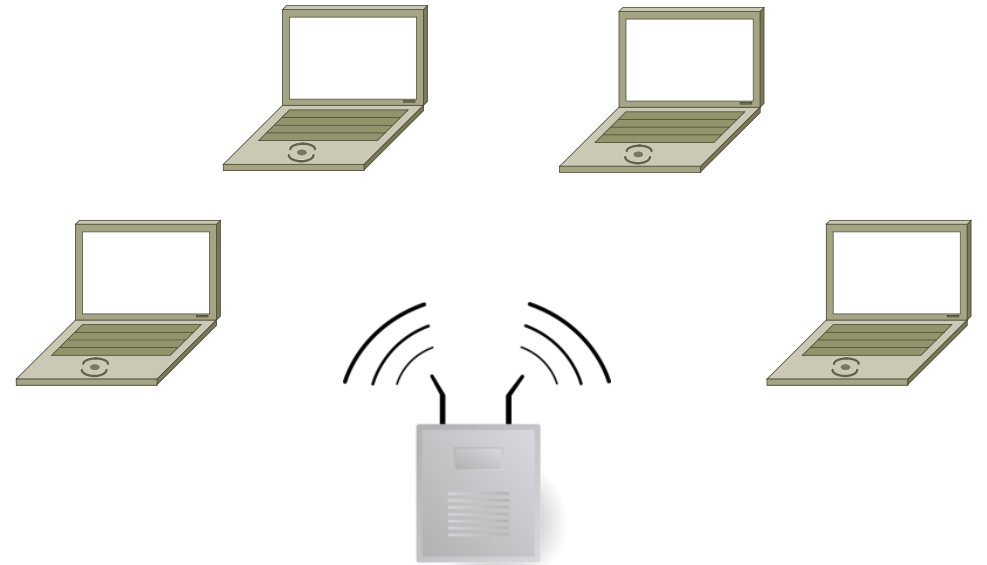


Types of Links

- Full-duplex
 - Bidirectional
- Half-duplex
 - Bidirectional
- Simplex
 - unidirectional

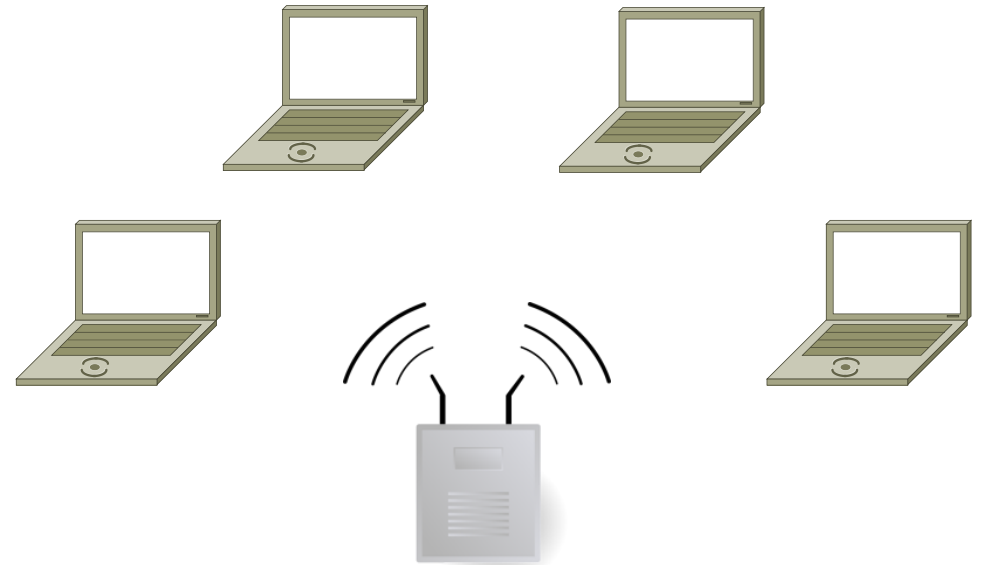
Wireless Links

- Message is broadcast
 - Received by all nodes in range
 - Not a good fit with our model



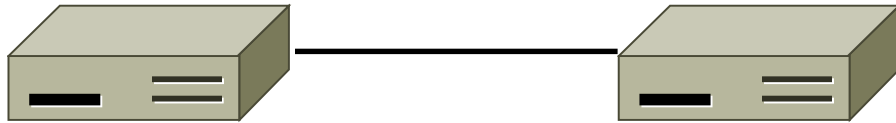
Wireless Links (2)

- Often show logical links
 - Not all possible connectivity

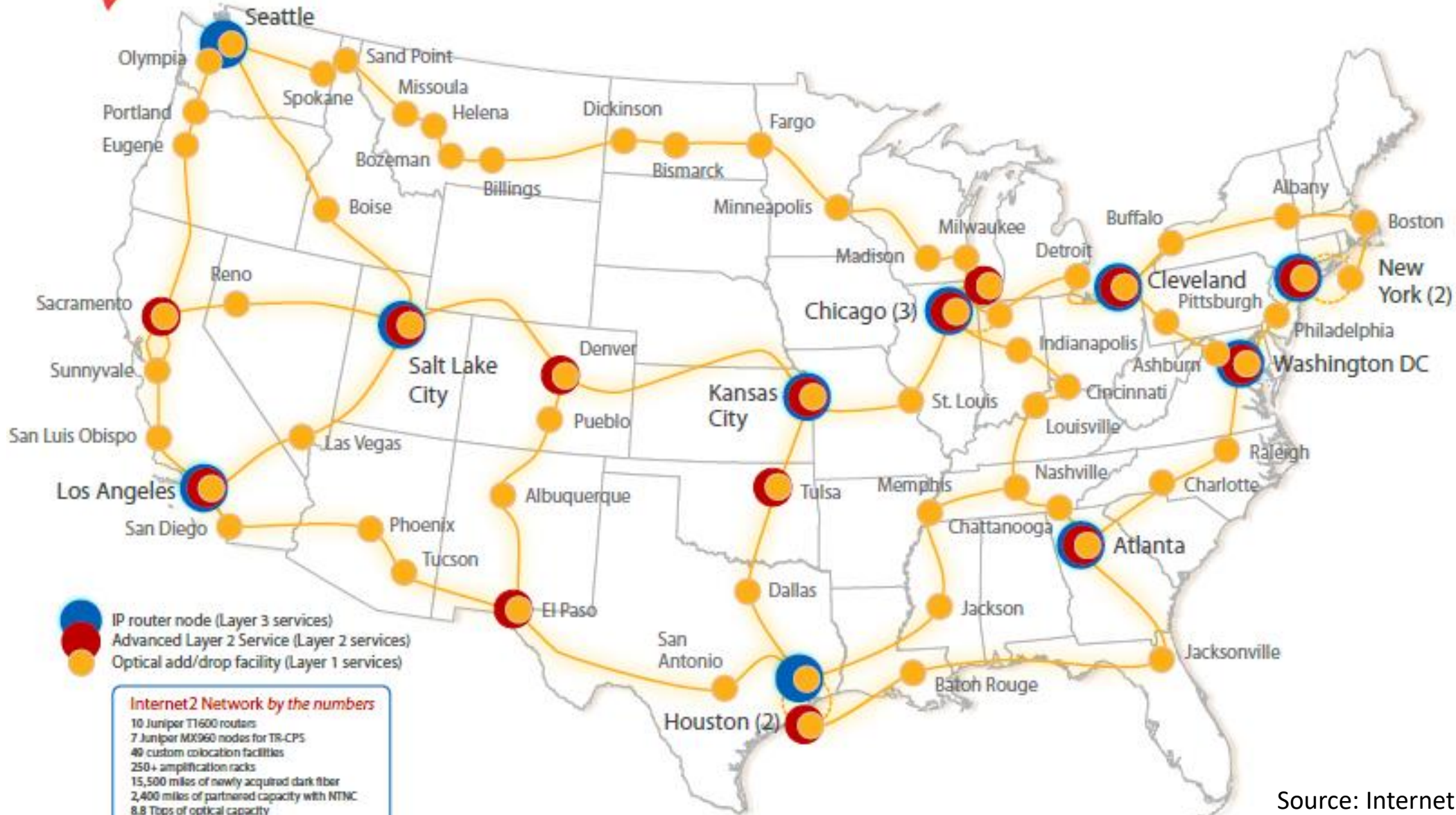


A Small Network

- Connect a couple of computers



- Next, a large network ...



- IP router node (Layer 3 services)
- Advanced Layer 2 Service (Layer 2 services)
- Optical add/drop facility (Layer 1 services)

Internet2 Network by the numbers

- 10 Juniper T1600 routers
- 7 Juniper MX960 nodes for TR-CPS
- 40 custom colocation facilities
- 250+ amplification racks
- 15,500 miles of newly acquired dark fiber
- 2,400 miles of partnered capacity with NTNC
- 8.8 Tbps of optical capacity
- 100 Gbps of IP capacity
- 300+ Ciena ActiveFlex 6500 network elements



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NETWORKS



Example Computer Networks?

Example Computer Networks

- WiFi (802.11)
- Enterprise / Ethernet
- ISP (Internet Service Provider)
- Cable / DSL
- Mobile phone / cellular (2G, 3G, 4G)
- Bluetooth
- Telephone
- Satellite ...

Computer network names by scale

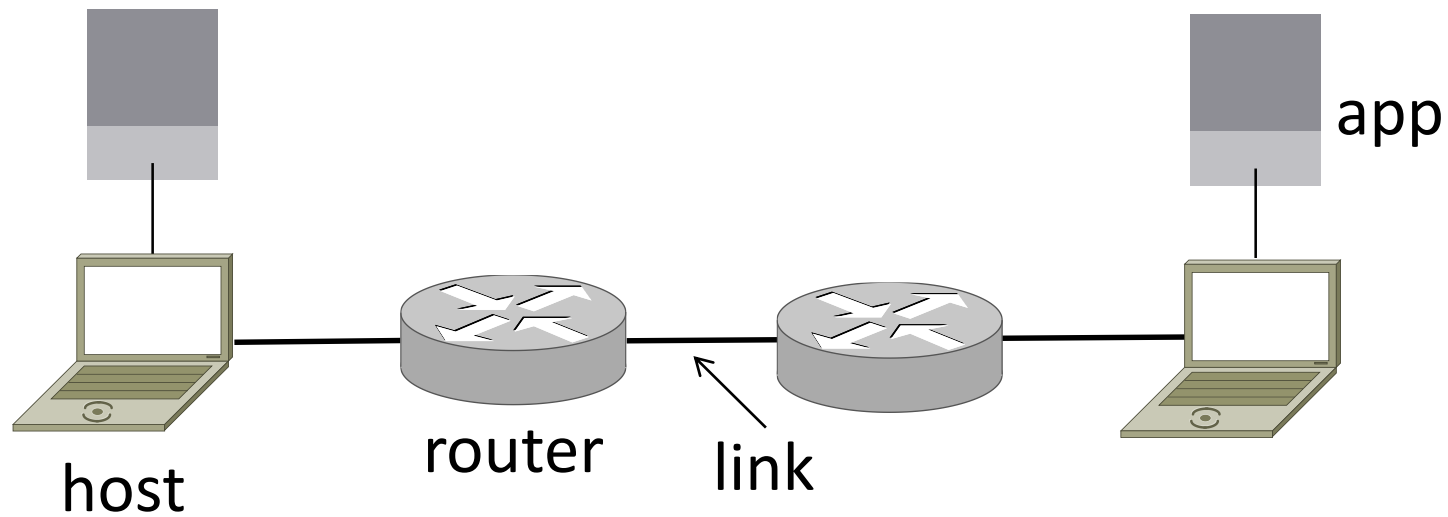
| Scale | Type | Example |
|--------------|--|---------------------------|
| Vicinity | <u>PAN</u> (Personal Area Network) | Bluetooth (e.g., headset) |
| Building | <u>LAN</u> (Local Area Network) | WiFi, Ethernet |
| City | <u>MAN</u> (Metropolitan Area Network) | Cable, DSL |
| Country | <u>WAN</u> (Wide Area Network) | Large ISP |
| Planet | The Internet (network of all networks) | The Internet! |

Internetworks

- An internetwork, or internet, is what you get when you join networks together
 - Just another network
- The Internet (capital “I”) is the internet we all use

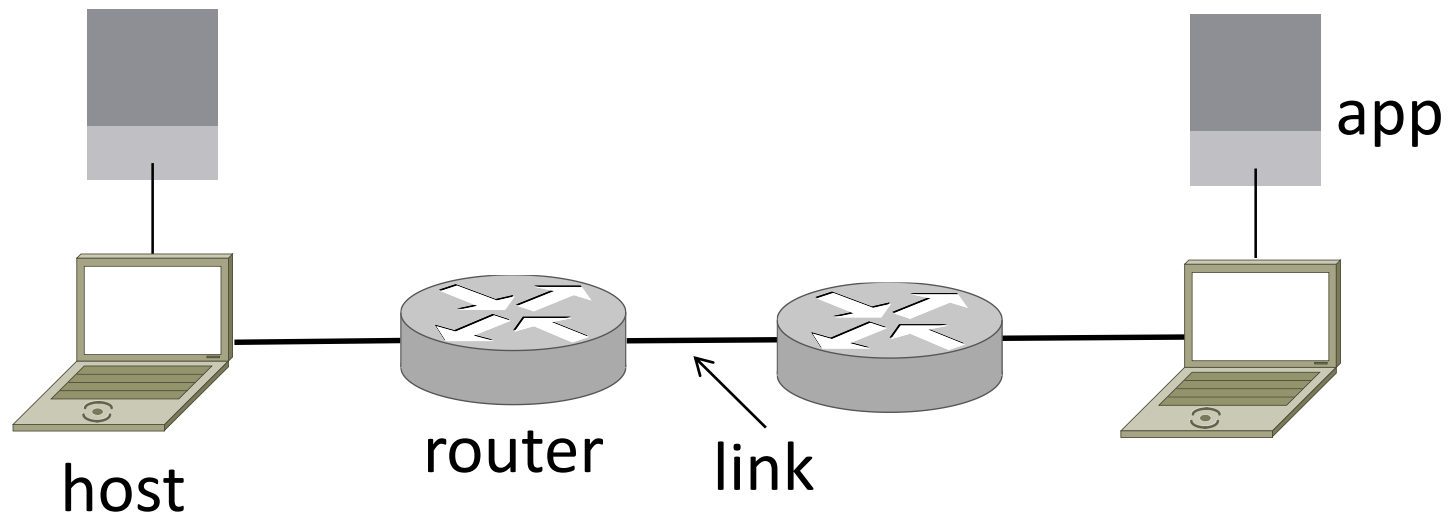
Network Boundaries

- What part is the “network”?



Network Boundaries (2)

- What part represents an “ISP”?



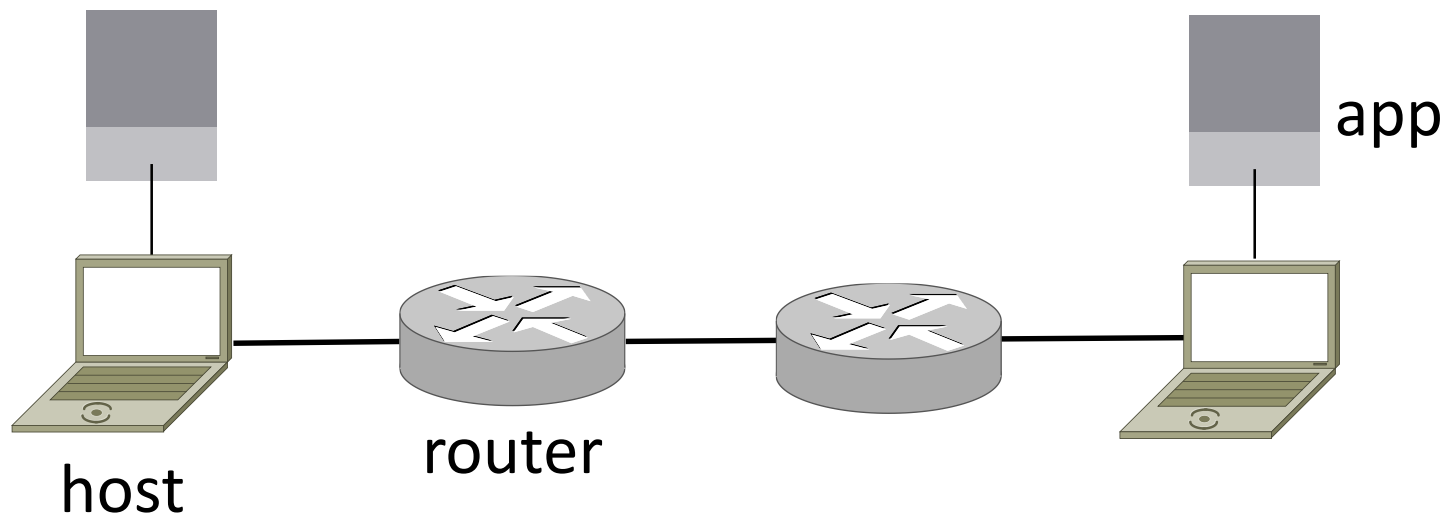
Network Boundaries (3)

- Cloud as a generic network



Key Interfaces

- Between (1) apps and network, and (2) network components



What API should networks provide?

Networks Need Modularity

- The network does much for apps:
 - Make and break connections
 - Find a path through the network
 - Transfers information reliably
 - Transfers arbitrary length information
 - Send as fast as the network allows
 - Shares bandwidth among users
 - Secures information in transit
 - Lets many new hosts be added
 - ...

Networks Need Modularity

- The network does much for apps:

We need a form of modularity, to help manage complexity and support reuse

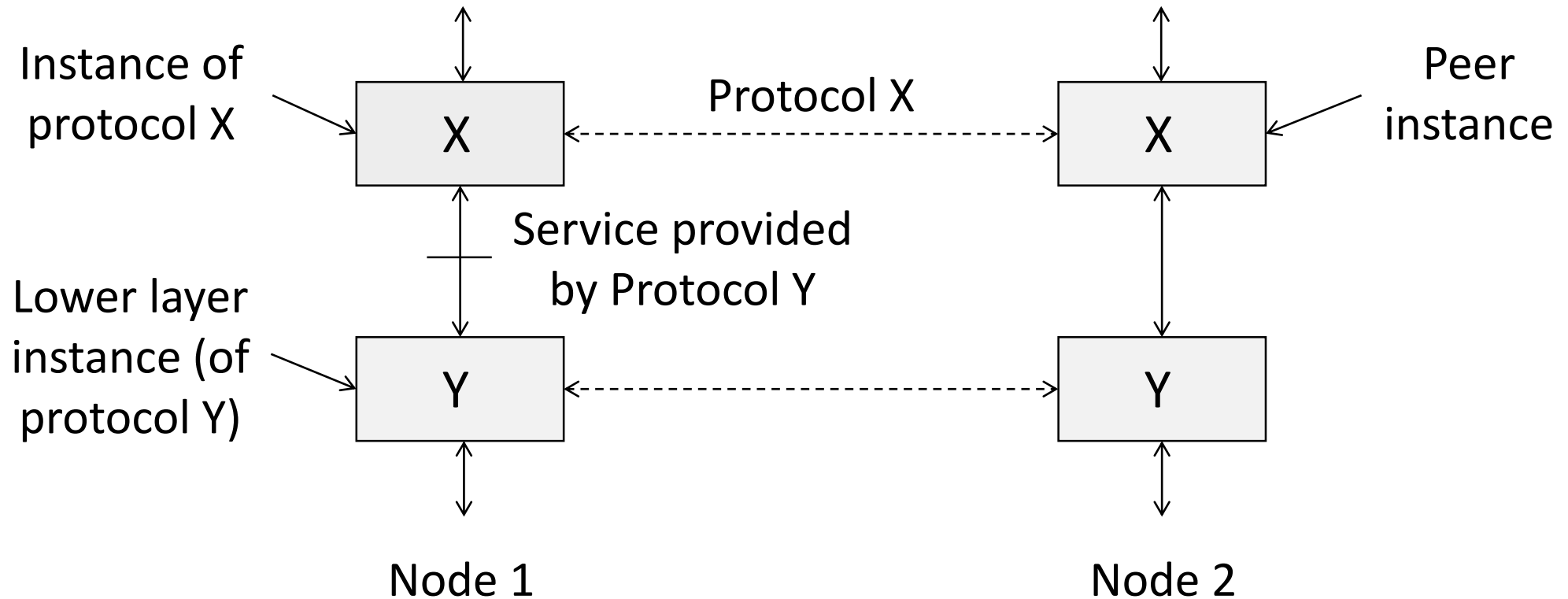
- Secures information in transit
- Lets many new hosts be added
- ...

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

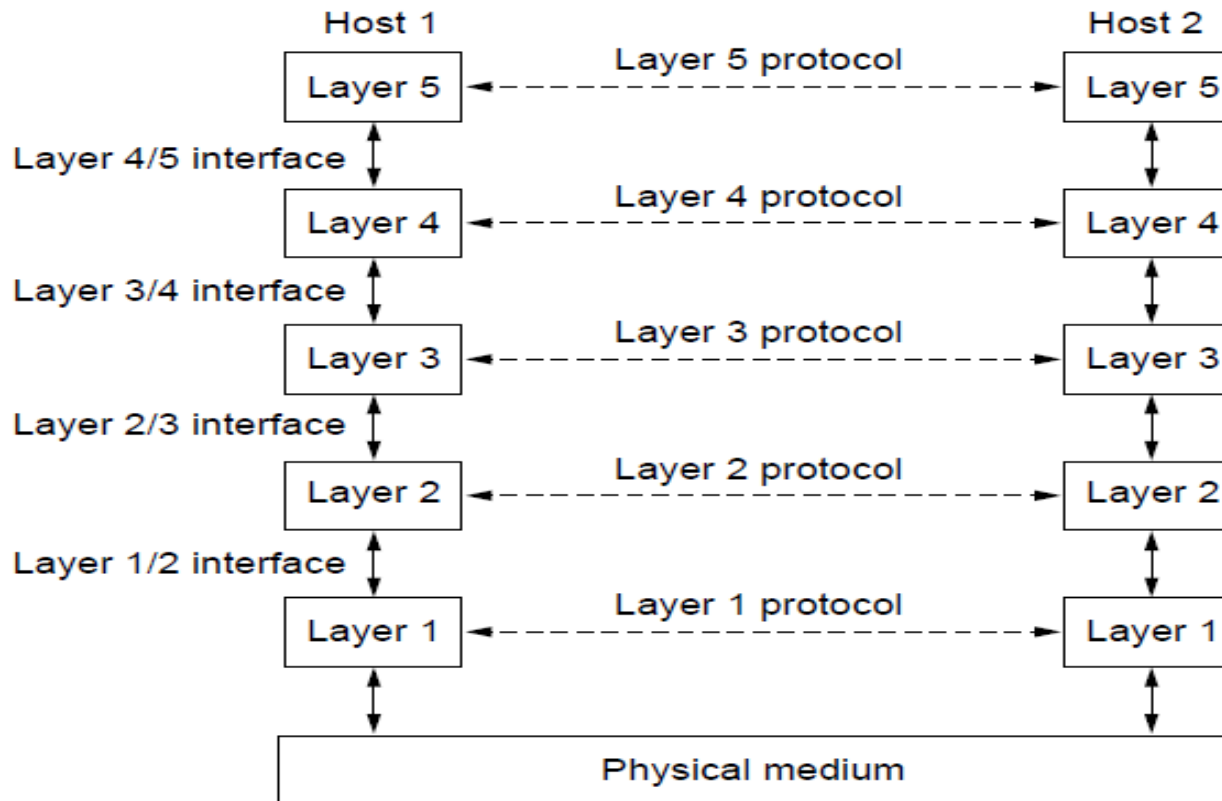
Protocols and Layers (2)

- Protocols are horizontal, layers are vertical



Protocols and Layers (3)

- Set of protocols in use is called a protocol stack

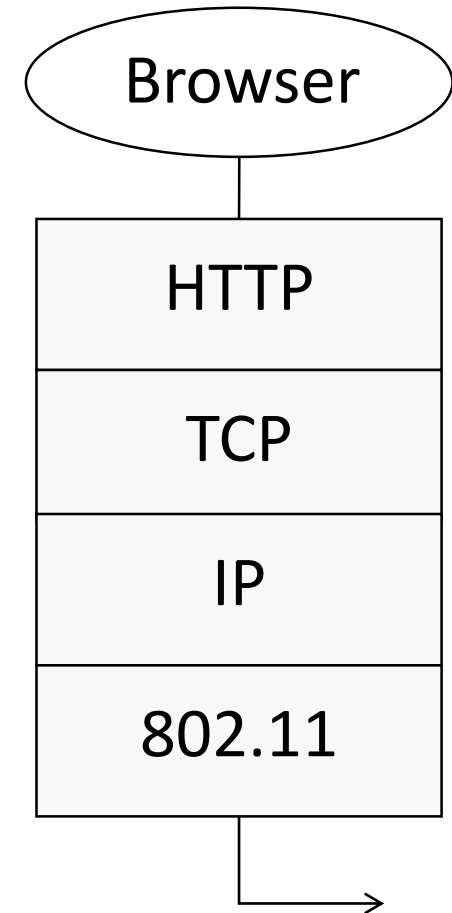


Protocols and Layers (4)

- Protocols you've probably heard of:
 - TCP, IP, 802.11, Ethernet, HTTP, SSL, DNS, ... and many more

Protocols and Layers (5)

- 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

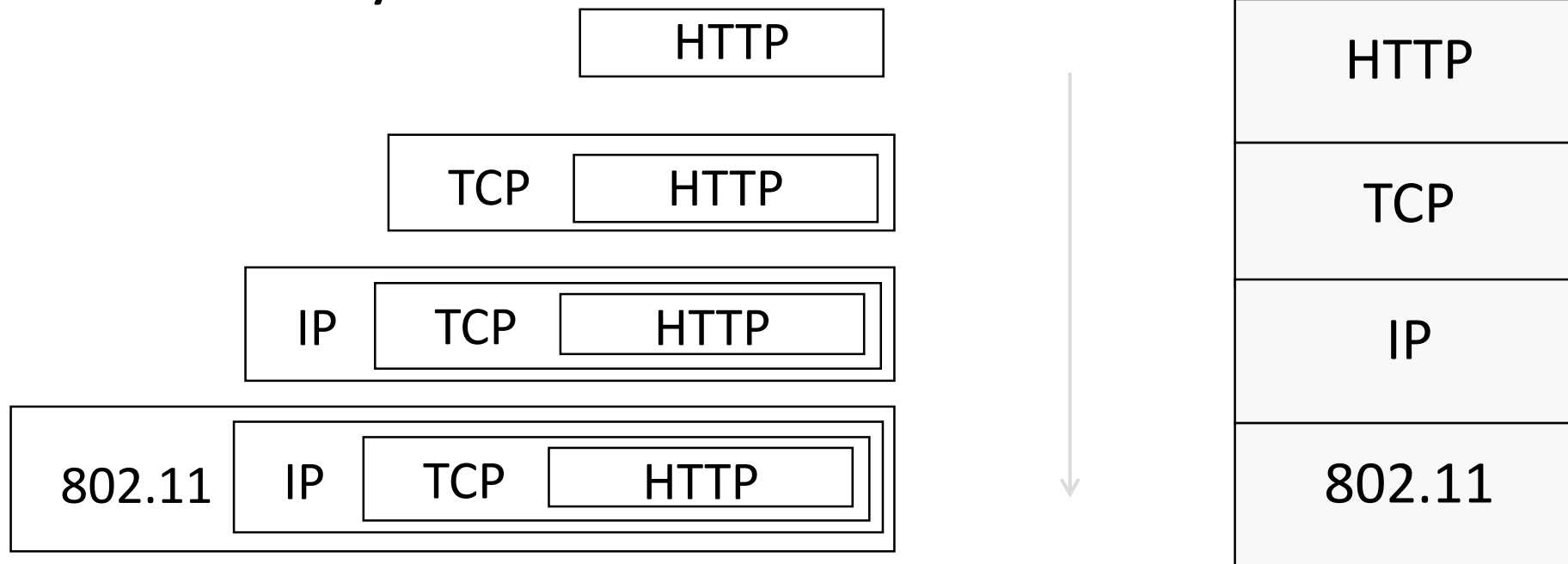


Encapsulation

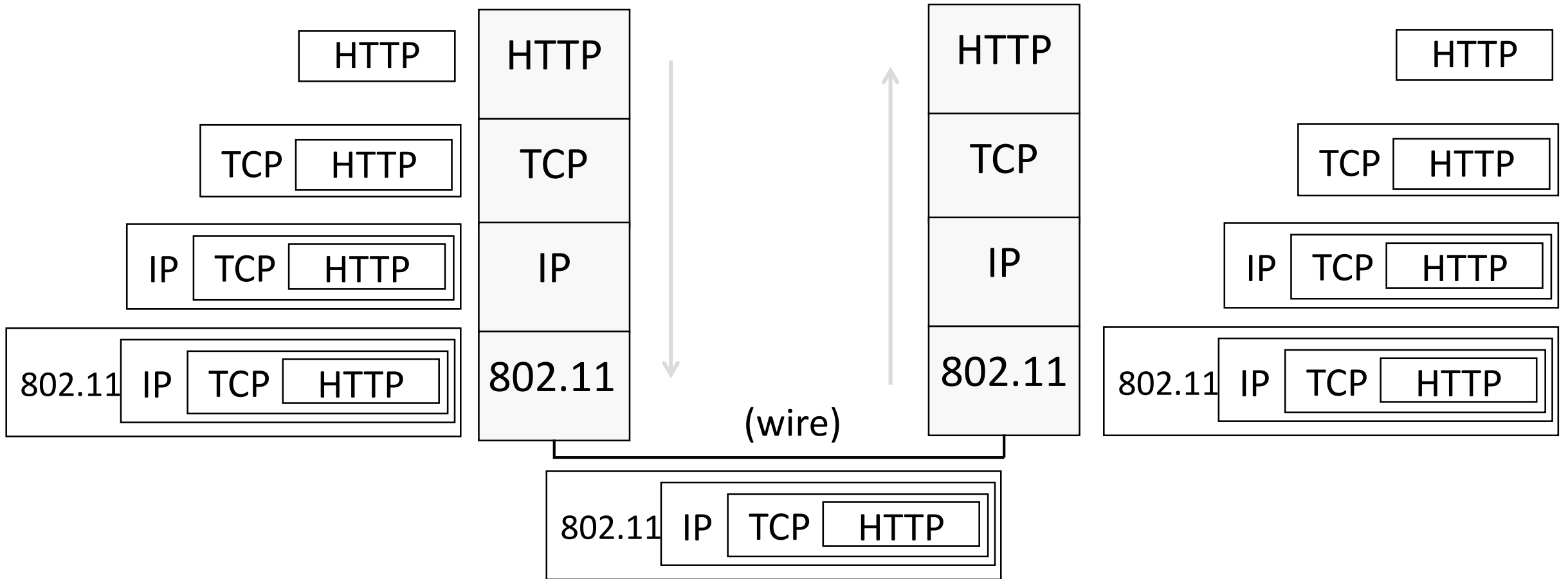
- Encapsulation is the mechanism used to effect protocol layering
 - Lower layer wraps higher layer content, adding its own information to make a new message for delivery
 - Like sending a letter in an envelope; postal service doesn't look inside

Encapsulation (2)

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

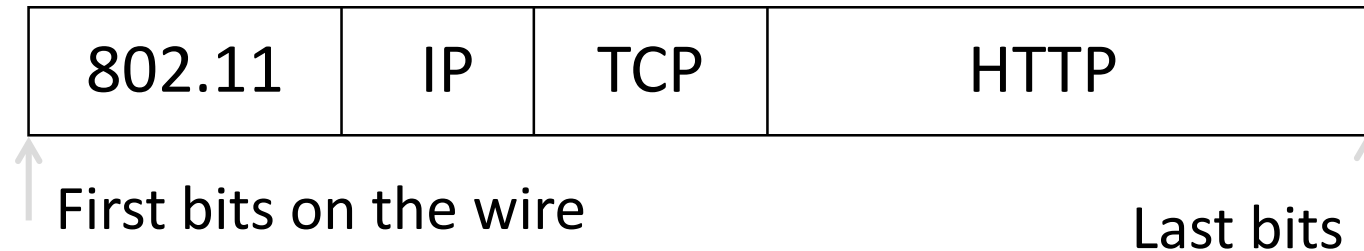


Encapsulation (3)



Encapsulation (4)

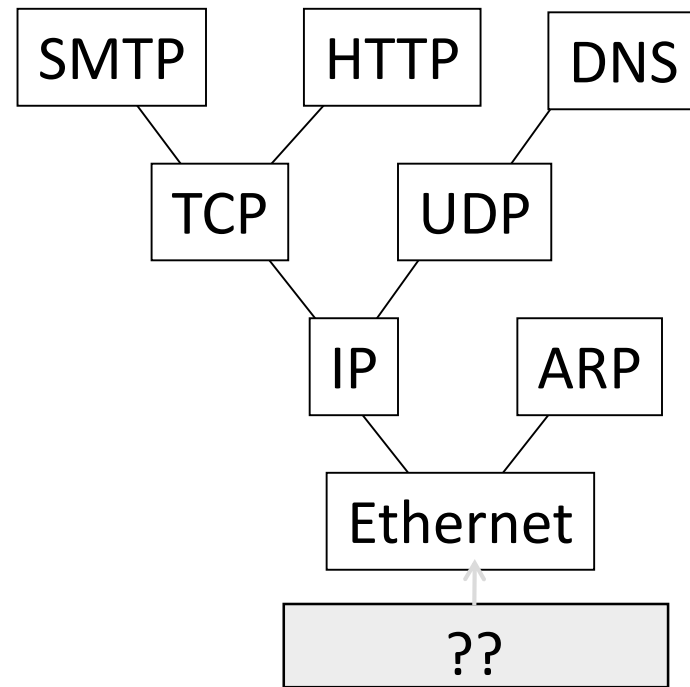
- Normally draw message like this:
 - Each layer adds its own header



- More involved in practice
 - Trailers as well as headers, encrypt/compress contents
 - Segmentation (divide long message) and reassembly

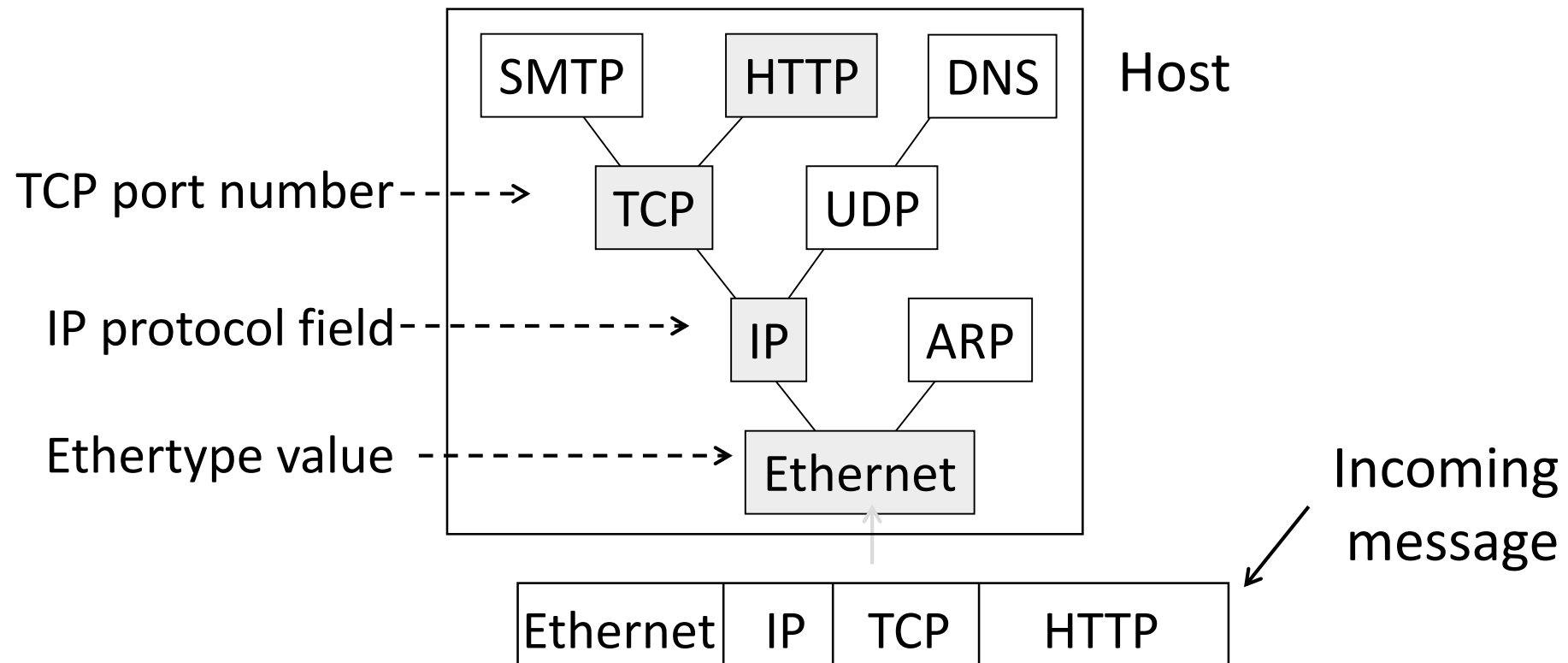
Demultiplexing

- Incoming message must be passed to the protocols that it uses



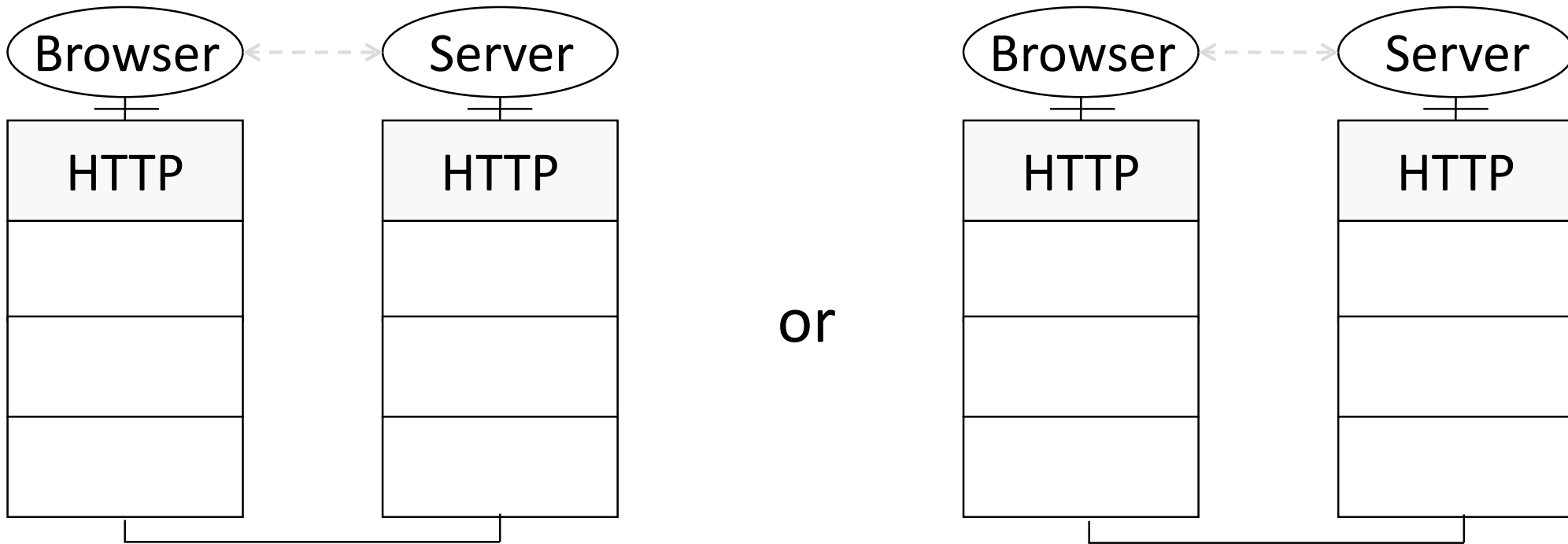
Demultiplexing (2)

- Done with demultiplexing keys in the headers



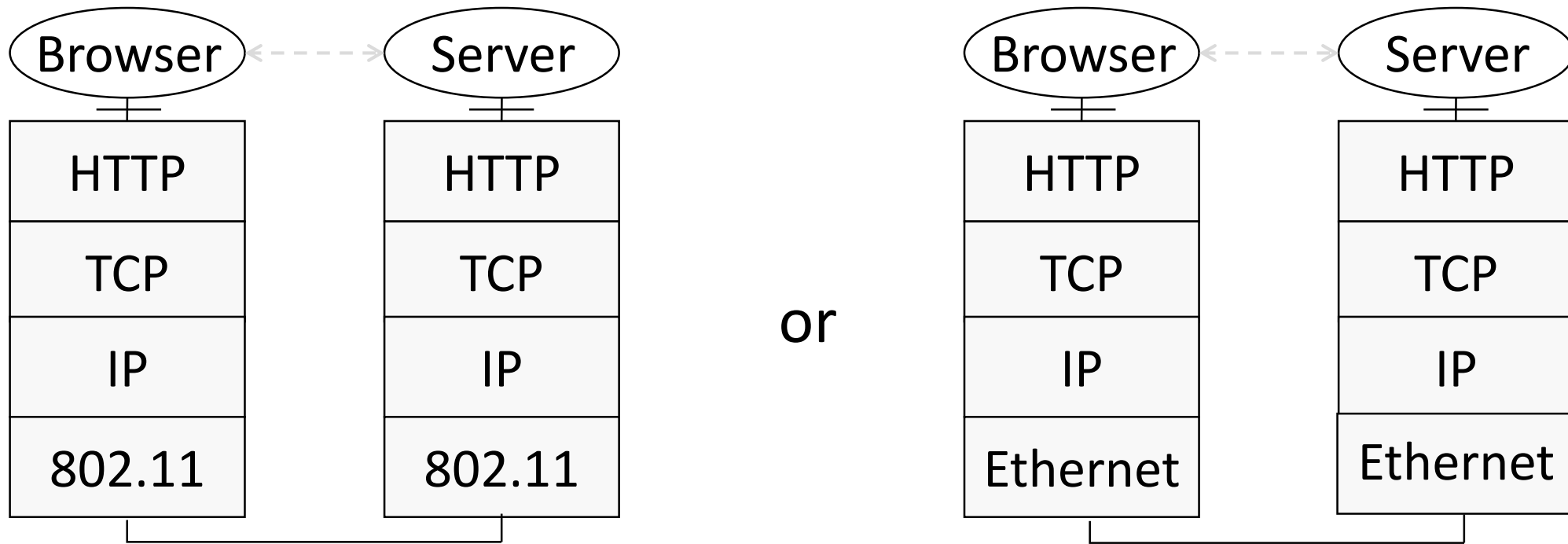
Advantage of Layering

- Information hiding and reuse



Advantage of Layering (2)

- Information hiding and reuse



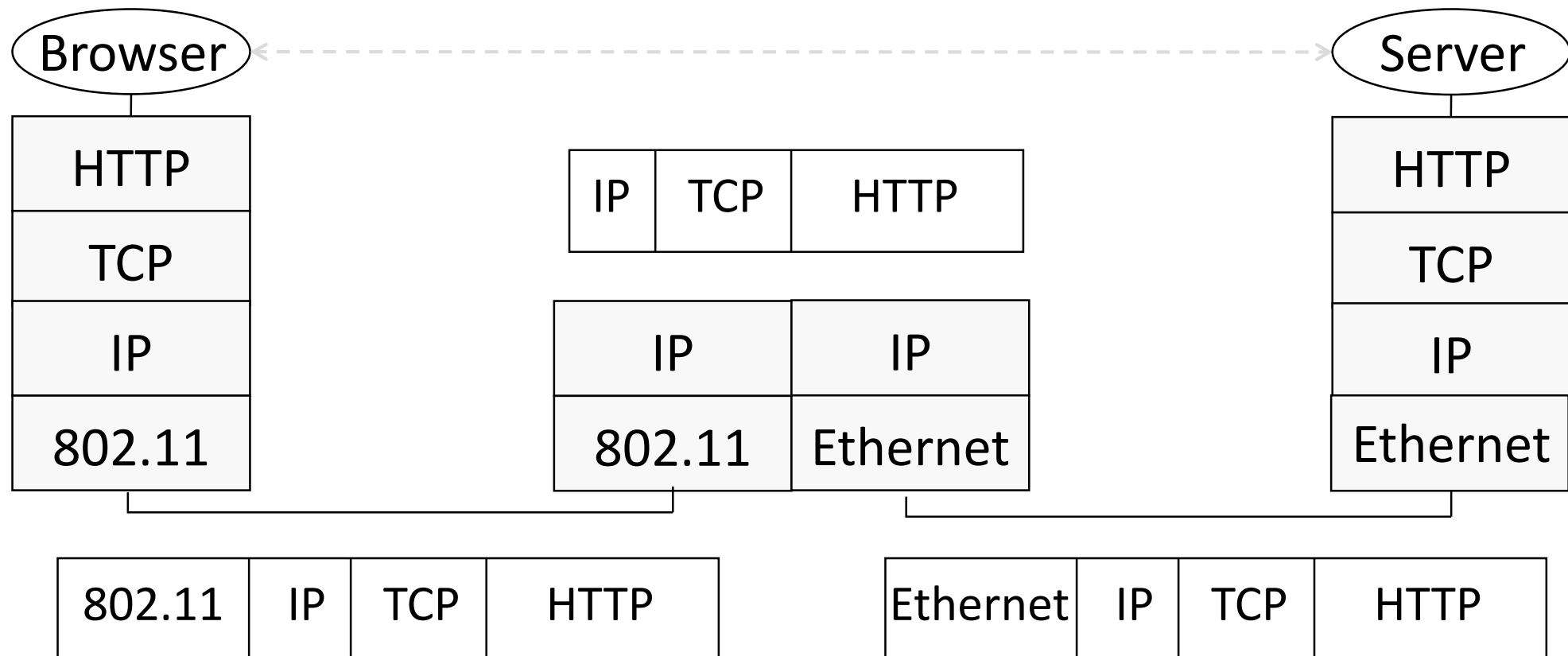
Advantage of Layering (3)

- Using information hiding to connect different systems



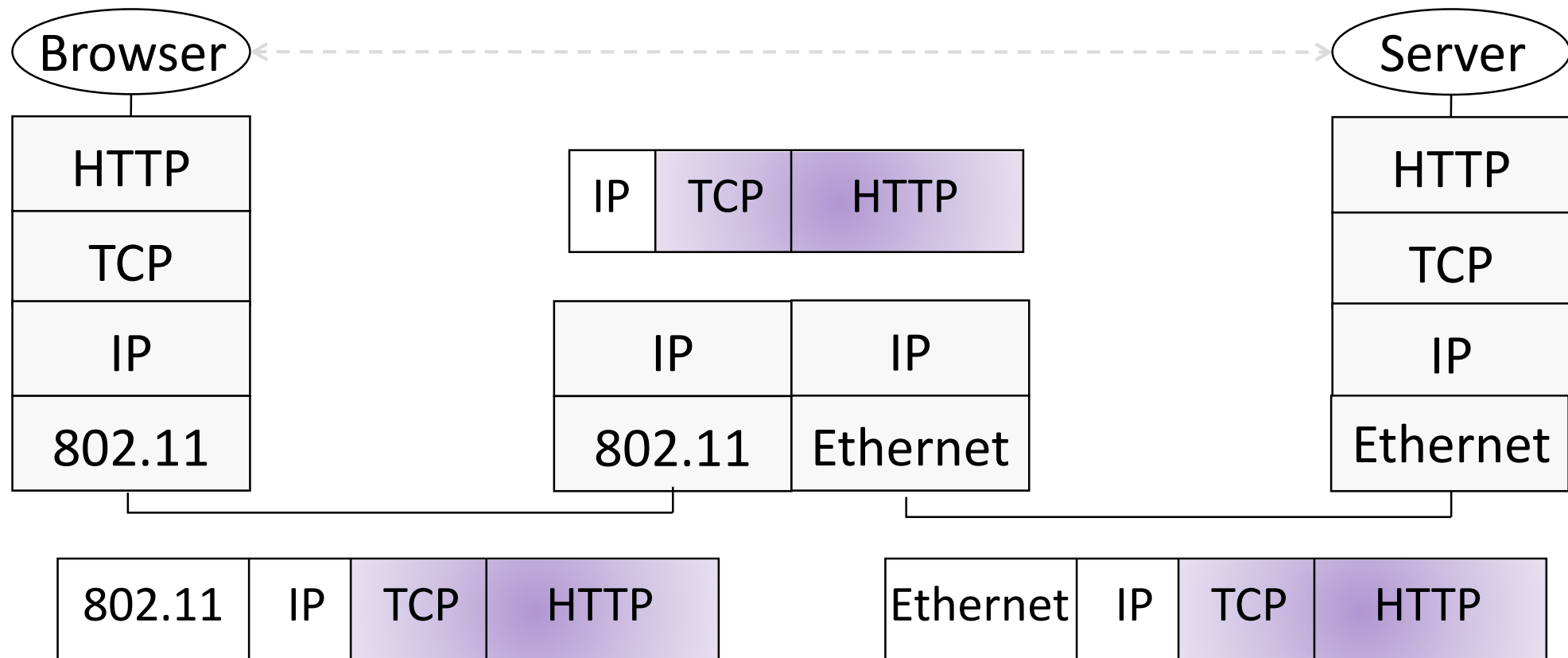
Advantage of Layering (4)

- Information hiding to connect different systems



Advantage of Layering (5)

- Information hiding to connect different systems



Disadvantages of Layering

- ?

Disadvantage of Layering

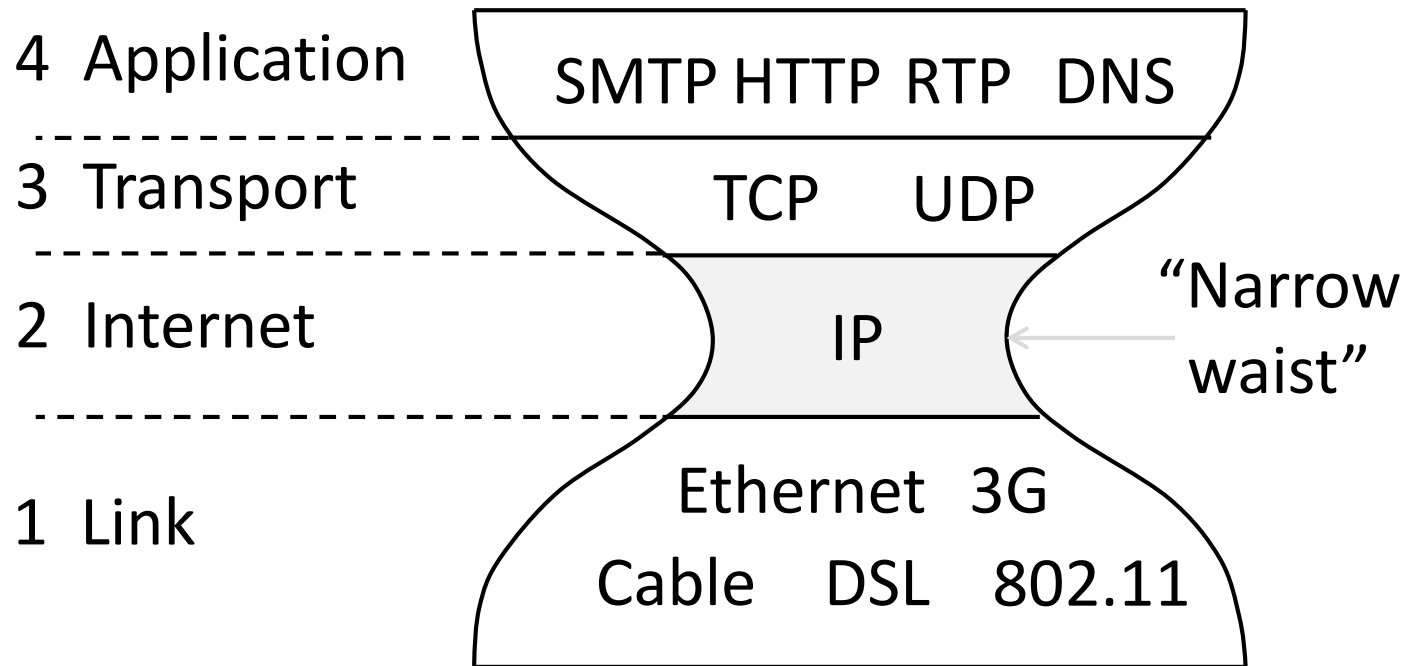
- Adds overhead
 - More problematic with short messages
- Hides information
 - App might care about network properties (e.g., latency, bandwidth, etc)
 - Network may need to know about app priorities (e.g., QoS)

OSI Layers

| Layer | Function | Example |
|-------------------------|--|---------------------------|
| Application (7) | Services that are used with end user applications | SMTP, |
| Presentation (6) | Formats the data so that it can be viewed by the user Encrypt and decrypt | JPG, GIF, HTTPS, SSL, TLS |
| Session (5) | Establishes/ends connections between two hosts | NetBIOS, PPTP |
| Transport (4) | Responsible for the transport protocol and error handling | TCP, UDP |
| Network (3) | Reads the IP address from the packet. | Routers, Layer 3 Switches |
| Data Link (2) | Reads the MAC address from the data packet | Switches |
| Physical (1) | Send data on to the physical wire. | Hubs, NICs, Cable |

Protocols and Layering

- The real internet protocol stacks:



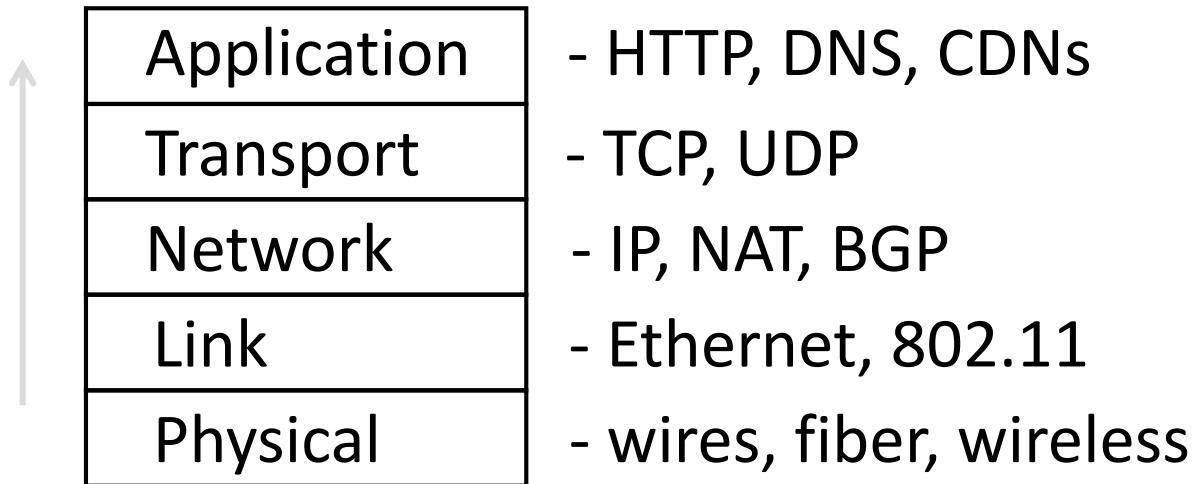
Course Reference Model

- We mostly follow the Internet
 - A little more about the Physical layer, and alternatives

| | | |
|---|-------------|---------------------------------------|
| 5 | Application | – Programs that use network service |
| 4 | Transport | – Provides end-to-end data delivery |
| 3 | Network | – Send packets over multiple networks |
| 2 | Link | – Send frames over one or more links |
| 1 | Physical | – Send bits using signals |

Lecture Progression

- Bottom-up through the layers:



- Followed by more detail on cross-cutting elements:
 - Quality of service, Security (VPN, SSL)