CS 43: Computer Networks

02: Protocols & Layering

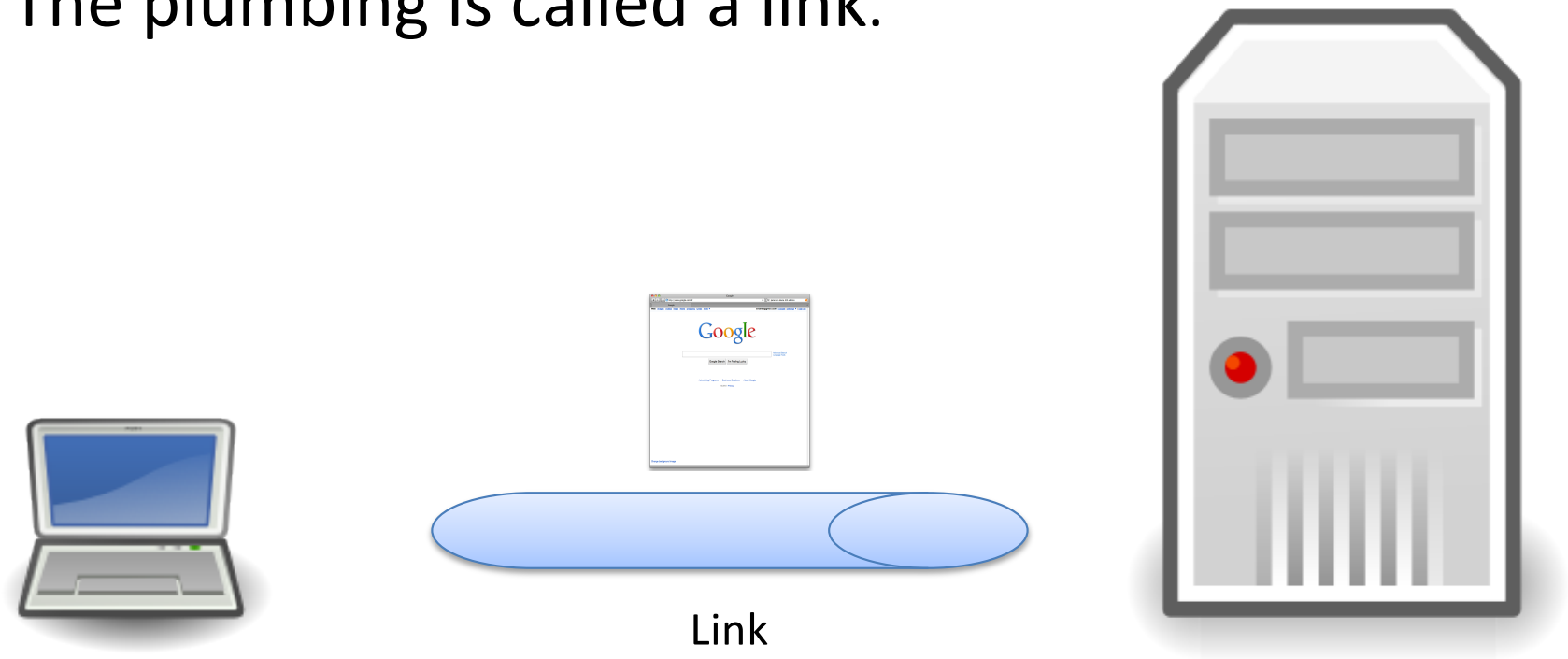
September 10, 2020

Slides adapted from Kurose & Ross, Kevin Webb

A "Simple" Task

Send information from one computer to another

- hosts: endpoints of a network
- The plumbing is called a link.

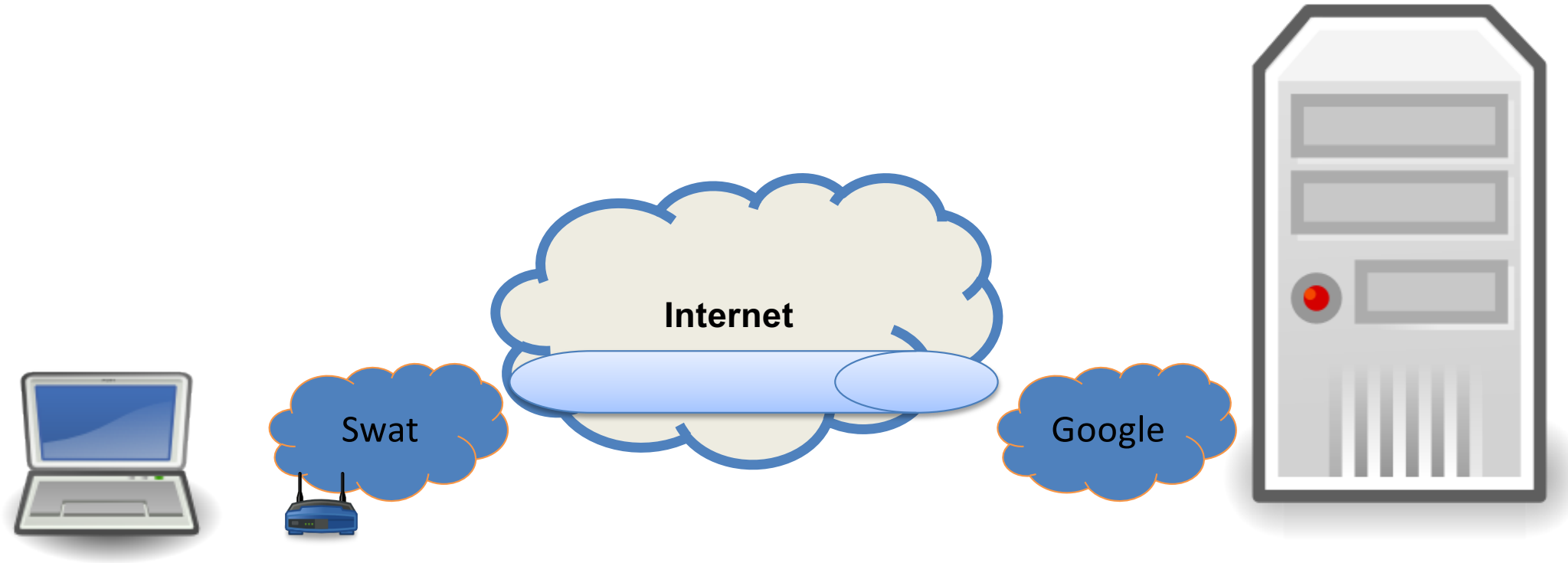


Host
(PC)

Link

Host
(Server)

Not Really So Simple…



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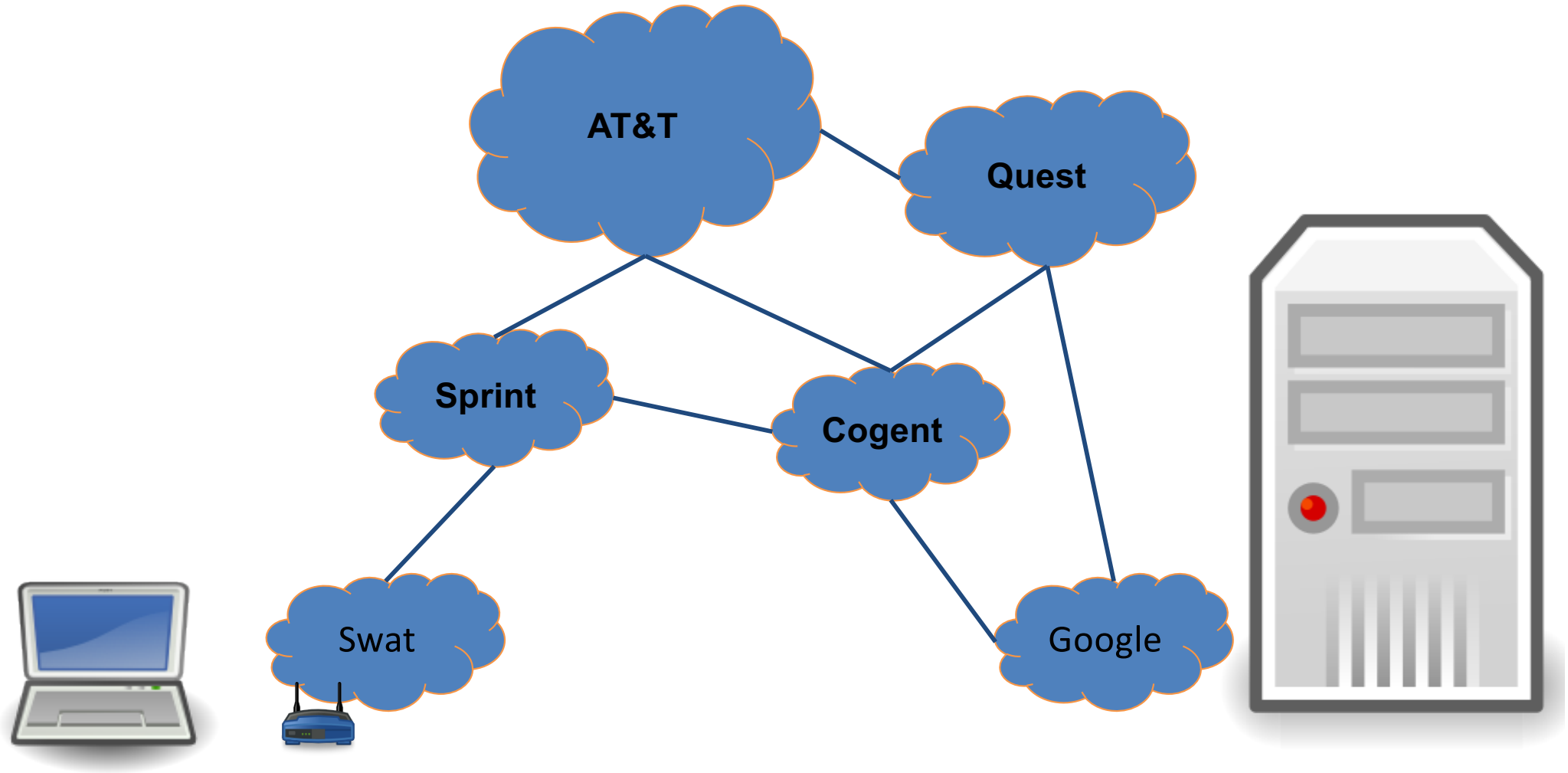

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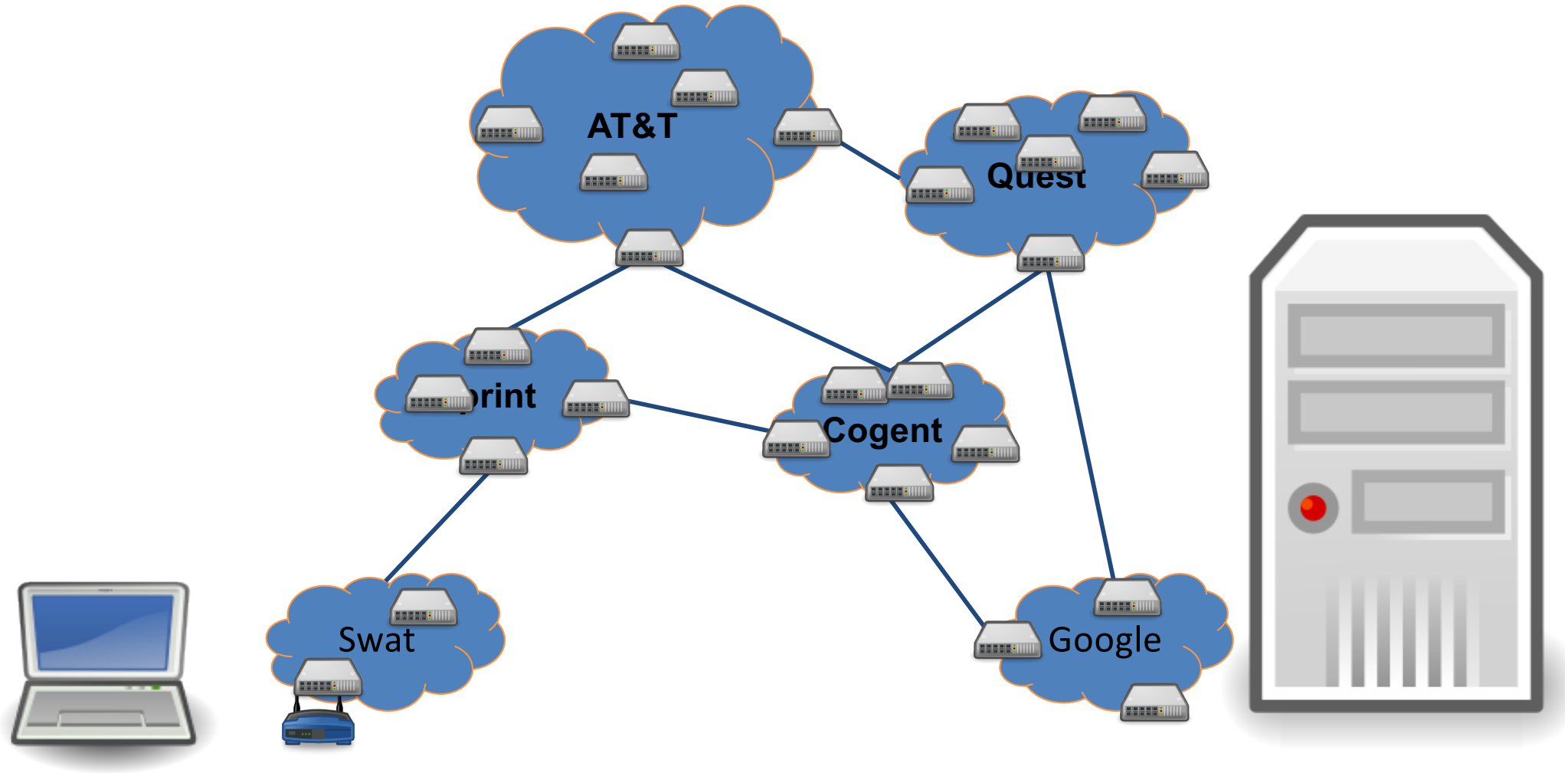

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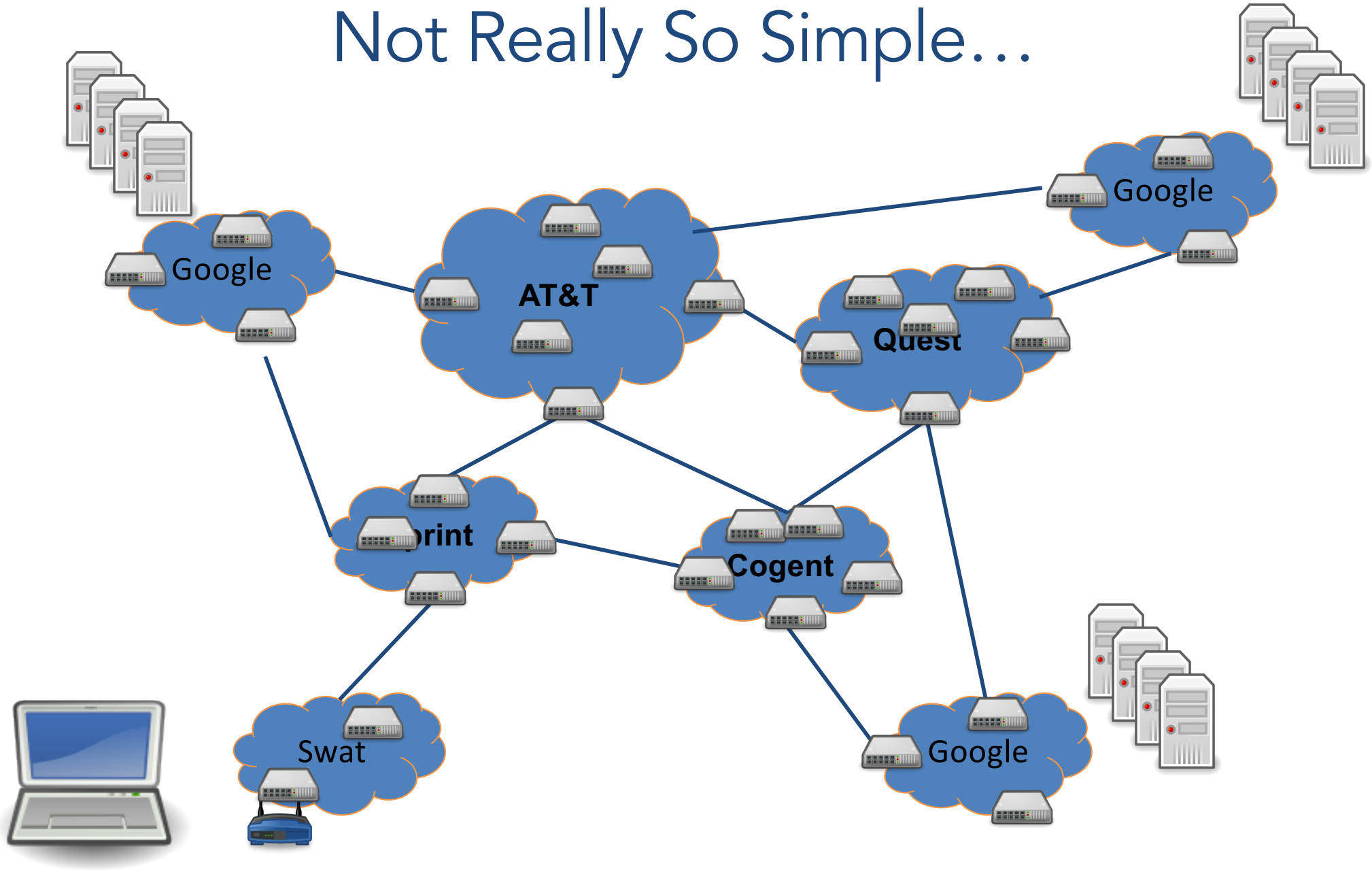
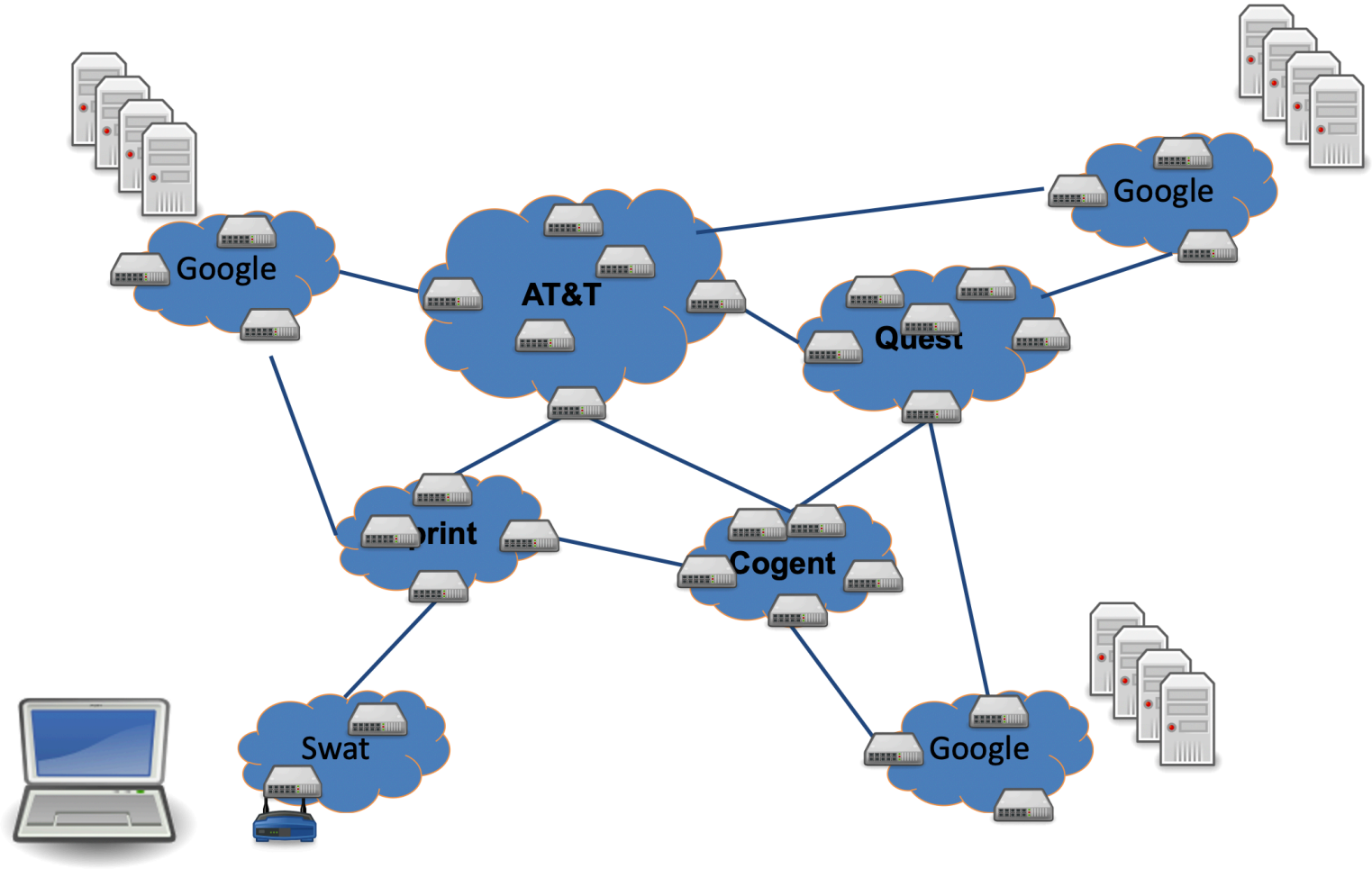
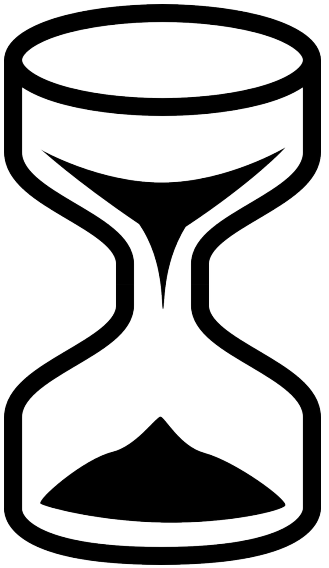


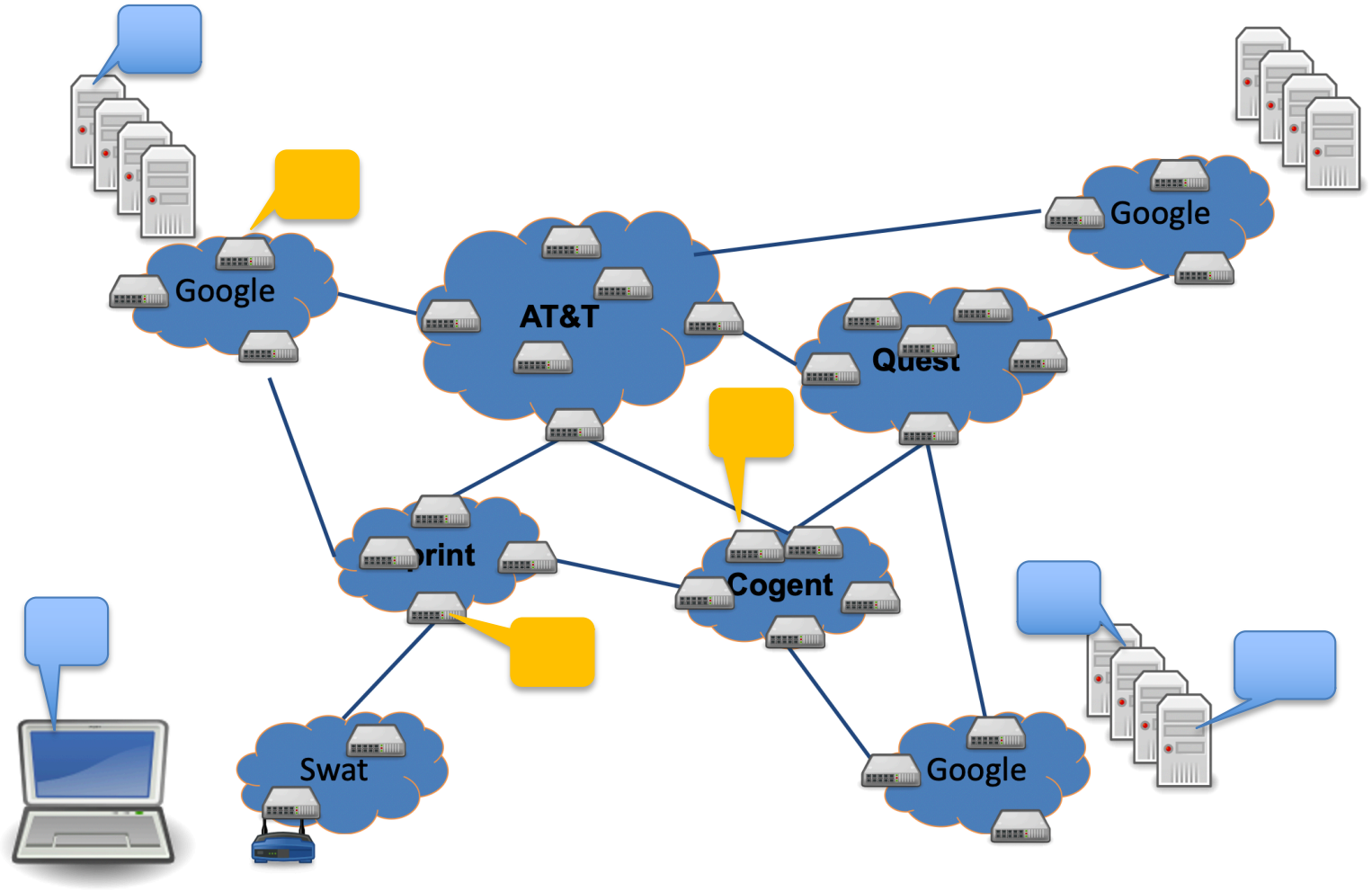
We only need... ?





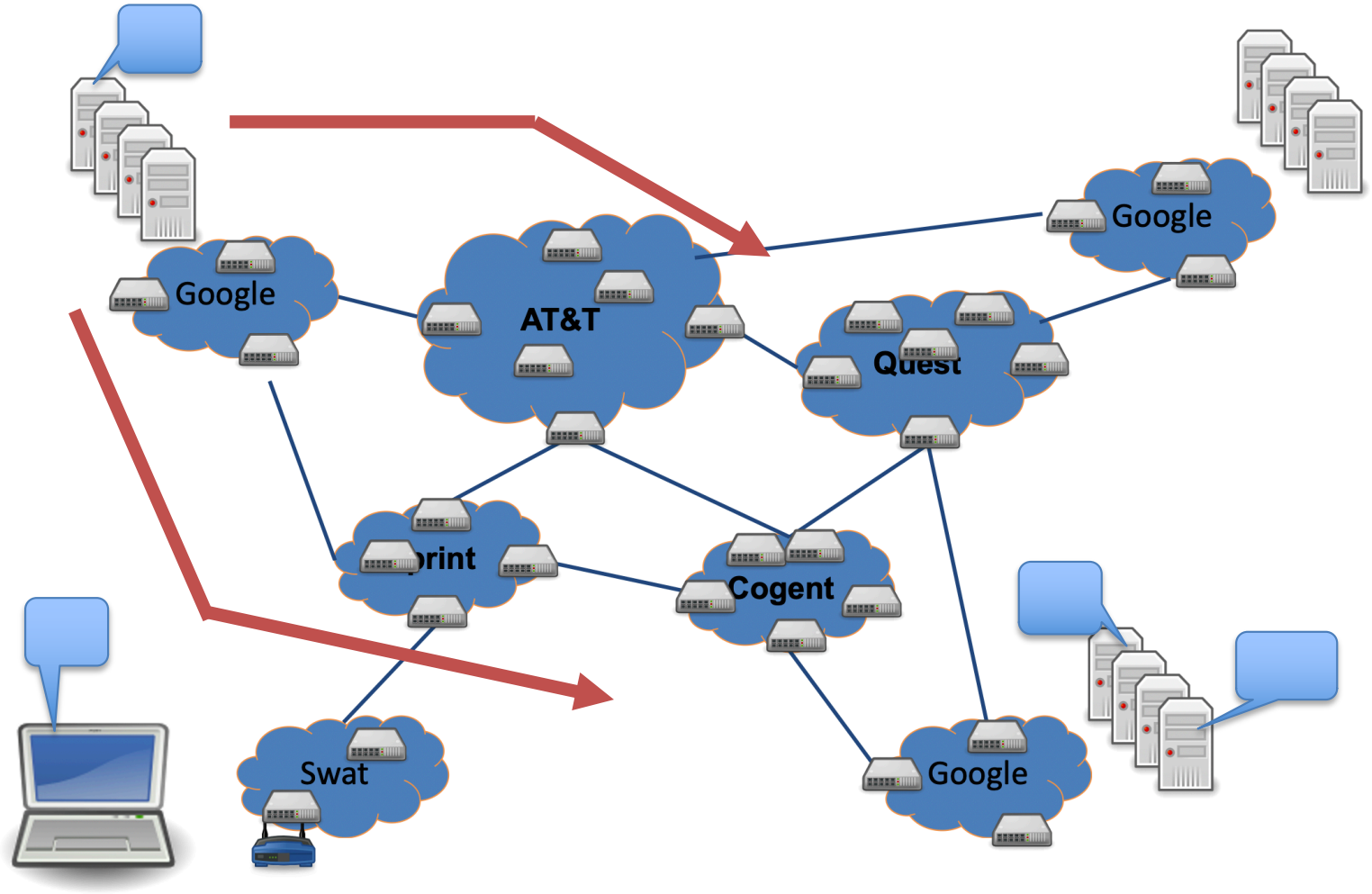
We only need... naming and addressing

Agreeing on how to describe/express a host, application, network, etc.



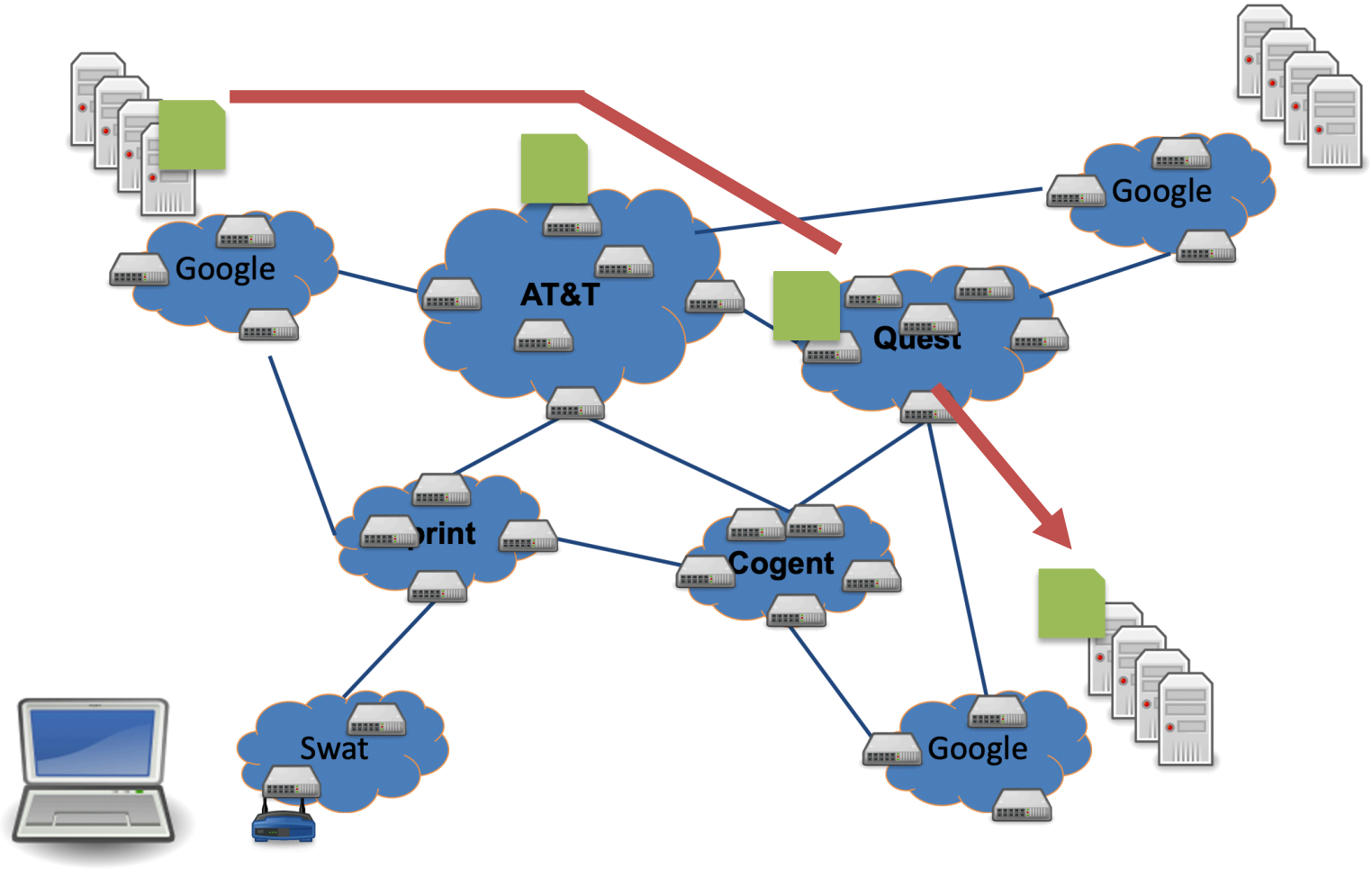
We only need… moving data to the destination

Routing: deciding how to get it there



We only need… moving data to the destination

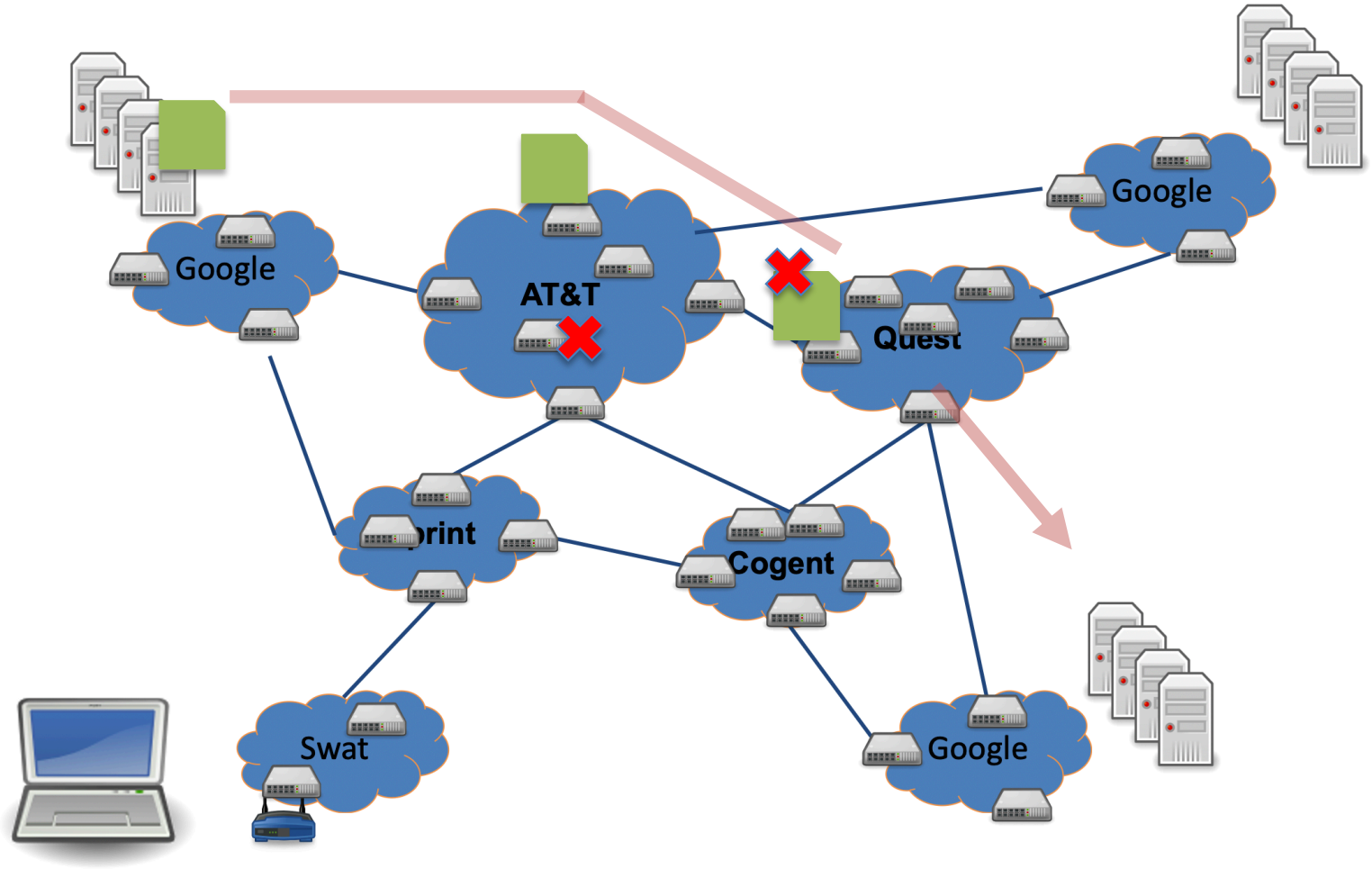
Forwarding: copying data across devices/links



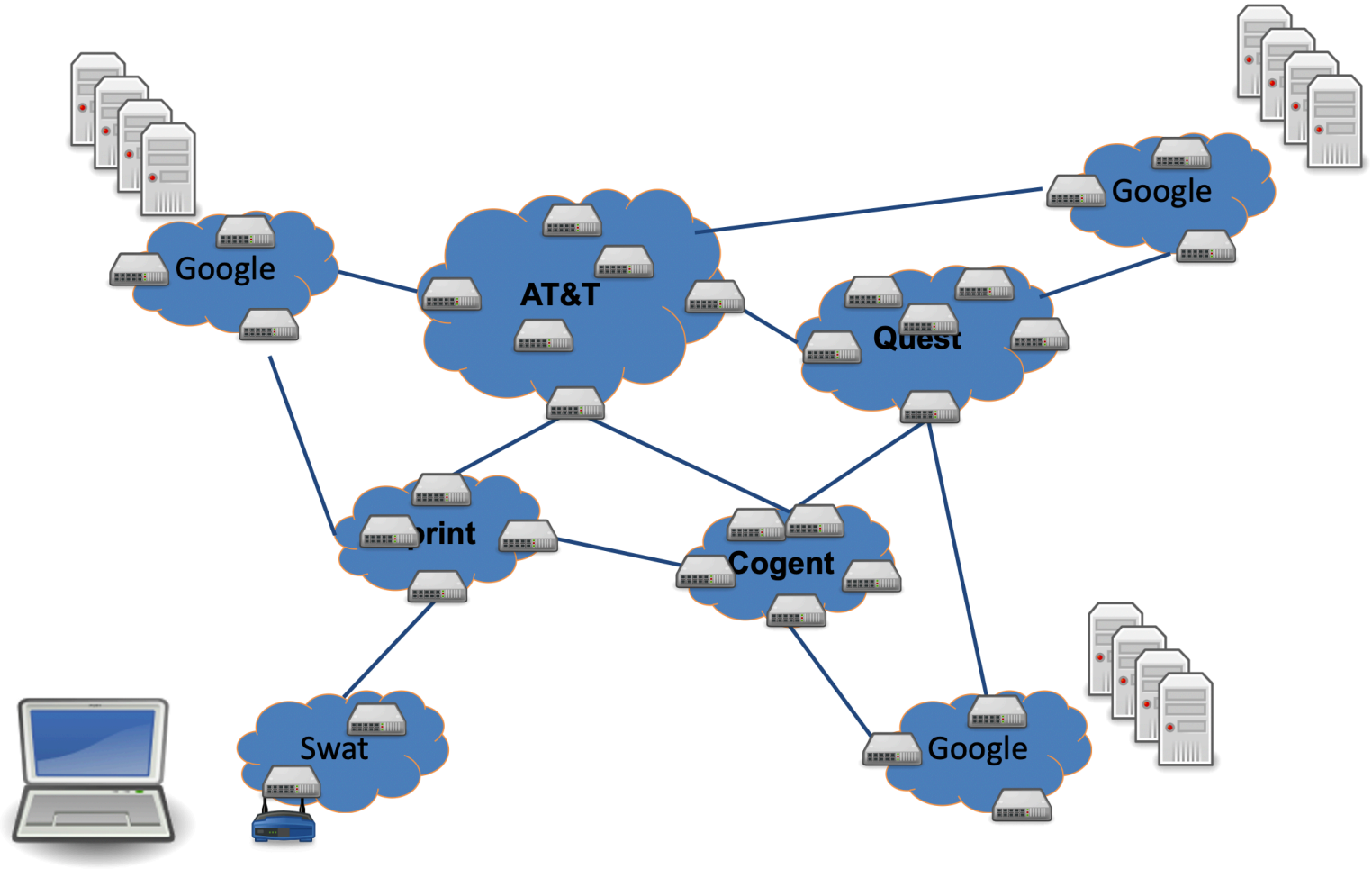
We only need... reliability and fault tolerance

how can we ...guarantee that the data arrives?

...handle link or device failures?

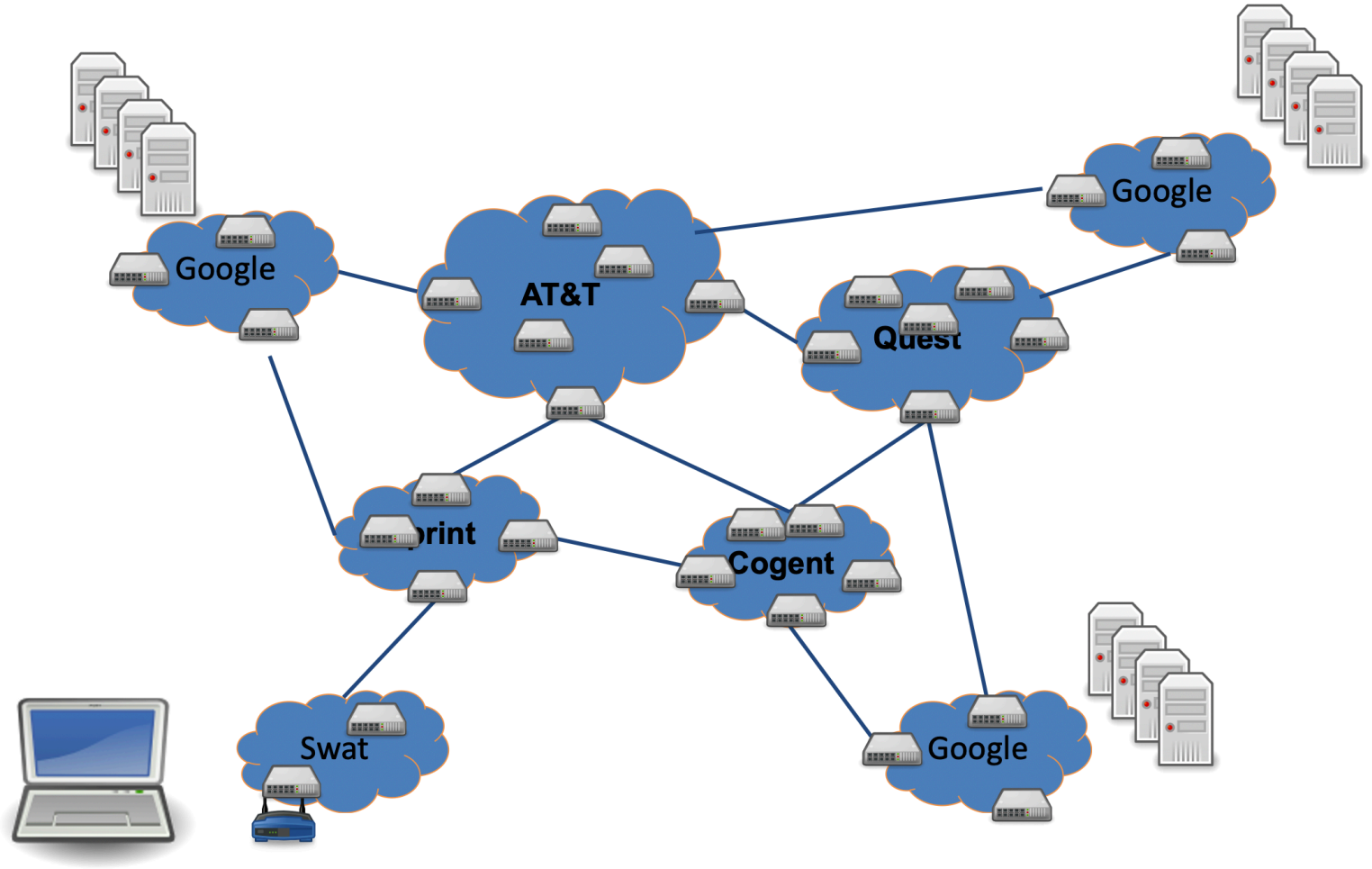


We only need... security and privacy



We only need... to manage complexity and scale up

Layering abstraction: divide responsibility
Protocols: standardize behavior for interoperability



We only need…

- Manage complexity and scale up
- Naming and addressing
- Moving data to the destination
- Reliability and fault tolerance
- Resource allocation, Security, Privacy..

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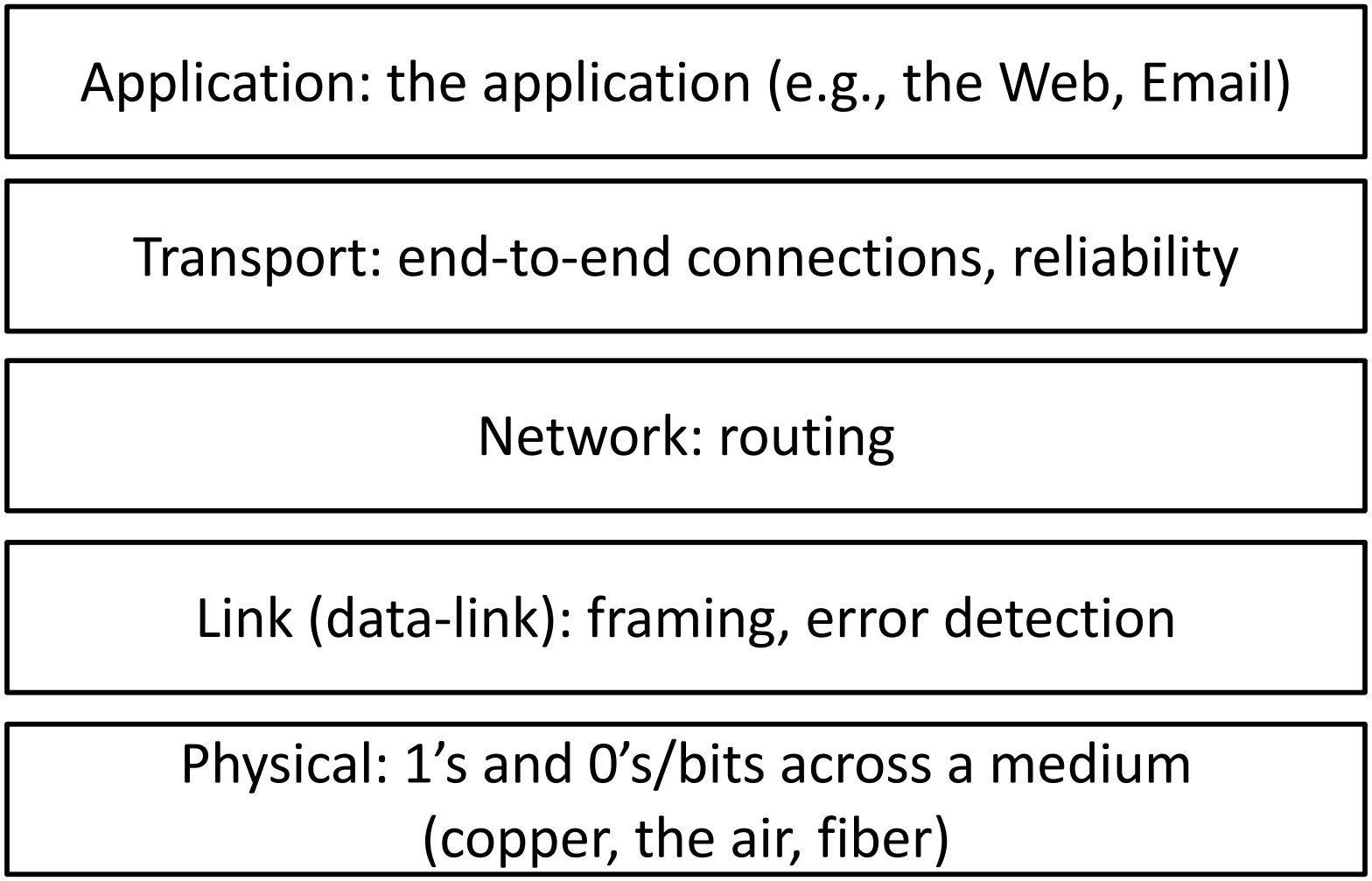
(Lots of others too.)

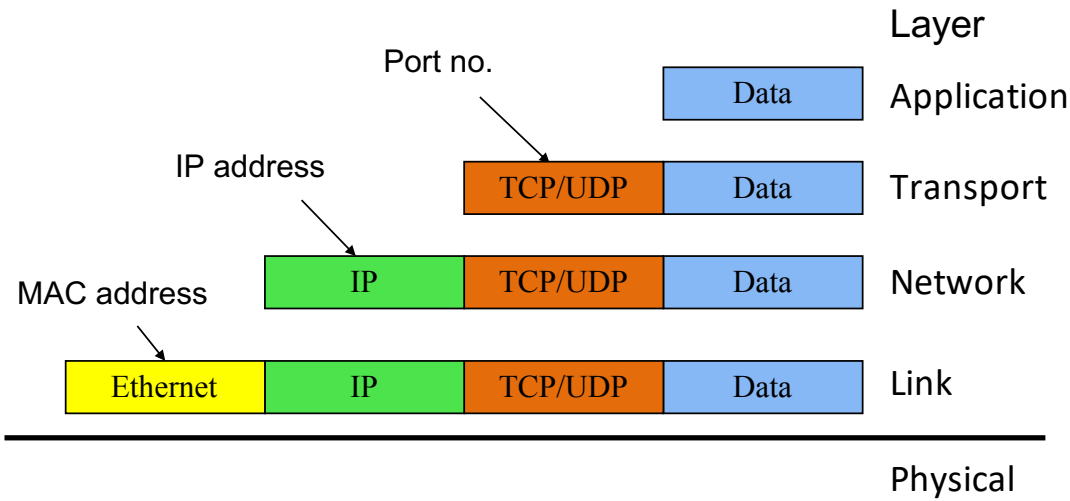
Five-Layer Internet Model



Application Layer (HTTP, FTP, SMTP, Skype)

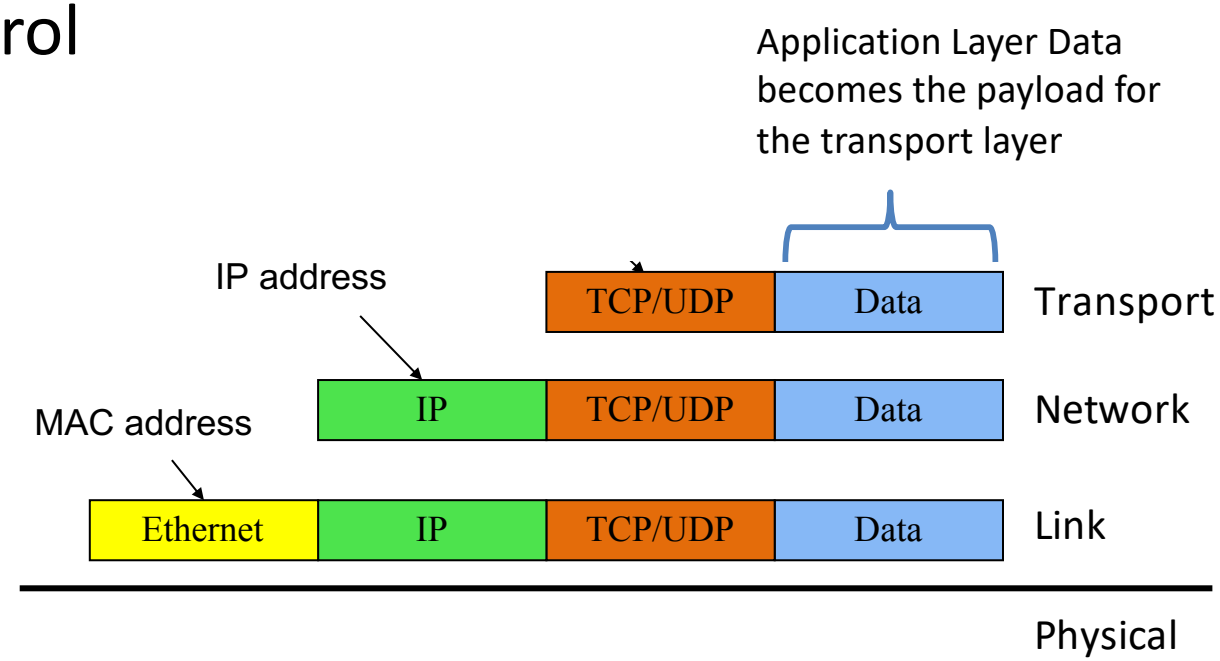
- Does whatever an application does!



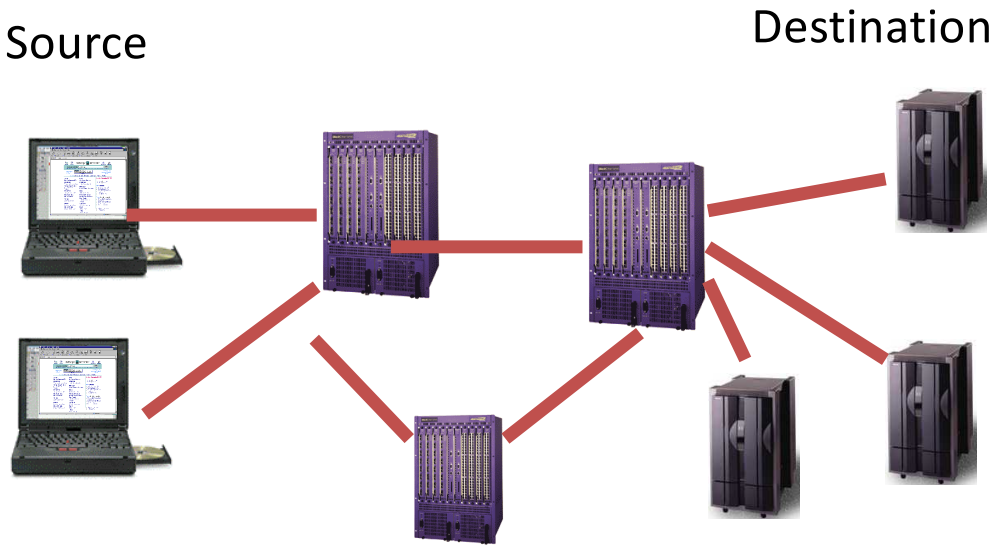
Transport Layer (TCP, UDP)

- Provides
  - Ordering
  - Error checking
  - Delivery guarantee
  - Congestion control
  - Flow control
- Or doesn't!

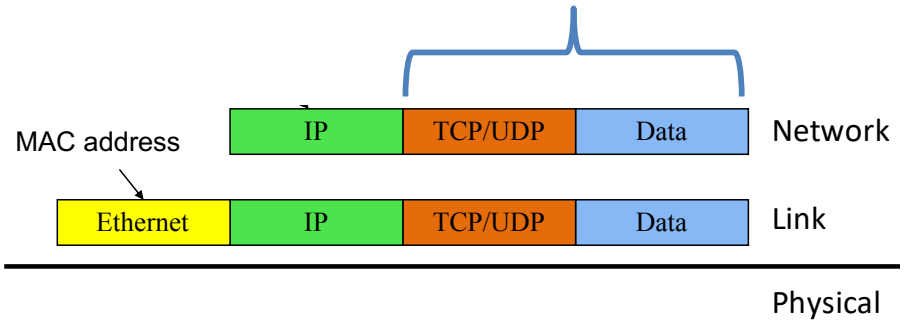


Network Layer (IP)

- **Routers**: choose paths through network

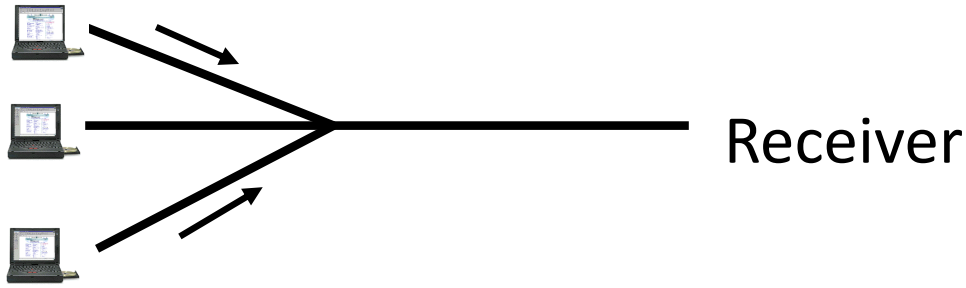


Transport layer data + header becomes payload for the network layer

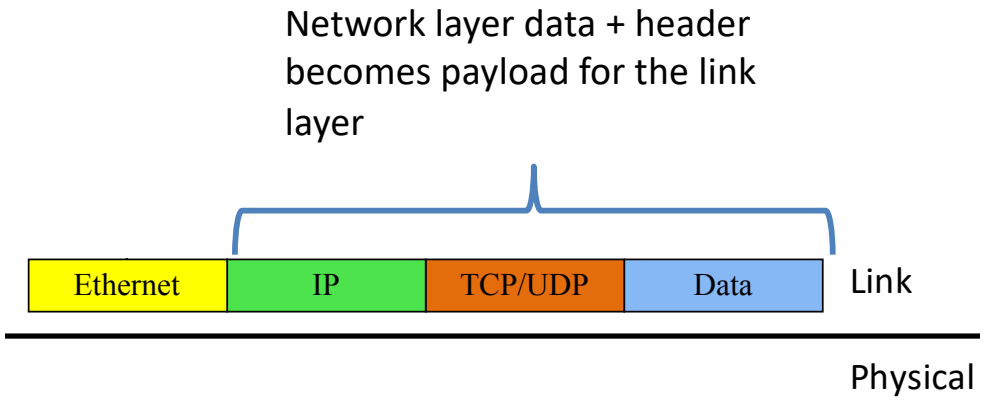


Link Layer (Ethernet, WiFi, Cable)

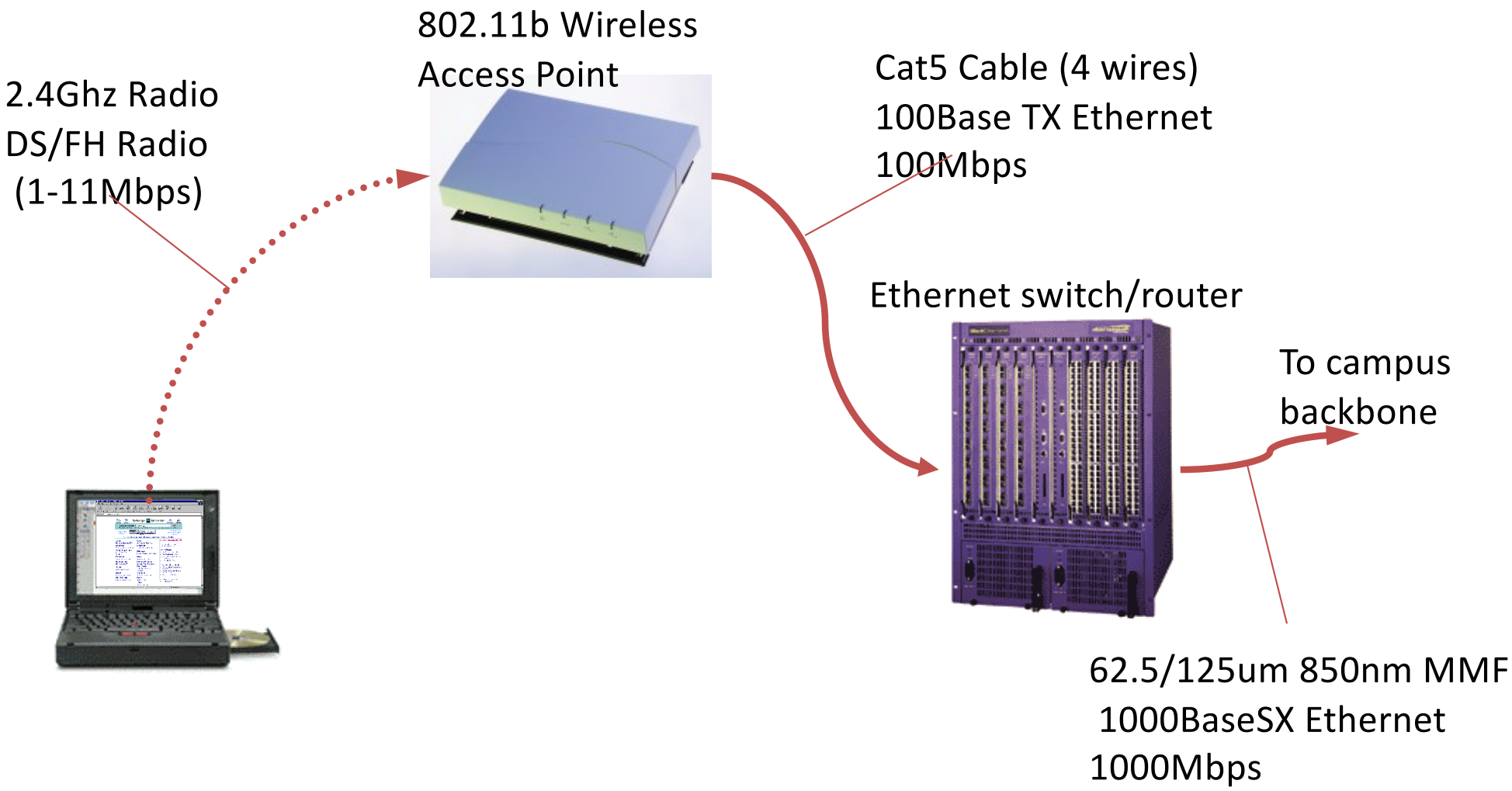
- Who's turn is it to send right now?
- Break message into frames
- Media access: can it send the frame now?



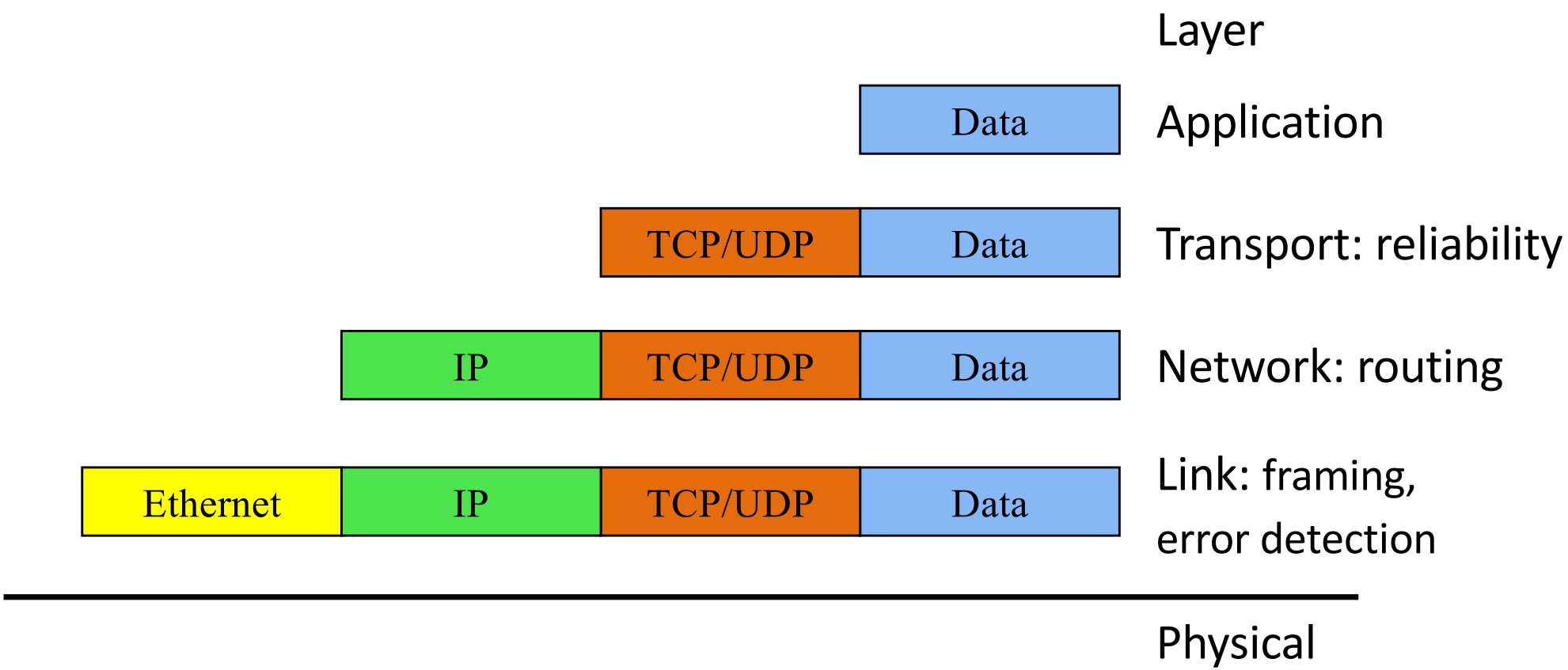
- Send frame, handle "collisions"



Physical layer – move actual bits! (Cat 5, Coax, Air, Fiber Optics)



Layering and encapsulation



Layering: Separation of Functions

- explicit structure allows identification, relationship of complex system's pieces
  - layered reference model for discussion
  - reusable component design
- modularization eases maintenance
  - change of implementation of layer's service transparent to rest of system,
  - e.g., change in postal route doesn't effect delivery of lette

Abstraction!

- Hides the complex details of a process
- Use abstract representation of relevant properties make reasoning simpler
- Ex: Your knowledge of postal system:
  - Letters with addresses go in, come out other side

Five-Layer Internet Model

Application: the application (e.g., the Web, Email)

Transport: end-to-end connections, reliability

Network: routing

Link (data-link): framing, error detection

Physical: 1's and 0's/bits across a medium (copper, the air, fiber)

OSI Seven-Layer Model

Application: the application (e.g., the Web, Email)

Presentation: formatting, encoding, encryption

Session: sockets, remote procedure call

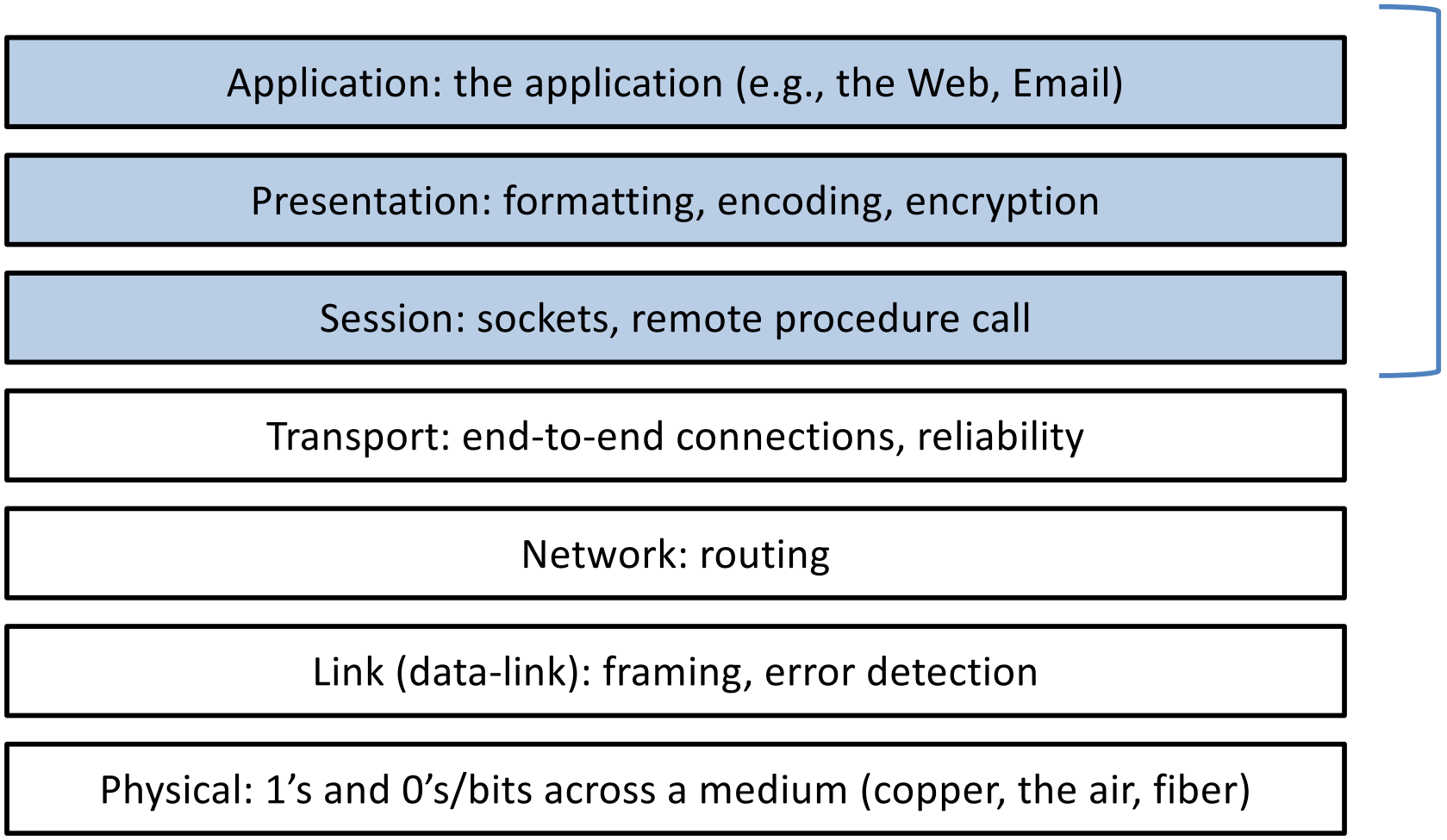
Transport: end-to-end connections, reliability

Network: routing

Link (data-link): framing, error detection

Physical: 1's and 0's/bits across a medium (copper, the air, fiber)

OSI Seven-Layer Model



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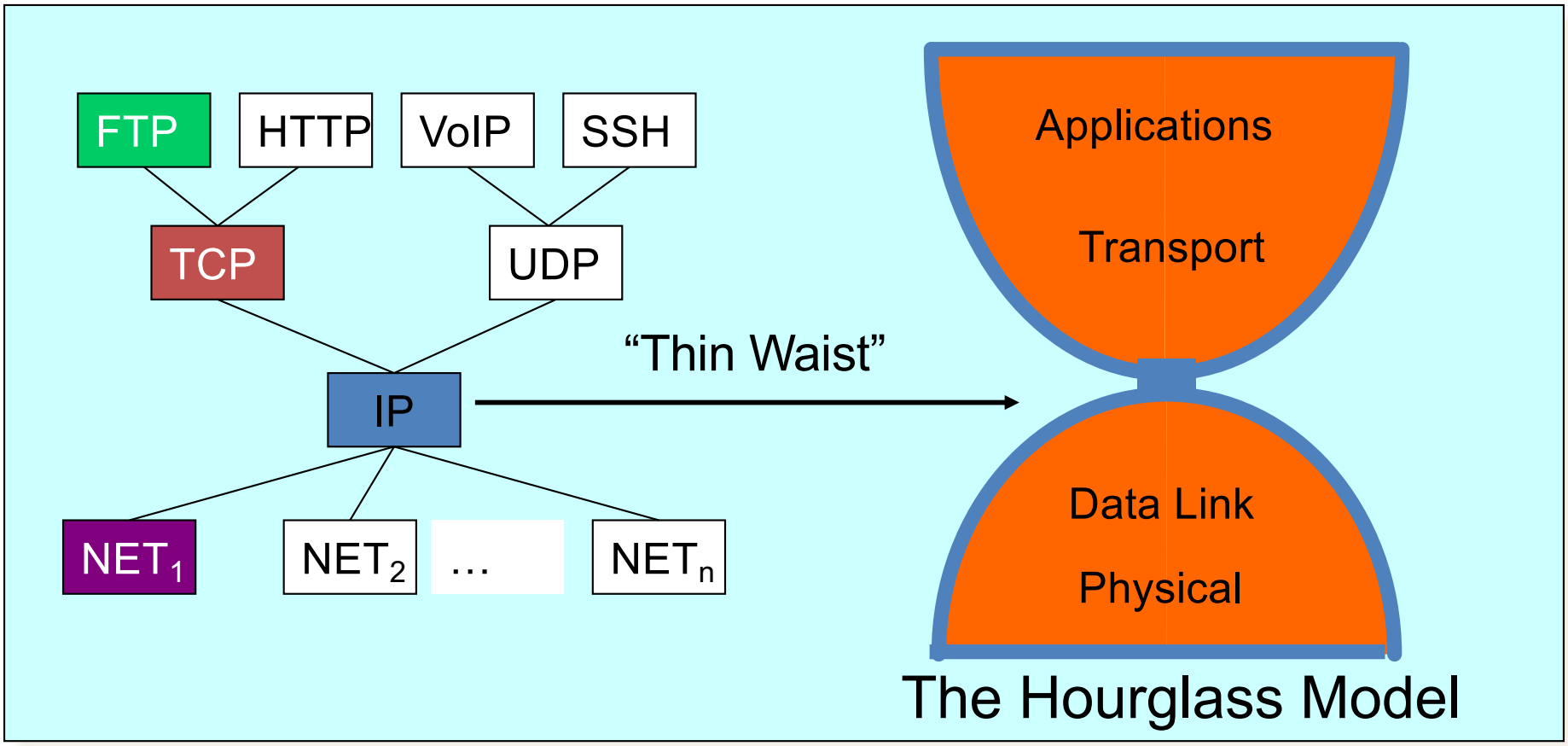
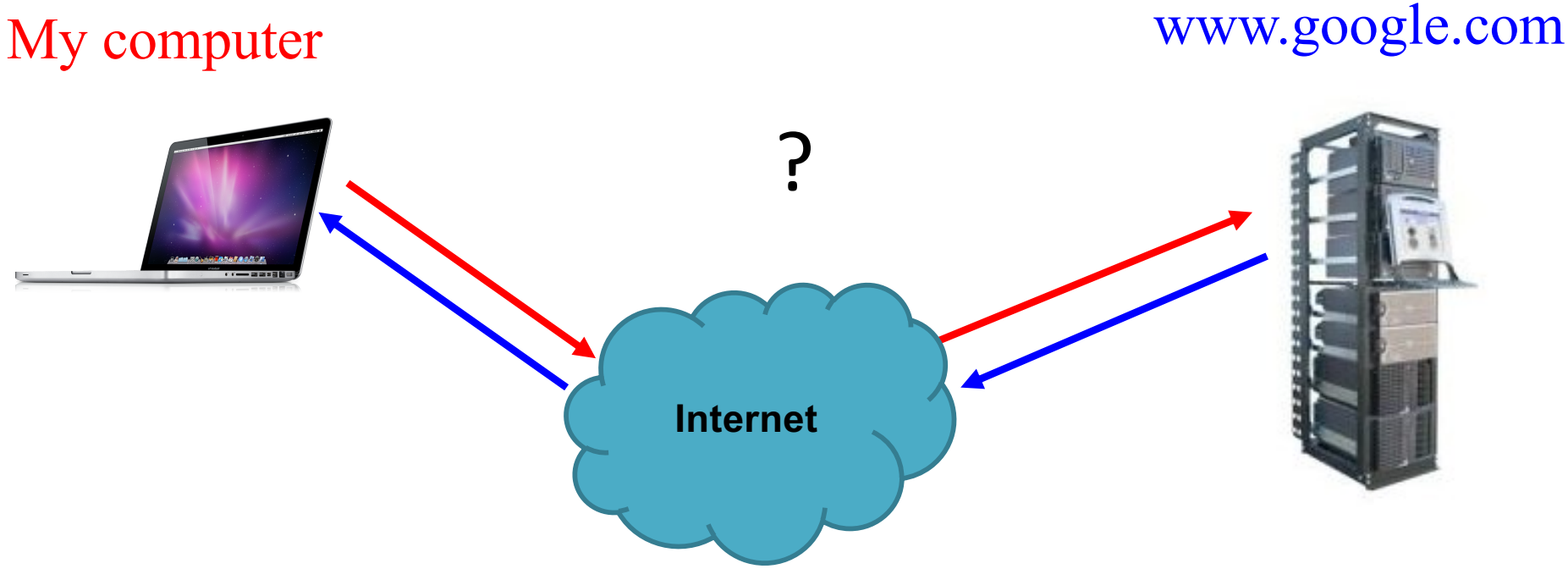
Internet Protocol Suite



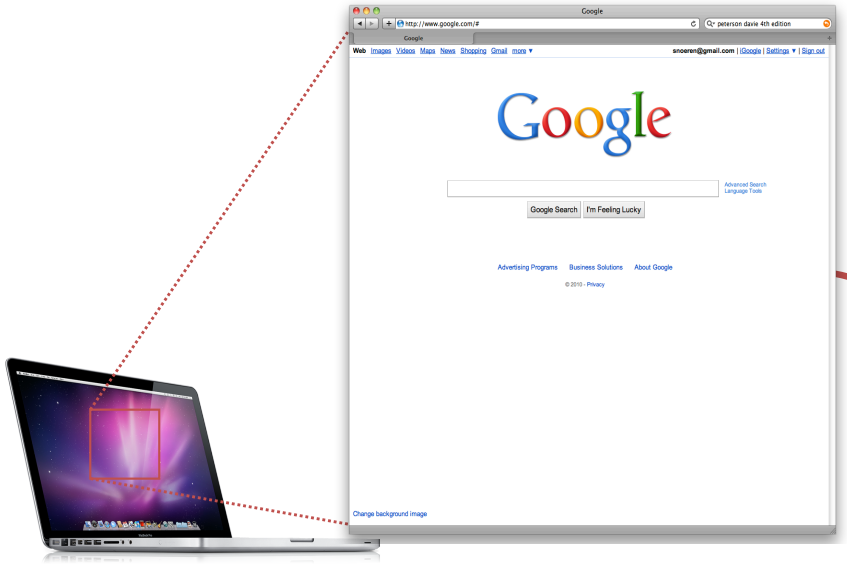
Putting this all together

- **ROUGHLY**, what happens when I click on a Web page from Swarthmore?



Application Layer: Web request (HTTP)

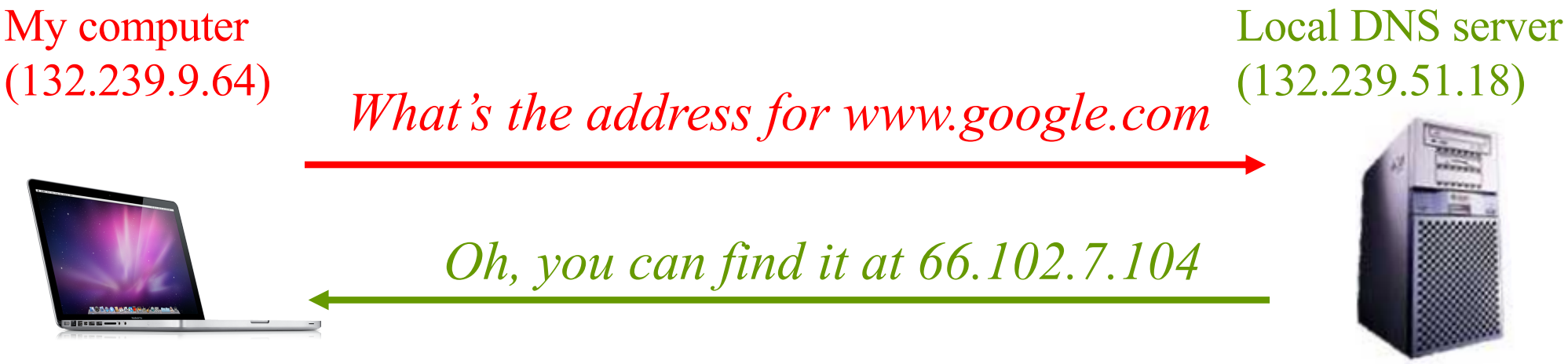
- Turn click into HTTP request



GET http://www.google.com/ HTTP/1.1
Host: www.google.com
…

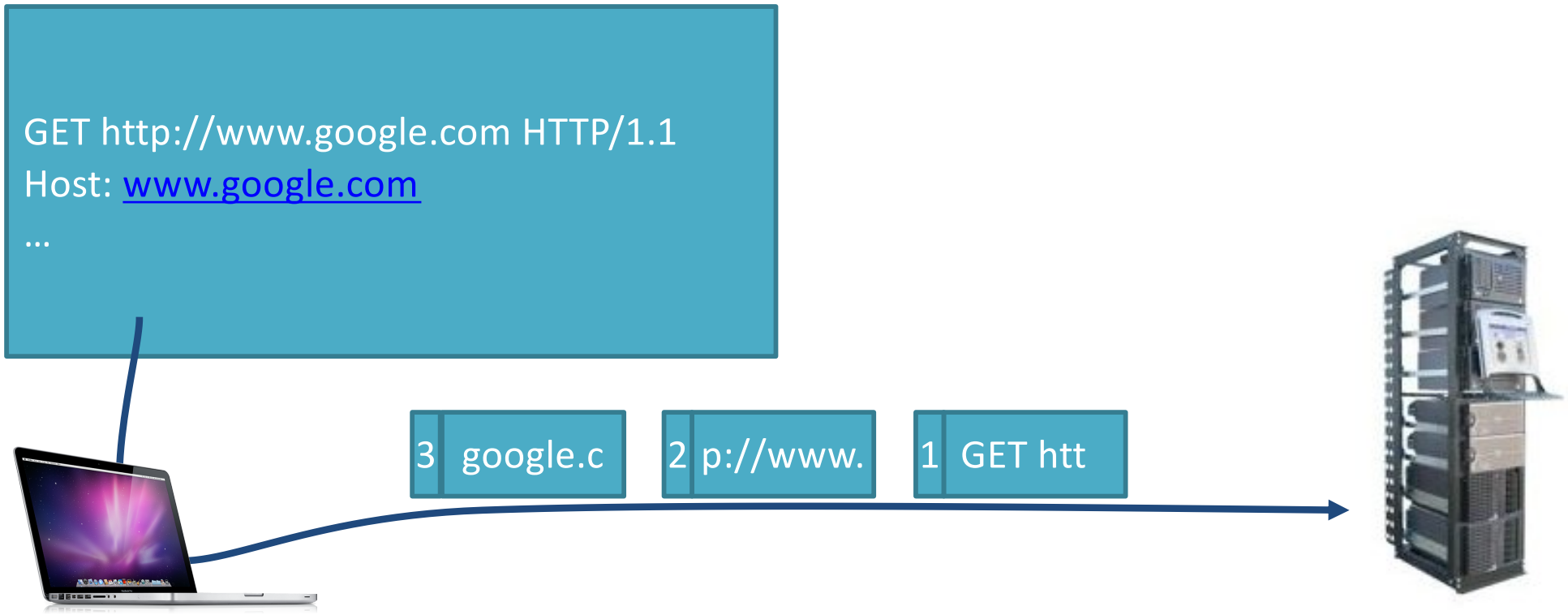
Application Layer: Name resolution (DNS)

- Where is www.google.com?



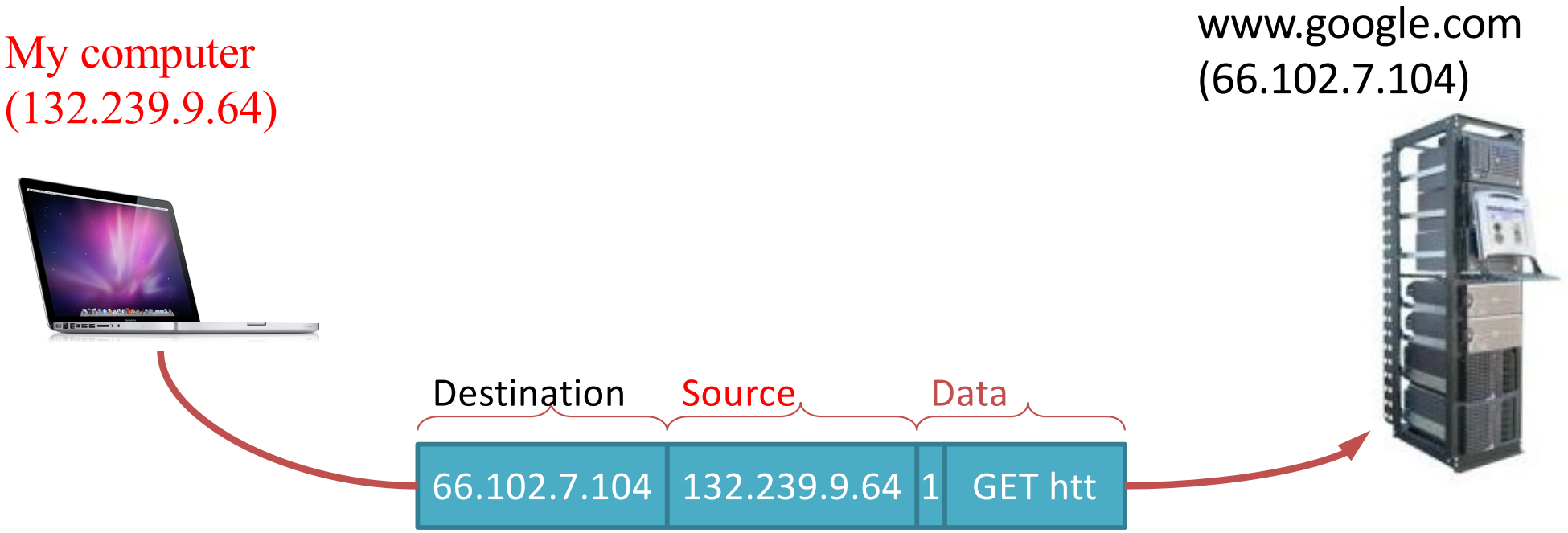
Transport Layer: TCP

- Break message into packets (TCP segments)
- Should be delivered reliably & in-order



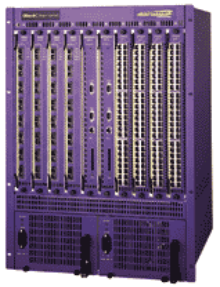
Network Layer: Global Network Addressing

- Address each packet so it can traverse network and arrive at host



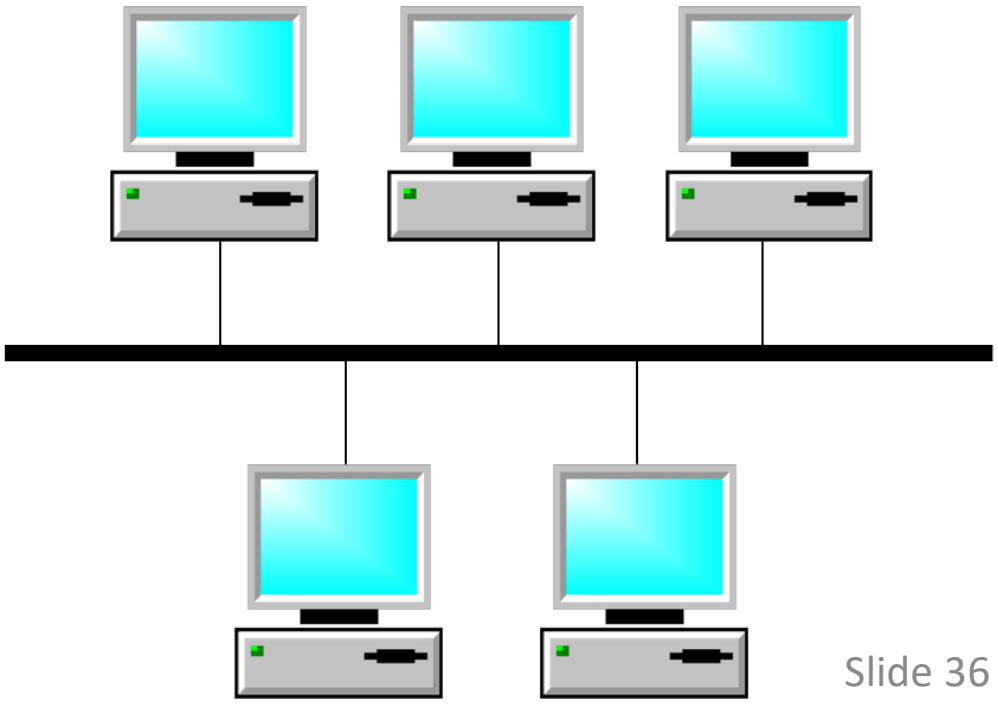
Network Layer: (IP) At Each Router

- Where do I send this to get it closer to Google?
- Which is the best route to take?

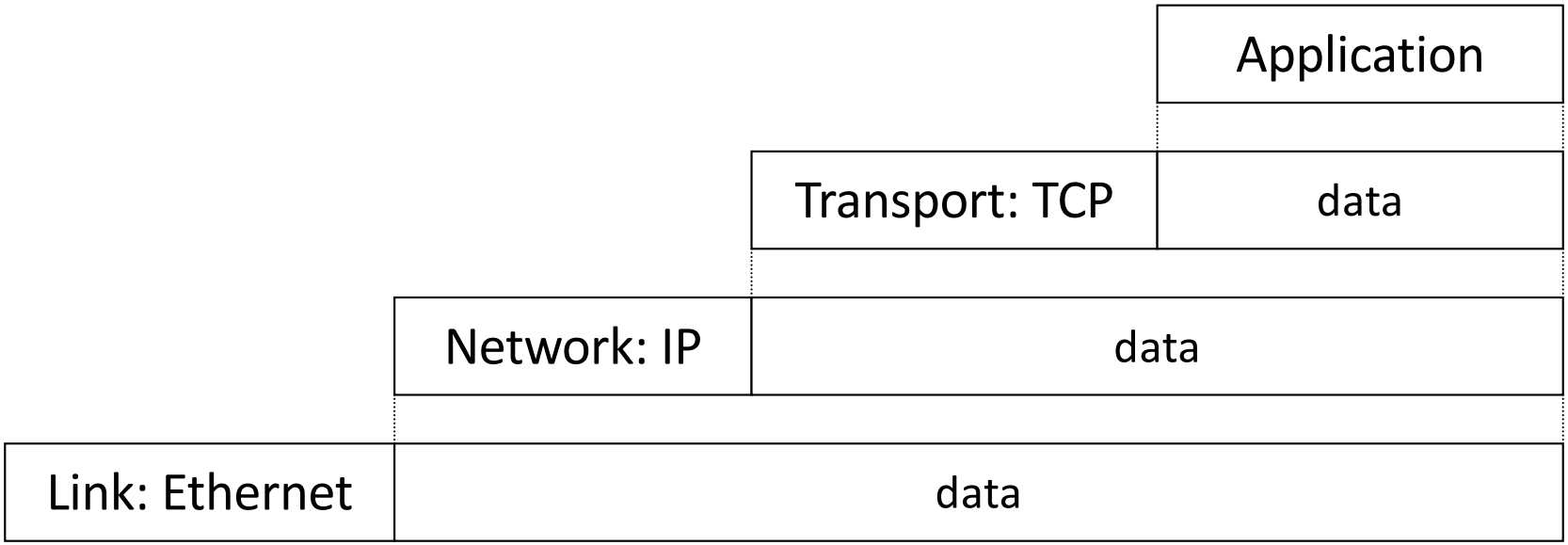


Link & Physical Layers (Ethernet)

- Forward to the next node!
- Share the physical medium.
- Detect errors.

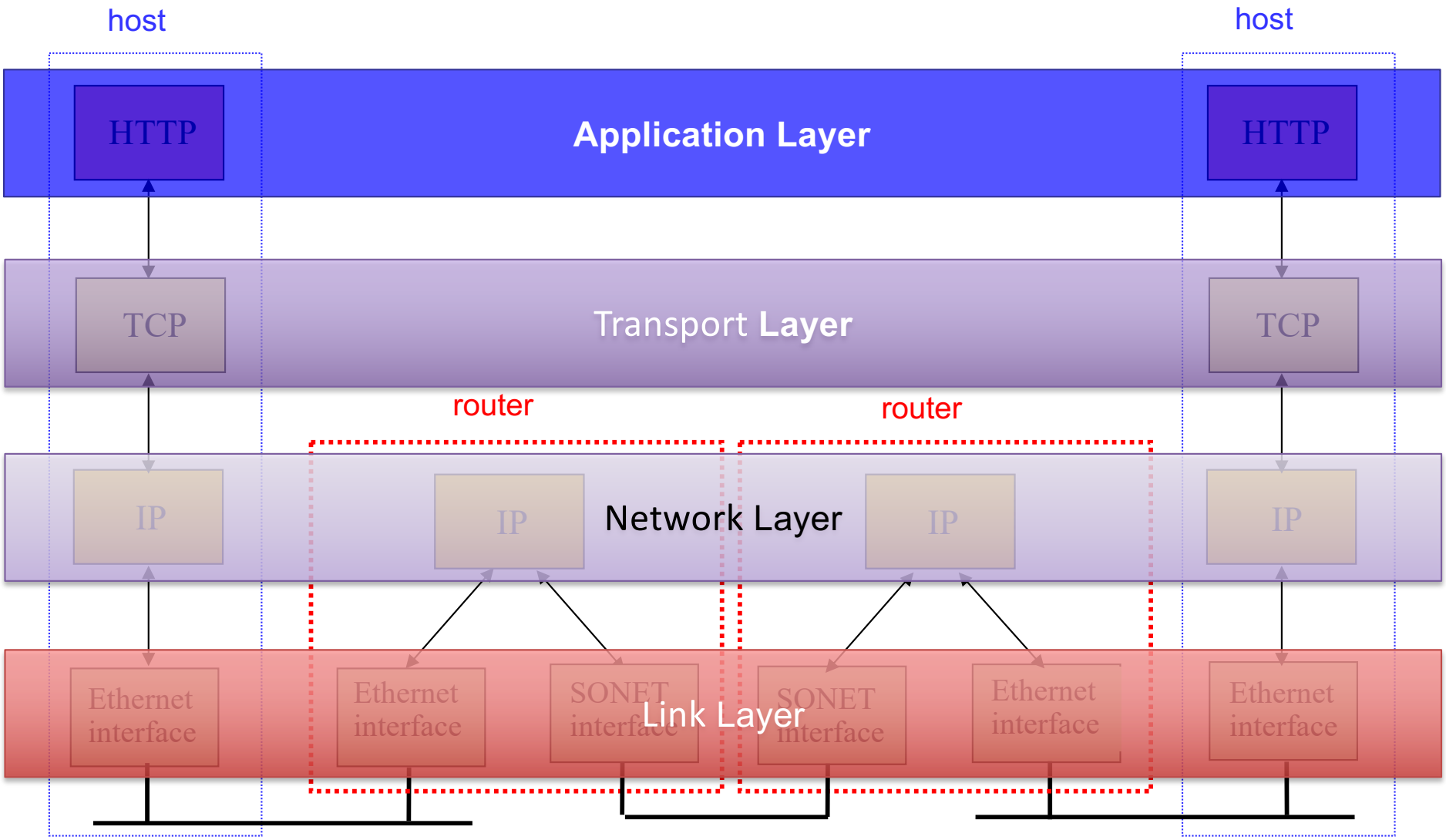


Message Encapsulation



- Higher layer within lower layer
- Each layer has different concerns, provides abstract services to those above

TCP/IP Protocol Stack



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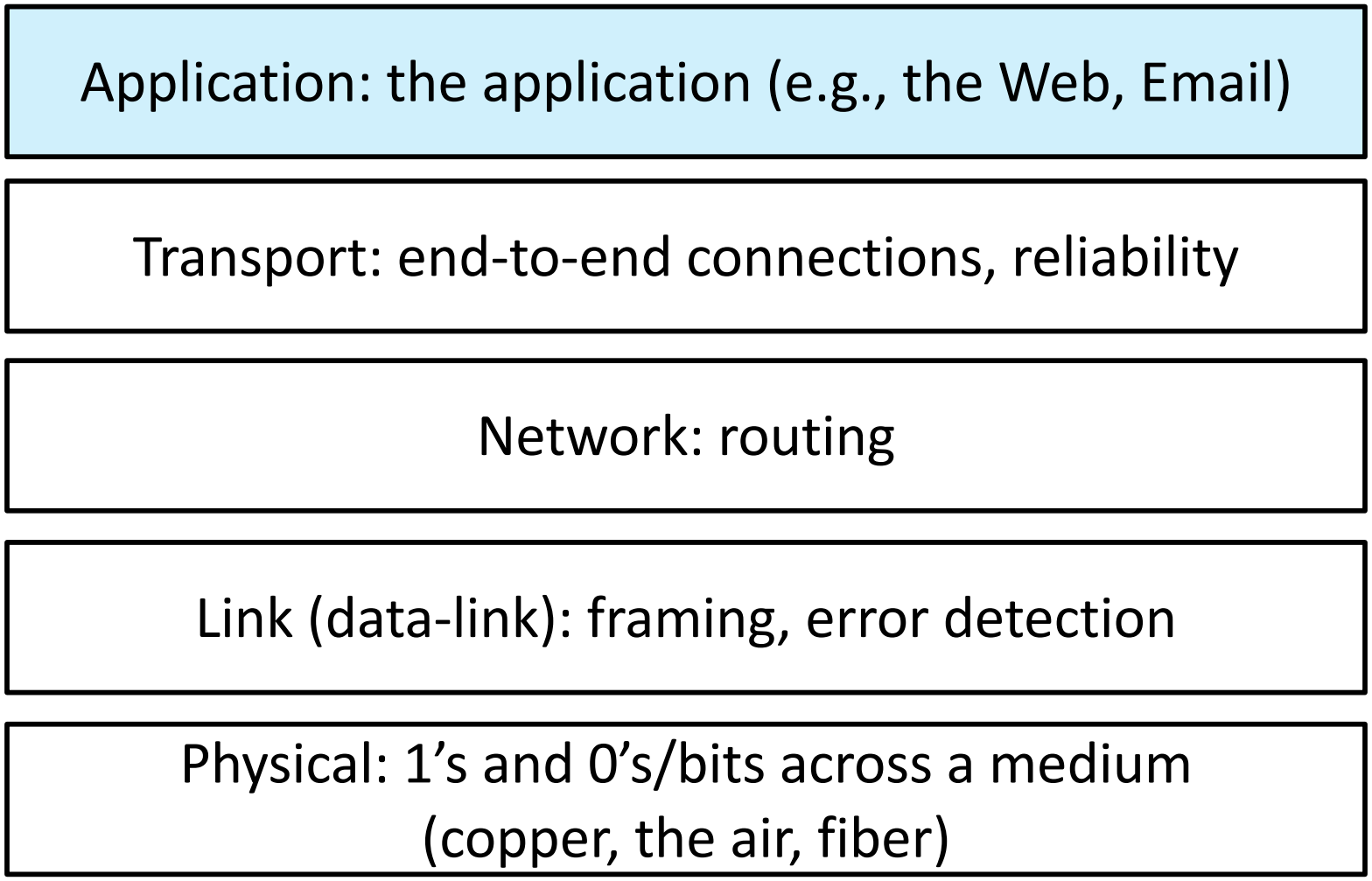
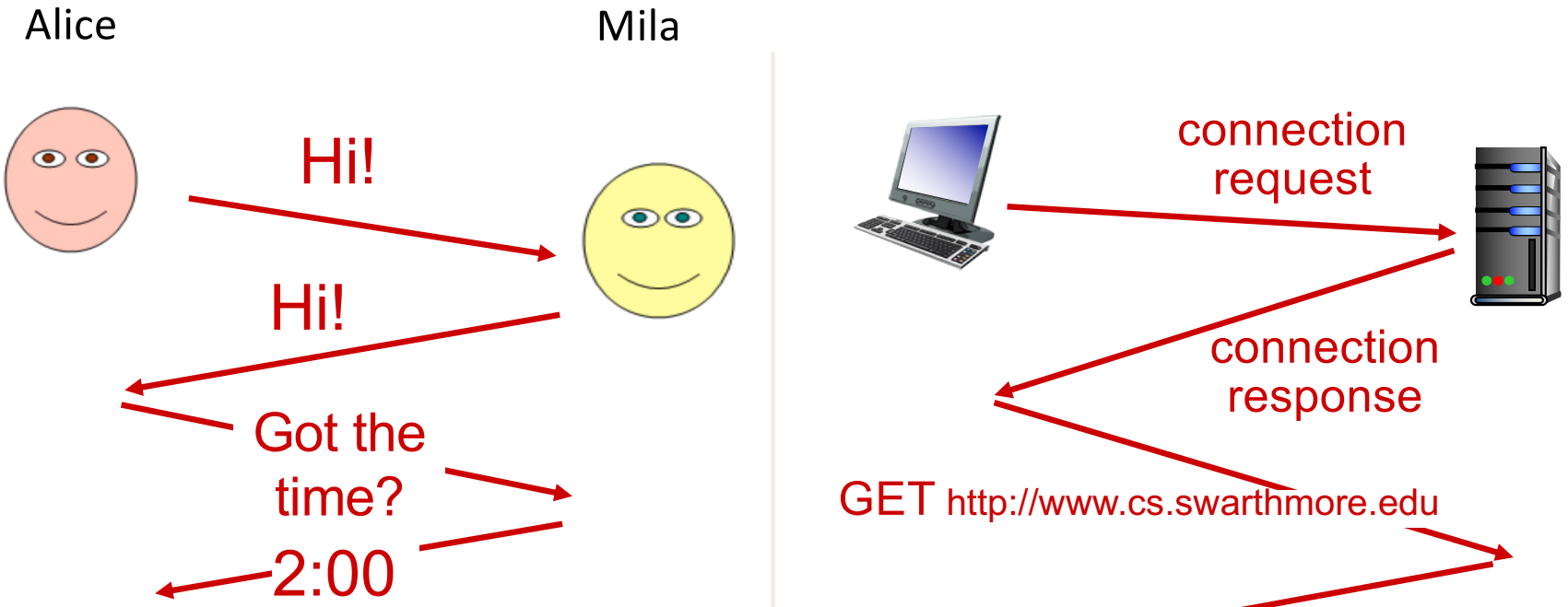


What is a protocol?

Protocol: message format + transfer procedure



Human Protocol

Network Protocols (defined in RFCs)

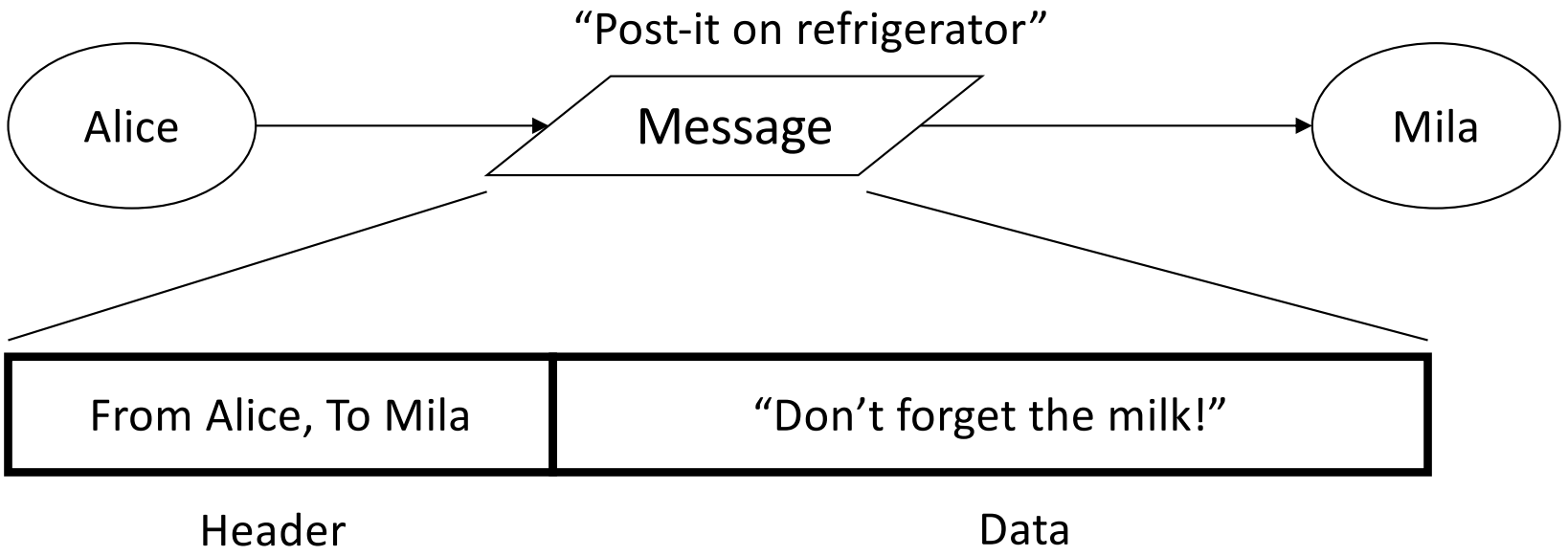
What is a protocol?

Goal: get message from sender to receiver

Protocol: message format + transfer procedure

- Expectations of operation
  - first you do x, then I do y, then you do z, ...
- Multiparty! so no central control
  - sender and receiver are separate processes

A "Simple" analogous task: Post-it Note



Write a protocol to write a note /post—it to your housemate

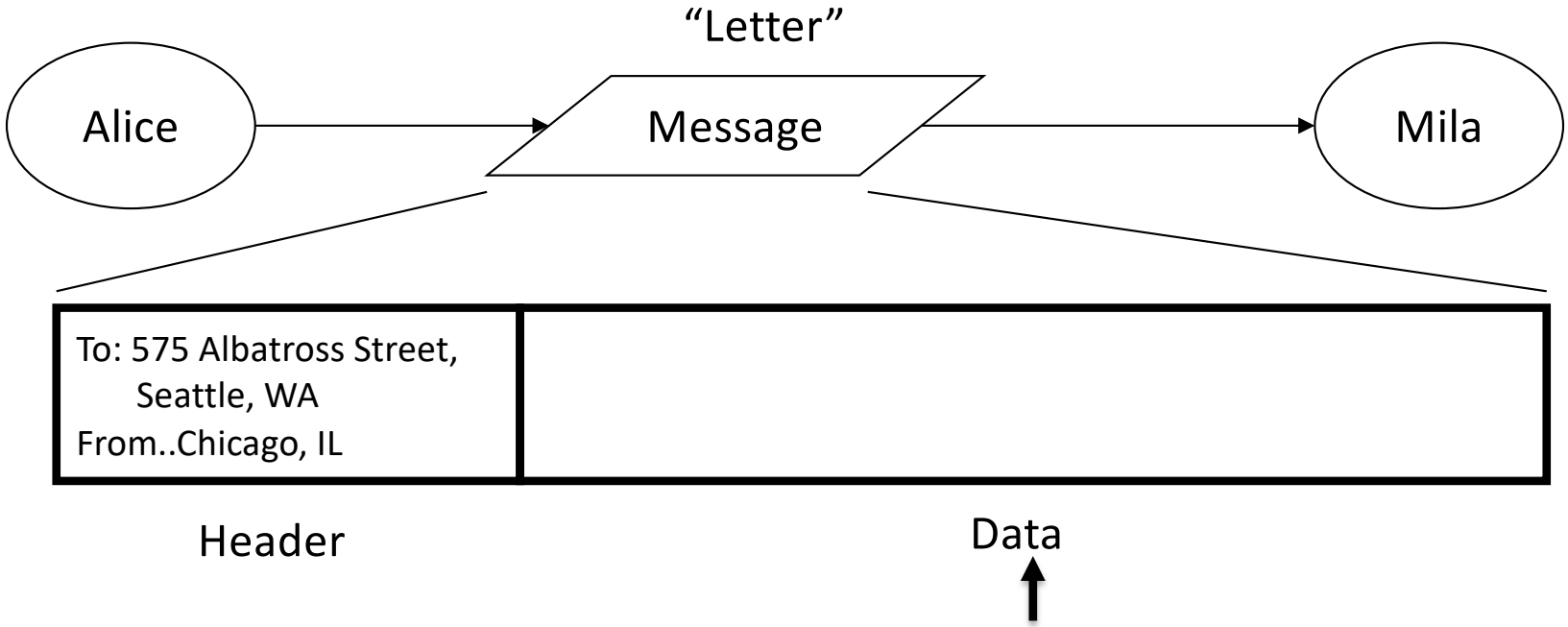
Protocol: message format + transfer procedure

- Message format: (from, to), message contents
- Transfer procedure: post on refrigerator

Message = Header + Data

- Header: information to support protocol
  - Source and destination addresses
  - State of protocol operation
  - Error control (to check integrity of received data)

A "Simple" analogous task: Postal Mail



The post office does NOT care about what's in here, and shouldn't be looking at it…

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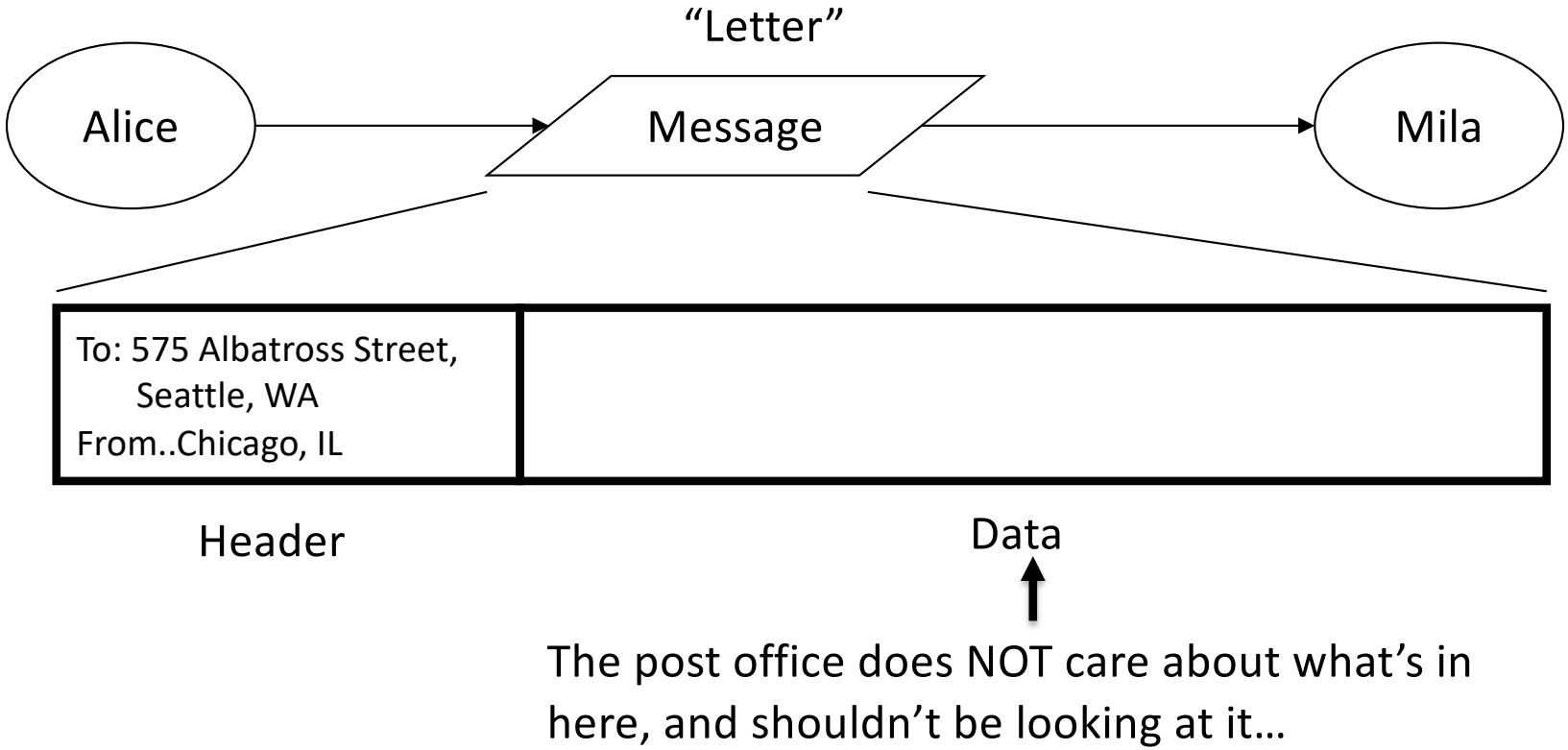
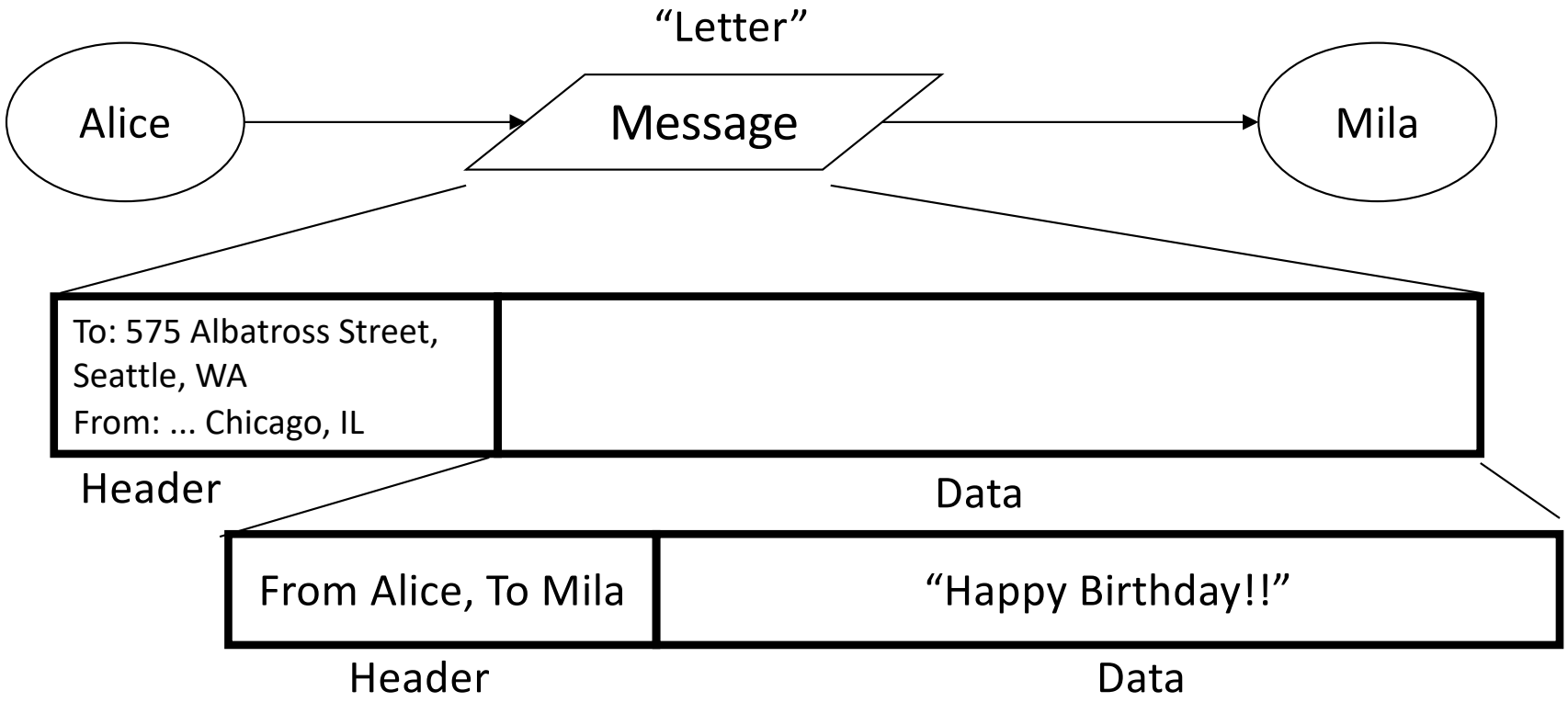


- **Mail Sending Protocol**
  - Message format: (from, to), message contents
  - Transfer procedure: post mail in mailbox (agreed upon convention)

A "Simple" analogous task: Postal Mail: other protocols in use?



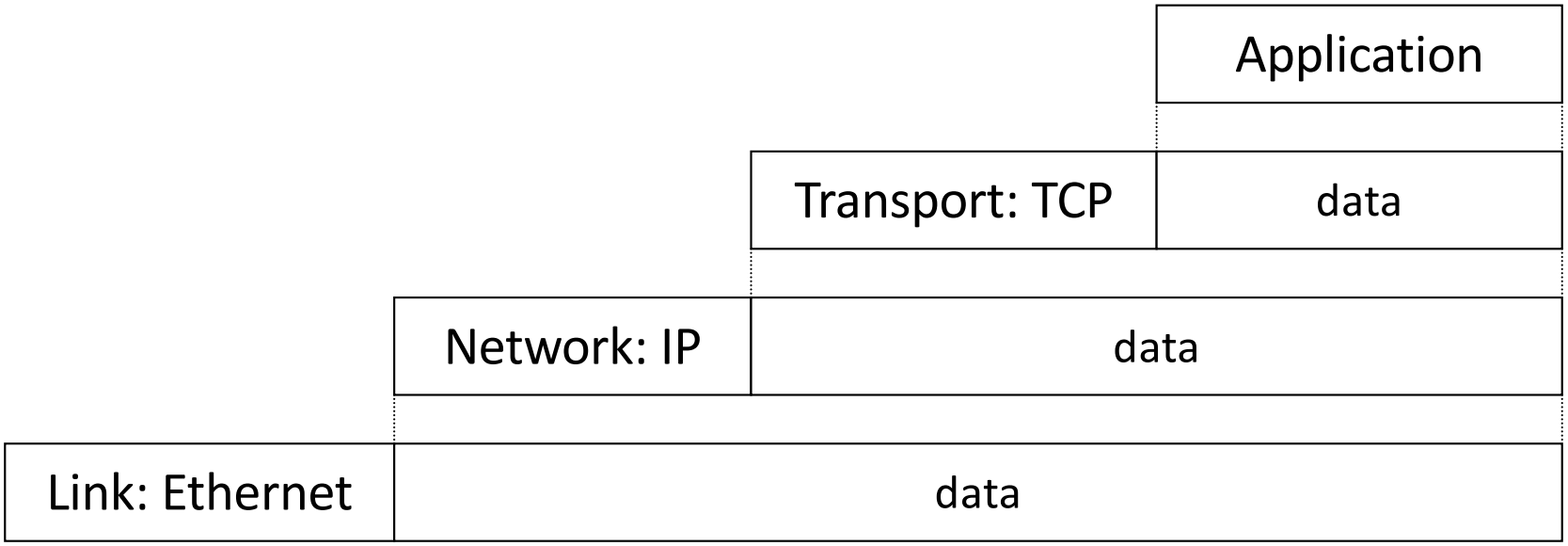
Mail Protocol

- Message format: (from, to), message contents
- Transfer procedure: post mail in mailbox (agreed upon convention)

Card Protocol (within the mail protocol!)

- Message format: (from, to), message contents

Message Encapsulation



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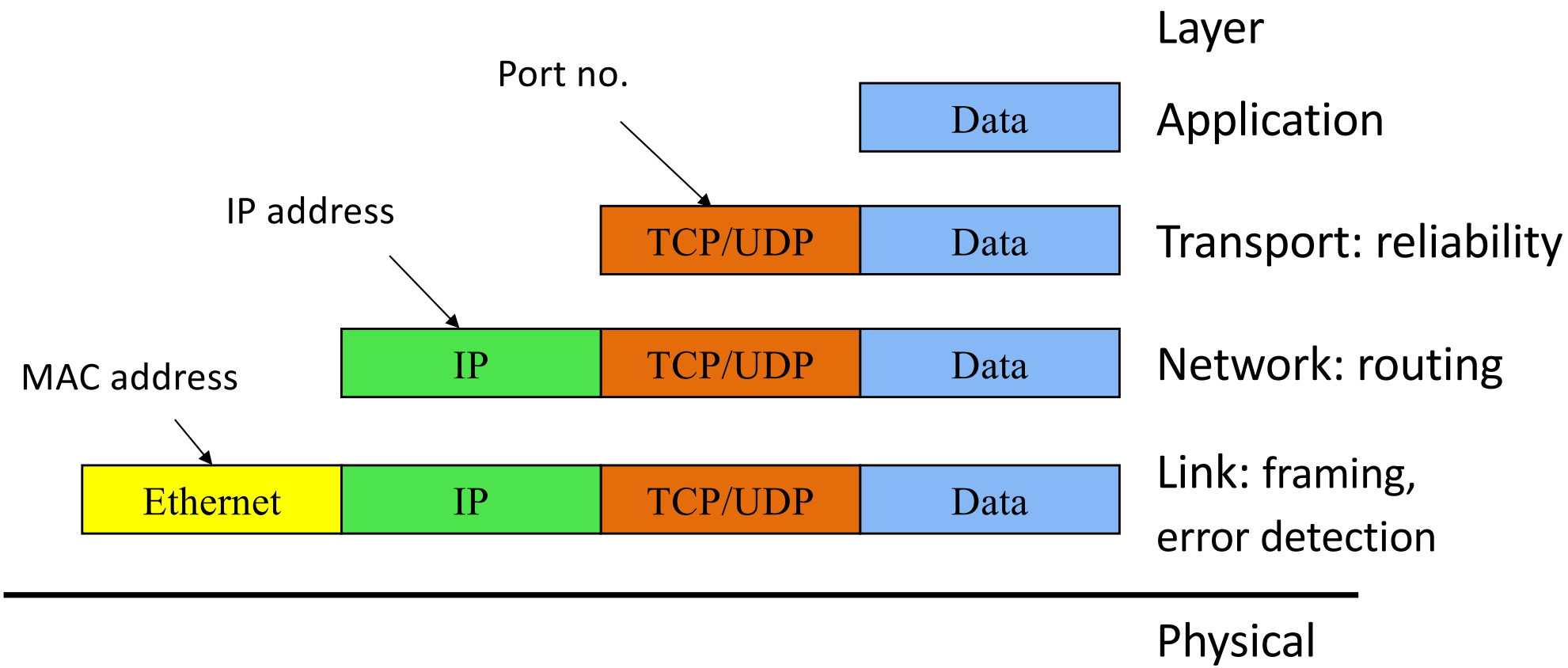
Layering and encapsulation



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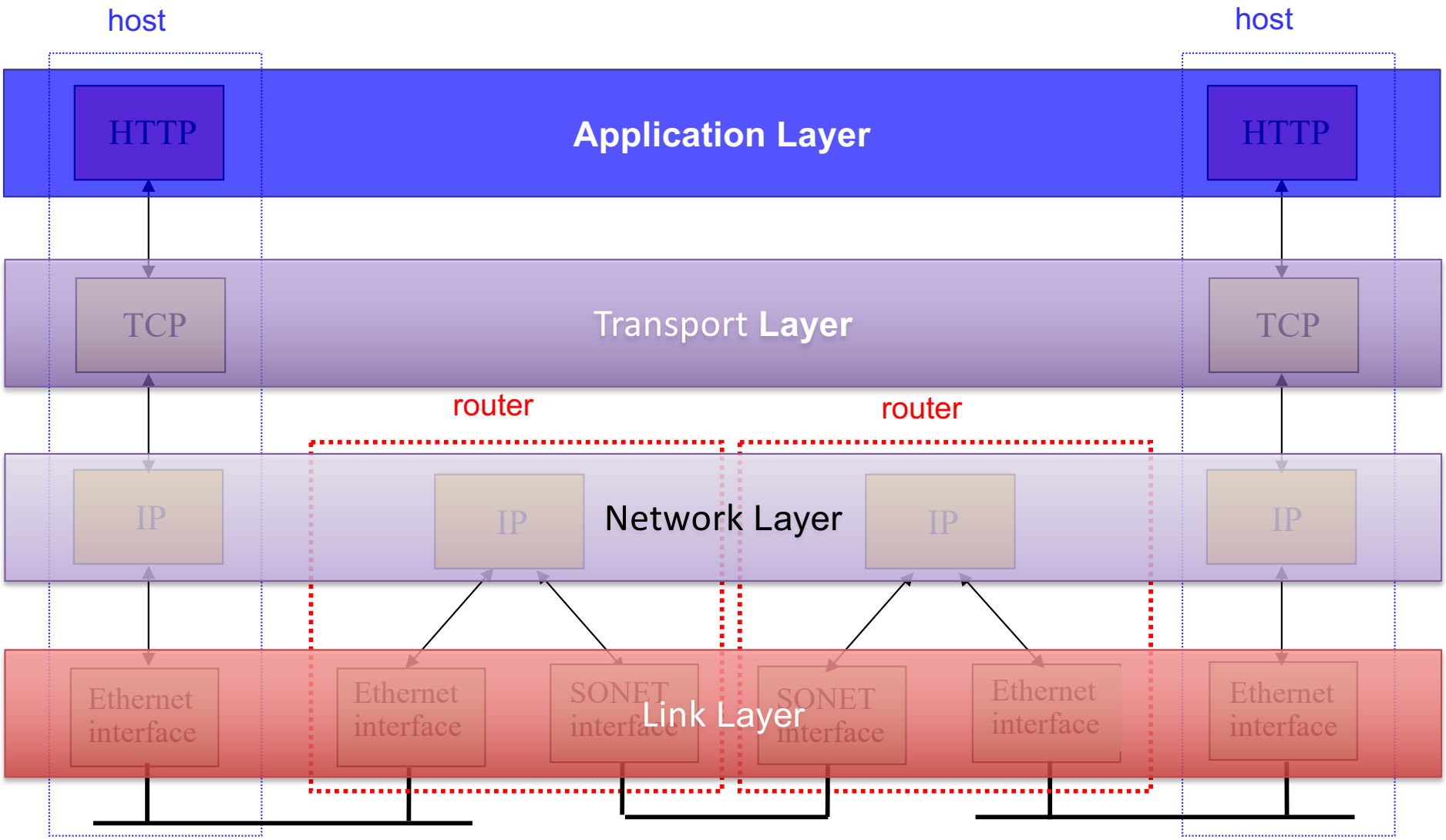


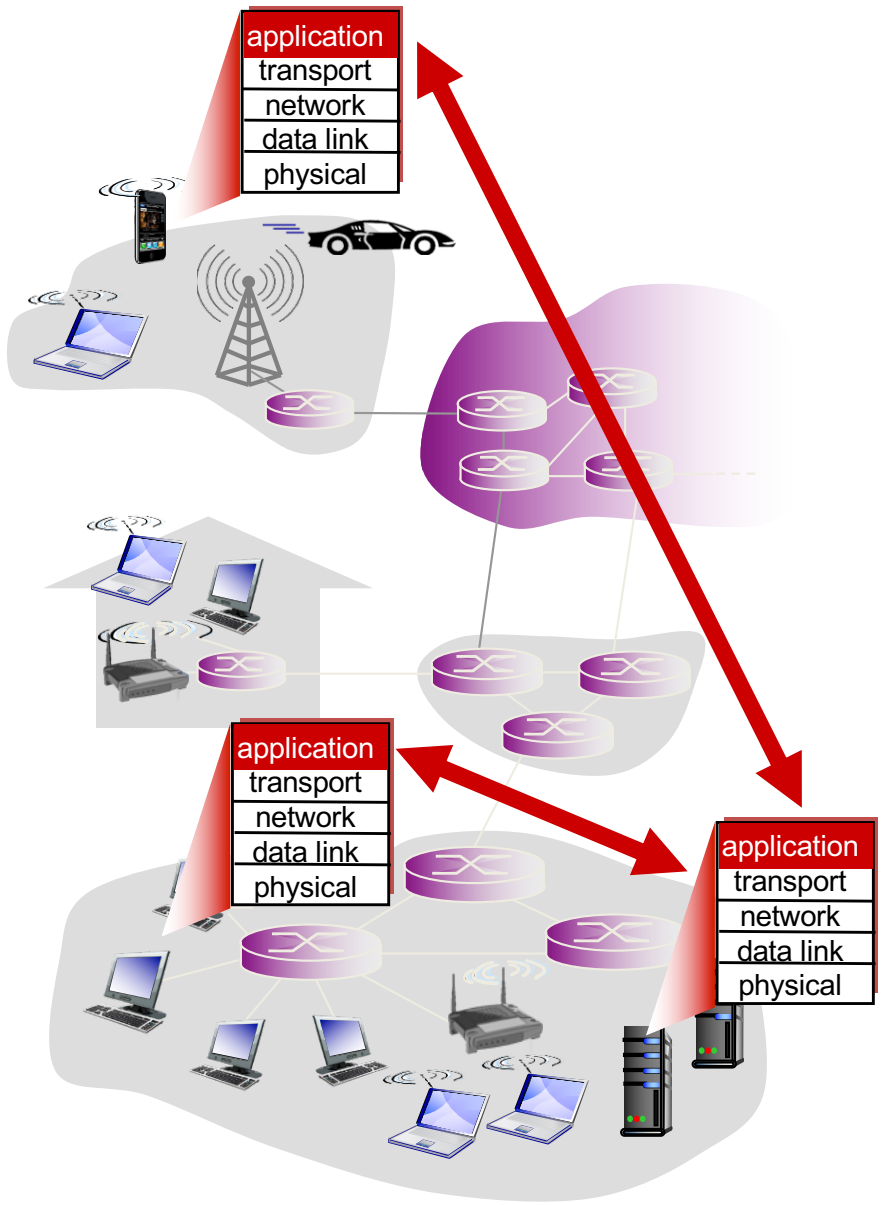
Creating a network app

write programs that:

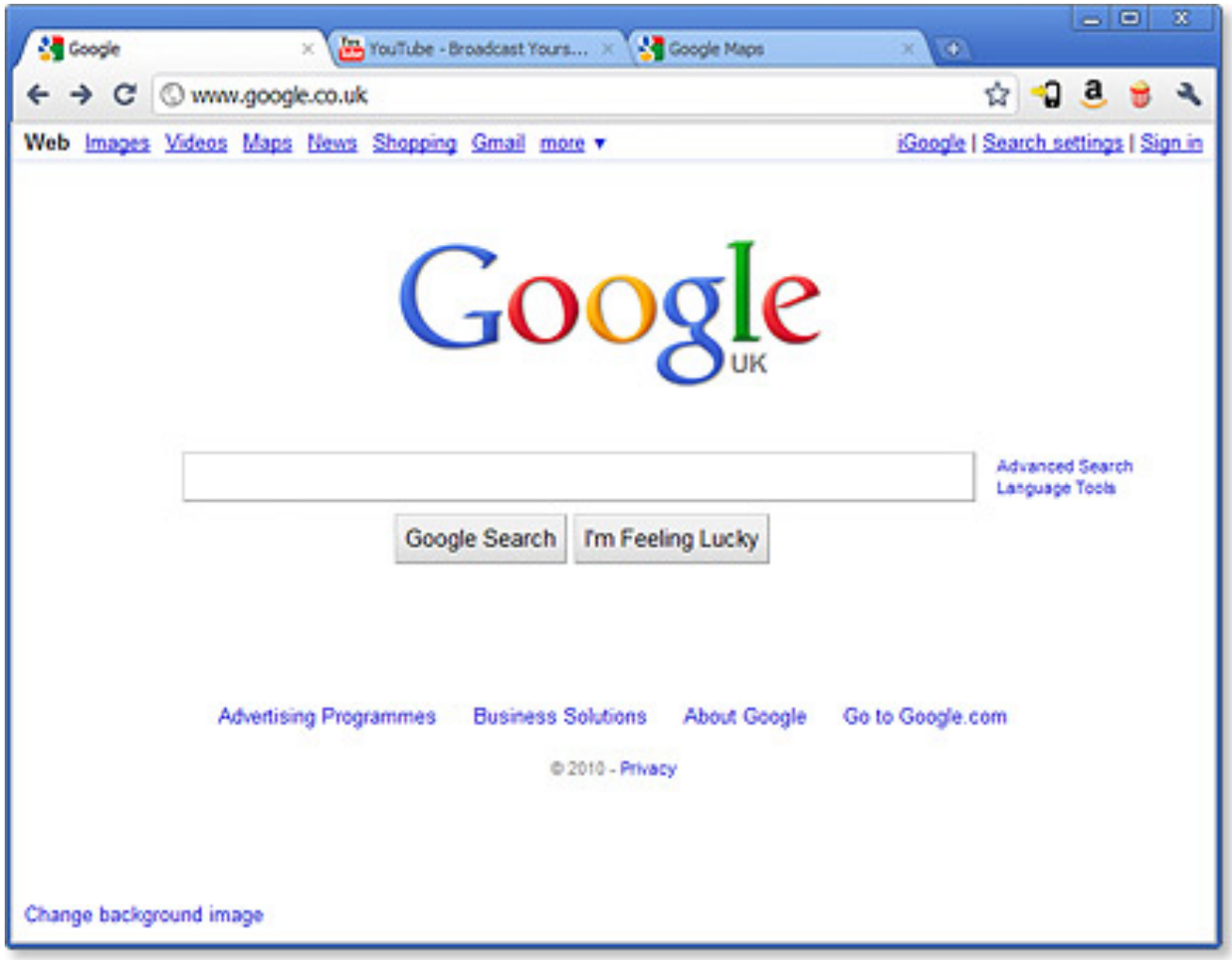
- run on (different) *end systems*
- communicate over network
- e.g., web server software communicates with browser software

no need to write software for network-core devices

- network-core devices do not run user applications
- applications on end systems allows for rapid app development, propagation



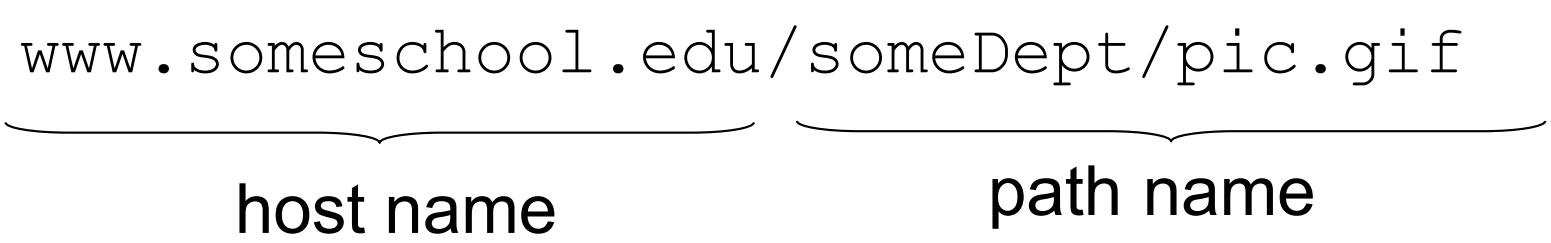
What IS A Web Browser?



HTTP and the Web

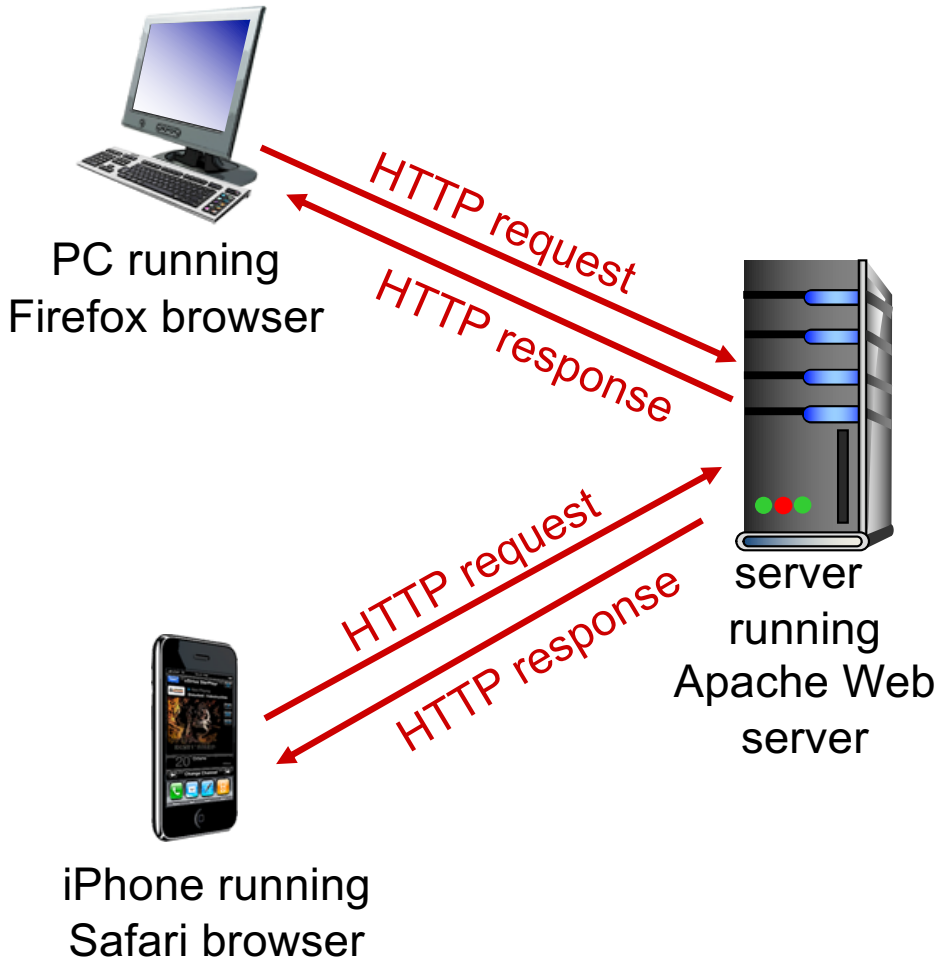
First, a review…

- web page consists of objects
- object can be HTML file, JPEG image, Java applet, audio file,…
- web page consists of base HTML-file which includes several referenced objects
- each object is addressable by a URL, e.g.,



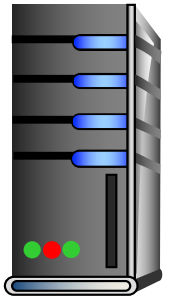
HTTP: Hypertext transfer protocol

- client/server model
  - client: browser that requests, receives, (using HTTP protocol) and "displays" Web objects
  - server: Web server sends (using HTTP protocol) objects in response to requests



Adapted from: Kurose and Ross

HTTP Overview

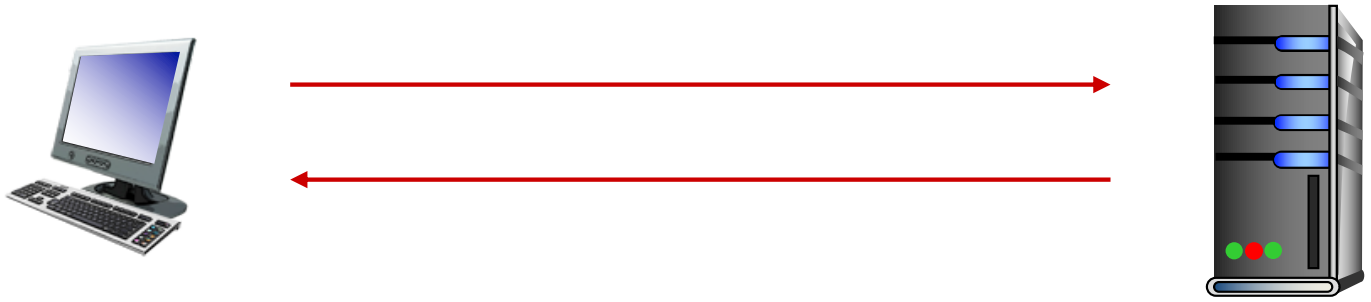


1. User types in a URL.

http://some.host.name.tld/directory/name/file.ext

host name | path name

HTTP Overview



2. Browser establishes connection with server.
   - Looks up “some.host.name.tld”
   - Calls connect()

HTTP Overview

3. Browser requests the corresponding data.

   GET /directory/name/file.ext HTTP/1.0
   Host: some.host.name.tld
   [other optional fields, for example:]
   User-agent: Mozilla/5.0 (Windows NT 6.1; WOW64)
   Accept-language: en

HTTP Overview

4. Server responds with the requested data.

   HTTP/1.0 200 OK

   Content-Type: text/html

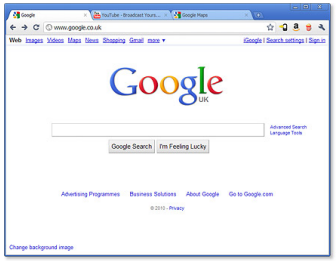
   Content-Length: 1299

   Date: Sun, 01 Sep 2013 21:26:38 GMT

   [Blank line]

   (Data data data data…)

HTTP Overview



5. Browser renders the response, fetches any additional objects, and closes the connection.

HTTP Overview

1. User types in a URL.
2. Browser establishes connection with server.
3. Browser requests the corresponding data.
4. Server responds with the requested data.
5. Browser renders the response, fetches other objects, and closes the connection.

It's a document retrieval system, where documents point to (link to) each other, forming a "web".

HTTP Overview (Lab 1)

1. User types in a URL.
2. Browser establishes connection with server.
3. Browser requests the corresponding data.
4. Server responds with the requested data.
5. ~~Browser renders the response, fetches other objects,~~ and closes the connection.

It's a document retrieval system, where documents point to (link to) each other, forming a "web".

Trying out HTTP (client side) for yourself

1. Telnet to your favorite Web server:

```
telnet demo.cs.swarthmore.edu 80
```

Opens TCP connection to port 80 (default HTTP server port) at example server. Anything typed is sent to server on port 80 at demo.cs.swarthmore.edu

2. Type in a GET HTTP request:

```
GET / HTTP/1.1
Host: demo.cs.swarthmore.edu
(blank line)
```

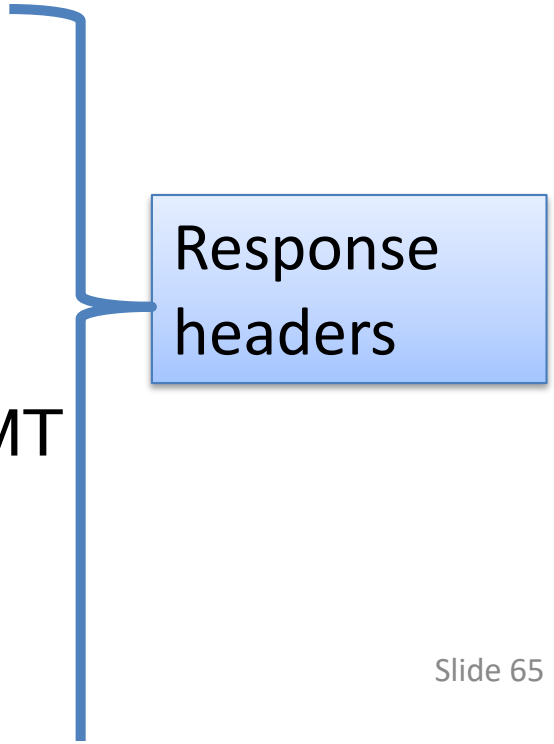
(Hit carriage return twice) This is a minimal, but complete, GET request to the HTTP server.

3. Look at response message sent by HTTP server!

Example

```
$ telnet demo.cs.swarthmore.edu 80
Trying 130.58.68.26...
Connected to demo.cs.swarthmore.edu.
Escape character is '^]'.
GET / HTTP/1.1
Host: demo.cs.swarthmore.edu

HTTP/1.1 200 OK
Vary: Accept-Encoding
Content-Type: text/html
Accept-Ranges: bytes
ETag: "316912886"
Last-Modified: Wed, 04 Jan 2017 17:47:31 GMT
Content-Length: 1062
Date: Wed, 05 Sep 2018 17:27:34 GMT
Server: lighttpd/1.4.35
```



Example

```
$ telnet demo.cs.swarthmore.edu 80
Trying 130.58.68.26...
Connected to demo.cs.swarthmore.edu.
Escape character is '^]'.
GET / HTTP/1.1
Host: demo.cs.swarthmore.edu
```

Response headers

```
<html><head><title>Demo Server</title></head>
<body>
.....
</body>
</html>
```

Response body (This is what you should be saving in lab 1.)

HTTP request message

- two types of HTTP messages: **request, response**
- **HTTP request message:** ASCII (human-readable format)