ECE469: UEFI Booting

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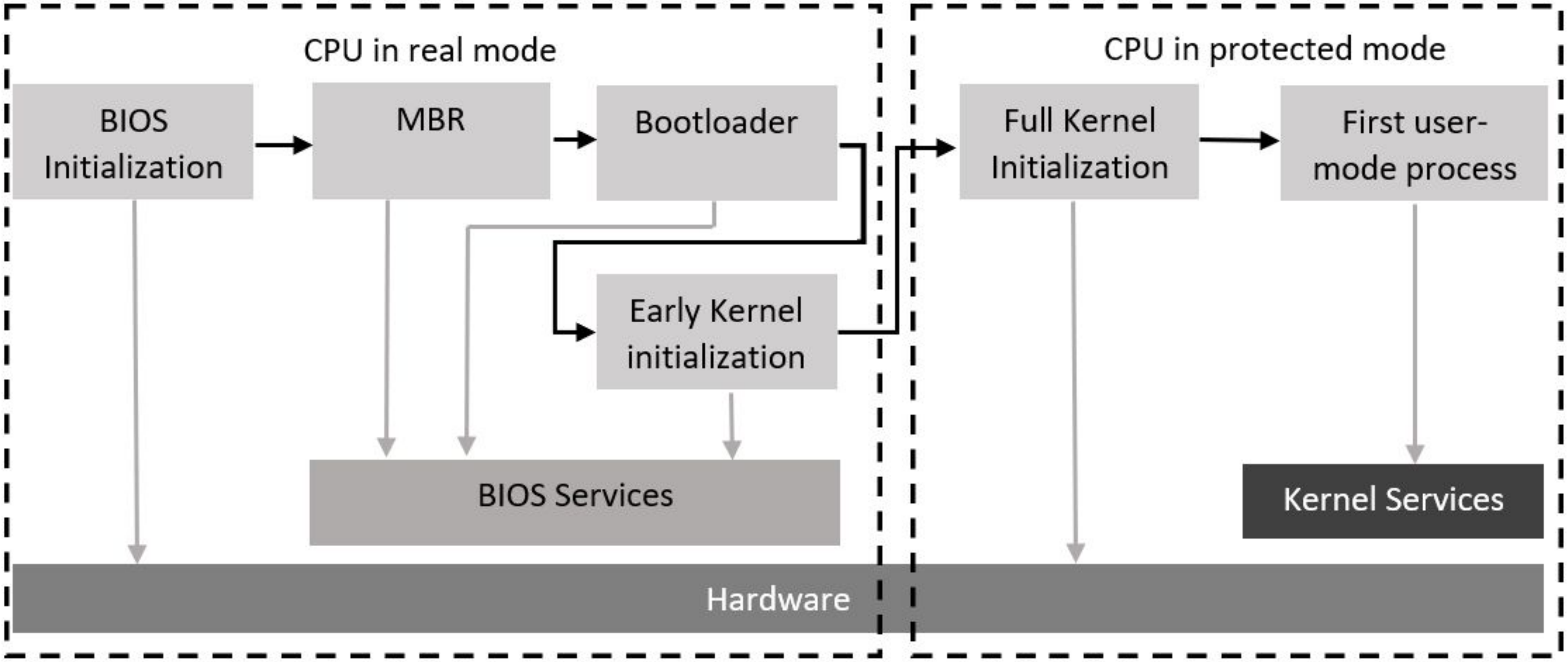
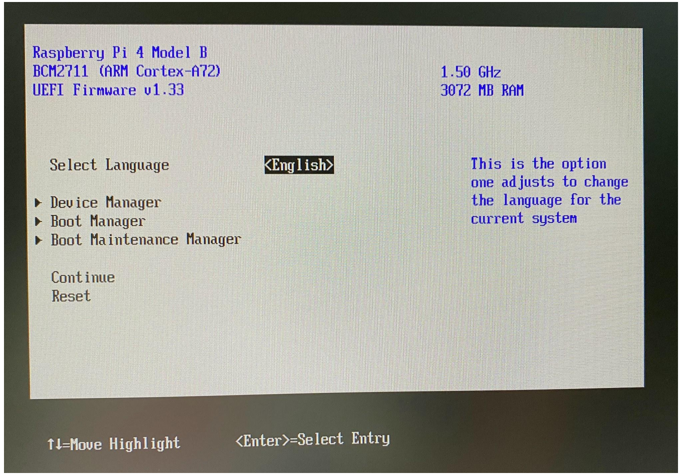
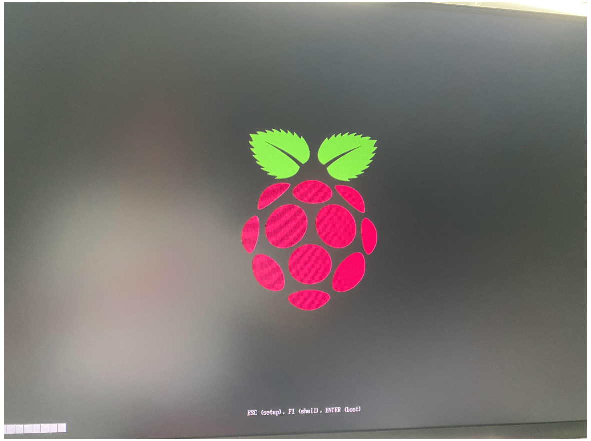
Recap: BIOS Booting



What happens, when we turn on the machine?

1. UEFI:
   a. Unified Extensible Firmware Interface.
   b. Enables basic device access.





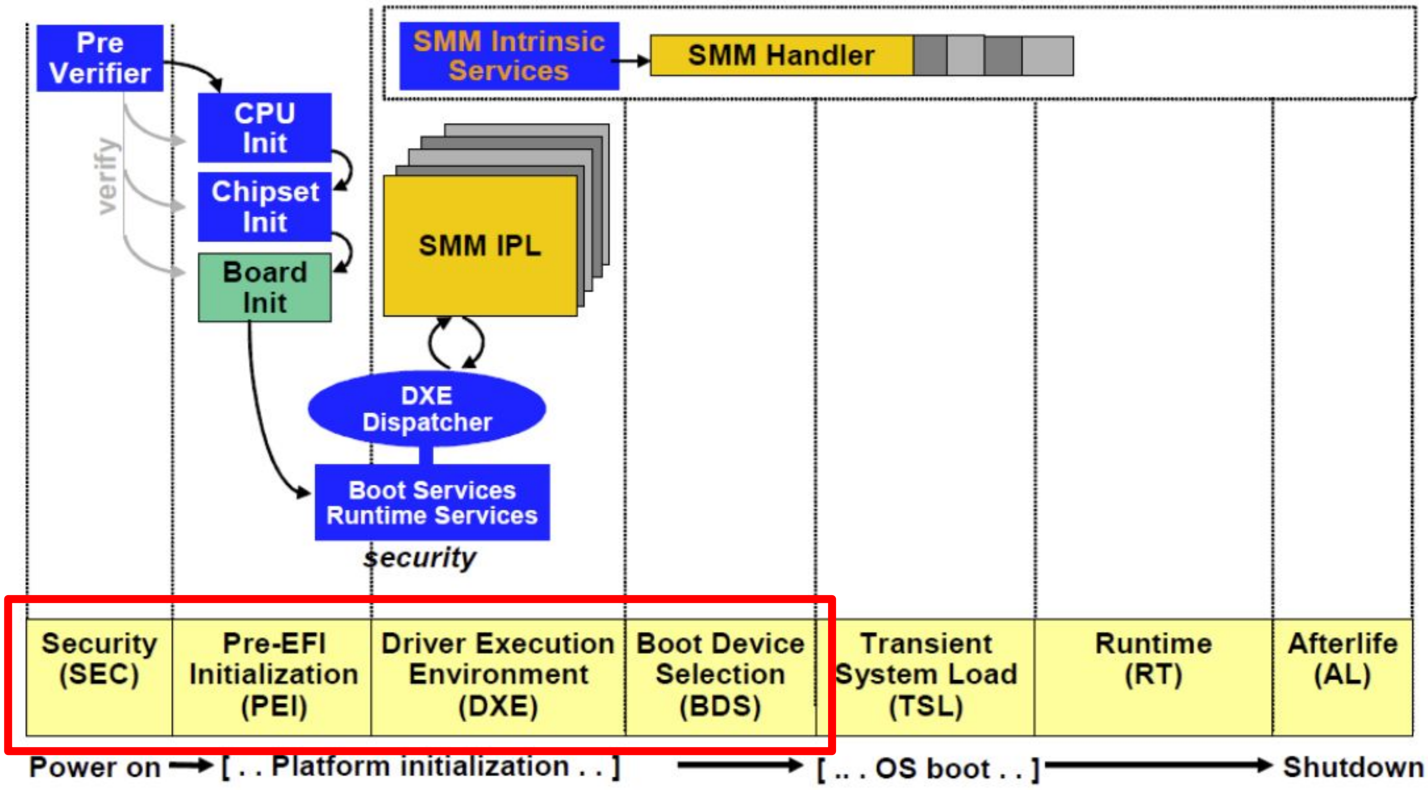
What is UEFI?

- Modular in design (uses generalized communication protocols)
- User friendly interface (sometimes with mouse support)
- Advanced security features (e.g. Secure Boot)
- Larger disk sizes (greater than 2TB)
- Only operates in protected mode
- Easier to maintain (written in C)
- Supports other boot options (e.g. Network Boot)

UEFI vs. BIOS

	Legacy Bios	UEFI Firmware
Architecture	All vendors did something different	Unified specifications (EDK1/EDK2)
Implementation	Mostly Assembly	C/C++
Memory Model	16-bit real mode	32/64-bit protected mode
Bootstrap	MBR and VBR	None
Partition	MBR	GPT
Disk I/O	System Interrupts	UEFI services
Bootloaders	Bootmgr and winload.exe	Bootmgfw.efi and winload.efi
OS Interaction	BIOS Interrupts	UEFI services
Boot Configuration	CMOS Memory	UEFI NVRAM variable

UEFI Boot Phases



Security

- Executes hardware specific firmware.
  - Written in assembly (16-/32-bit) (SecMain).
- Creates the foundation for the root-of-trust methodology.
  - Authenticates the Pre-EFI Initialization (PEI) Foundation code.
- Creates temporary memory using CPU caches.
- Locates the PEI foundation on the SPI flash.
- The SEC phase is executed on the SPI flash.
  - Address entry point is the reset vector at address space 4GB - 0x10
  - Only the bootstrap processor(BSP) is running.

Pre-Environment Initialization

- The boot code is loaded from the SPI flash in this phase (PeiCore).
- It initializes the permanent memory, but until then everything is executed in the CPU cache. (InitializeMemory)
- This is where the runtime and boot services begin execution. (InitialzeDXE -> DXELoadCore)
- Creates hand off block (HOB) list for later phases.
- The final module is the block to load the next phase (PeimInitializeDxeIpl).
- The most architecture depend part of the code.

Driver Execution Environment

- This is the main phase of the boot process. (EntryPoint)
- The System Management Mode (SMM) is initialized during this phase.
- SMM is executed in Ring -2, while everything else is in Ring 0.
- The boot and runtime services finish initialization during this phase.
- All images are loaded:
  - Driver - permanent
  - Application - temporary
- Images are loaded and executed in two ways:
  - Through the DriverOrder option in the NVRAM
  - The default boot order

What is NVRAM?

- The NVRAM stores the UEFI variable.
- The UEFI variable contains all of the variables and parameters needed throughout the boot process :

BootOrder	An in-order array of 16-bit integers that refer to the boot order.
Boot####	One of the devices that is to be booted and the #### refers to the hex identification number.
DriverOrder	An in-order array of 16-bit integers that refer to the driver order.
Driver####	A driver that is to be loaded and the #### refers to the hex identification number.

UEFI Services

- This is an important component of the boot process.
- It consists of two components:
  - Boot Services
  - Runtime Services
- The Boot Services run in physical addressing mode while runtime services run in both physical and virtual addressing.
- These services begin initialization in the PEI phase when the permanent memory is established, but the initialization finishes during the DXE phase.

Boot Services

- Boot services are used to create, manage, and stop events during the boot process (All Services):
  - Protocol services
  - Device Protocols - how to communicate between different peripherals
  - Device handle-based boot services
  - Global boot service interface
- These services are important for communicating between drivers.
- CopyMem, which is used when copying the drivers into permanent memory or into the SMRAM is a common example.
- Primarily needed for setting everything up for the OS loader.
- They are terminated when ExitBootServices() is called in the OS Loader.

Runtime Services

- These are system call functions that create some abstraction between the kernel and the hardware.
- The service calls don’t require interrupts to be called but do use them by default.
- The memory where the runtime services are stored can’t be modified by the kernel because they interact with the hardware.
- Part of the Runtime code is stored in the SMRAM, the part pertaining to the direct hardware modification.
- The function SMMLoadImage is used to load images into SMRAM.

System Management Mode (SMM)

- Operates inside protected memory called SMRAM
- It is similar to Arm's TrustZone
- It has the highest privilege on the system (Ring -2)
- Operates in 16-bit mode
- It is responsible for direct hardware controls and power management
    - Flash System Firmware, write to the MMIO, etc
- A System Management Interrupt (SMI) is required to call anything inside of the SMM

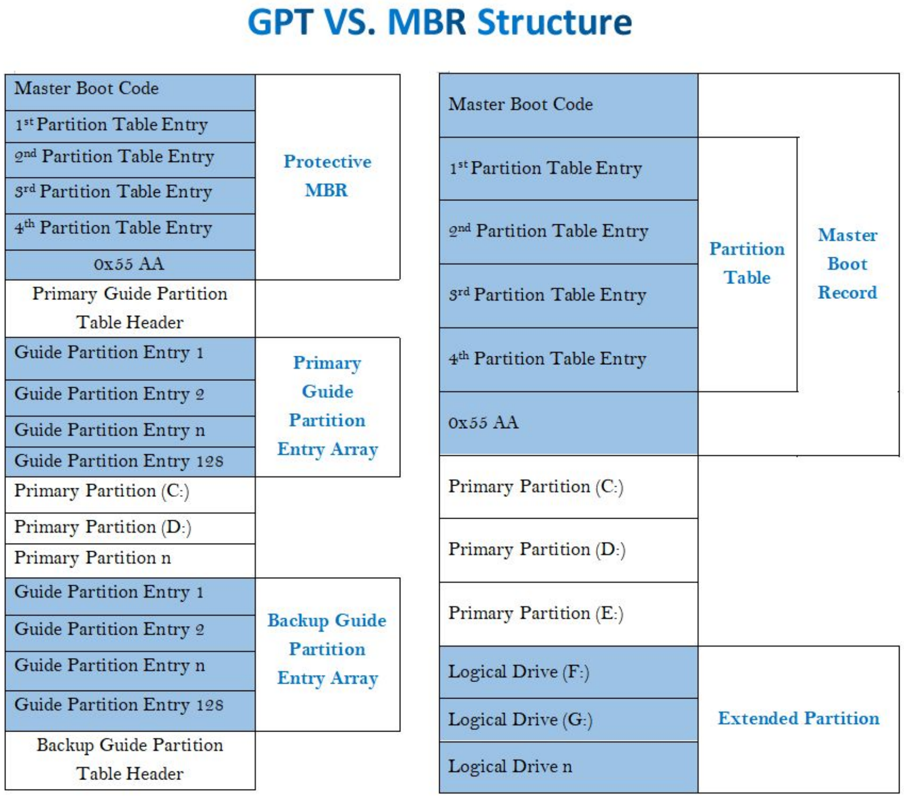
What is SMRAM?

- The SMRAM is apart of the DRAM
- SMBASE is a fixed address in a CPU register
  - Used to find the starting location of the SMRAM
- Only the SMI handler can modify the SMRAM
  - That means anyone can read the SMRAM
- There is a specific bit called the D_LCK bit
  - If set then no SMRAM configuration bits can be changed

Boot Device Selection

- This is when the boot partition is selected.
- It is either defaulted to the active partition or will allow an option if there are multiple operating systems present.
- It will also handle executing the boot manager and OS drivers from the system partition.
- The boot manager utilizes the DXE drivers that were created to complete its tasks.
- The OS loader is stored on the EFI system partition that uses a GUID Partition Table instead of the traditional MBR.

GPT vs. MBR



- GUID Partition Table (GPT) can support a much larger number of partitions.
- Utilizes a 16-byte identification number.
- System partition path is stored in the NVRAM.

UEFI vs. BIOS (Review)

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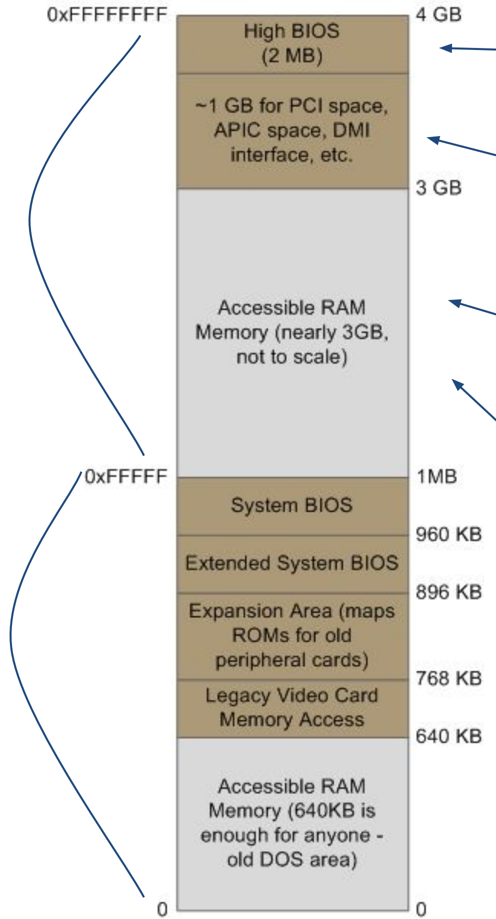
Summary!

UEFI Firmware

Reserved for BIOS



Mapped Code

MMIO and other peripheral Mappings

Scratch Memory for different device drivers

The extra memory provides more flexibility in system configurations