Genesis: From Raw Hardware to Processes

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Operating Systems

CS 3430

How does it all begin?

- How we go from nothing to the operating system
- How the operating system starts up processes (services)

Booting Sequence

- The address of the first instruction is fixed
- It is stored in read-only-memory (ROM)
  - Why ROM instead of RAM?

Booting Procedure

- ROM stores a ***Basic Input/Output System (BIOS)***
  - BIOS contains information on how to access storage devices

BIOS Code

- Performs Power-On Self Test (POST)
  - Checks memory and devices for their presence and correct operations
  - During this time, you will hear memory counting, which consists of noises from the floppy and hard drive, followed by a final beep

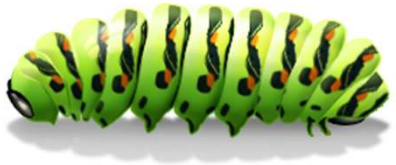
After the POST

- The ***master boot record (MBR)*** is loaded from the ***boot device*** (configured in BIOS)
- The MBR is stored at the first logical sector of the boot device (e.g., a hard drive) that
  - Fits into a single 512-byte disk sector (***boot sector***)
  - Describes the physical layout of the disk (e.g., number of tracks)

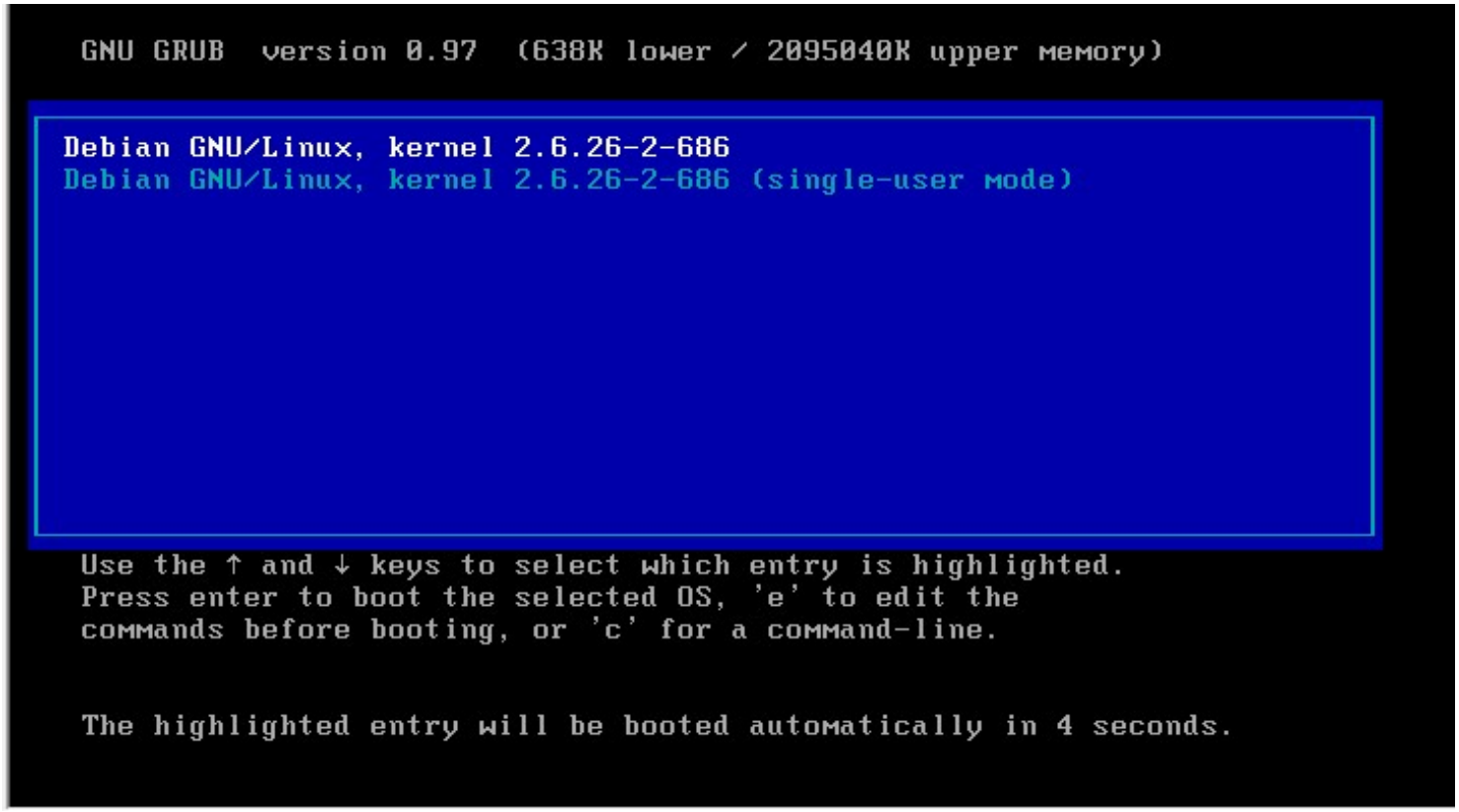
After Getting the Info on the Boot Device

- BIOS loads a more sophisticated loader from other sectors on disk
- The more sophisticated loader loads the operating system

Operating System Loaders



- GRUB (*GRand Unified Bootloader*)



More on OS Loaders

- Is partly stored in MBR with the disk partition table
  - A user can specify which disk partition and OS image to boot
  - Windows loader assumes only one bootable disk partition
- After loading the kernel image, OS loader sets the kernel mode and jumps to the entry point of an operating system

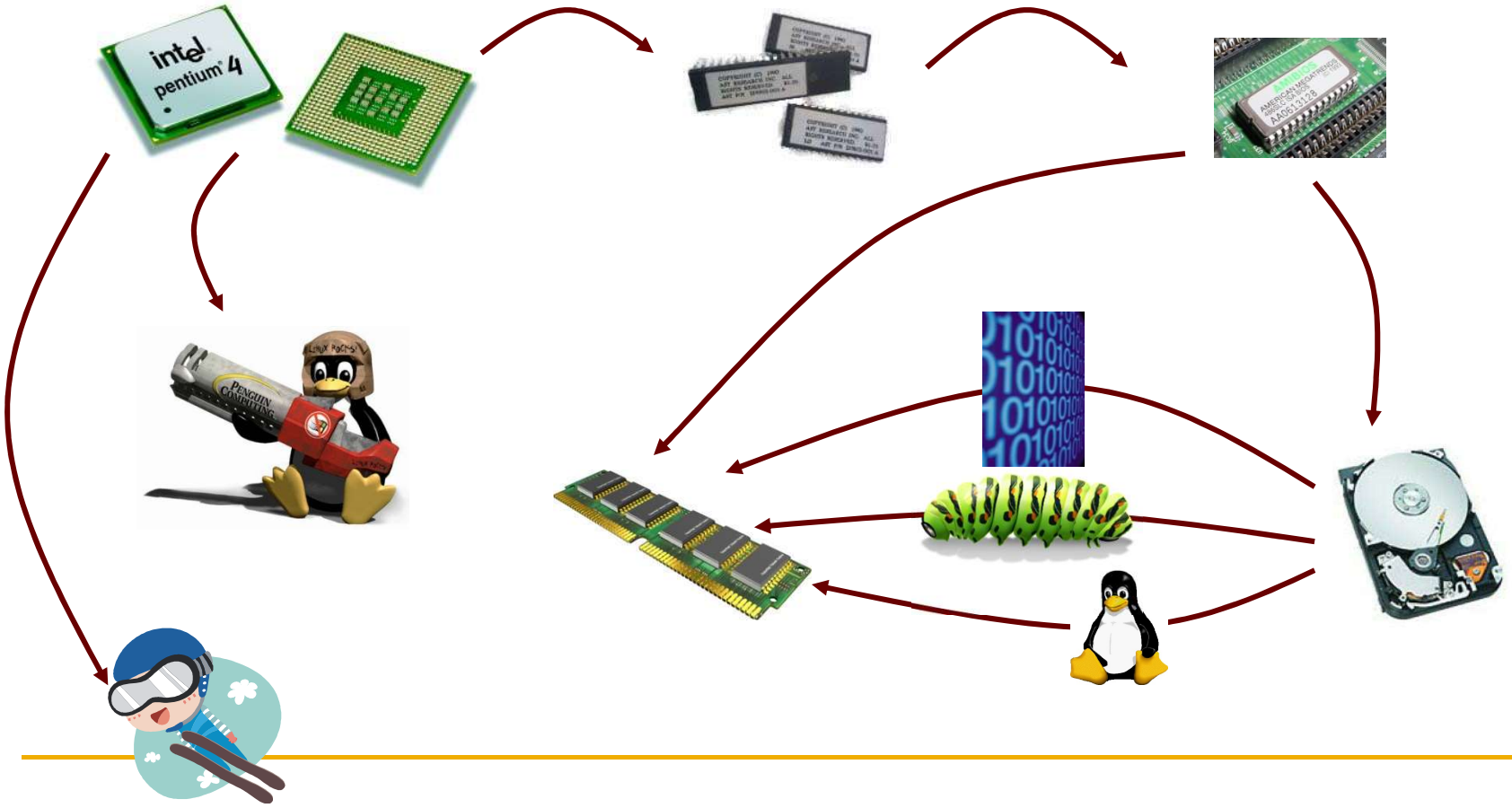
Kernel Mode?

- Two hardware modes: kernel mode and user mode
  - Implemented as a single bit
  - Some privileged instructions can only be run in kernel mode to protect OS from errant users
  - Operating system must run in kernel mode

Booting Sequence in Brief

- A CPU jumps to a fixed address in ROM,
- Loads the BIOS,
- Performs POST,
- Loads MBR from the boot device,
- Loads an OS loader,
- Loads the kernel image,
- Sets the kernel mode, and
- Jumps to the OS entry point.

Booting Sequence Visualized



Linux Initialization

- Set up a number of things:
  - Trap table
  - Interrupt handlers
  - Scheduler
  - Clock
  - Kernel modules (hardware and software drivers)
  - …
  - Process manager

Process 1

- Is instantiated from the ***init*** program
- Is the ancestor of all processes
- Controls transitions between ***runlevels***
- Executes startup and shutdown scripts for each runlevel

Runlevels

- Level 0: shutdown
- Level 1: single-user (command-line only)
- Level 2 - 5: the GUI (called “X” in Linux)
  - These levels are typically duplicated
- Level 6: reboot

- ***These runlevels map to /etc/rc**x**.d, where **x** is 0-6 or S for “Single User”***

Runlevels

- SysV (“System 5”) runlevels meant that you would process them this way:
  - Booting: start with 1, go up each run level to default stop level, executing scripts that start with “S” for “start”
  - Shutdown: start at your current runlevel, go down one at a time until you reach 0, executing scripts that start with “K” for “kill”

Runlevels

- Systemd is the newer system, although a lot of the old runlevel stuff is still preserved.
- Instead of thinking about numbers, you think about labels mapped to numbers
  - Easier? Hmmm….

    - Run level 0 is matched by poweroff.target (and runlevel0.target is a symbolic link to poweroff.target).
    - Run level 1 is matched by rescue.target (and runlevel1.target is a symbolic link to rescue.target).
    - Run level 3 is emulated by multi-user.target (and runlevel3.target is a symbolic link to multi-user.target).
    - Run level 5 is emulated by graphical.target (and runlevel5.target is a symbolic link to graphical.target).
    - Run level 6 is emulated by reboot.target (and runlevel6.target is a symbolic link to reboot.target).
    - Emergency is matched by emergency.target.

https://www.tecmint.com/change-runlevels-targets-in-systemd/

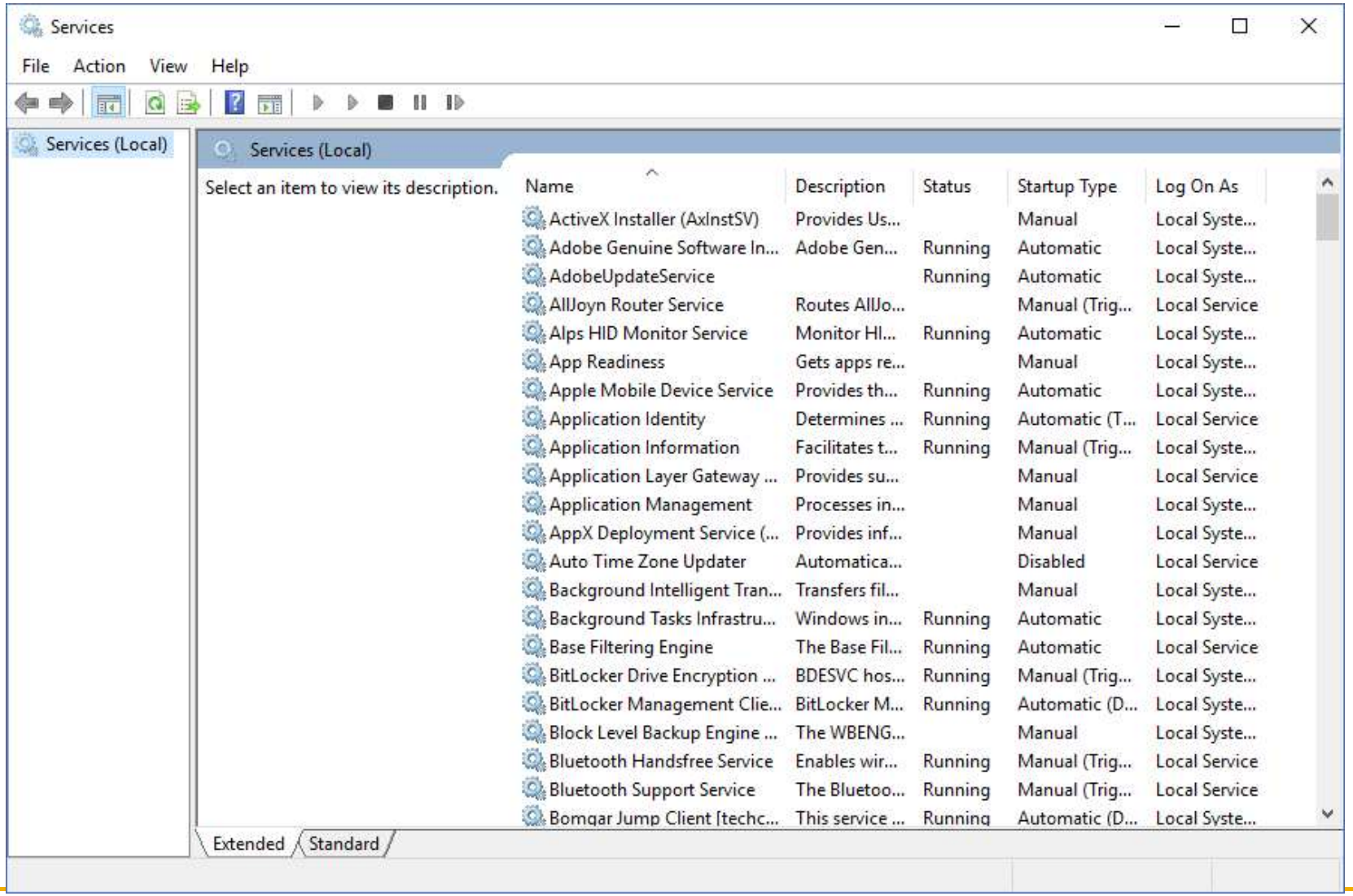
Runlevels

- You can start and stop services with the systemctrl command

```
# systemctl start [name.service]
# systemctl stop [name.service]
# systemctl restart [name.service]
# systemctl reload [name.service]
$ systemctl status [name.service]
# systemctl is-active [name.service]
$ systemctl list-units --type service --all
```

https://www.linux.com/learn/understanding-and-using-systemd

Windows?


Services
File Action View Help
Services (Local)
Services (Local)
Select an item to view its description.
Name
Description
Status
Startup Type
Log On As
ActiveX Installer (AxInstSV) Provides Us... Manual Local Syste...
Adobe Genuine Software In... Adobe Gen... Running Automatic Local Syste...
AdobeUpdateService Running Automatic Local Syste...
AllJoyn Router Service Routes AllJo... Manual (Trig... Local Service
Alps HID Monitor Service Monitor Hl... Running Automatic Local Syste...
App Readiness Gets apps re... Manual Local Syste...
Apple Mobile Device Service Provides th... Running Automatic Local Syste...
Application Identity Determines ... Running Automatic (T... Local Service
Application Information Facilitates t... Running Manual (Trig... Local Syste...
Application Layer Gateway ... Provides su... Manual Local Service
Application Management Processes in... Manual Local Syste...
AppX Deployment Service (... Provides inf... Manual Local Syste...
Auto Time Zone Updater Automatica... Disabled Local Service
Background Intelligent Tran... Transfers fil... Manual Local Syste...
Background Tasks Infrastru... Windows in... Running Automatic Local Syste...
Base Filtering Engine The Base Fil... Running Automatic Local Service
BitLocker Drive Encryption ... BDESVC hos... Running Manual (Trig... Local Syste...
BitLocker Management Clie... BitLocker M... Running Automatic (D... Local Syste...
Block Level Backup Engine ... The WBENG... Manual Local Syste...
Bluetooth Handsfree Service Enables wir... Running Manual (Trig... Local Service
Bluetooth Support Service The Bluetoo... Running Manual (Trig... Local Service
Bomgar Jump Client [techc... This service ... Running Automatic (D... Local Syste...
Extended Standard

Process Creation

- How does the init process create all these other processes (services) that run independently??

- Via the ***`fork`*** system call family

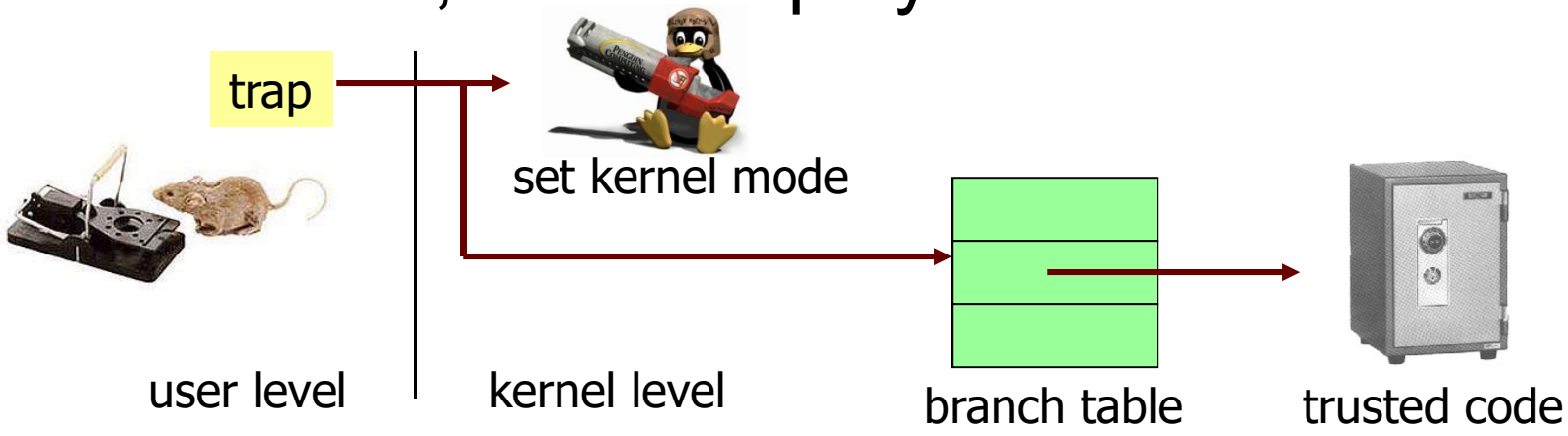
Before we discuss process creation, a few words on system calls…

System Calls

- ***System calls*** allow processes running at the ***user mode*** to access kernel functions that run under the ***kernel mode***
- Prevent processes from doing bad things, such as
  - Halting the entire operating system
  - Modifying the MBR

UNIX System Calls

- Implemented through the ***trap*** instruction
- Causes an interrupt and allows the OS to switch to kernel mode
- From there, it looks up system call and runs it



More on Fork

- ***Fork*** is a system call to create a new process
  - What does each process have (two things)??
- Two processes may be bulky
  - Can create multiple ***threads*** instead
  - For now, we will concentrate on processes