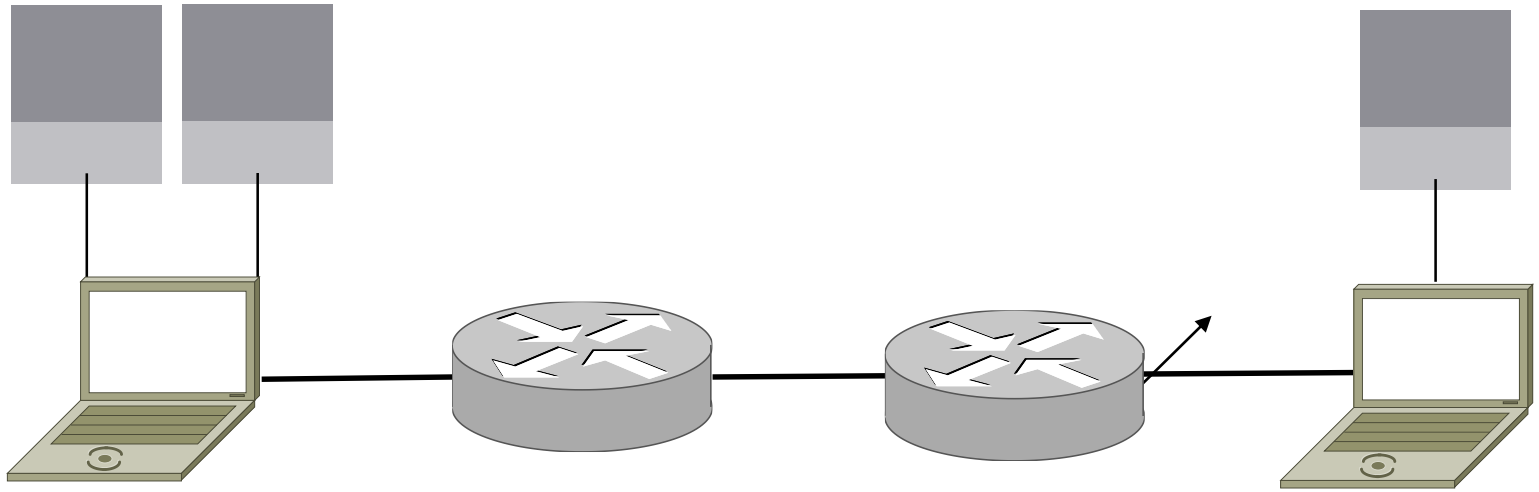
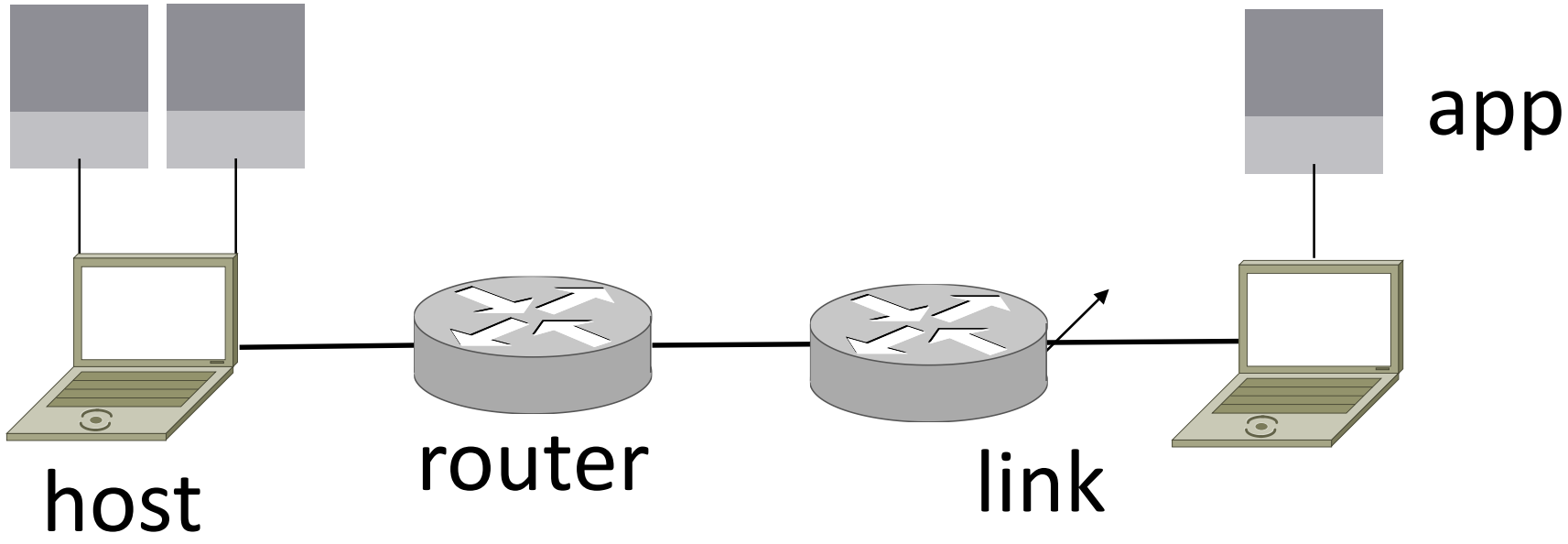
Network Components

Parts of a Network



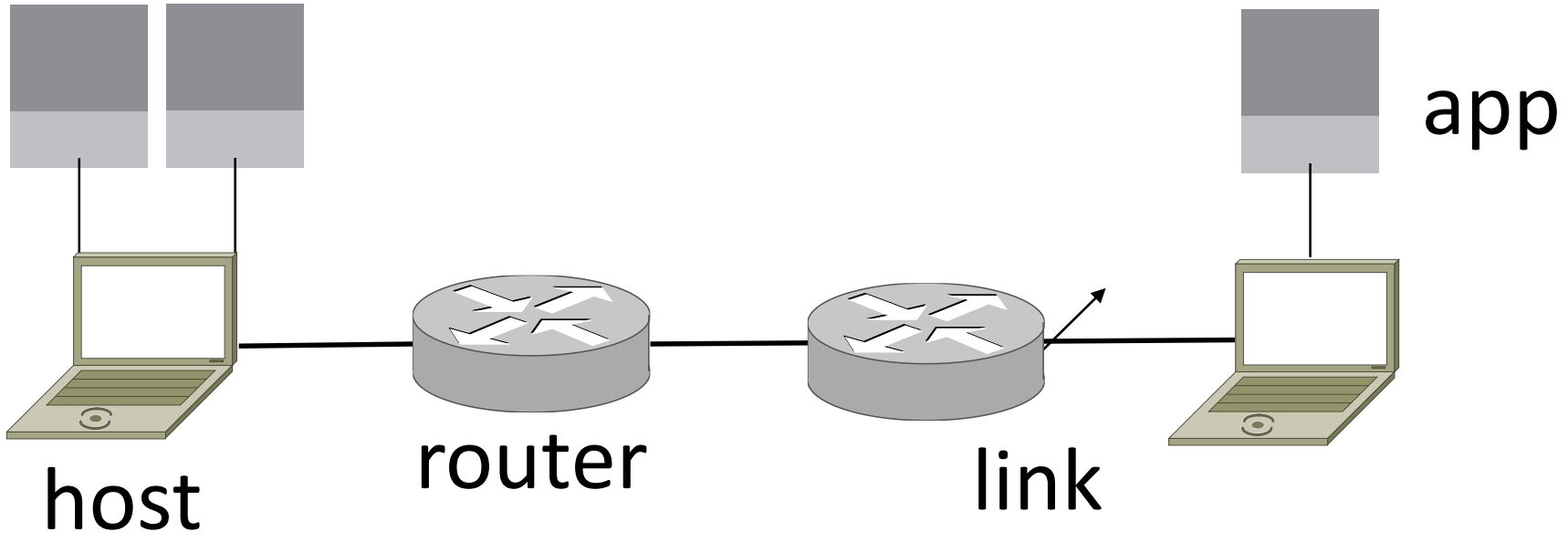
Parts of a Network



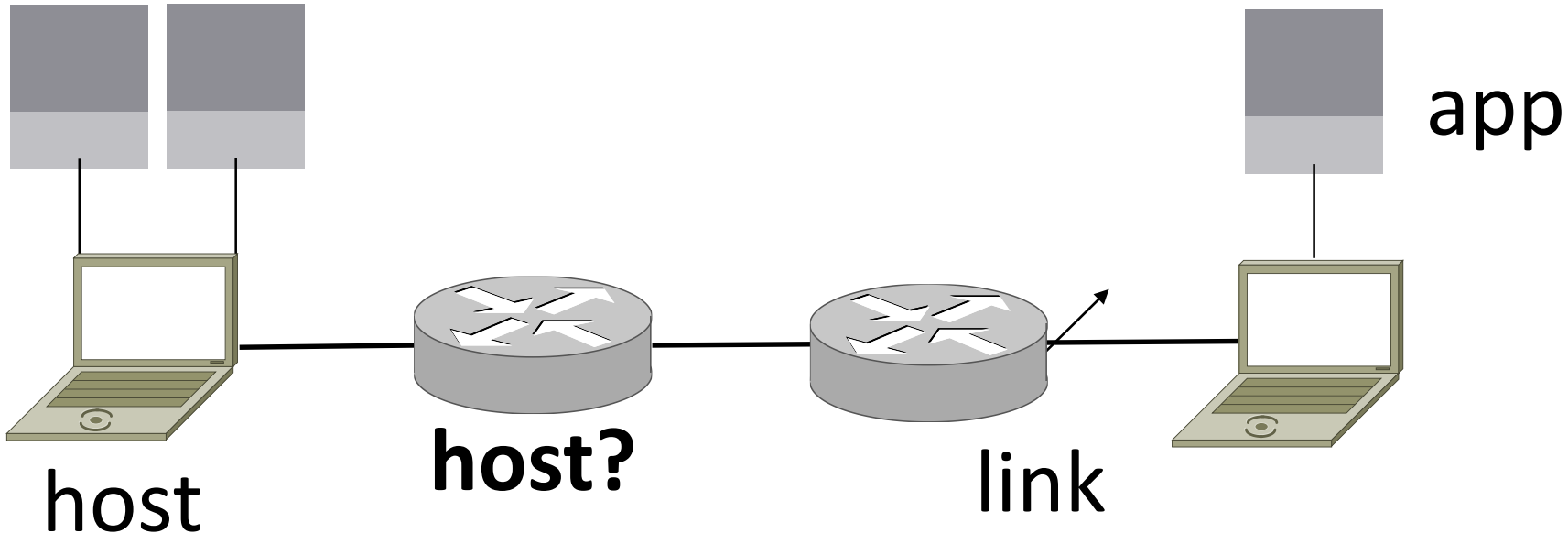
Component Names

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

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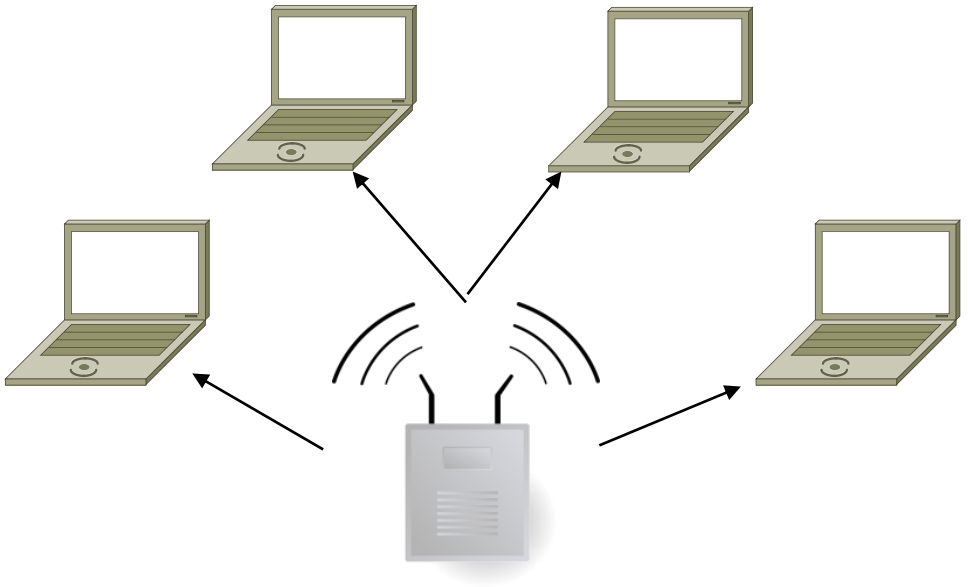
- **Simplex**
  - **unidirectional**

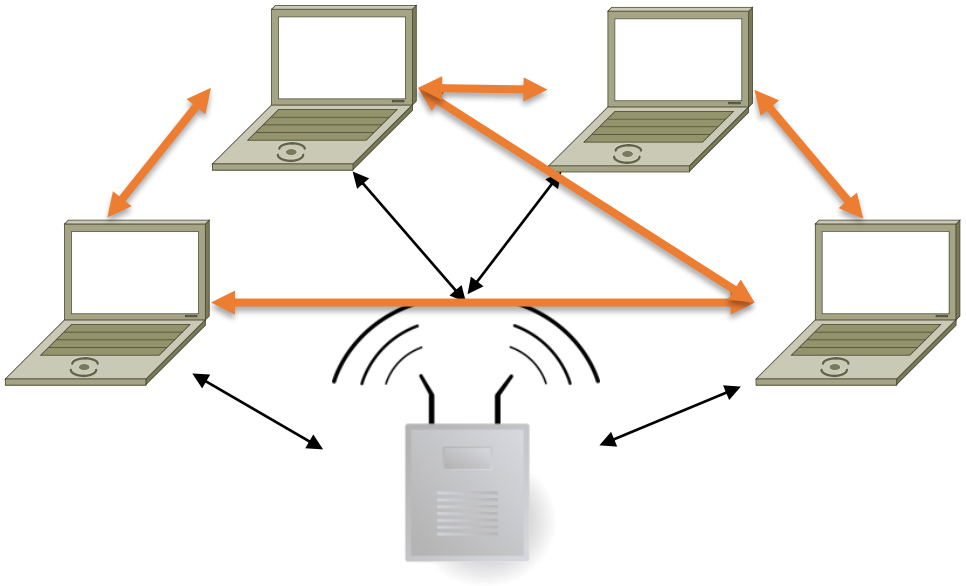
Wireless Links

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



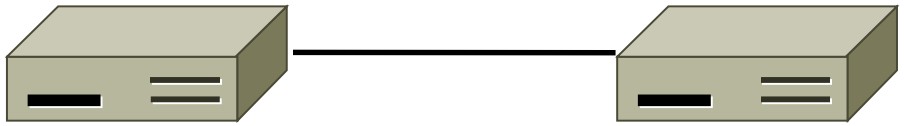
Wireless Links (2)

- Often show logical links
  - Not all possible connectivity



A Small Network

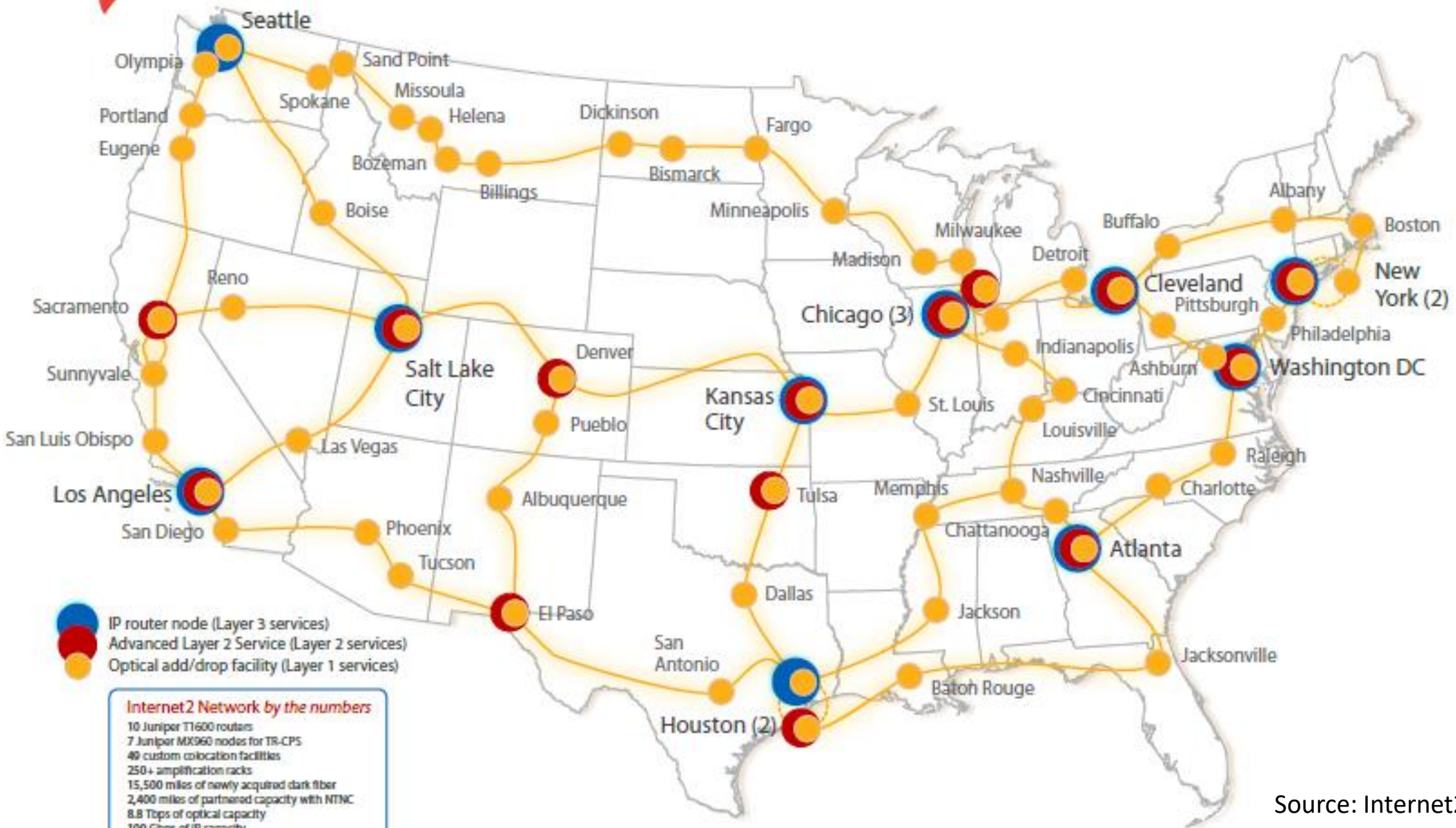
- Connect a couple of computers



- Next, a large network …

Internet2 Network Infrastructure Topology

October 2012



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

IN SUPPORT OF U.S.UCAN

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INDIANA UNIVERSITY

Infinera

JUNIPER NETWORKS

Source: Internet2

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	PAN (Personal Area Network)	Bluetooth (e.g., headset)
Building	LAN (Local Area Network)	WiFi, Ethernet
City	MAN (Metropolitan Area Network)	Cable, DSL
Country	WAN (Wide Area Network)	Large ISP
Planet	The Internet (network of all networks)	The Internet!

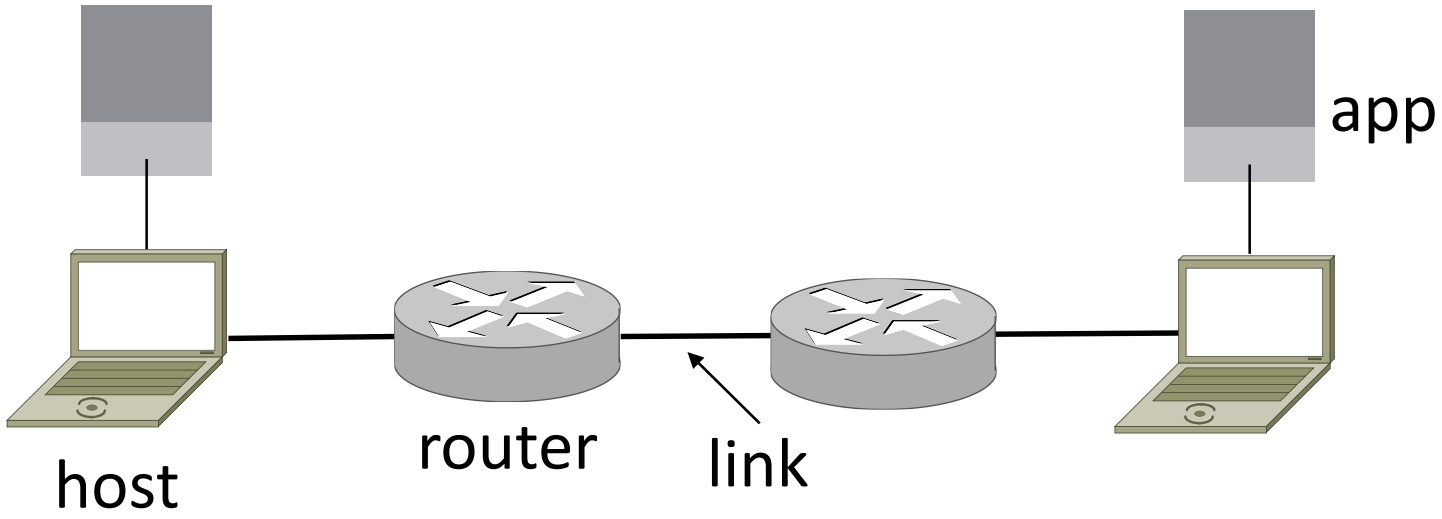
Internetworks

- 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

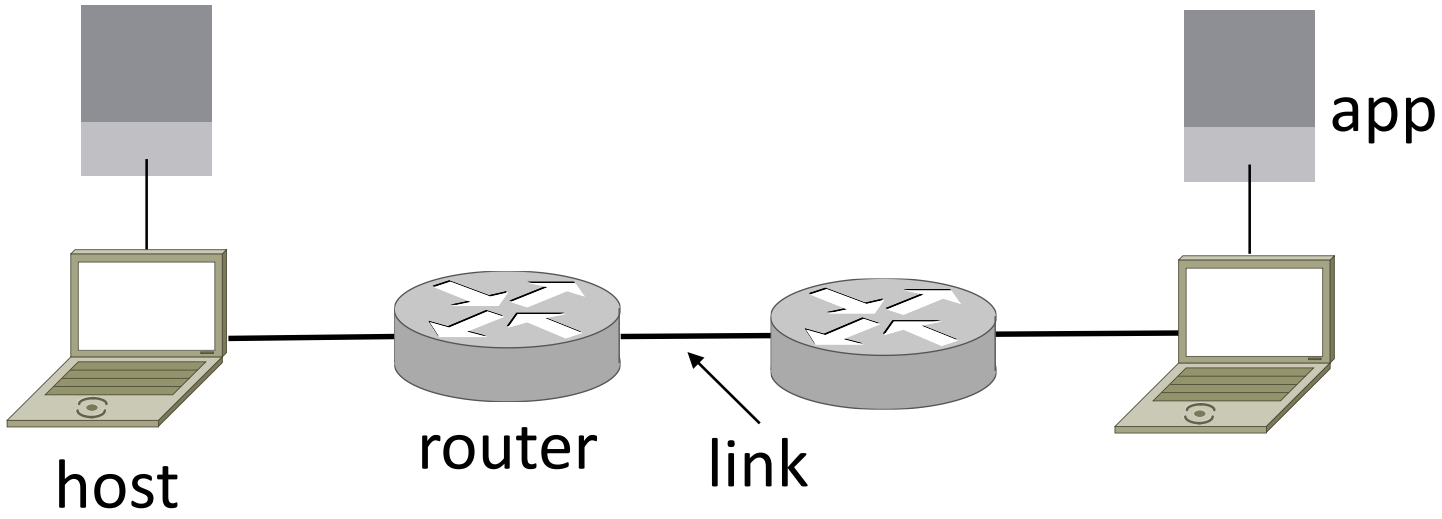
Network Boundaries

- What part is the “network”?



Network Boundaries (2)

- What part represents an “ISP”?

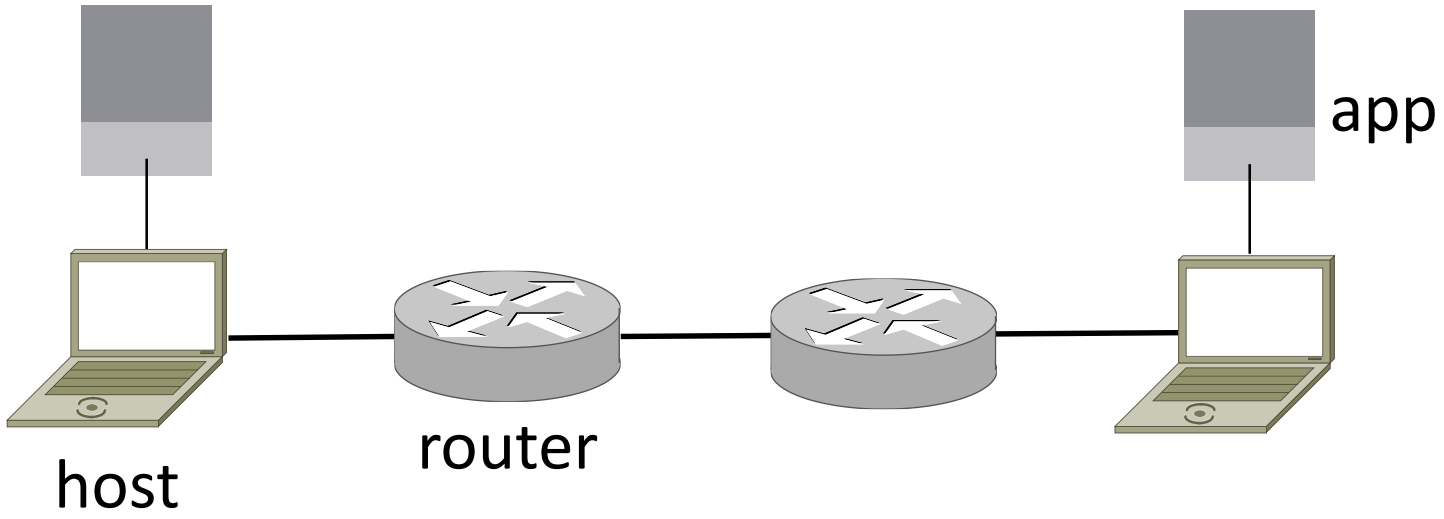


Network Boundaries (3)

- 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:
  - Secures information in transit
  - Lets many new hosts be added
  - …

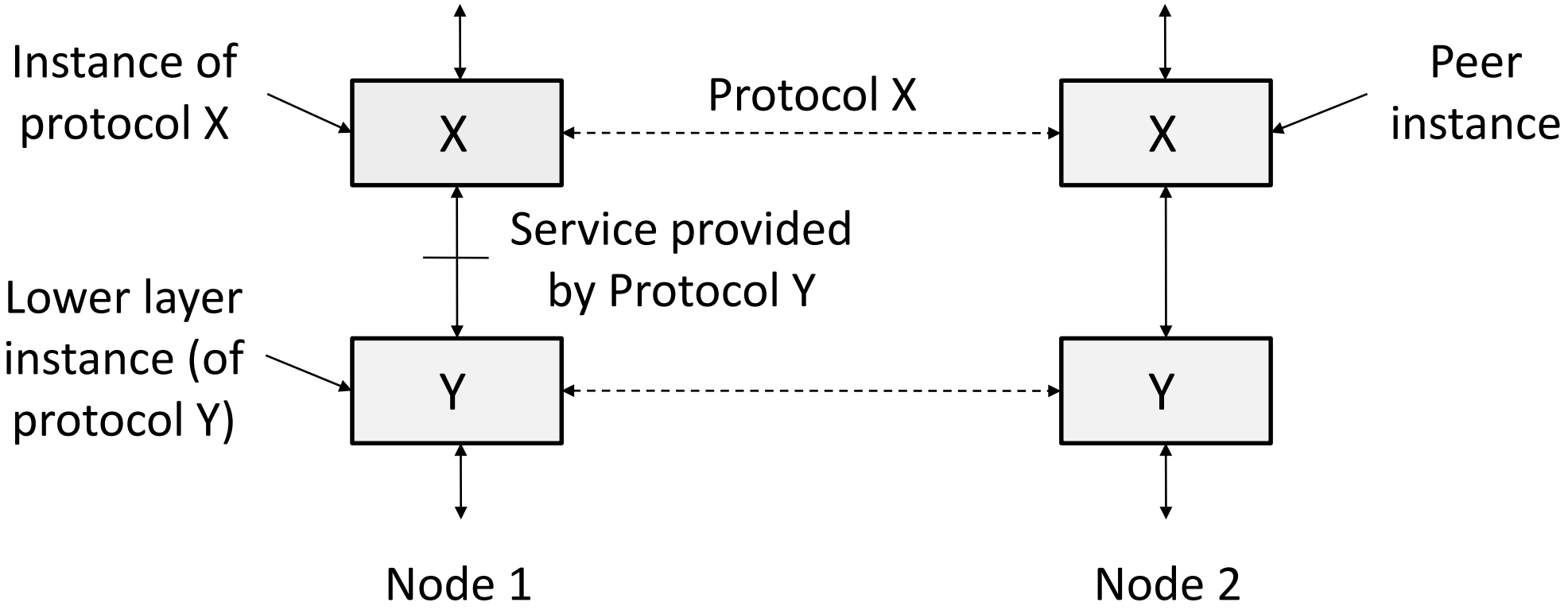
We need a form of modularity, to help manage complexity and support reuse

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

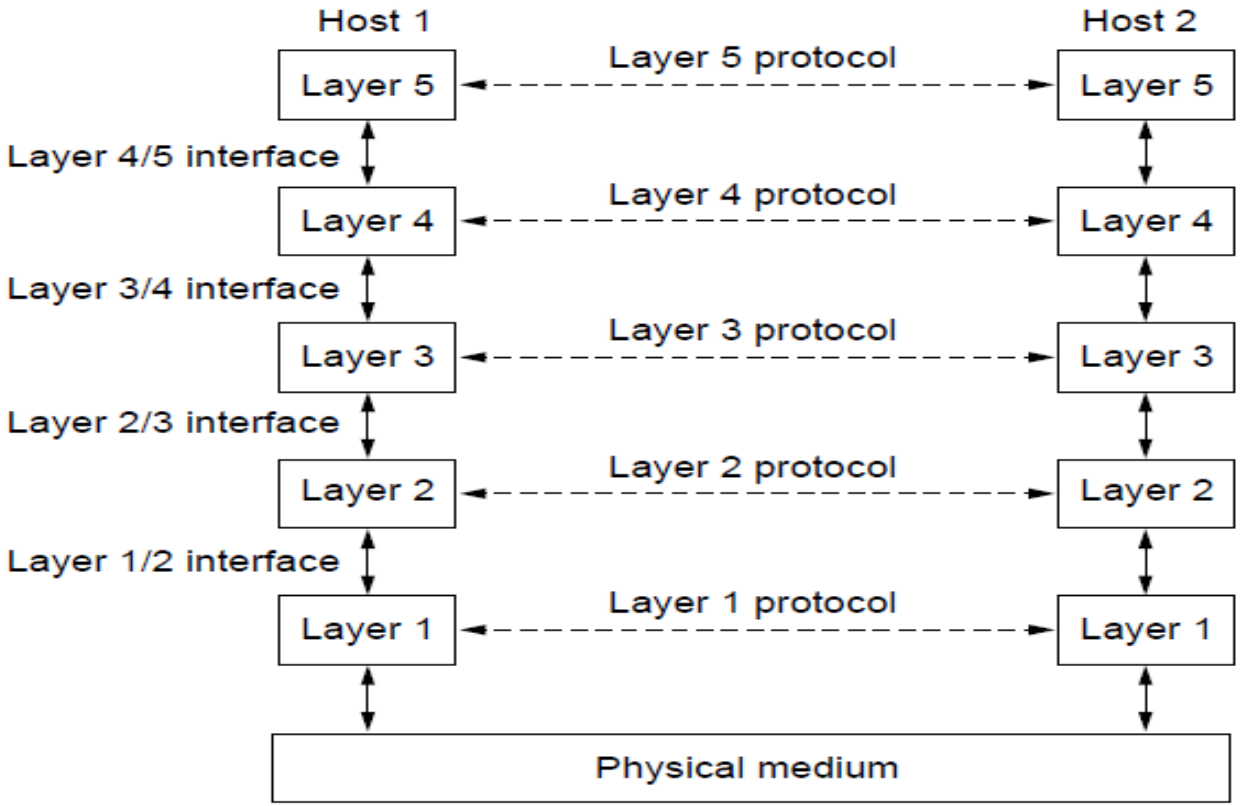
Protocols and Layers (2)

- Protocols are horizontal, layers are vertical



Protocols and Layers (3)

- Set of protocols in use is called a protocol stack

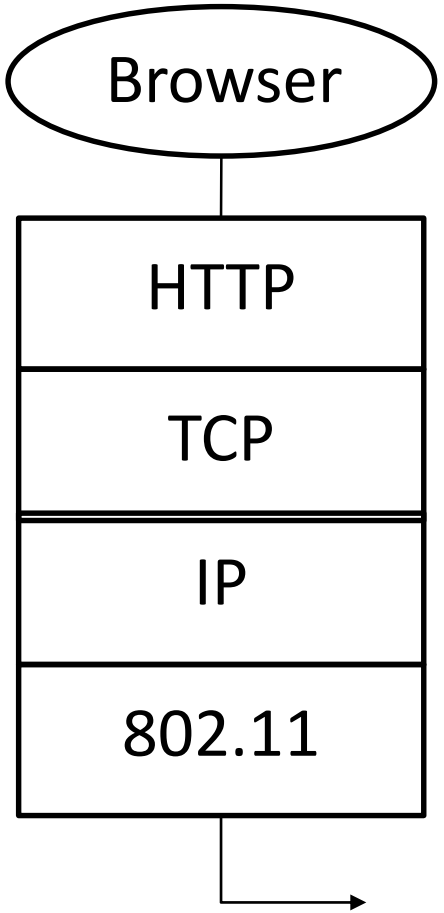


Protocols and Layers (4)

- 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

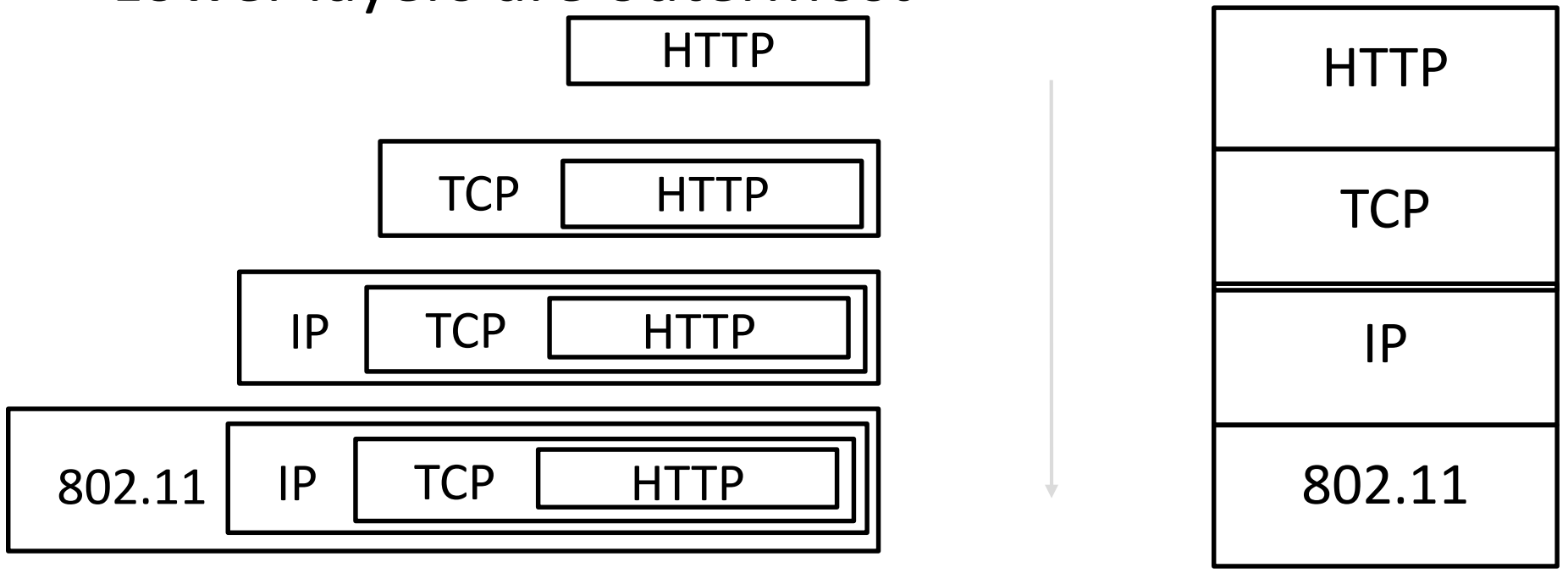


Encapsulation

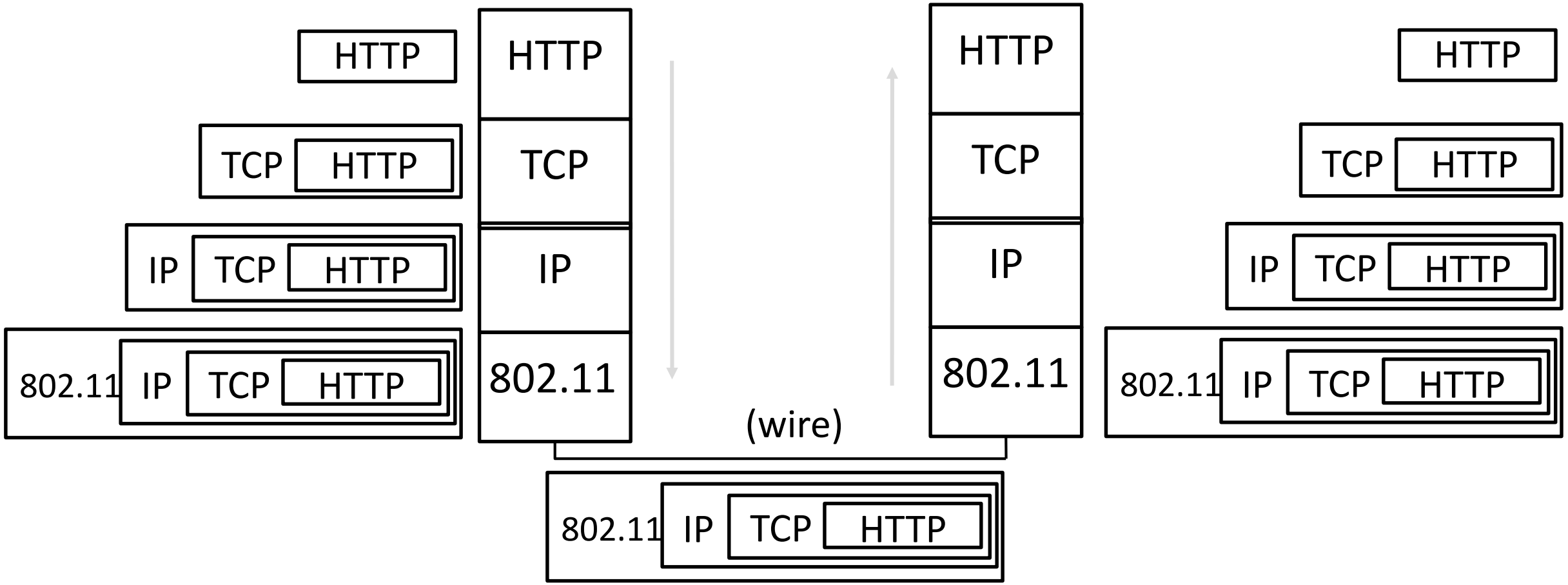
- Encapsulation is the mechanism used to effect protocol layering
  - Lower layer wraps higher layer content, adding its own information to make a new message for delivery
  - Like sending a letter in an envelope; postal service doesn't look inside

Encapsulation (2)

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

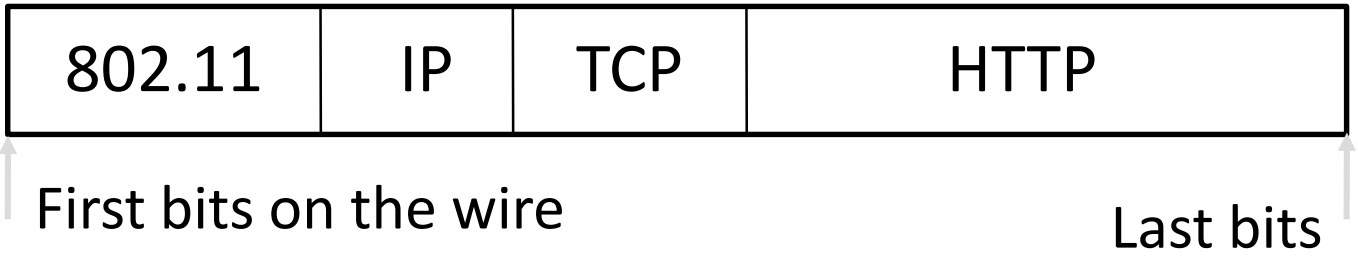


Encapsulation (3)



Encapsulation (4)

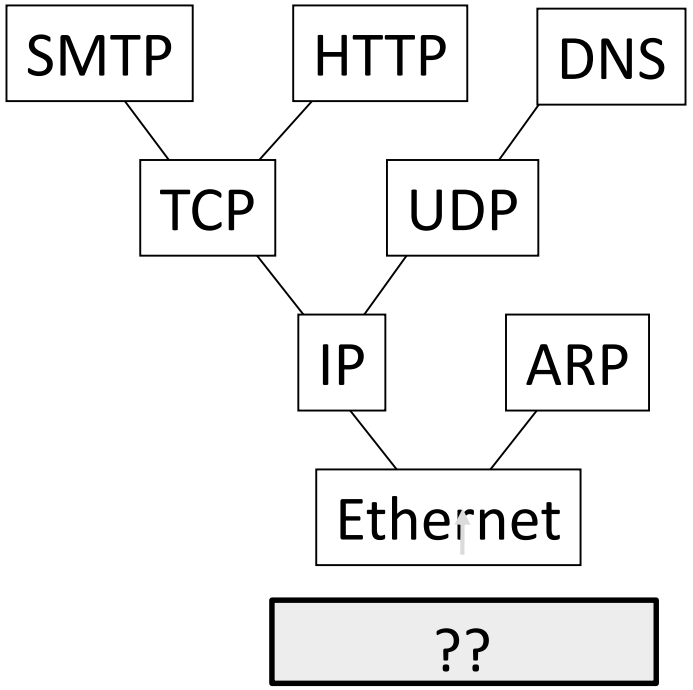
- Normally draw message like this:
  - Each layer adds its own header



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

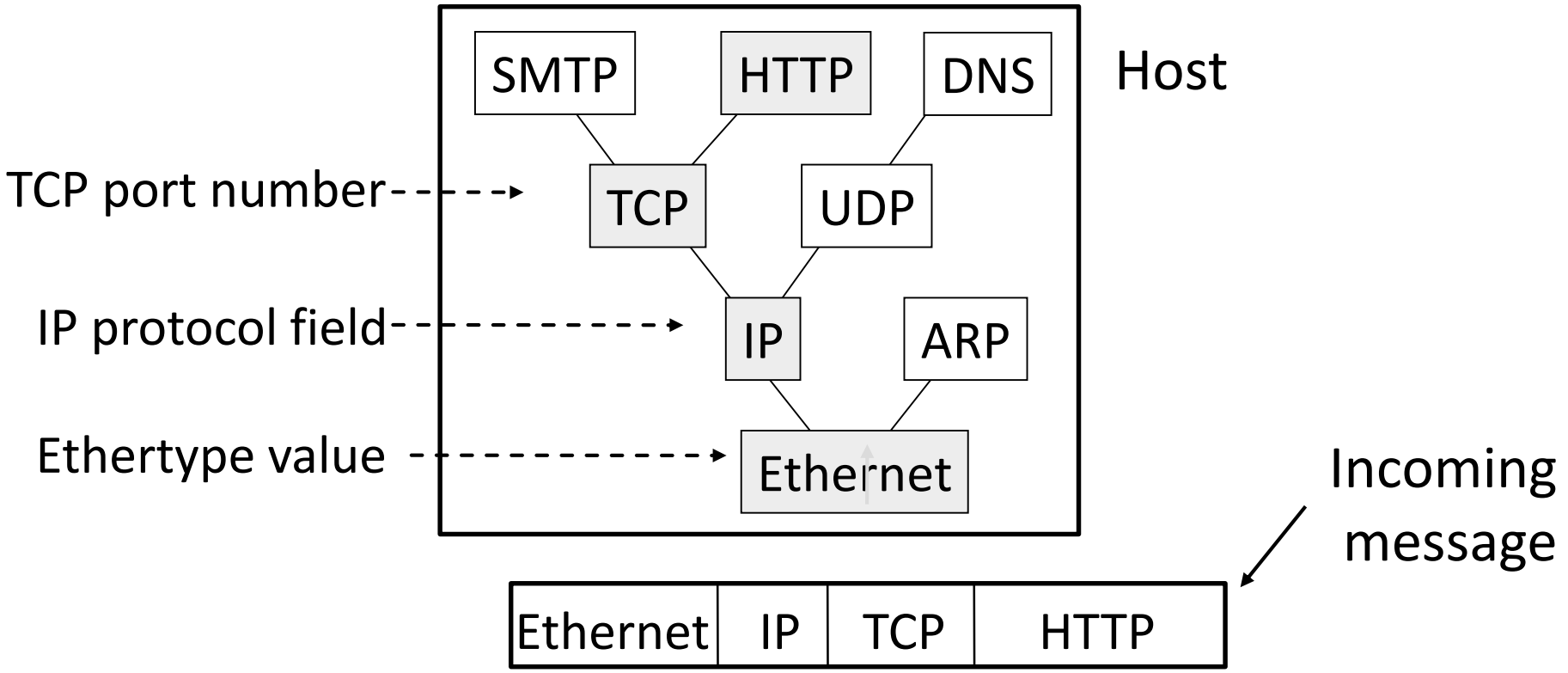
Demultiplexing

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



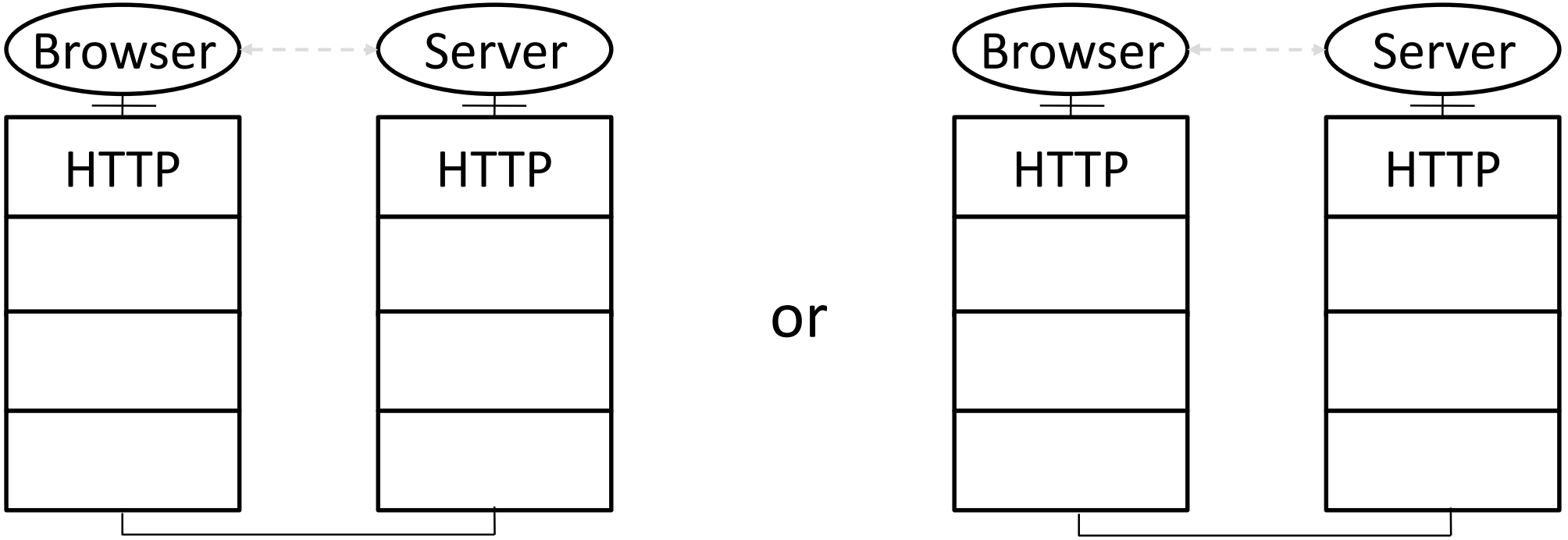
Demultiplexing (2)

- Done with demultiplexing keys in the headers



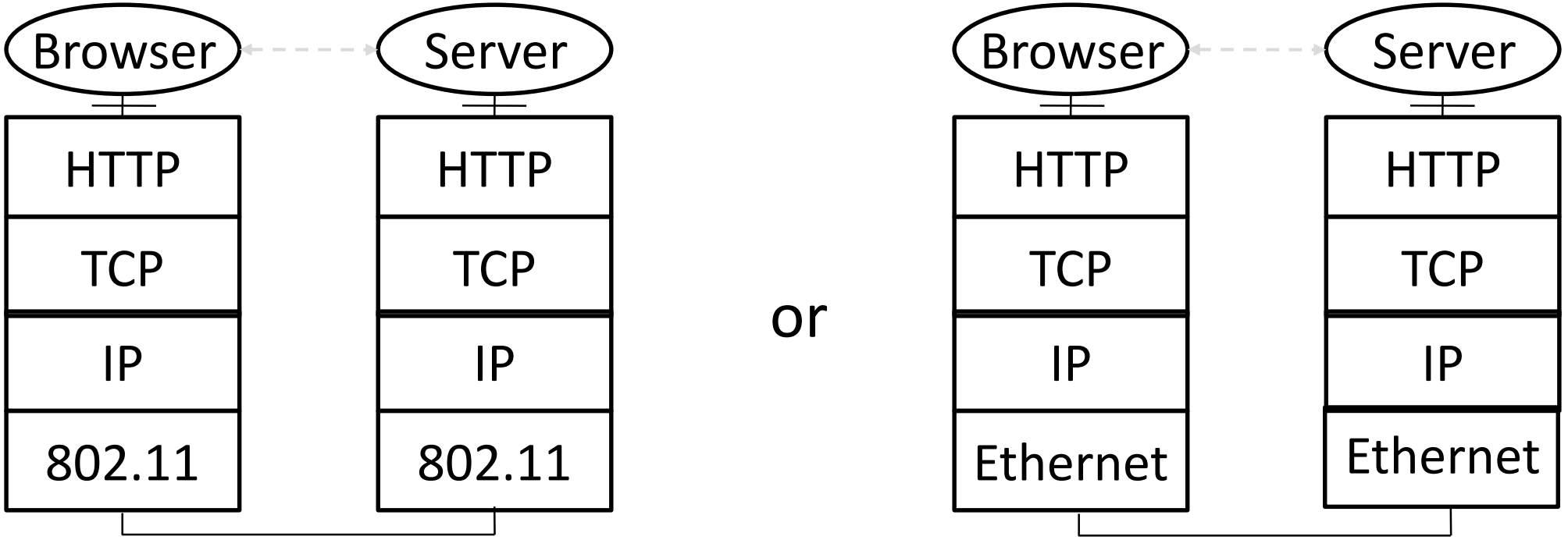
Advantage of Layering

- Information hiding and reuse



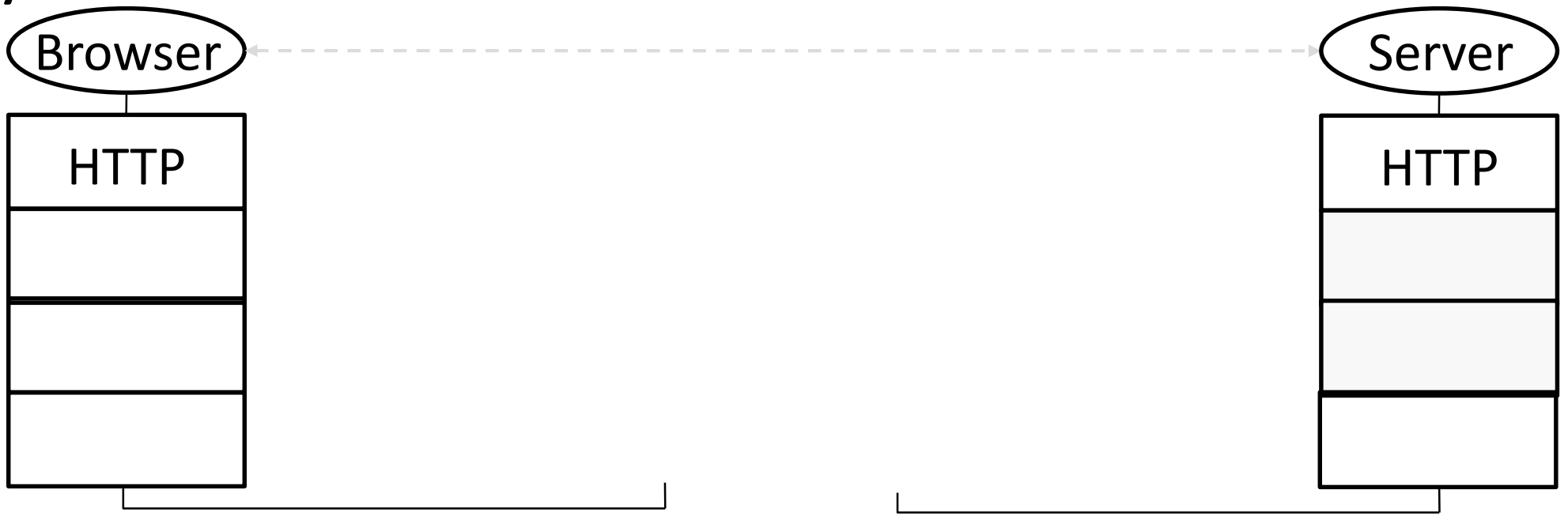
Advantage of Layering (2)

- Information hiding and reuse



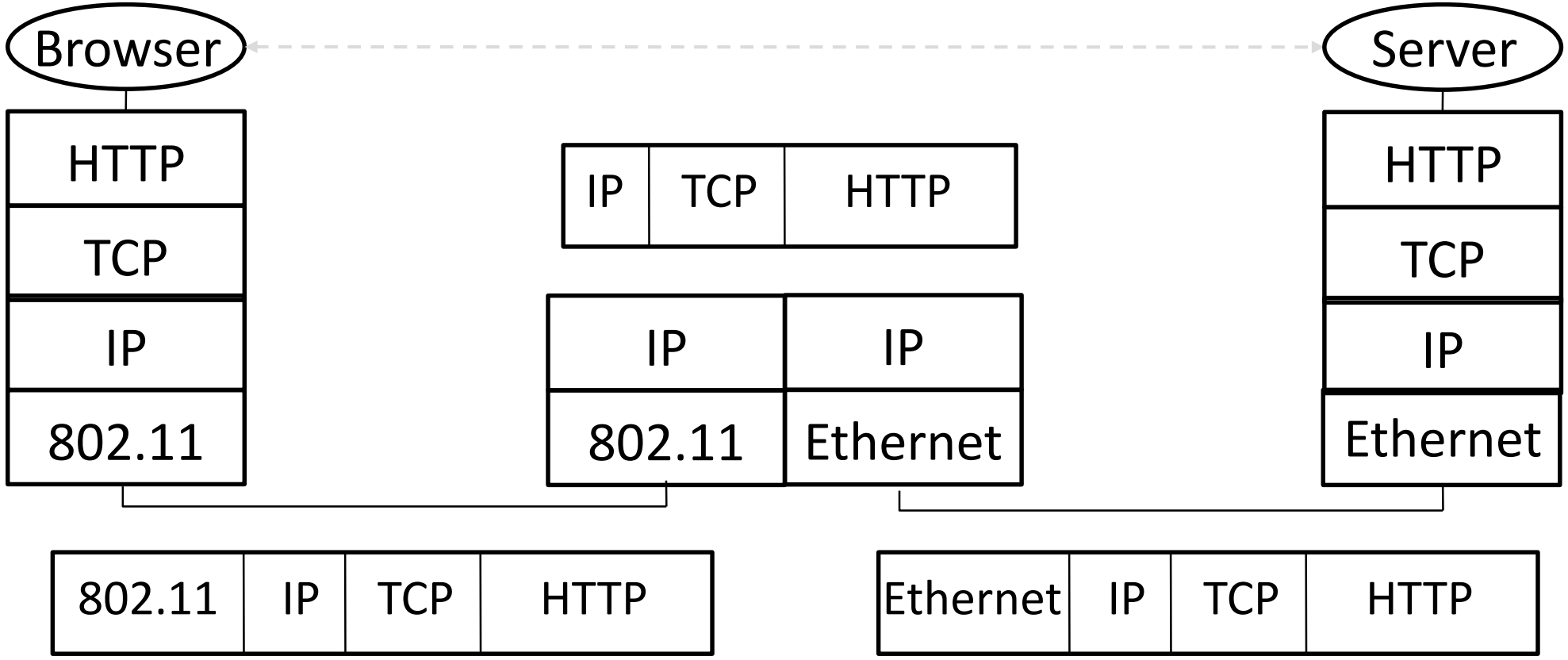
Advantage of Layering (3)

- Using information hiding to connect different systems



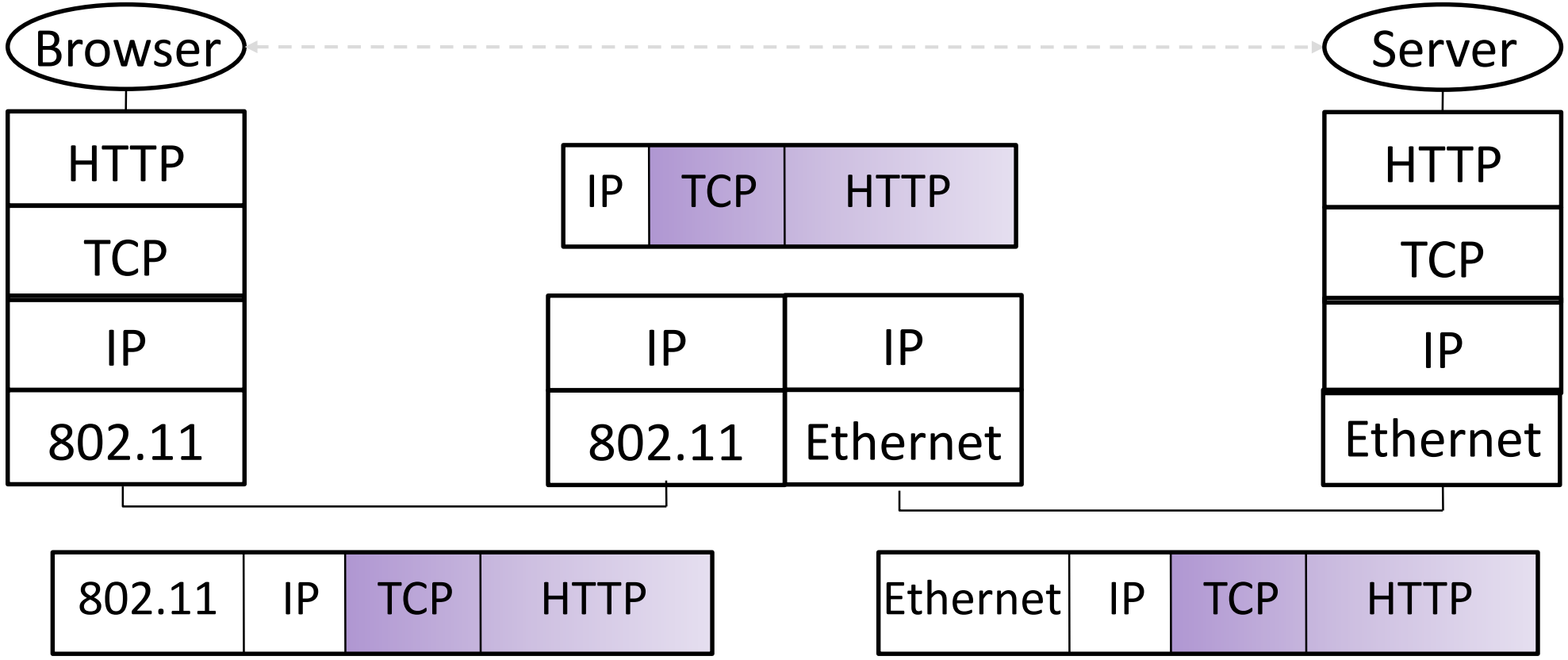
Advantage of Layering (4)

- Information hiding to connect different systems



Advantage of Layering (5)

- Information hiding to connect different systems



Disadvantages of Layering

- ?

Disadvantage of Layering

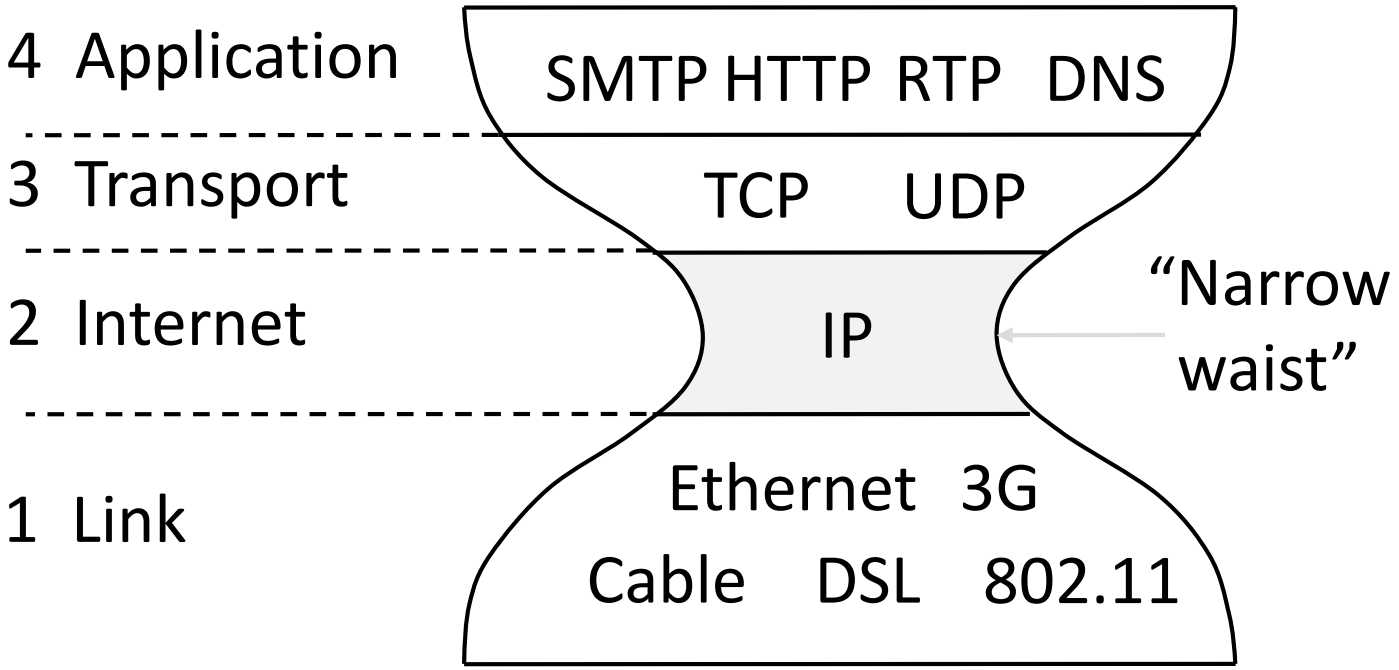
- Adds overhead
  - More problematic with short messages
- Hides information
  - App might care about network properties (e.g., latency, bandwidth, etc)
  - Network may need to know about app priorities (e.g., QoS)

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 form 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

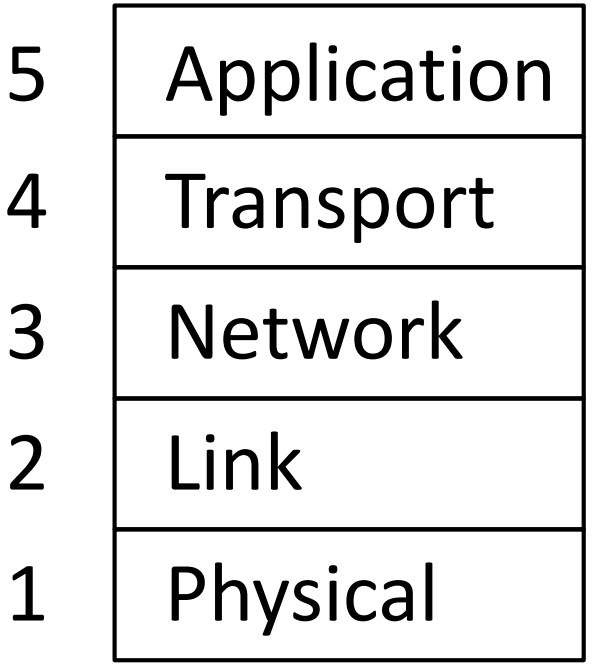
Protocols and Layering

- The real internet protocol stacks:



Course Reference Model

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



– Programs that use network service

– Provides end-to-end data delivery

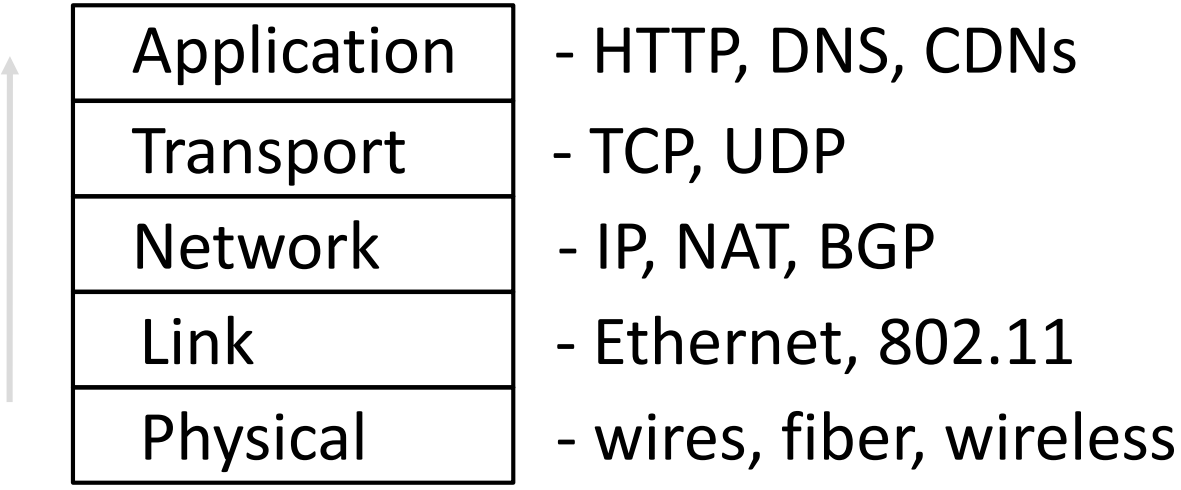
– Send packets over multiple networks

– Send frames over one or more links

– Send bits using signals

Lecture Progression

- Bottom-up through the layers:



- HTTP, DNS, CDNs
- TCP, UDP
- IP, NAT, BGP
- Ethernet, 802.11
- wires, fiber, wireless

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