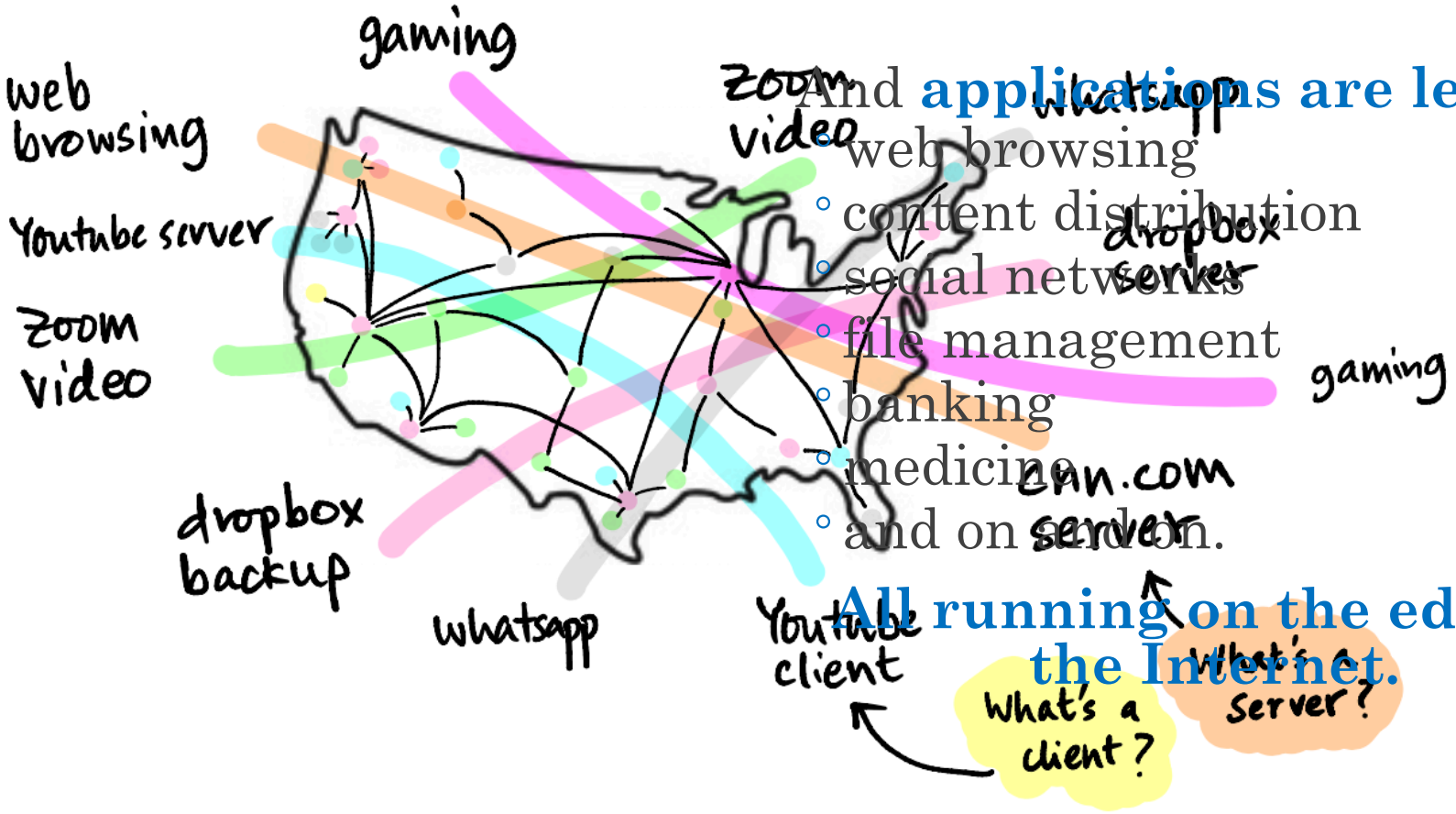
University of Illinois at Urbana-Champaign
Dept. of Electrical and Computer Engineering

ECE 101: Computing Technologies and the Internet of Things

Client-Server: Providing Services on the Internet

Applications running on the "edge"



And **applications are legion!**

- web browsing
- content distribution
- social networks
- file management
- banking
- medicine
- and on and on.

All running on the edge of the Internet.

A Server Provides Some Sort of Service

Some computer may **provide a certain service**, such as

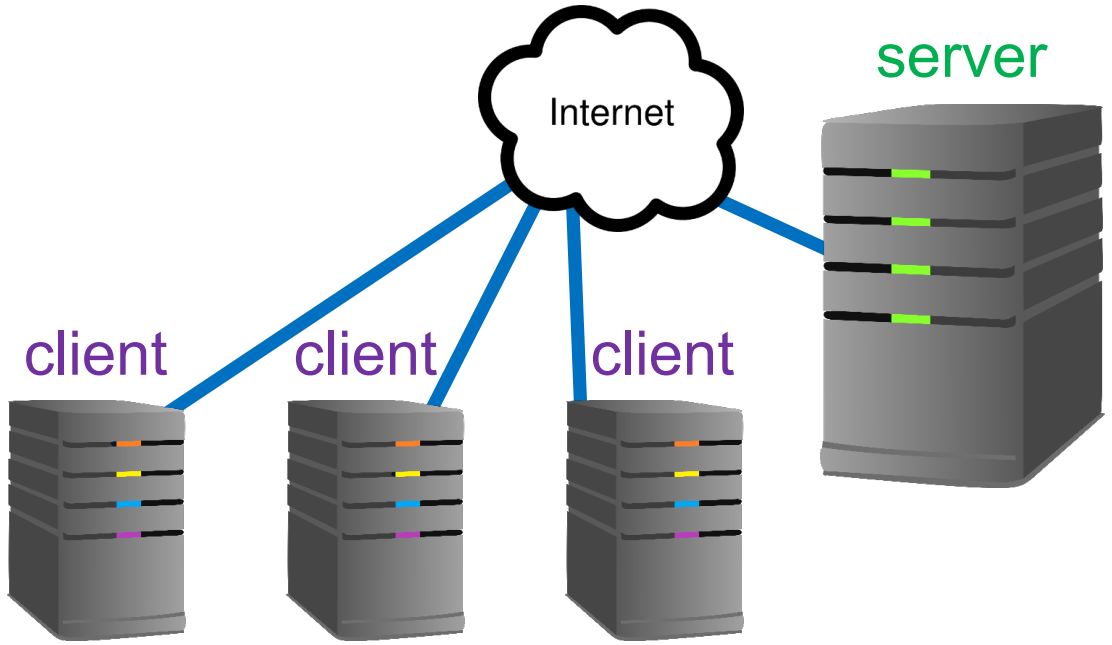
- providing copies of published IRS tax documents,
- accepting paper submissions to a research conference, or
- computing turbulence in fluid flow around a structure,

We call that computer a **server**.

A Server's Clients Make Use of that Service

Other computers **contact that computer, and use the service**.

These computers are the **clients** for that server.

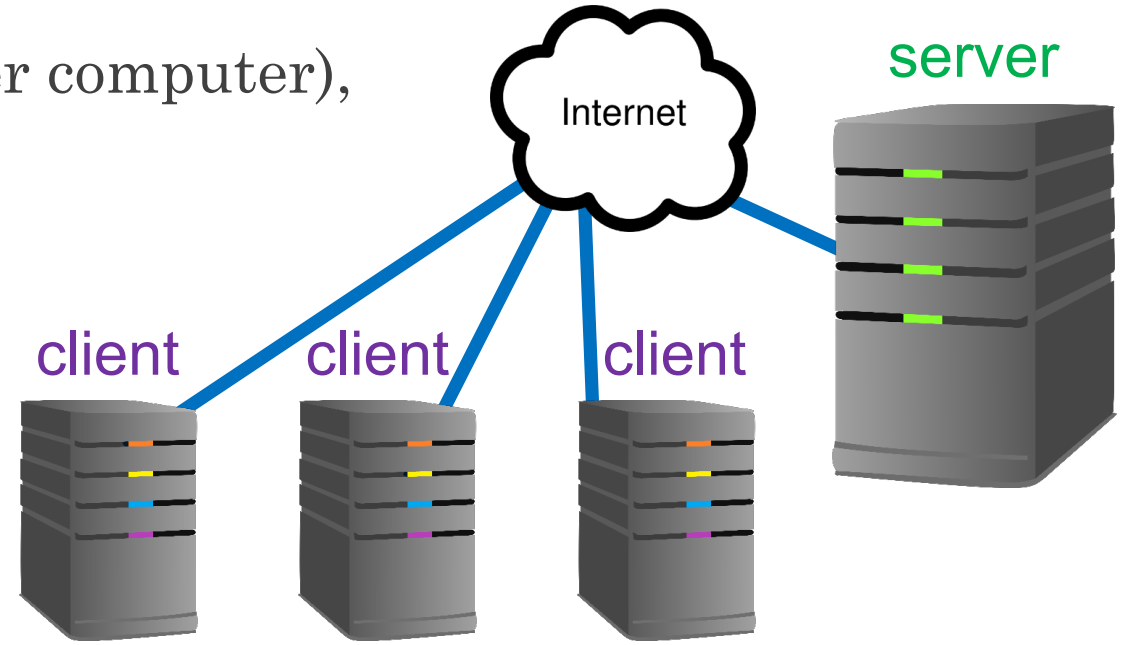


Any Computer Can Provide or Use a Service

Note that a **server**

- **may also be a client**
- to another server (another computer),
- and vice-versa.

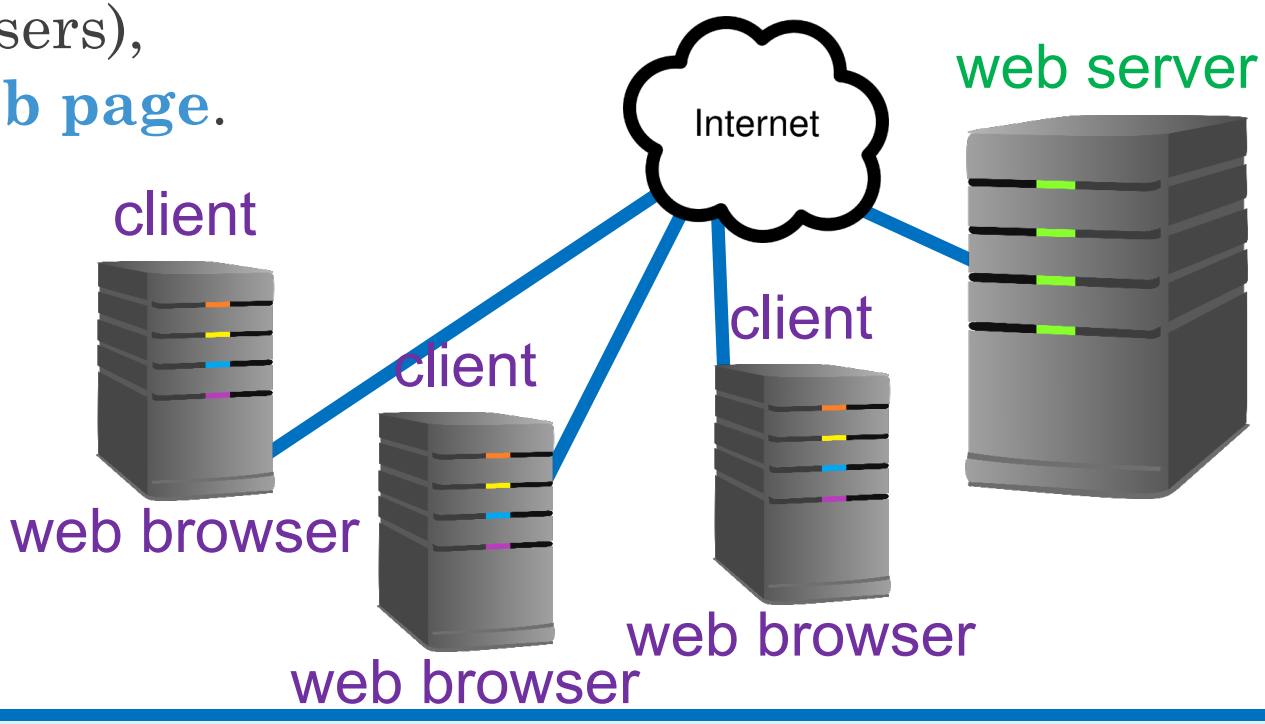
Client and server are just roles for a given service.



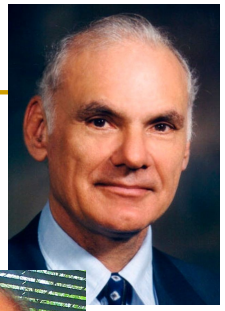
Example of a Service: the World Wide Web

The **server**
- **offers the web page**

The **clients** (web browsers),
- **want to see the web page**.



What Good is the Internet?



1969 - Larry Roberts created ARPANET (first packet network, the the precursor to the Internet).

Mid 1970s - Vint Cerf and Bob Kahn built TCP/IP

1989 - **Tim Berners-Lee** invents World Wide Web

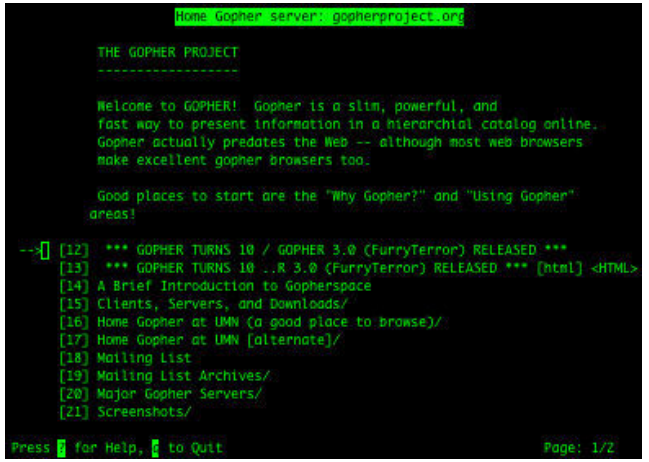
1993 - NCSA releases Mosaic (first widely available web browser)

Researchers used the Internet

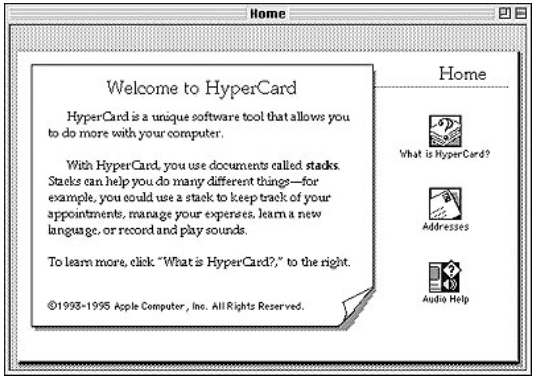
- for more than a decade
- before UIUC made it important
- to the other 99.9% of the world

Examples of Early Services: Gopher and HyperCard

Early Internet services such as **Gopher**
- allowed clients to **explore text documents**
- spread **across multiple servers**
- such as guidance on the requirements for undergraduate curriculum at UIUC.



Apple's **HyperCard**
- enabled users to **move from page to page**
- **by clicking on** a **keyword** or an icon.
- **Sound familiar?**

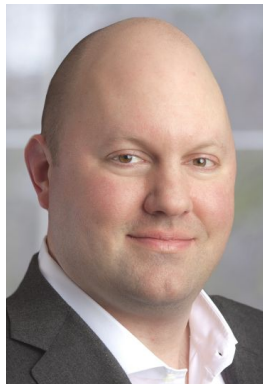


What Most People View as the Internet Arrived in 1993

These ideas were **combined into a single protocol** (HyperText Transfer Protocol, **HTTP**) in 1989 by **Tim Berners-Lee** (at CERN).

The **first web browser** (integrating images with text), **Mosaic**, was **developed by Marc Andreessen** and others (at UIUC) in 1992, and made public in 1993.

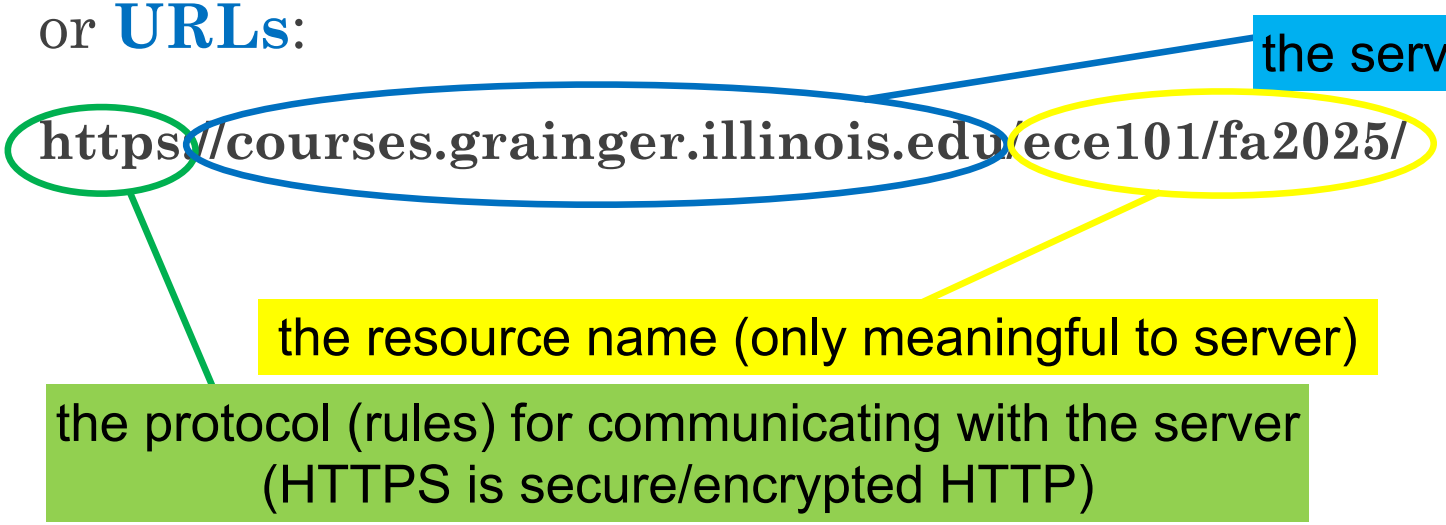
The browser made the Internet interesting to the rest of humanity.



HTTP Protocol Perhaps Familiar to You?

A **web server** is an example of an **Internet service**.

Online resources are named using "Universal Resource Locators", or **URLs**:



Web Browser is a Client to a Web Server

A **web browser**
- is **client software**
- that enables a human
- **to** make use of **web servers**.

Last week, we talked about how a web browser communicates with a server.

The URL is what a human (or another web page) provides to identify which server to contact.

In a couple of weeks,
- we'll look at **web search**,
- **another Internet service**
- that allows one to find interesting URLs.

The World Wide Web is NOT the Internet

(Some people may call the WWW “the Internet”)

But not students of ECE101…

https://www.bbc.co.uk/newsround/av/47523993

The World Wide Web is NOT the Internet

The Web is an internet **service** - consisting of websites, pages and other web services scattered around the world on many different computers acting as web servers.

It's provided on the distributed network of computers (clients, servers, routers, etc.) which is **the Internet**.

Clients and Servers Must Interact Correctly

Each **Internet service** is unique:

- **defines what it provides,**
- defines the **rules for clients** to make requests for services, **and**
- defines the **form of answers** and how they are returned to clients.

Clients must know these things—generally, **every service has distinct client software**!

Another Simple Service: Use That Computer?

What if I just want to
let someone else use my computer
(over the Internet)?

Before we can answer that question, we need to understand the role of the operating system —we'll call it the OS.

Most Modern Operating Systems Based on Unix

Can you name some operating systems (OSs)?

Most operating systems today are

- **based on** Bell Labs' **Unix** (1970s)
- (Windows, MacOS, Chrome OS, Linux, Android, iOS, and so forth).

Operating System Interfaces Applications to Hardware

What exactly is an OS?

Software that
- sits **between applications**
- **and the hardware** (computer, monitor, keyboard, mouse)
- and **provides** …

…**services**!

(We like that word a lot.)

Operating System Simplifies Use of Devices

What does the OS do?

Abstracts – **simplifies** the **use of input and output devices**: keyboard, mouse, display, network, printer

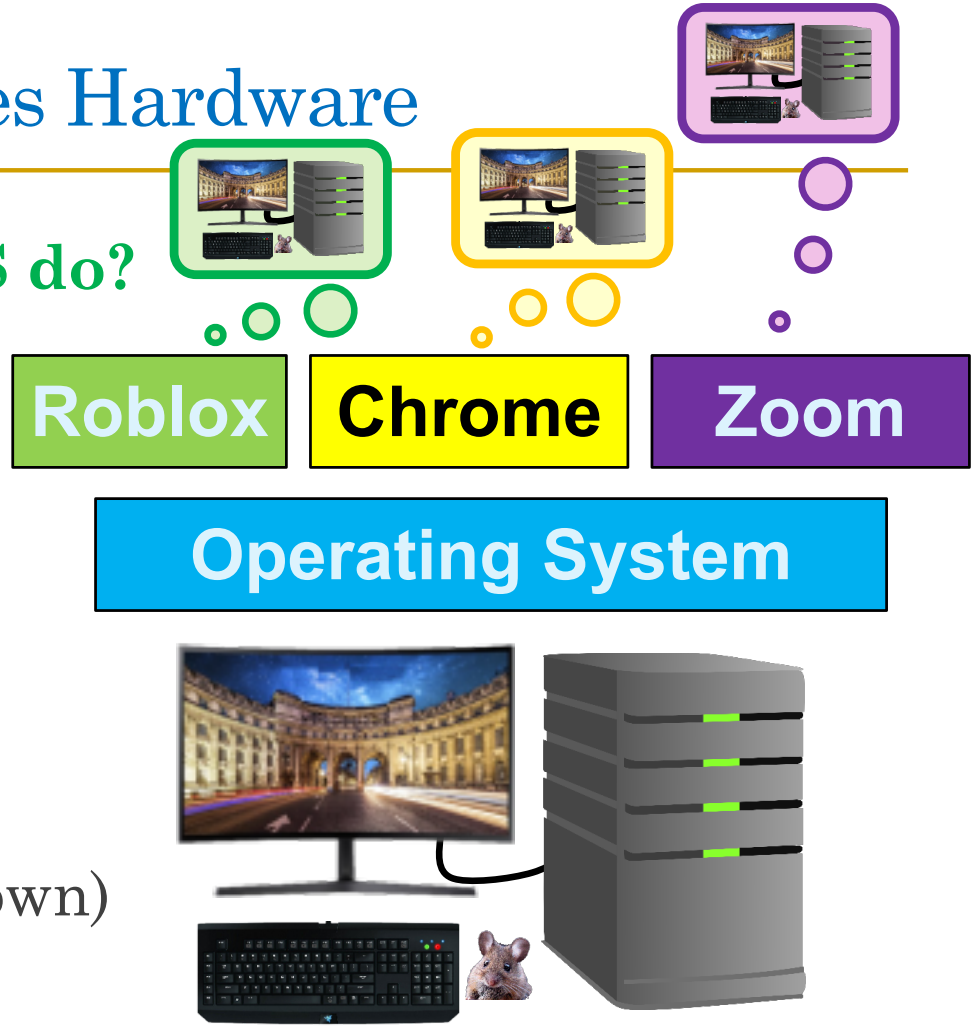
(Hardware devices often define vendor-specific, complicated protocols and do not tolerate errors.)

Operating System Virtualizes Hardware

What does the OS do?

Virtualizes – **makes** small number of physical **resources available** to many programs **at the same time**, as if each program had private hardware

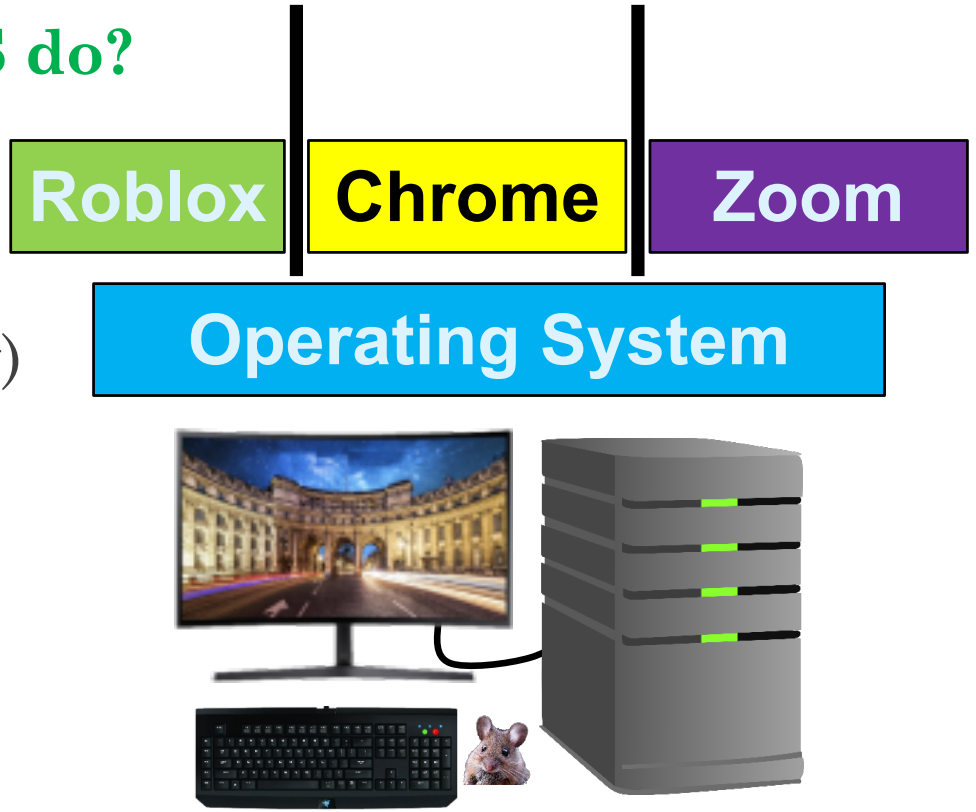
(includes memory, which isn't shown)



Operating System Protects Programs (and Hardware)

What does the OS do?

Protects—stops programs from interfering with each other (deliberately or accidentally) or with the hardware



Virtual Machine: Software that Mimics a Computer

- In the 1960s IBM created a "**virtual machine**", a program that **simulates a real computer**
  - A computer is hardware.
  - Write software to do the same thing as hardware - so it can pretend to be the hardware.

Cheap Computers Eliminated Need for Virtual Machines

Then the PC (personal computer) appeared, and

- computers became cheap, and
- the idea went away.

Mostly.

Until the 1990s.

(This kind of coming and going happens a lot in technology!)

Can Someone Else Use that Computer Now?

In the 80s and 90s, computers were still somewhat of a luxury item—most families did not own one.

Universities, on the other hand, had many (tens or even hundreds!).

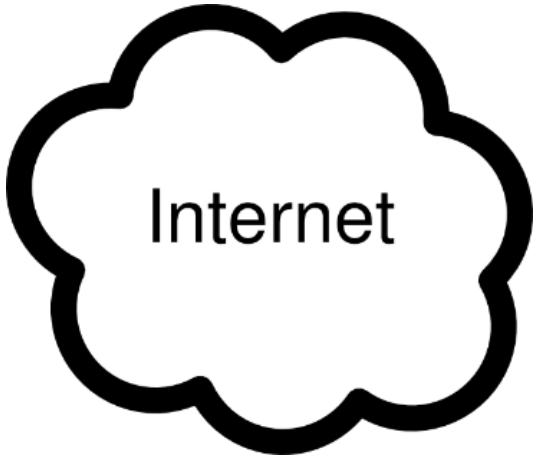
Why not create a model in which someone could use a computer for a little while, whenever they needed one?

Computing as a Service … in the "Cloud" !

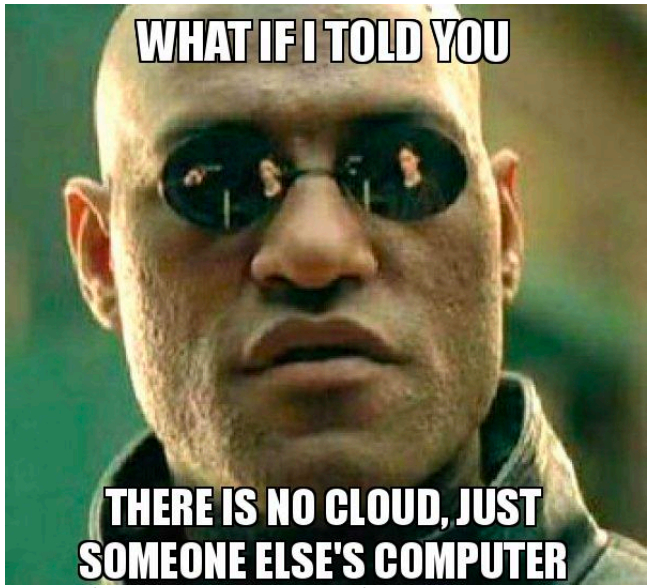
Eventually, this idea became **cloud computing**, the idea of **using someone else's computer as a service**.

Not just individuals:

- company A can use company B's computers
- to provide a public Internet service.
- Customers (or ads!) pay A, and A pays B.



Is it just someone else's computer?



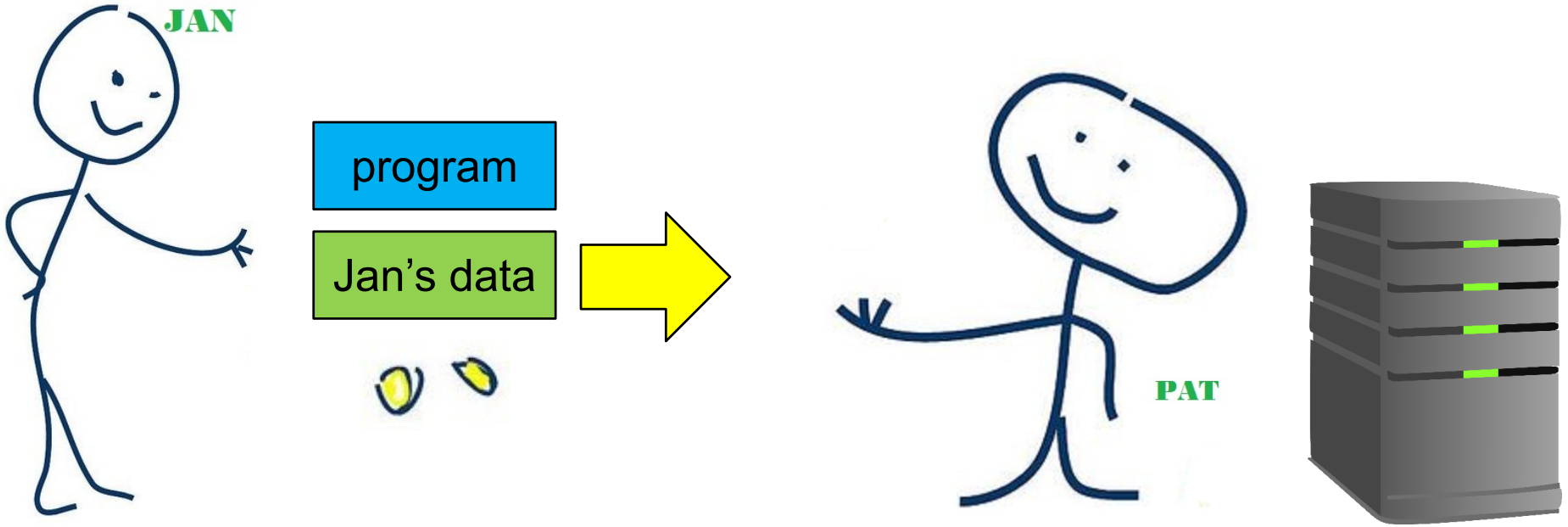
https://makeameme.org/meme/what-if-i-s1sk9l

The Cloud is much more - a complex system of interconnecting parts.

https://www.techrepublic.com/article/is-the-cloud-really-just-someone-elses-computer/

Cloud Computing Model with Jan and Pat

There are some challenges…
Imagine that Jan wants to use Pat's computer.



Trust is a Big Issue for Cloud Computing

Does Jan trust Pat with the program?

Pat could use the program for Pat's own purposes without paying!

Does Jan trust Pat with Jan's data?

Pat could do many things with Jan's data!

Does Pat trust Jan's programs not to hurt Pat's computer or something else, such as by attacking another computer?

Pat could lose the computer or get in trouble!

Technologies Can Help with the Trust Issues

Some technologies were developed to help…

Sandboxing

- program executes in a "**sandbox**,"
- which **keeps** the **program from hurting anything** outside the sandbox
- Today, this technology is fairly mature,
  - but only if you use it!
  - Be extremely careful about running unknown code on your computer, phone, and so forth!

Harder to Hide Information from the Computer Itself

Encrypted computing

- **hide** the **program and**/or **data** from the computer that uses it
- Still fairly undeveloped—mostly the trust here is handled through human trust and/or contracts/law.

A Better Solution: Use Virtual Machines (VMs)!

Late 90s/early 2000s – virtual machines re-emerge!
Connectix developed virtual machines
- to help consumers use software
- developed for other computers,
- such as **VirtualPC** (x86 virtual machines)
- as well as Sony Playstation emulation
- (Sony sued, lost, bought, and terminated)

VMWare was one of the first and most important in terms of cloud computing

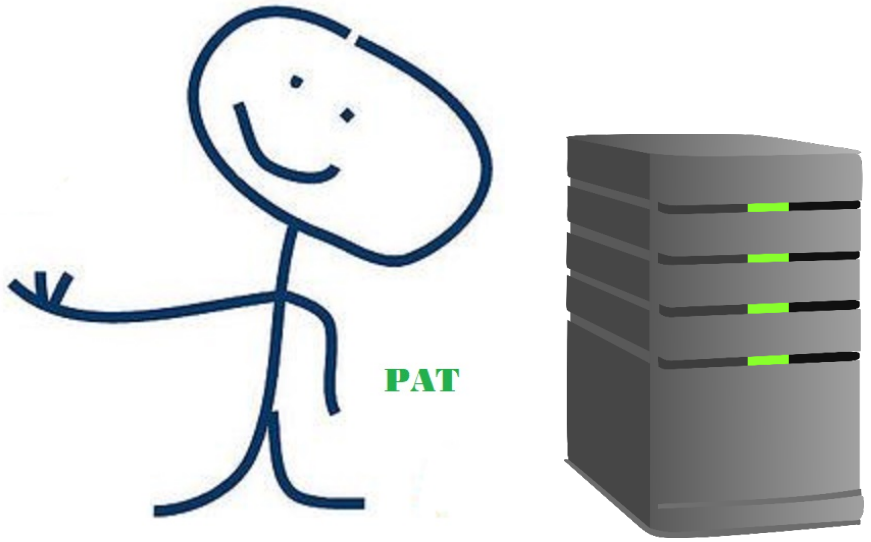
Sun VirtualBox (now Oracle) is still a good choice for home use.

Virtual Machines Enabled Cloud Computing

Today, Pat can provide a VM for Jan!

Hardware and software configuration completely **known in advance**!

VMs enabled cloud computing: use of someone else's computer as a service.



Virtual Machines also Made Sandboxing Accessible

VMs also enabled sandboxing at home.

- If affected by a virus,
- Wipe the virtual machine—no problem!

Today, Cloud Computing Offers Computers as a Service

Today, if you **want to use**
- a computer, or
- **1,000 computers, or**
- powerful **GPUs**,

for
- an hour, or
- a day, or
- a month, or
- on demand,

you can **rent from** one of many **cloud computing providers**!

Data Storage also a Service

Some cloud computing providers:

- Amazon Web Services
- Google Cloud
- IBM Cloud
- Microsoft Azure

These companies **also** offer to **store your data**, which

- **reduces need for** repeated data **transfers**,
- **But** also **locks you in** as their client:
- it's quite difficult to move Exabytes of data to another provider quickly.

Trust Issues? You Just Have to Trust Your Provider

Terminology You Should Know from These Slides

- client and server
- forwarding (a message or packet)
- virtual / overlay network
- HTTP: HyperText Transfer Protocol
- URL: Universal Resource Locator
- operating system (OS)
- virtual machine (VM)
- cloud computing
- sandboxing
- lock-in (by a company, product, or service)

Concepts You Should Know from These Slides

- examples of Internet services (and clients), including Web servers (and browsers)
- roles for the OS: abstract, virtualize, and protect
- issues resolved by virtual machines and cloud computing: use on demand and security
- issues resulting from cloud computing: trust and variability/ compatibility