UNIT 11B

The Internet: Higher-level protocols

Demo

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simple network access in Python

Sending email

```
# mail (run where there is a local mail server)

import smtplib
from email.mime.text import MIMEText

def mail_demo() :
    msg = MIMEText('Give me an A!')
    msg['Subject'] = 'My grade'
    msg['From'] = 'student@example.org'
    msg['To'] = ‘teacher@andrew.cmu.edu'
    server = smtplib.SMTP('localhost')
    server.send_message(msg)
    server.quit()
```

Fetching a web page

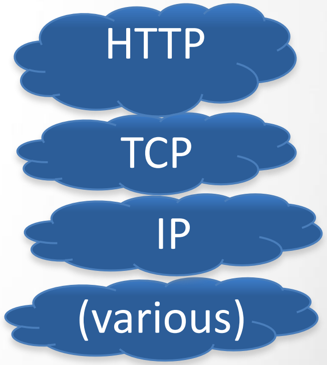
```
# web (run this wherever)

from urllib.request import urlopen

def web_demo() :
    page = urlopen('https://www.cs.cmu.edu/~15110-n15/other/webDemo.html')
    print("Opened URL ", page.geturl())
    print("Contents:")
    for line in page :
        print(line.decode('ISO-8859-1'))
```

Higher-level protocols

Networking for human beings

“Higher” and “lower” level protocols

- Network protocols are organized in *layers*
  - IP packet delivery is the lowest *layer* of the Internet protocol *stack*
  - “Higher” layers use services provided by “lower” layers
  - Each layer is responsible for a type of service



HTTP

TCP

IP

(various)

Layers of the Internet (“higher” to “lower”)

Application Layer *serves to human beings*

- Handles requests from the user for data on the Internet
  - *e.g.* browser, email client, Skype

Transport Layer *serves to a*pplications

- Handles splitting messages into packets for delivery.
  - converts between application messages and IP packets
  - figures out which application to deliver a message to
  - possibly detects and corrects delivery errors

Internet Layer *serves to tran*sport layer

- Handles the task of sending packets across one or more networks.

Link Layer *serves to inter*net layer

- Handles the physical transfer and reception of bits.

Example: Layering the Web

CLIENT MACHINE		SERVER MACHINE
ask for a web page	HTTP	send a web page
request connection	TCP	acknowledge request
best-effort packets	IP	best-effort packets
physical data transport	(various)	physical data transport

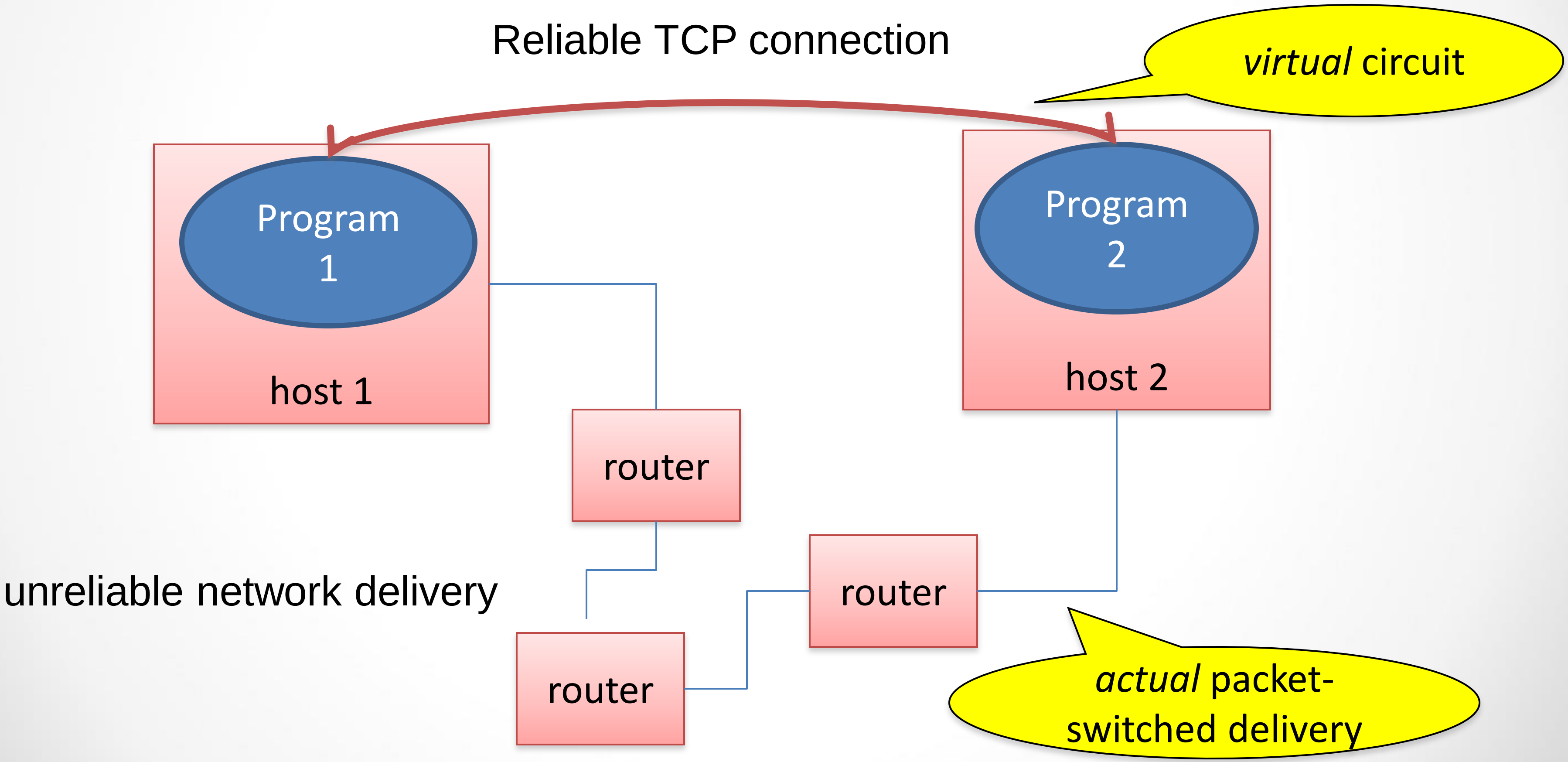
Transport Layer

from IP packets to application messages

Transport Layer

- Splits **application messages** into **IP packets** and **maps applications to *port number***
  - IP address identifies machine, but port number identifies an application operating on that machine (web, email, etc.)
- Transport Control Protocol (**TCP**)
  - Creates **a *reliable* bi-directional** stream (source address/port and destination address/port)
- User Datagram Protocol (**UDP**)
  - Creates a **single one-way** message to a remote application (destination address/port)
    - used for voice, video, DNS lookup, …

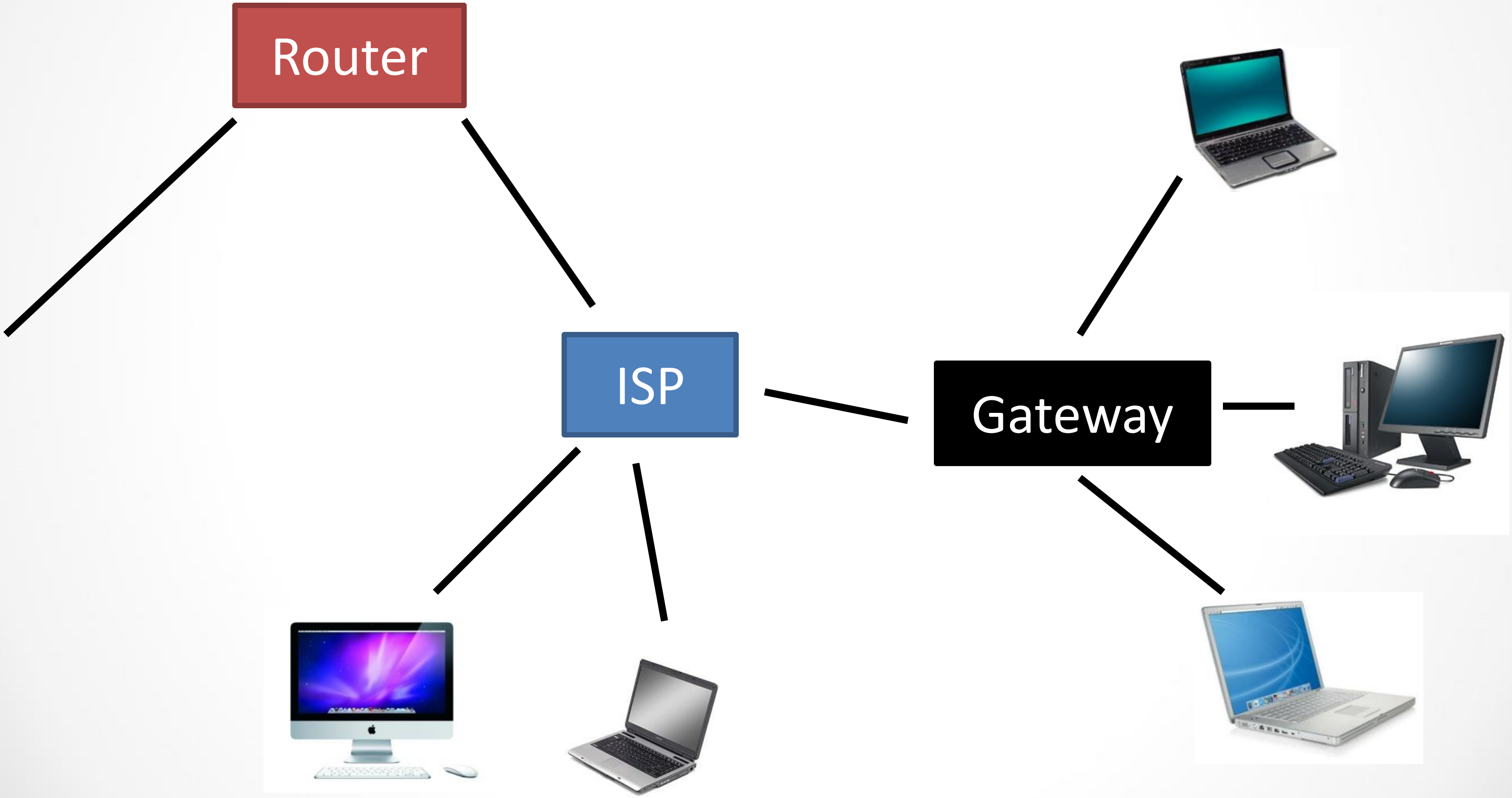
Transport Layer



Reliable Communication with TCP

- Suppose A and B are the TCP programs of two computers.
  - An application asks A to send a message to an application at B.
  - A breaks the message into several packets.
    - Each packet includes parity information, so B can check it for accuracy.
    - Packets are sent via IP.
  - B receives the packets.
    - If B is missing a packet or receives a corrupt packet, it can request retransmission.
    - If the packet is OK, B sends an acknowledgement.
  - If A doesn’t get an acknowledgement, it will retransmit.
  - B assembles the incoming packets in order and provides the message to the appropriate application.

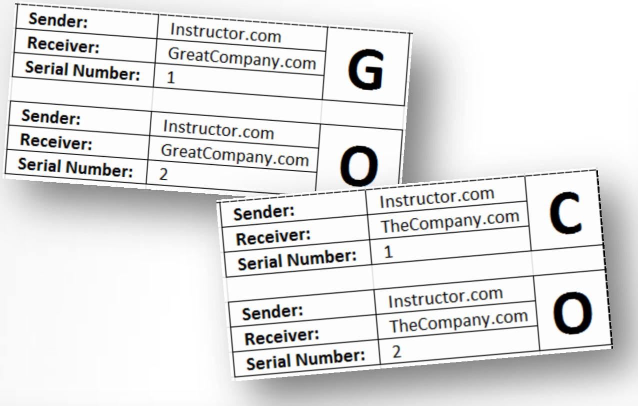
Network Address Translation (NAT)



Network Address Translation (NAT)

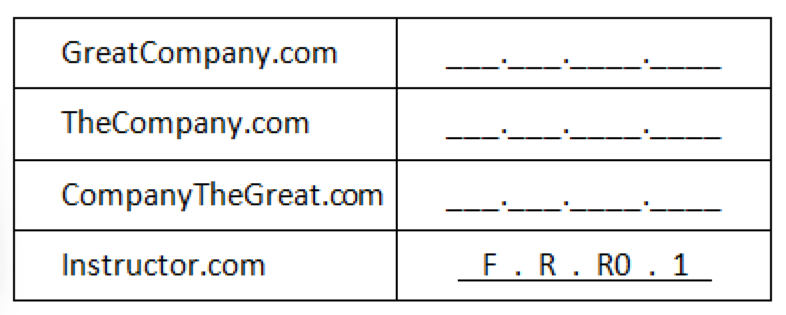
- Used to accommodate more users on the Internet, security, and administration.
- The gateway assigns an additional code called a port for each user. Packets are tagged with the port.
  - Against end-to-end delivery
- The gateway knows where to route the messages on the private network, but all messages from that private network share the same single IP address.

Remember the Class Activity

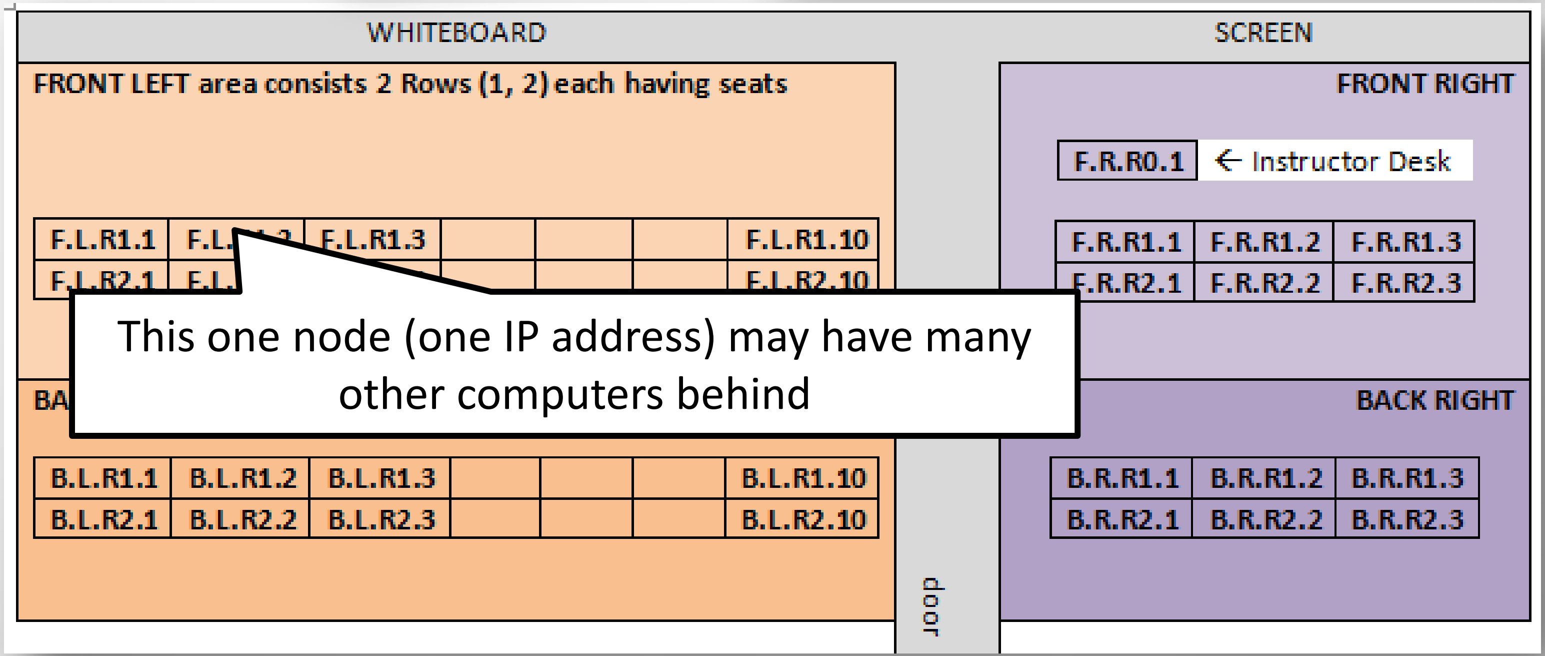


Sender:	Instructor.com	**G**
Receiver:	GreatCompany.com	
Serial Number:	1	
Sender:	Instructor.com	**O**
Receiver:	GreatCompany.com	
Serial Number:	2	

Sender:	Instructor.com	**C**
Receiver:	TheCompany.com	
Serial Number:	1	
Sender:	Instructor.com	**O**
Receiver:	TheCompany.com	
Serial Number:	2	



GreatCompany.com	___.___.____.____
TheCompany.com	___.___.____.____
CompanyTheGreat.com	___.___.____.____
Instructor.com	F . R . R0 . 1



WHITEBOARD

SCREEN

FRONT LEFT area consists 2 Rows (1, 2) each having seats

F.L.R1.1	F.L.[illegible]	F.L.R1.3				F.L.R1.10
F.L.R2.1	F.L.[illegible]					F.L.R2.10

FRONT RIGHT

F.R.R0.1	← Instructor Desk

F.R.R1.1	F.R.R1.2	F.R.R1.3
F.R.R2.1	F.R.R2.2	F.R.R2.3

This one node (one IP address) may have many other computers behind

BA

B.L.R1.1	B.L.R1.2	B.L.R1.3				B.L.R1.10
B.L.R2.1	B.L.R2.2	B.L.R2.3				B.L.R2.10

BACK RIGHT

B.R.R1.1	B.R.R1.2	B.R.R1.3
B.R.R2.1	B.R.R2.2	B.R.R2.3

Domain names

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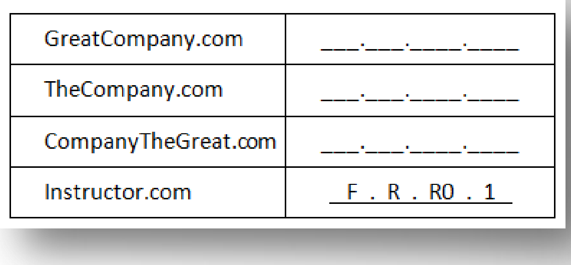
from **98.139.183.24** to **yahoo.com**

From names to IP addresses

- URL: http://www.cs.cmu.edu/~15110-n15/index.html
- Email address: teacher@andrew.cmu.edu
- We don’t want IP addresses in our URLs or email addresses—why not?
- Domain Name Service (DNS) *translates* names to addresses

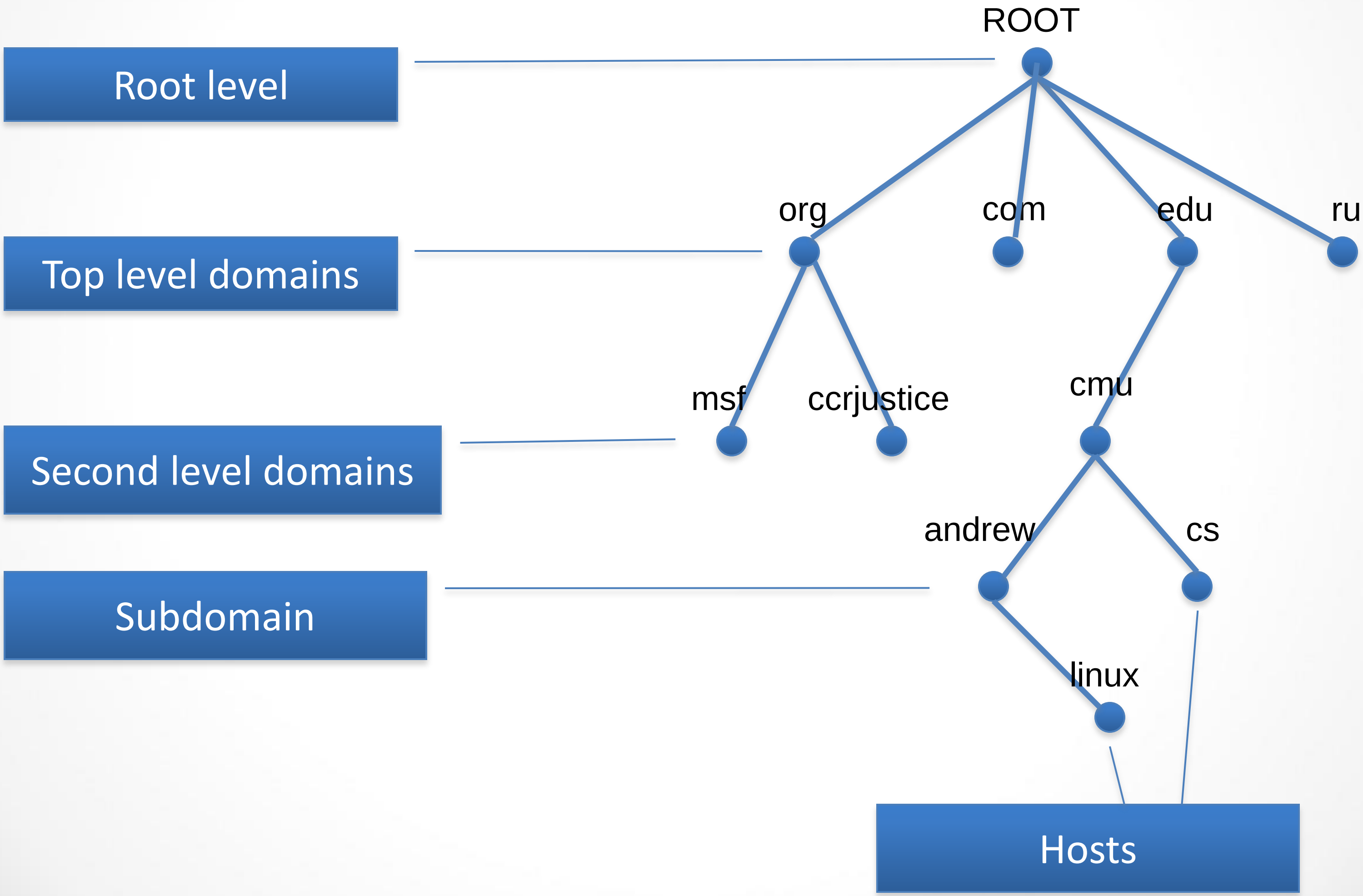
DNS design



GreatCompany.com	___.___.____.____
TheCompany.com	___.___.____.____
CompanyTheGreat.com	___.___.____.____
Instructor.com	F . R . RO . 1

- Problem: so many names! How to make lookup fast?
- Solution: hierarchy of name servers
  - Each machine knows a name server, which knows how to find a **root name server**
  - root name servers know DNS servers for each **top-level domain** (e.g., "edu”, “com”, “net”, “uk”, “ru”)
  - top-level domain servers know DNS servers for each **second-level domain** (e.g., "cmu.edu”, “co.uk”)
  - second-level domain servers know **each host** directly in their domain (e.g., "www.cmu.edu") and DNS servers for each **third-level** domain (e.g., "andrew.cmu.edu")

DNS Hierarchy (fragment)



Root level

Top level domains

Second level domains

Subdomain

Hosts

DNS Lookup

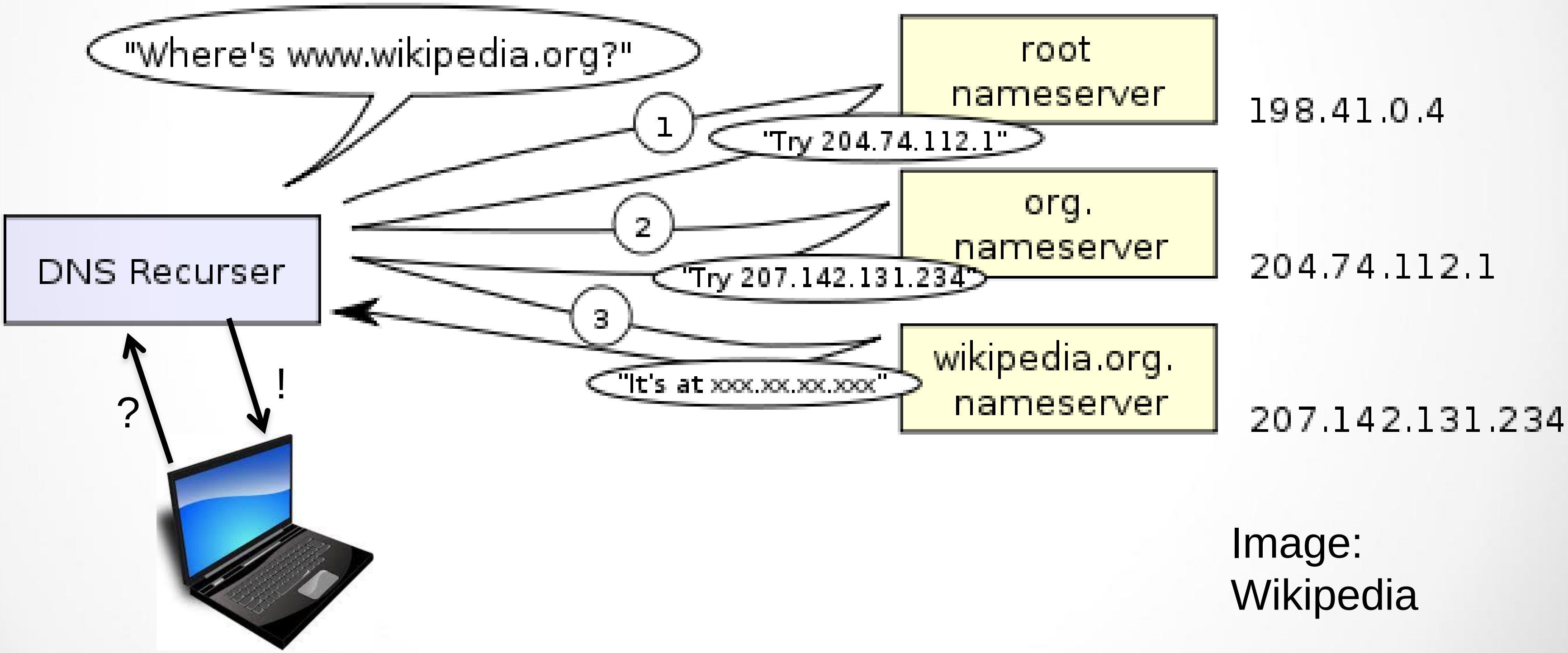
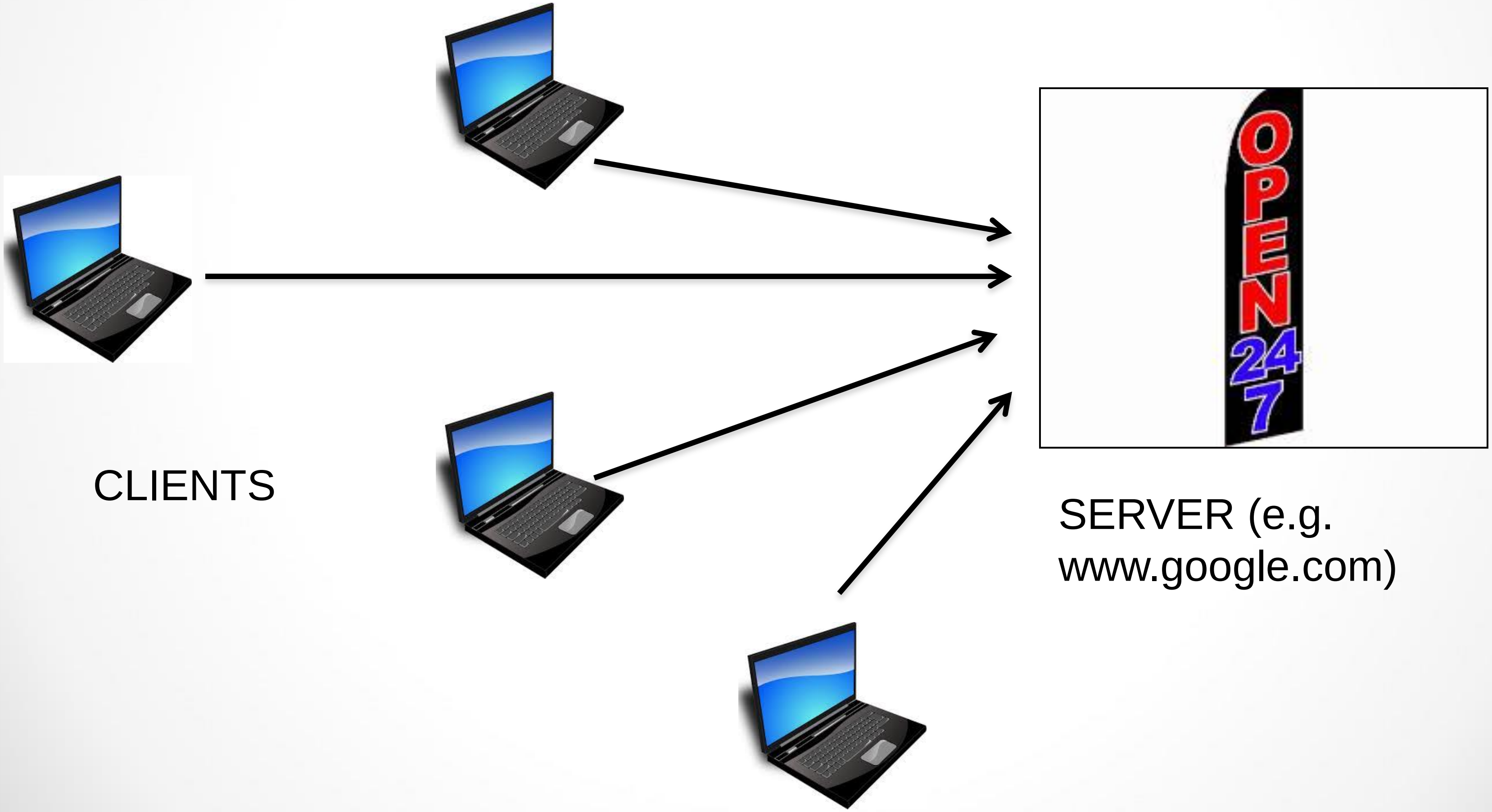


Image: Wikipedia

Client-server architectures

web, mail, streaming video, and more

Client-server Architectures



CLIENTS

SERVER (e.g. www.google.com)

Client-server Architectures

- Architecture: an organizing principle for a computing system
- Most common architecture for Internet applications: *client-server*
- Server is always on, waiting for requests
  - *server software* (e.g. Apache) tells TCP (transport layer software) on its own machine "please listen for messages with port number 80"
  - *client software* (e.g. Chrome) tells TCP "please send this message to machine xxx.xxx.xxx.xxx with port number 80"
  - TCP gives message to IP, which sends it through internet to server machine; IP at server machine delivers to TCP at server machine
  - TCP at the server machine delivers the message to Apache

The Web

- World Wide Web = html + http

- html = HyperText Markup Language, an encoding
  - tells what a page should look like and
  - what other pages it links to

- http = HyperText Transfer Protocol
  - agreement on how client and server interact

HTML: an encoding

- Example: using your favorite plain-text editor create the following text file:

```
<html><head>
<title>15110, Spring '14,
Example web page</title>
</head>
<body>
<h1>Hello World!</h1>
</body></html>
```

Nothing to do with the Internet!

- In a browser type its name in the address bar, e.g.

```
file:///Users/pennyanderson/CMU/110/week11/example1.html
```

HTML: networked hypertext

- Now add

```
<a href=http://en.wikipedia.org/wiki/Hello_world_program>
Hello World!</a>
```

Code for getting information across the Internet

- save as example2.html

  and load

HTTP: hypertext transfer protocol

- Protocol for communication between web **client** *application* (e.g. Chrome, Safare, IE, Firefox) and web **server** *application* (e.g. Apache)

- Agreement on how to ask for a web page, how to send data entered into a form, how to report errors (codes like *404 not found*), etc.

Uniform Resource Locators

- A Web page is identified by a Uniform Resource Locator (URL)

  protocol://host address/page

- A URL

http://www.cs.cmu.edu/~15110/index.html

Protocol to use

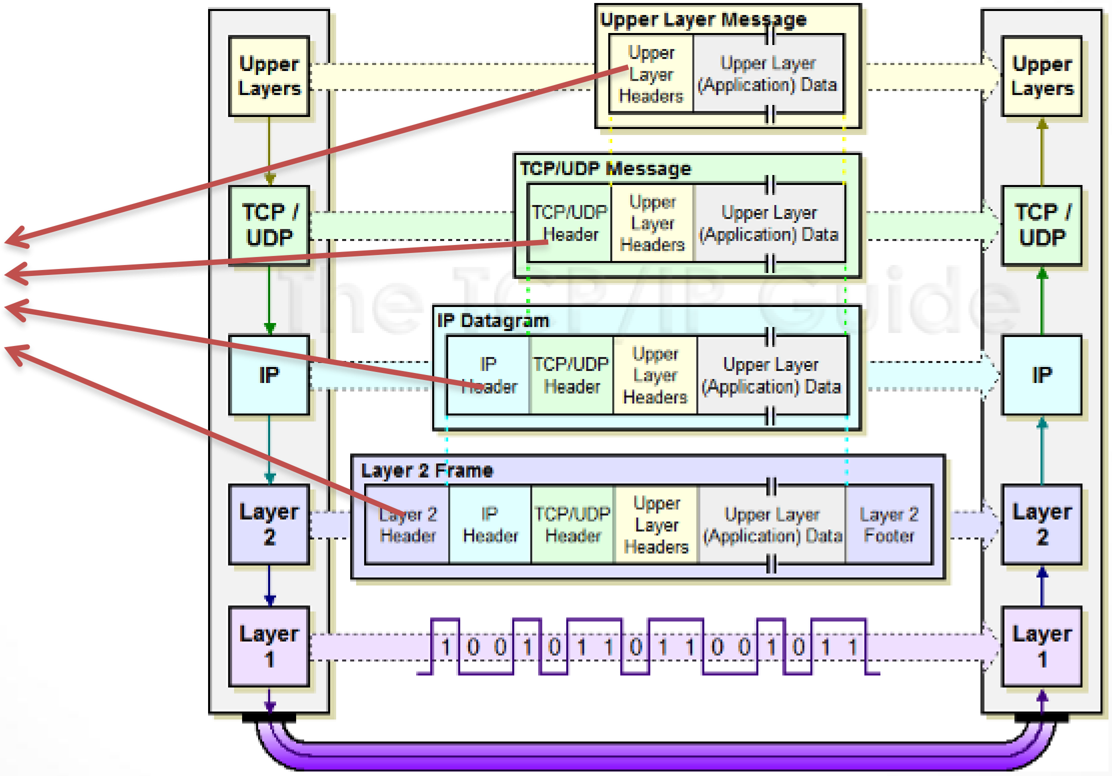
Overview of web page delivery

1. Web browser (client) translates name of the server to an IP address (e.g. 128.2.217.13) (using DNS)
2. Establishes a TCP connection to 128.2.217.13 port 80
3. Constructs a message

   GET /~15110/index.html HTTP/1.1
4. Sends the message using TCP/IP
5. Web server locates the page and sends it using services of TCP/IP
6. The connection is terminated

Layers and Encapsulation

Headers added by sender



Headers removed by receiver

Every protocol defines the layout of a *header*—a kind of envelope or *capsule* for a message

Peer-to-peer architectures

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another widely used organizing principle for Internet applications

Peer-to-peer architecture

- Alternative to client-server
- Applications:
  - file sharing (BitTorrent etc.)
  - streaming media (Skype etc.)
  - Bitcoin
  - volunteer computing (SETI@home etc.)

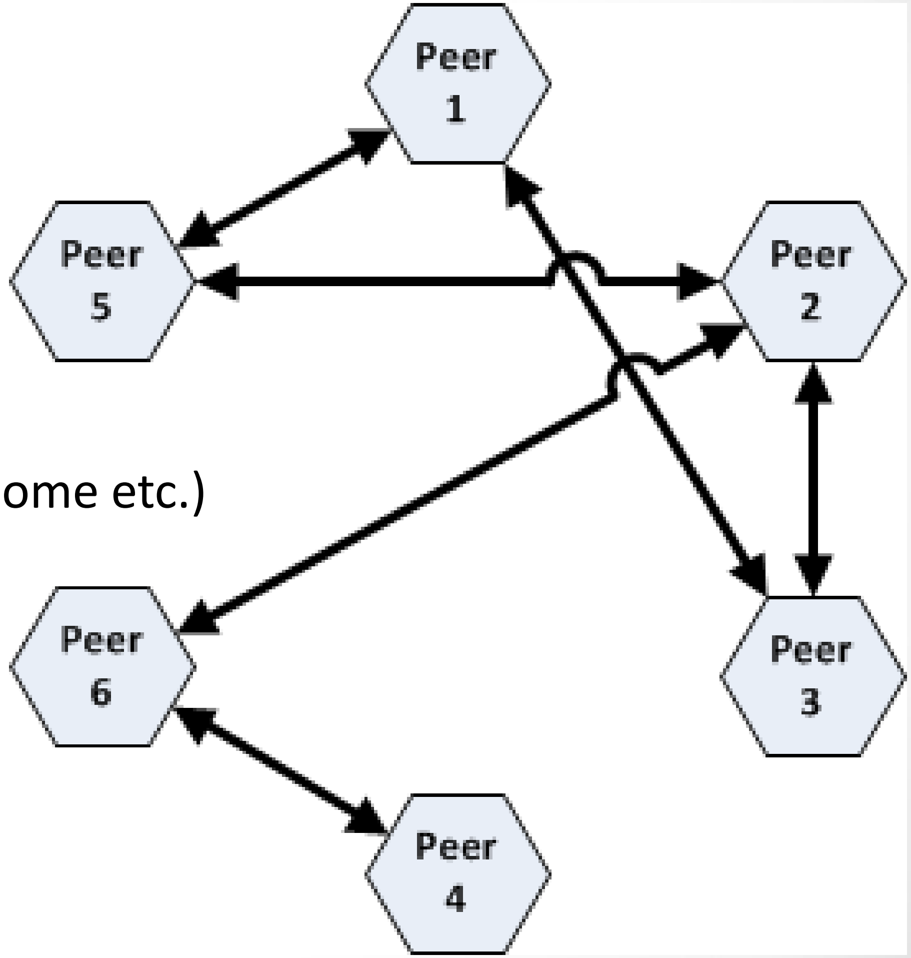


image: https://www.clear.rice.edu/comp310/f12/lectures/lec26/

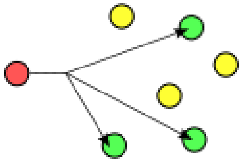
Streaming media

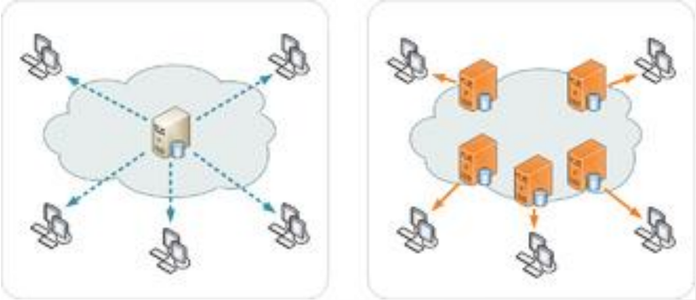
- One of the most demanding applications of the Internet
  - high bandwidth (lots of data really fast)
  - constant delivery rate to the user’s screen (headphones, whatever)
  - reliable enough to create a seamless user experience
  - in *real time* for applications like videoconferencing

- *Remember, IP doesn’t even guarantee that all packets sent will get there, or when!*

Technology to support streaming media

- Compression
  - reduces amount of data to be sent
- IP multicast
- Adaptive bitrate streaming
  - sends lower-quality images/sound in lower-speed conditions
- Content Delivery Network
  - spreads the work of sending the data over many machines
  - peer-to-peer





Summary

- Applications communicate on the Internet via ***application protocols*** like
  - HTTP for the web
  - SMTP for email
  - RTSP for streaming media
- **Application protocols** rely on
  - Domain Name Servers for name translation, and
  - *transport protocols* like
    - TCP for reliable two-way connections
    - UDP for one-way "datagrams"
- **Transport protocols** rely on IP for packet delivery

Next Time

Network security and cryptography

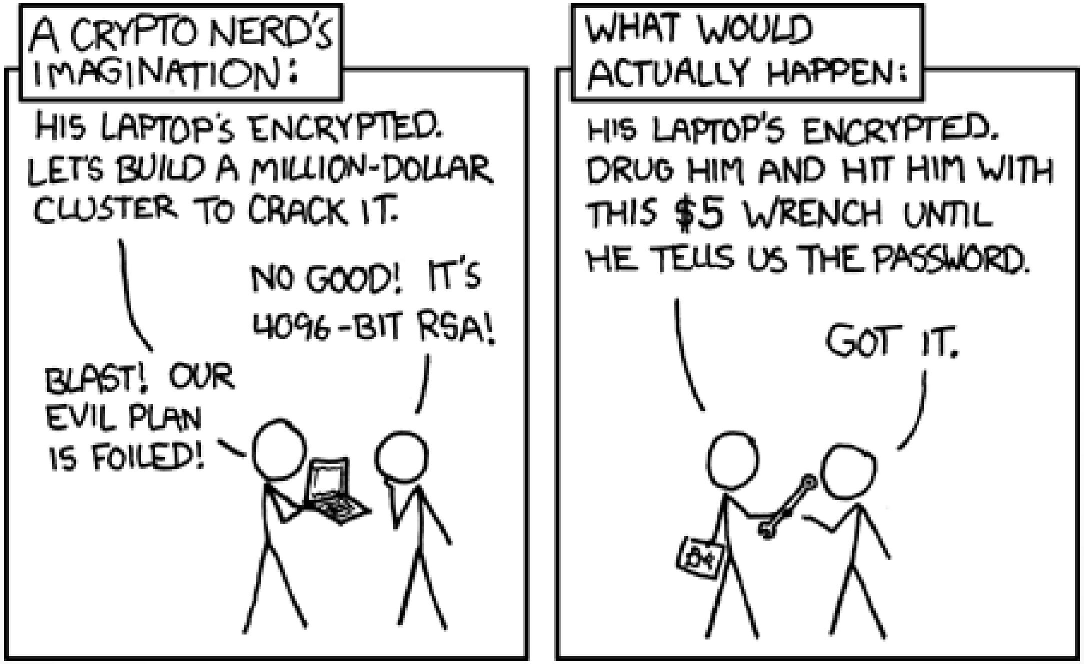

A CRYPTO NERD'S IMAGINATION:
HIS LAPTOP'S ENCRYPTED. LET'S BUILD A MILLION-DOLLAR CLUSTER TO CRACK IT.
NO GOOD! IT'S 4096-BIT RSA!
BLAST! OUR EVIL PLAN IS FOILED!
WHAT WOULD ACTUALLY HAPPEN:
HIS LAPTOP'S ENCRYPTED. DRUG HIM AND HIT HIM WITH THIS $5 WRENCH UNTIL HE TELLS US THE PASSWORD.
GOT IT.

image: http://xkcd.com/538/