

Virtualization Overview

NSRC

Terminology

- Virtualization: dividing available resources into smaller independent units
- Emulation: using software to simulate hardware which you do not have
- The two often come hand-in-hand
 - e.g. we can *virtualize* a PC by using it to *emulate* a collection of less-powerful PCs

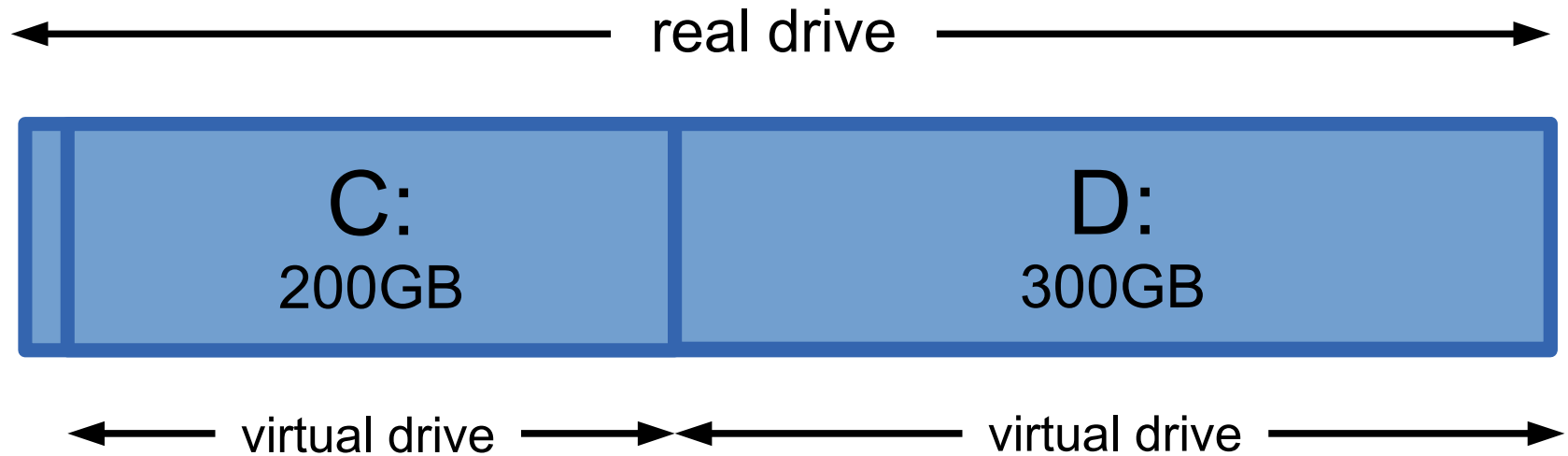
Benefits

- Consolidation
 - Most systems are under-utilized, especially the CPU is idle for much of the time
 - Do more work with less hardware
 - Reduced space and power requirements
- Management
 - Less hardware inventory to manage
 - Concentrate your resilience efforts
 - Increased isolation between services
 - Abstract away (hide) differences in hardware

Benefits

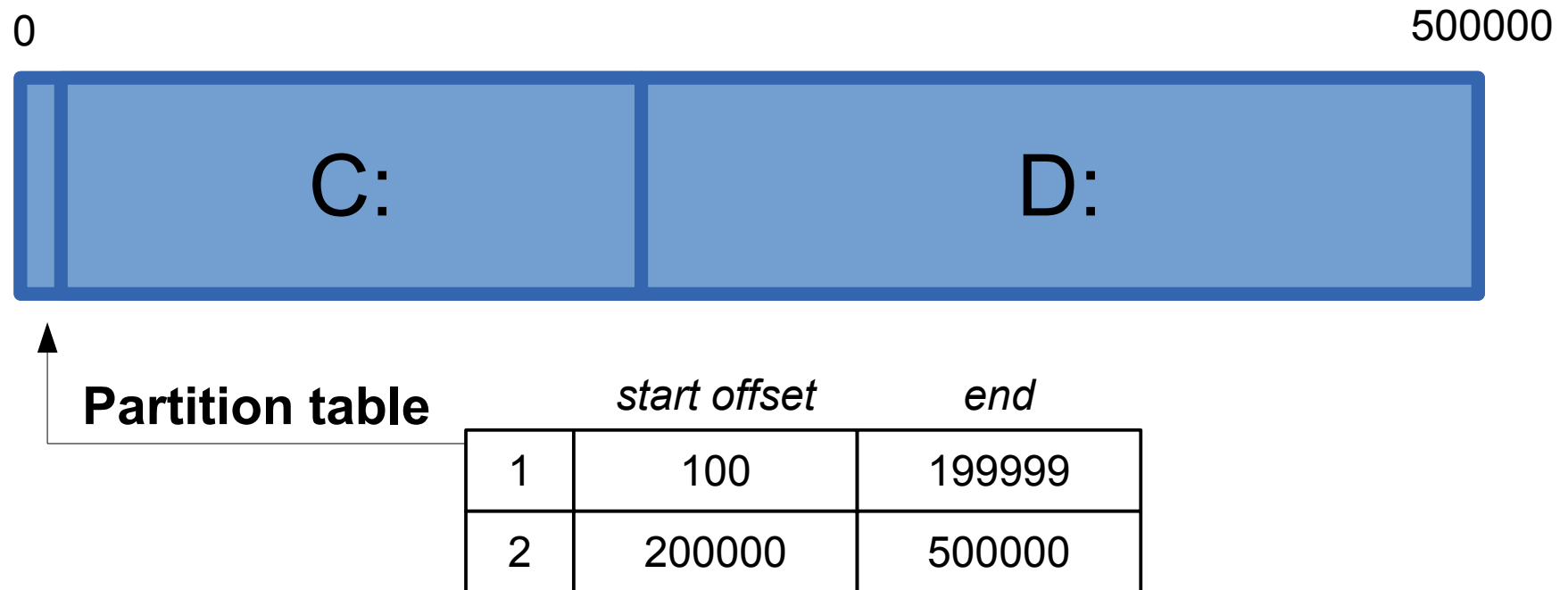
- Flexibility
 - Grow systems on demand (e.g. allocate more CPU or RAM where it is needed)
 - Create new services quickly without having to install new hardware every time
 - Dynamically create and destroy instances for testing and development
- New capabilities
 - Snapshot/restore, cloning, migration, ...
 - Run different OSes on the same machine at once

Virtualization: a familiar example



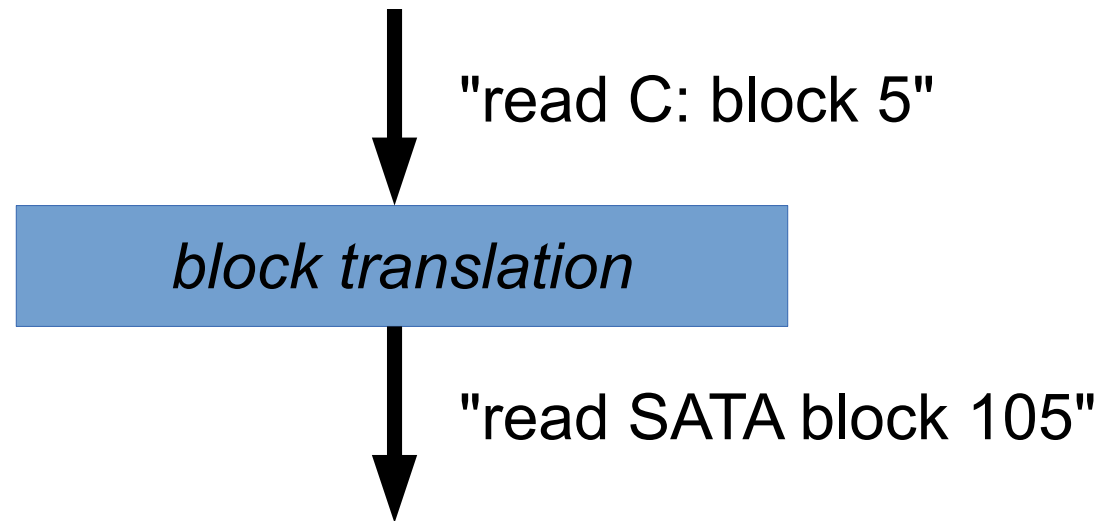
- Who has not seen this before?!
- Like having two (or more) hard drives
 - you get to choose the sizes
- Why is this useful?

How does partitioning work?



- Partition table is an example of *metadata*
- When the OS wants to access the N^{th} block, the real disk access is block $(N + \text{offset})$

Implementation: translation layer

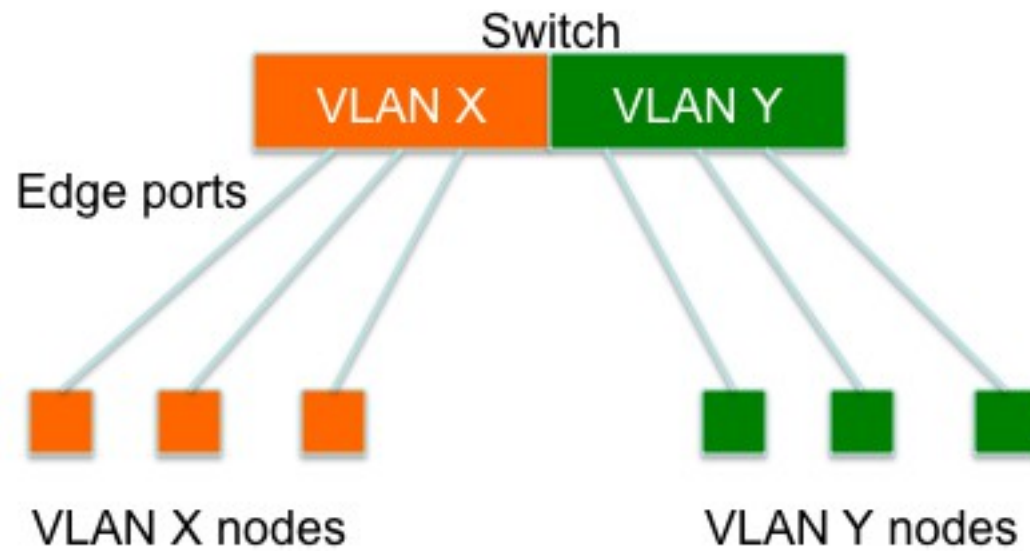


- Very simple and fast: just add offset
- Data is contiguous on disk
- Moving/resizing a partition can require copying all the data on the disk :-)

Another example

- Virtualize a switch: VLANs
 - like dividing a switch into separate switches
- Benefits:
 - can keep traffic separate (broadcast domains)
 - can create VLANs and how they are assigned to ports, purely through software configuration
 - can combine VLANs onto a single cable and split them out again (tagging/trunking)

VLANs

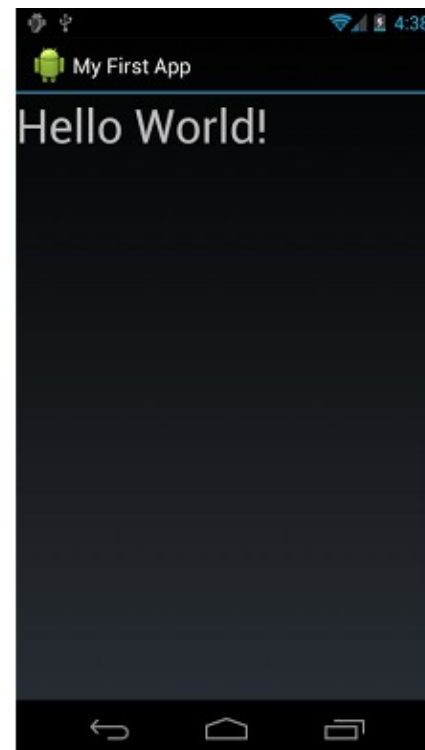
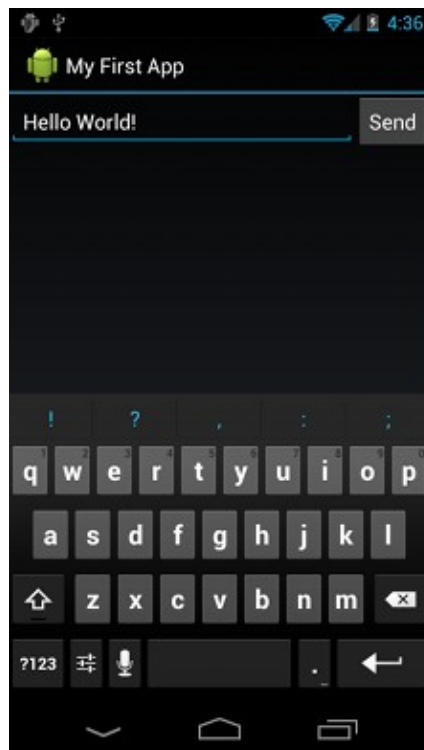


Emulation

- In software, you can simulate the behaviour of a device which doesn't exist
- Example: emulation of a CD-ROM drive using an ISO file
 - a request to read block N of the (virtual) CD-ROM drive instead reads block N of the ISO file
 - similar to partition mapping
- You can simulate any hardware - including the CPU or an entire system!

Entire system emulation - examples

- Android SDK
 - Emulates an Android smartphone with ARM CPU
 - The "screen" is mapped to a window on your PC



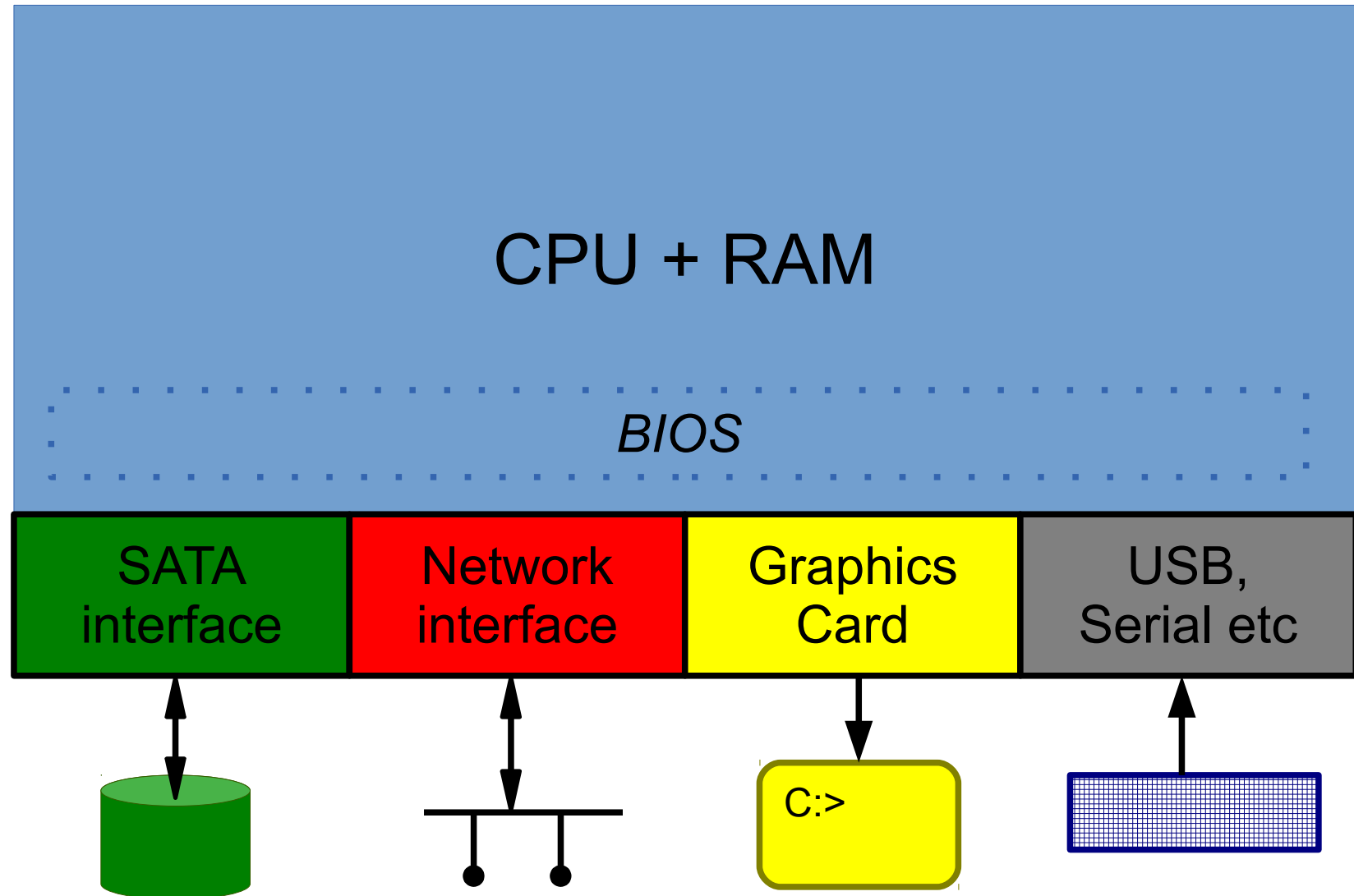
Emulated devices

- There is no physical phone hardware
- So when the software executes an instruction which tries to write to the "screen", this is intercepted and does something else
- It instead updates a buffer in memory which then gets drawn in a window
- The software running inside the emulator is unaware that this is happening

More system emulation examples

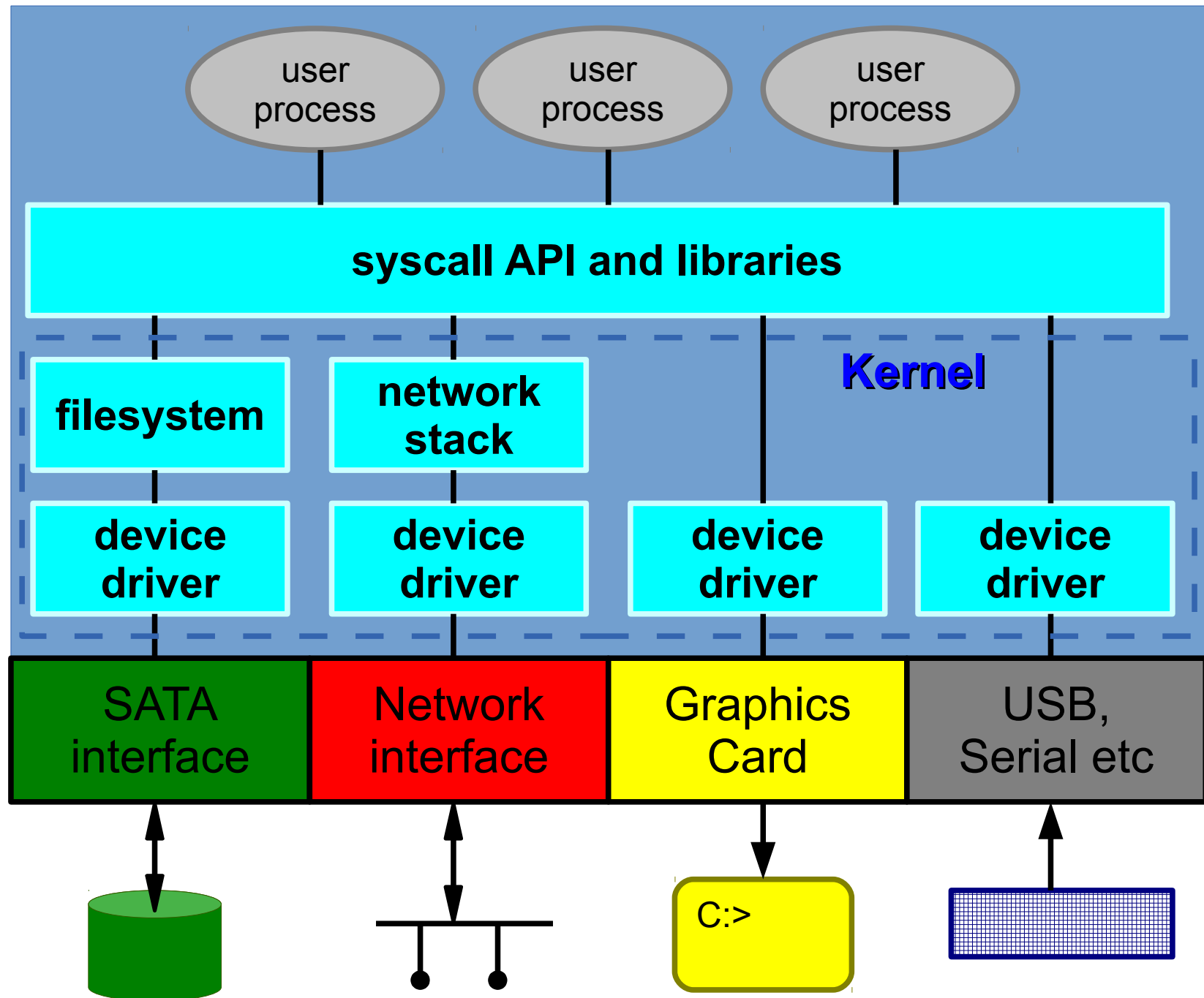
- Dynamips / Dynagen / GNS3
 - Emulates a Cisco router with MIPS CPU and network interfaces
- QEMU
 - Emulates an entire PC (i386 processor and interfaces)

What's in a PC?



Boot up sequence

- A small program (the BIOS) runs when machine is switched on
- It uses the hardware to load an operating system
 - boot from hard drive, USB/CD-ROM, network...
- Modern operating systems then ignore the BIOS from that point onwards
- The next slide shows a machine after it has booted up (simplified)



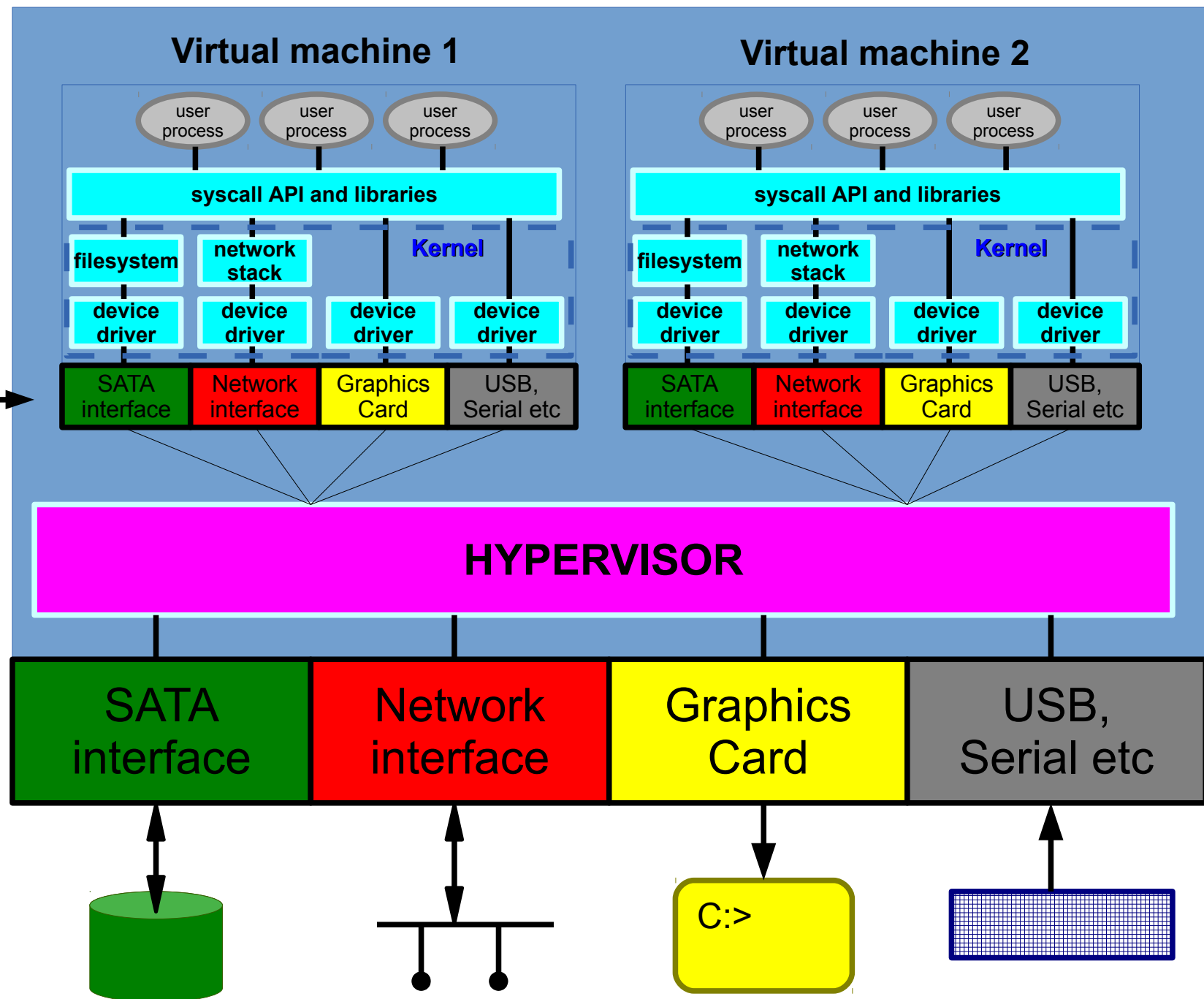
Points to note

- The device drivers in the OS interact with the hardware
- User processes are forbidden by the OS from interacting directly with the hardware
 - the OS configures protection mechanisms to enforce this

What we need

- To emulate a PC we must emulate all the components of the PC
 - hard disk interface, network card
 - graphics card, keyboard, mouse
 - clock, memory management unit etc
- We want multiple instances to co-exist and not be able to interfere with each other
 - access to memory must also be controlled
- The software to do this is called a hypervisor

emulated
hardware

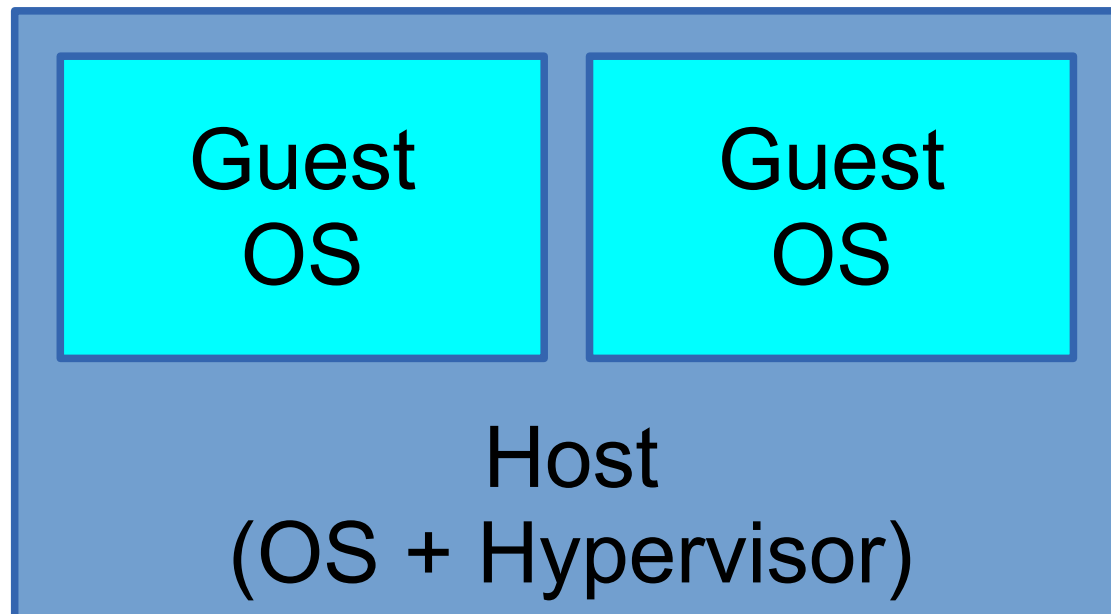


Virtual Machines

- Each emulated PC is a "virtual machine"
- Hypervisor allocates some real system RAM to each VM, and shares the CPU time
- Hypervisor emulates other hardware, e.g. disk and network interfaces
- Within each VM you can boot an operating system
- Full hardware virtualization means different VMs can be running different OSes

Virtualization terminology

- The host is the machine running the emulation
- The guest is the emulated (virtual) machine
- One host could be running many guests



The Hypervisor

- Note that the Hypervisor itself is a component of an operating system *
 - It needs device drivers, a filesystem, a network stack for remote management, etc
- So there is a host OS for the hypervisor, plus guest OSes

* Even so-called "bare-metal" or "Type 1" Hypervisors include a cut-down operating system

Emulated disk hardware

- A hard drive is a "block device"
 - OS makes requests like "read block number 42", "write block number 99"
- Real hard drives have a fixed size!
 - This is what the guest OS will expect to see
- So the hypervisor must redirect these accesses to something else

Emulated disk hardware

- Options include:
 - a disk image file on the host (simple)
 - a partition or logical volume on the host (faster)
 - a remote file or remote block device (via network)
- A disk image file is easy to backup and transfer from host to host
- There are different ways to make a disk image file. Suppose we want the guest to see a 10GB virtual hard drive?

Options for a 10GB image file (1)

- A "raw" file is just a plain 10GB data file
 - N^{th} block of the virtual hard drive corresponds to the N^{th} block in the image file
 - if this is allocated up-front, you use 10GB of (hopefully) contiguous space on the host
 - Fast in operation, avoids fragmentation on the host
 - Wasteful of space
 - Slow to create
 - Slow to copy

Options for a 10GB image file (2)

- Some OSes support "sparse" files or "holes"
 - still looks like a plain 10GB file
 - doesn't allocate space until each block is written to
 - reading from unallocated space reads zeros
 - the size of the file ("ls -l") is larger than the disk space used by the file ("ls -s" or "du")
 - can lead to fragmentation
 - can lead to failures if filesystem becomes full
 - if you are not careful, may expand to full 10GB when you copy it

Options for a 10GB image file (3)

- Custom VM image format with header and data
 - doesn't require OS support for sparse files
 - can be copied without losing its "sparseness"
 - also leads to fragmentation, unless you pre-allocate all the space
- Various formats, e.g. VDI (virtualbox), VMDK (VMware), QCOW2 (qemu/kvm)
- Also add features like snapshots

Disk image types

Raw file (preallocated)



Raw file (sparse)



Growable image file



Pre-allocated image file



Emulated network hardware

- Each guest NIC gets a fake MAC address
- Different ways to interconnect with host NIC
- "NAT": outbound packets translated to share the host's IP address
- "Bridging": packets sent/received untranslated over the host's physical NIC
 - Each VM gets its own IP address on the ext network
 - More transparent
 - Does not always work on wireless NICs though

Summary

- Virtualization can make better use of your hardware by emulating more machines than you really have
- The emulated environment is provided by a hypervisor
- The hypervisor (host) lets you start up virtual machines (guests) each with its own operating system and emulated devices
- Guest hardware emulated using resources on the host