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
Part 2

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, 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.)

| Tetris | Chrome | Blender |

Operating System

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.)

Tetris	Chrome	Blender

Operating System

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
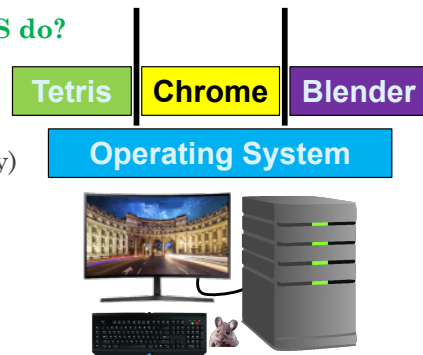
(includes memory, which isn't shown)

Tetris	Chrome	Blender
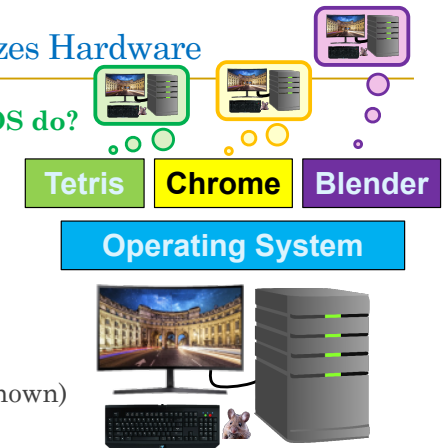
Operating System

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

Tetris	Chrome	Blender

Operating System

Virtual Machine: Software that Mimics a Computer

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

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!)

Time for a Poll

How many of you have a calculator?

A computer?

**A top-of-the-line graphics card
(graphics processing unit, or GPU)?**

A supercomputer?

**What if you wanted to
use a supercomputer for a few minutes?**

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
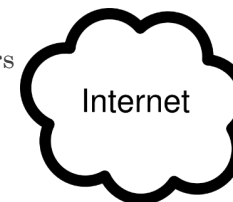needed one?

Computing as a Service … in the "Cloud" !

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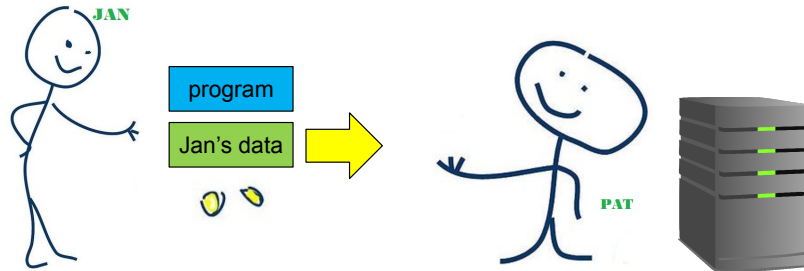the idea of **using someone else's computer as a
service**.

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.

Internet

Cloud Computing Model with Jan and Pat

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

JAN

program

Jan's data

PAT

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!

program

Jan's data

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.

Compatibility is a Major Hurdle

Exactly which processors, motherboard, disk drives, networking card, graphics card, operating system (including which patches?), other software (complete list, please!) are part of Pat's system?

Are they compatible with Jan's program?
What about my program?
What about yours?

PAT
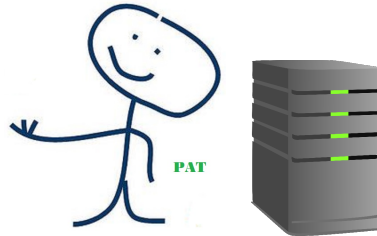
A Better Solution: Use Virtual Machines (VMs)!

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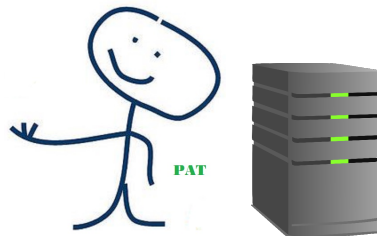**Sun VirtualBox** (now Oracle) is still a good choice for home use.

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.

PAT

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
° equivalent problem-solving capability of
  math/analysis, hardware, and software
° issues for cloud computing: trust and
  variability/compatibility