



White Paper

UEFI Plugfest 2015 - Challenges for UEFI and the Cloud

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Executive Summary

This paper talks about the challenges for Cloud computing. The Open Compute Project (OCP) [OCP] vies to provide interoperability between many elements in the data center, pioneering ‘open hardware’ precepts for this market area.

Just as the OCP goal is to have interoperability between all elements of the server complex, UEFI [UEFI-BOOK] attempts to provide similar business interoperability. Specifically, the UEFI/PI/ACPI designs have followed the same spirit, effecting this intent through industry standard API’s. Through these API’s we can have plug and play binaries between different business elements.

UEFI can help open up the boot and management firmware elements of OCP that have traditionally been vendor specific and not fully interoperable.

This paper isn’t exhaustive but instead attempts to highlight some Cloud challenges with corresponding solutions based upon UEFI.

Prerequisite:

This paper assumes that audience has basic EDKII/UEFI firmware development experience.

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Cloud Firmware Challenges

Introduction – the Cloud

When designing a compute engine, one must strive to work around three main constraints, as shown in below Figure, namely –

- Constraints from Physics
- How to deploy the compute engine?
- How to manage the compute?

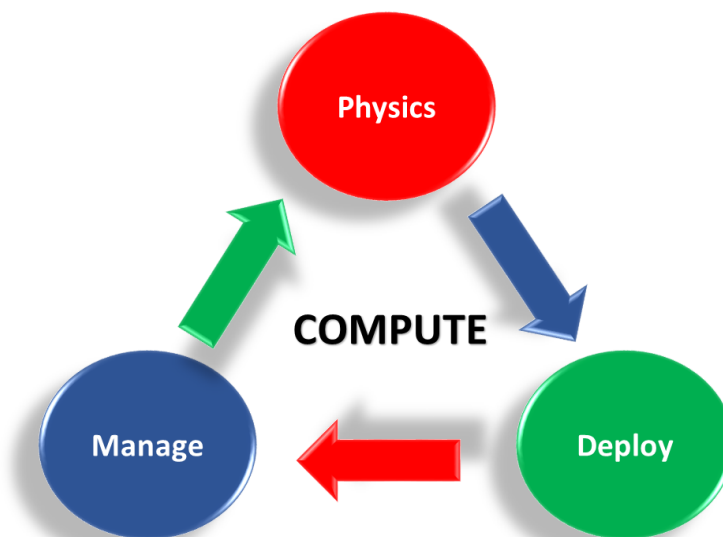


Figure: Challenge Vectors

Hypothetically, let us imagine possibility of an ideal compute node that can cater to all the conceivable compute in the universe. This will simply trivialize the deployment challenges as we have to prepare the hardware once. Then we have to install the firmware stack, OS and software stack exactly once. But this is clearly not viable from the viewpoint of performing compute as there are power delivery challenges, thermal, mechanical and availability challenges etc. The Cloud [CLOUD] server paradigm offers elegant answer to this problem via its inherent scale. In particular, it addresses various challenges such as power deliver, thermal, mechanical, availability, etc. associated with concentration of compute. This is accomplished by distribution of compute across thousands of compute nodes. Such compute nodes are usually symmetric, but that is not a requirement. The advantage of cloud paradigm is that with varying compute needs, the size of Cloud can be changed accordingly. However, this does pose new challenges related to “deploying” the compute as well as “managing” the compute, such as–

- ensuring that firmware updates can be deployed seamlessly on a broad scale
- ensuring that cloud can be provisioned seamlessly as per underlying specifications
- ensuring that cloud is secured both at a node level as well as at datacenter/cloud level
- ensuring that software tools and diagnostics can easily predict and/or detect, root-cause failures

This paper examines the opportunities and challenges that lie ahead with the UEFI, in order to solve above platform construction problems via standards.

Introduction – UEFI

UEFI stands for the “Unified Extensible Firmware Interface.” UEFI has several dimensions, including industry standards [UEFI] for purposes of interoperability between operating system loaders, pre-OS applications, and operating system runtimes. The UEFI Forum governs the UEFI Specification evolution and various companies, including Intel ®, contribute to the open source project.

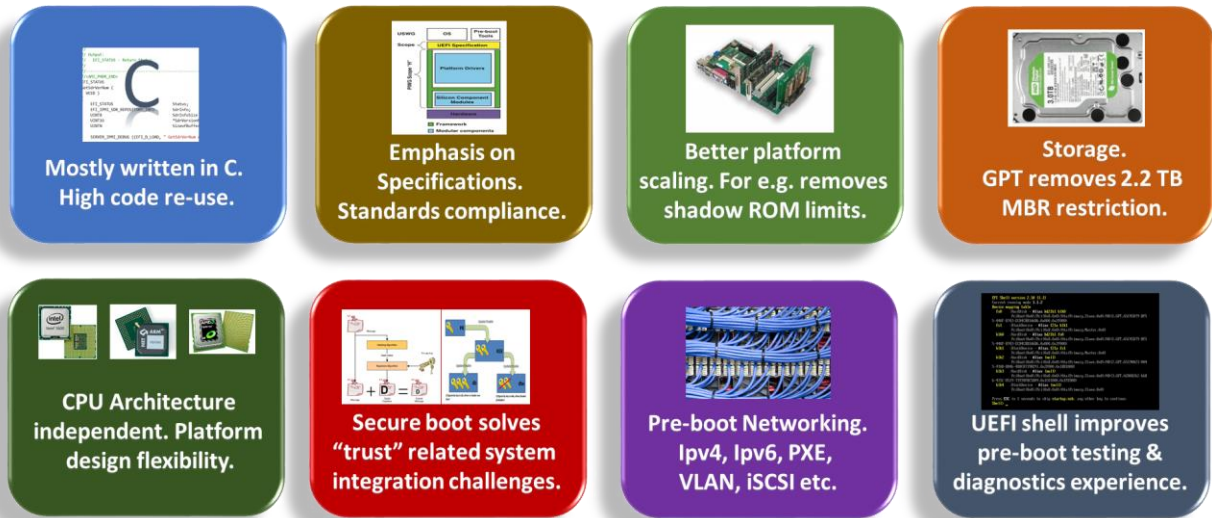
The salient details of the UEFI specification includes the definition of ANSI C-callable API’s that are published by the system board firmware implementation. The figure below describes various facets of UEFI, including the dynamically loadable UEFI drivers that can be installed on host-bus adapters (HBA’s). This allows for moving beyond the limitations of PC/AT BIOS wherein option ROM’s had to reside in a fixed location. The UEFI Specification defines a set of mandatory capabilities, including boot and runtime services. These services allow for managing memory, timers, events, UEFI variables, capsules, and loading code. Beyond those basic services, chapter 2.6 of the UEFI 2.4 Specification describes the mandatory and optional services. To be a compliant UEFI implementation, you don’t need much more than the boot services, runtime services, and loadfile protocol.

In addition to the API’s, the C-callable nature of the UEFI specification allows for platform and CPU architecture flexibility. As of writing this document, the UEFI specification support Intel 32-bit and 64-bit architecture, Intel Itanium ®, and ARM Ltd ® 32-bit and 64-bit CPU’s. There are some open source ports to other architectures, such as MIPS ® 32-bit, but they do not have an official binding in the specification. The reason for the binding is that it allows for interoperability between components built but different entities, from the system board vendors, sometimes known as the Original Equipment Manufacturer (OEM) or Original Device Manufacturer (ODM). Leading to the consumers of UEFI services, such as 3rd party UEFI driver extension from an Independent Hardware Vendor (IHV). And finally, there are pre-OS independent software vendors (ISV’s) and the hypervisor or operating system vendors. We will club the latter two together as “OSV’s” since for purposes of the boot firmware there is no distinction between a virtual machine monitor, such as a type1 VMM or hypervisor, and a static OS. UEFI services can be published by the bare metal motherboard or from within the hypervisor, such as in the case of ‘guest firmware.’

Another aspect of UEFI includes the GUIDed Partition Table (GPT). The GPT breaks away from today’s MBR and allows for breaking the 2 Terabyte disk limit. Strictly speaking the GPT definition can be used outside of platforms with underlying UEFI firmware implementations, too.

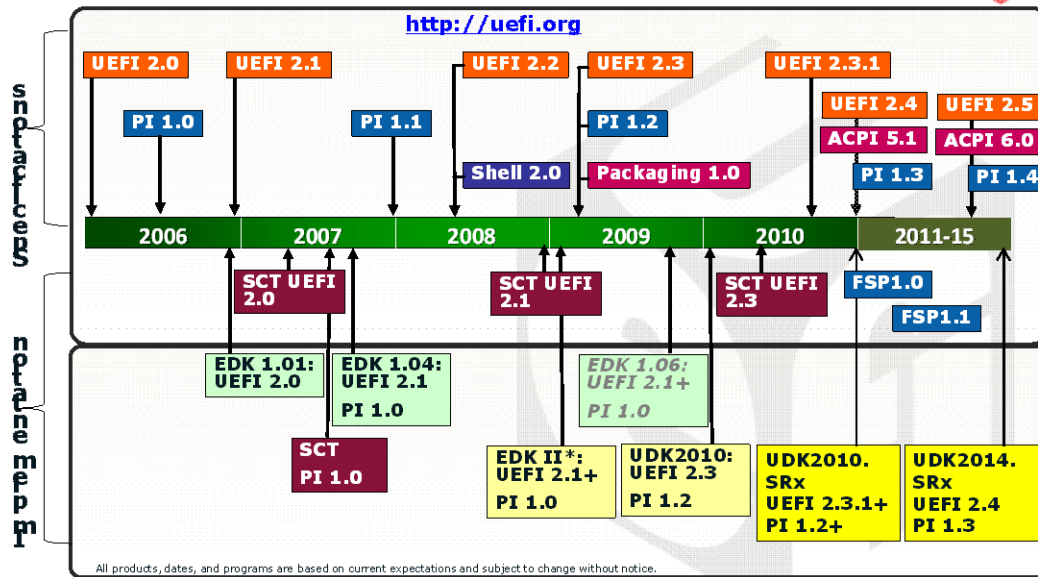
The figure below also highlights other capabilities of UEFI, including the ‘UEFI Secure Boot’ feature. More will be discussed about this capability, but the gist of the feature is to allow some administrative control of the extensible image loading found in UEFI. And what is potentially of interest to the cloud community includes the integrated networking capability of UEFI, along with a shell. In the spirit of the design-by-interface methodology of UEFI, these API’s for all of the

underlying networking interfaces, from the IHV-supplied lowest level wired networking driver up to the software-visible API's that correspond to the OSI stack, can all be found in the main UEFI Specification document. Correspondingly, the UEFI Shell has a specification hosted on [UEFI], too, alongside the main UEFI Specification. This mapping to documentation allows for interoperability and investment protection of applications that consume the network stack, shell script, and shell [UEFI-SHELL] applications, respectively.



In addition to the main UEFI specification, though, there is an open source reference implementation [EDK2]. Although the UEFI Forum does not officially endorse any specific implementation, the community has historically attempted to produce a reference implementation of the standard publically available along with the document production. As such, the figure below show how each version of the specification at the top has a corresponding implementation underneath. The underlying software technology used to build these implementations have evolved, from the EFI Development Kit (EDK) of the early UEFI Specifications to the present EDK II project.

Timeline



<http://tianocore.org>

<https://github.com/tianocore/edk2>

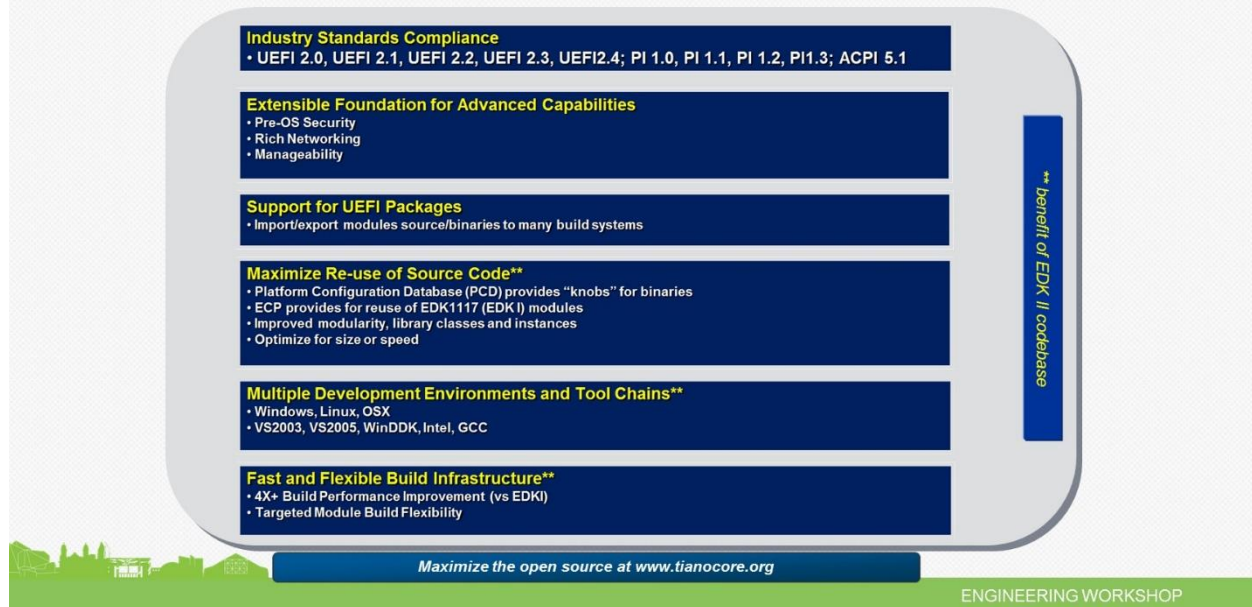
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www.uefi.org

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Speaking of EDK II, this is an open source implementation of the various specifications hosted on [EDK2]. Diagrammatically, the figure below shows the various facets of this project. It provides implementations of the UEFI specifications, the underlying Platform Initialization (PI) specifications, and the Advanced Configuration and Power Interface (ACPI) specification.

Specification & Tianocore.org Timeline



The open source has full implementations of the UEFI core elements, industry standard bus and class drivers, such as PCI, USB, SATA.

Summary

The Cloud poses many challenges for platform construction. Given the many business entities involved in deploying the Cloud, from OEM to IHV to ISV to OSV, the ability of UEFI to provide interoperability between the parties bears exploration. The following sections will provide a short, albeit incomplete, map into that exploration.

Firmware Update

Introduction

The cloud platform comprises of various hardware elements such as CPUs, chipset, BMC, ME, on-board PCI devices, add-on PCI devices, storage devices, FPGA based platform extensions etc. as shown in Figure 2. Often, there is an associated firmware stack associated with each of these hardware elements. Thus, in addition to System BIOS which is responsible for booting the platform, host of other firmware elements must be programmed and maintained throughout the life of a platform. In addition, cloud paradigm necessitates voluminous deployment of compute nodes housed within a datacenter.



Figure 2: Firmware Composition Challenge

The updateable firmware ingredients can be broadly classified into two categories, viz. system firmware and device firmware. A system firmware is one which is mandatory platform ingredient without which booting of the system is not possible. On the contrary, the device firmware relates to any firmware ingredient that is not required in order to successfully boot the platform. Examples of system firmware include UEFI/BIOS, BMC firmware, ME firmware etc. Examples of device firmware include SSD firmware, RAID firmware etc.

The firmware update process involves three key steps, viz. –

- 1) verifying the firmware binary integrity
- 2) updating the firmware
- 3) verifying update is successful or preform a rollback

These steps are shared by all firmware updates, irrespective of type of the firmware. Refer to Figure 3 for a high level flow chart describing key steps of firmware update.

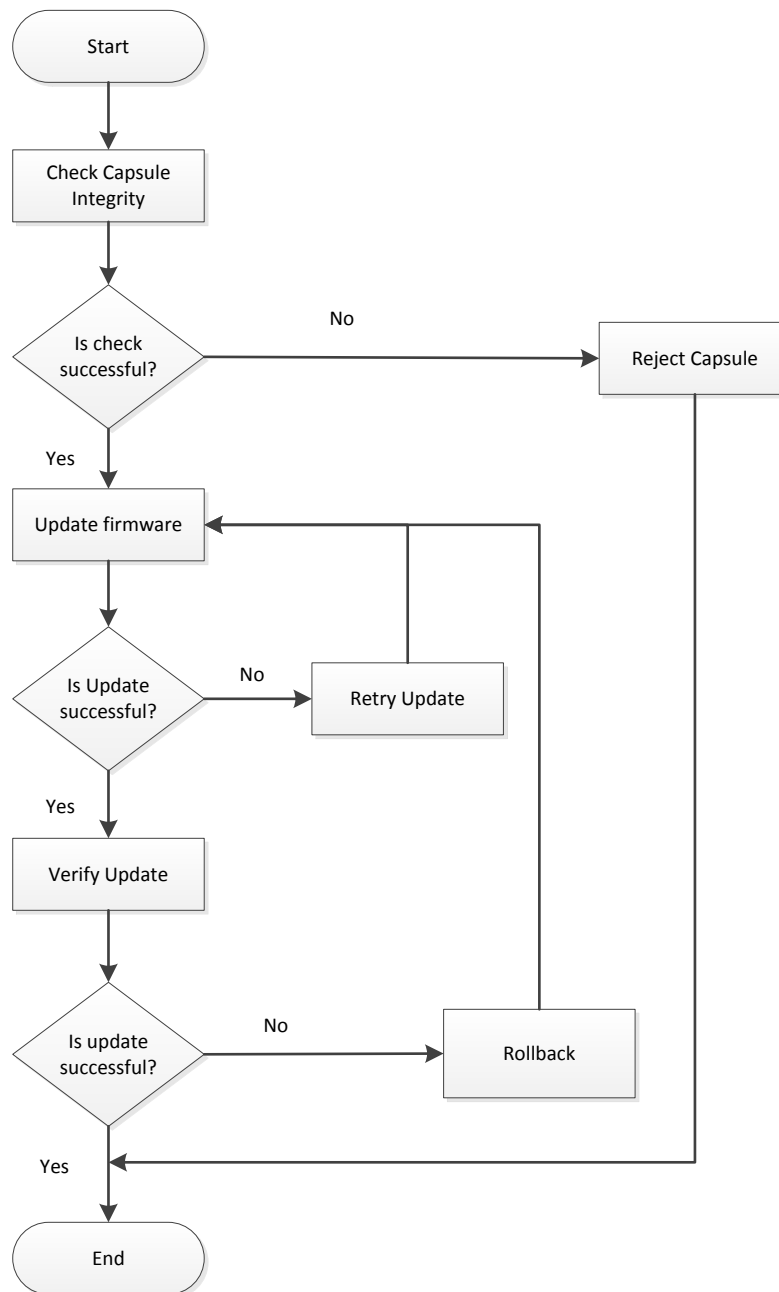


Figure 3: Typical Firmware Update Flow

One of the challenges in asserting firmware binary integrity is lack of a standard way of deploying the firmware. The UEFI specification offers support for capsule format. This specification can be uniformly applied to all updateable firmware ingredients on the platform. Typical layout of the capsule format is as depicted in Figure 4.

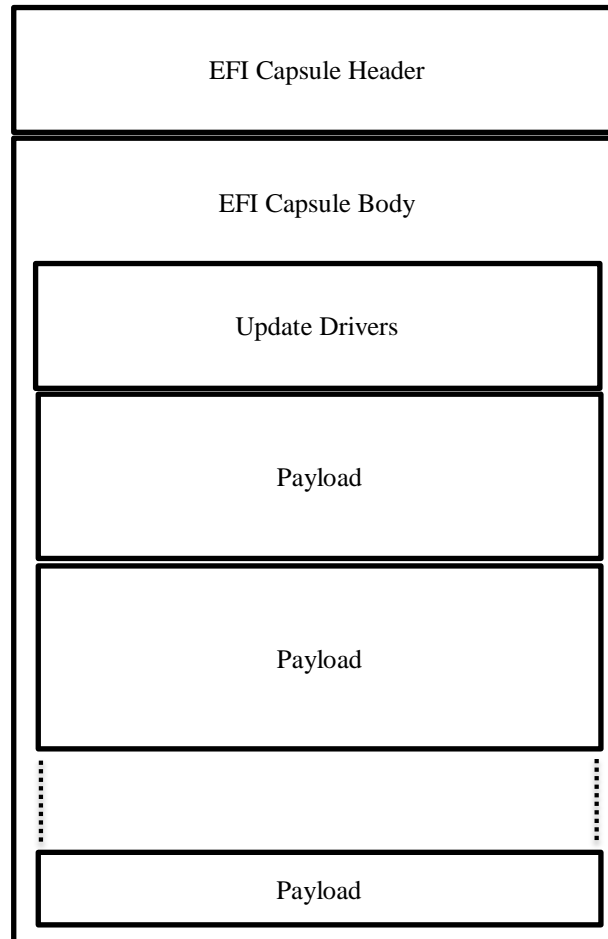


Figure 4: Capsule Format

Once the capsule format is adhered to by all platform firmware ingredients, the integrity check mechanism can be standardized. Also, the format is flexible and self-contained. In other words, the capsule format allows inclusion of update drivers within the capsule body. This approach has advantage as the update driver writer can use core BIOS support for various bus protocols for reading/writing to devices on buses such as SPI, HECI, KCS, I2C etc. Another advantage of capsule format is that multiple firmware images can be included in one capsule. Thus, both discrete as well as composite updates can be applied using EFI capsule format. The reference implementation of UEFI/PI includes tools for generation of capsules.

Another aspect of firmware updates is the ability to query the system for all the installed versions of various firmware elements on the system. This will be useful for both OS based as well as pre-boot based update mechanisms. A standard way to accomplish this is to publish EFI System Resource Table comprising of entries for each type of firmware update (Figure 5). The schema of such a table captures such information as a unique GUID entry denoting type of the firmware, current firmware version, and lowest version to which rollback is permissible, update status etc.

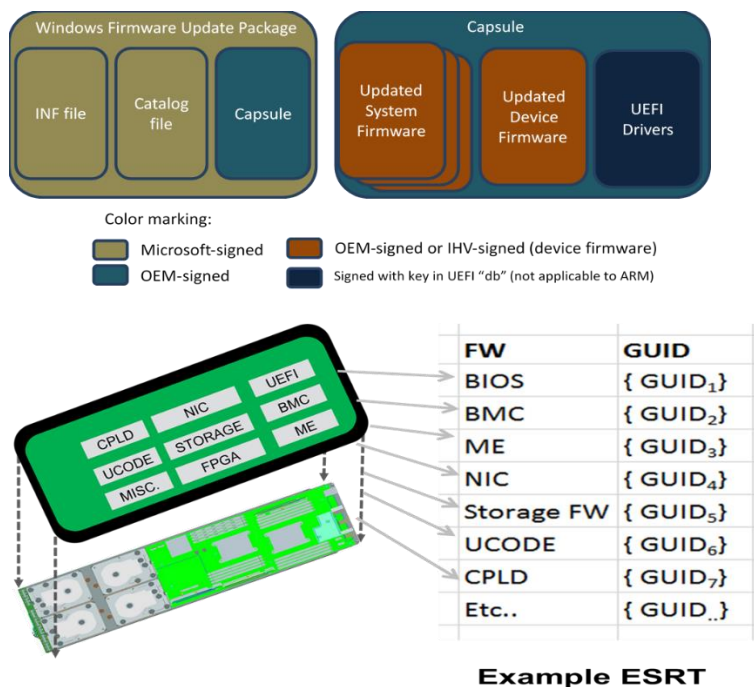


Figure 5: EFI System Resource Table

After a firmware update, one must verify that on-board chips are programmed correctly. If the update fails, typically an update is retried. If the update failures are persistent, a rollback must be attempted in order to reinstate the system into an operable condition. The UEFI 2.3 specification defines Firmware Management protocol which offers interfaces to validate, read and write firmware. The read interface, in particular, can be used to enact a rollback, if need be.

Summary

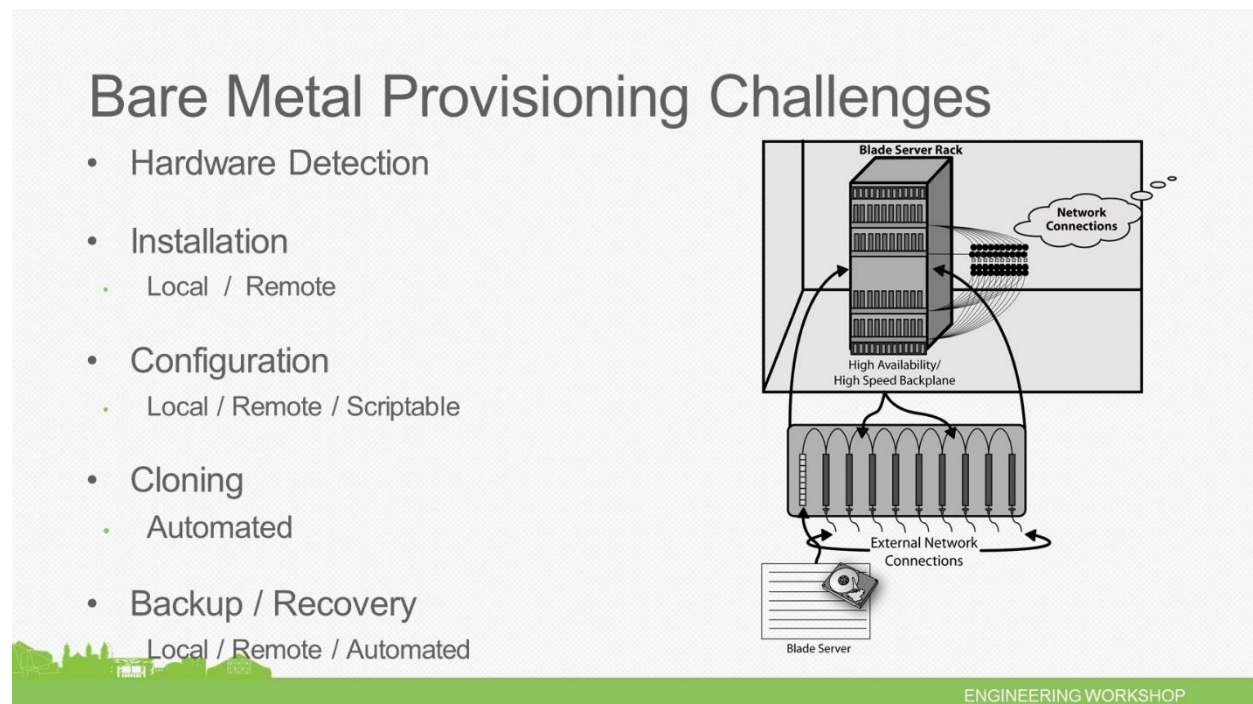
This section has provided an overview of firmware update.

Bare Metal Provisioning

This section will give an overview of bare metal provisioning.

Introduction

As shown in the figure below, the Cloud and warehouse-scale computes poses unique challenges for platform deployment. These challenges include how to detect the hardware, how to coordinate installation between an OEM system board and OSV operating system, configuring the system board, cloning the server so that an image can be mass-deployed to thousands of machines, and backing up settings in case of having to recover or re-deploy a machine. Given the scale of the machines, these tasks should be automated since having a user in front of each machine to do manual configuration is not economic.



The platform firmware has integral roles in provisioning. Whether it is the installation of an operating system during the factory or repurposing a data center, UEFI has many elements that come into play. There is the boot-strapping problem of how to get the OS or hypervisor onto the system board, or the chick-and-the-egg problem. UEFI was designed to allow for ease of OS installation and multi-booting. The mechanism put in place with UEFI provides a software environment for installation agents and OS loaders includes supplying mechanism to orchestrate discovery of boot code, managing policy of ‘from where to boot’ and ‘which console to use’ via the UEFI variables.

The bare metal provisioning scenarios where UEFI comes into play. For purposes of no touch automated installation, the UEFI Forum is now the maintainer of standards based network boot, such as PXE. PXE is both a wire protocol and API's. The API's to support IPV4, TFTP-based PXE can be found in the UEFI specification, and UEFI has also evolved those API's and the wire protocol to include IPV6. One key element of this evolution is RFC 5970 where the DHCP-based discovery of PXE has been extended to go from a file path to a URI. 5970 allowed for a discoverable IPV4 or IPV6 network boot to become:

- 'iscsi://address/bootfilename.efi'
- 'tftp://address/....'

Or HTTP. Or NFS. More information can be found at [UEFI-NETBOOT-BLOG].

This allows for evolving the boot experience, especially as there have been historical scaling issues and timeouts with connectionless protocols like UDP-based TFTP. Connection oriented platforms based upon TCP offer the future for scaling the network deployment of these large server deployments.

The UEFI specification provides blocking and non-blocking local block storage and networking API's to allow for high performance provisioning actions, such as reading an OS image from the network, overlapping I/O with compute like decompression, and writing to the local system board storage.

In addition, UEFI provides a very stylized means of configuration. [UEFI-CONFIG] describes some of the usages of the Human Interface Infrastructure (HII), which is a forms-based mechanism for configuration. Think of this as a richer variant of PC/AT BIOS CMOS settings. HII allows for having a set of internationalized questions or strings with corresponding settings in a binary format called IFR. HII forms can be presented by the system board for the equivalent of today's set, and the IHV drivers can also post HII. This allows for interoperable configuration. The forms also allow for scripting and cloning.

Finally, UEFI allows for mandatory persistent storage in the platform by way of the UEFI Variable interface. UEFI variables include mandatory elements to describe the boot policy, language, and settings. The authenticated variables include the ability to have owner control of updates via asymmetric cryptography. The binary encoding and storage medium of variables is not dictated by the specification, so options include local SPI NOR flash, BMC's, or other durable, protected stores in the system board.

More information on Authenticated Variables can be found in the "UEFI Networking and Pre-OS Security" paper [UEFI-ITJ].

- Need a 'no-touch', automated installation mechanism
 - Repurpose / Configure / Recover
- HII and IFR for consistent & scriptable configuration
- Non-blocking local disk and networking services for high throughput image delivery and recovery
- UEFI Variables for booting and Authenticated Variables for safe storage of settings, like UEFI secure boot database

The collage consists of five distinct diagrams:

- Top Left:** Illustrates the connection between hardware (motherboard, RAM), the Health Information Interface (HII), and external components like the System and Setup screen.
- Bottom Left:** Provides a detailed view of the TCP/IP network stack and its integration with the HII group, specifically highlighting network control stacks and drivers across multiple NIC controllers.
- Top Right:** Shows the interaction between the System, Setup screen, and Input devices.
- Bottom Right (Left):** A hierarchical tree diagram representing metadata and security information, such as ContentInfo, N/A, Certificate, X.509 Certificate, Type, Certificate, and Data Content.
- Bottom Right (Right):** Another hierarchical tree diagram focusing on signed hashes and extensions, linking them back to the Data Content.

is a figure depicting the implementation of the network stack in UEFI. In addition, provides a historical overview of the UEFI network stack.

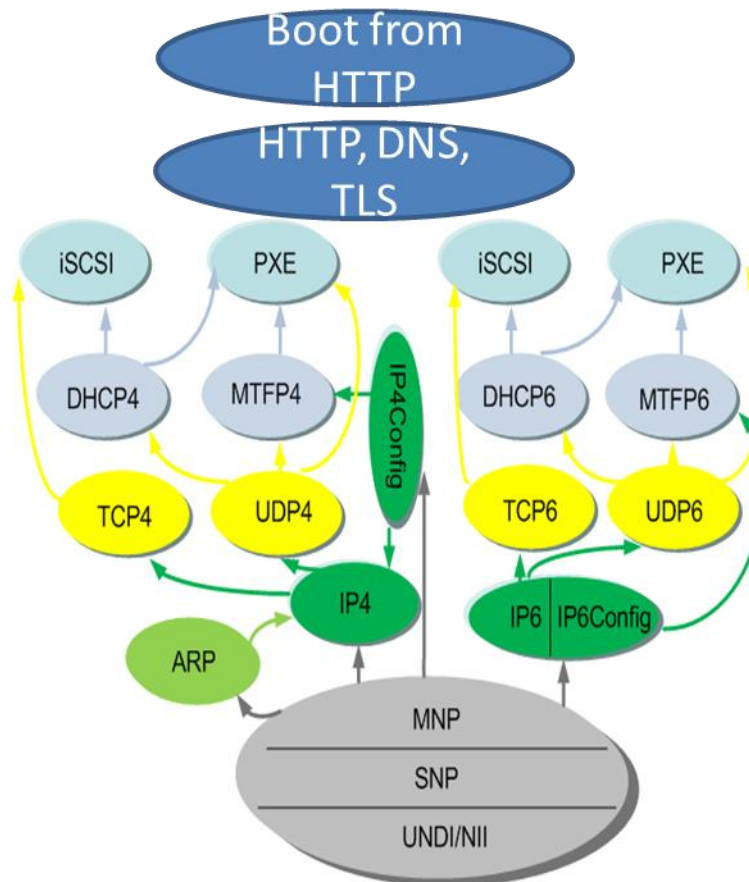


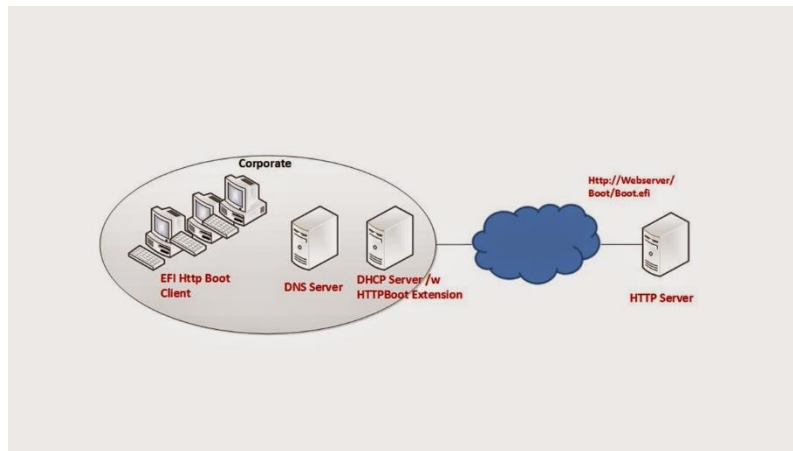
Figure: Network Stack in UEFI

The UEFI specification defines API's for both IPV4 and IPV6 networking. Other elements include VLAN, IPsec, ISCSI, TCP, and UDP. These API's are for pre-OS applications, such as deployment agents, OS loaders, and pre-OS applications. The UEFI specification also defines some wire protocols, such as netboot6, as the UEFI owns evolution of PXE.

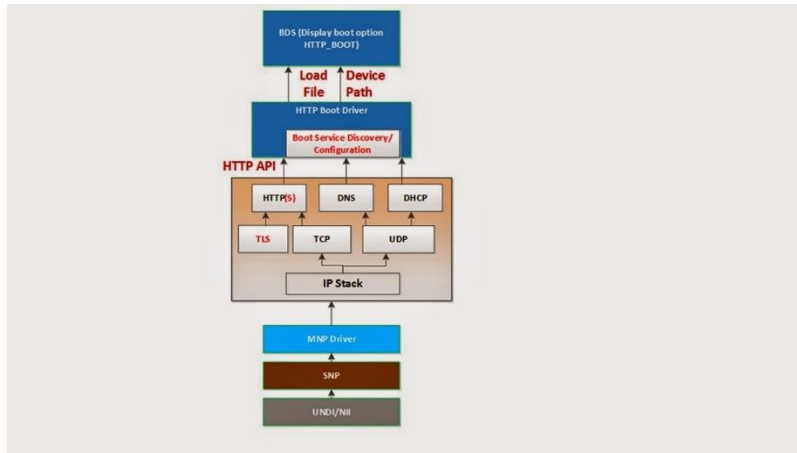
With the advent of UEFI2.5, the network boot experience was expanded. Specifically, the connectionless nature of today's PXE and netboot6, namely TFTP based upon UDP, led to scaling issues and time-outs. Non-standard based solutions [IPXE] started to prevail, thus the need for a standards-based approach. Enter UEFI2.5, PI1.4, and ACPI6.0.

Although I cannot hope to do this topic justice in this paper, below are some details on PI1.4 specification, ACPI6.0, and UEFI2.5, as described in the press release [UEFI-PRESS].

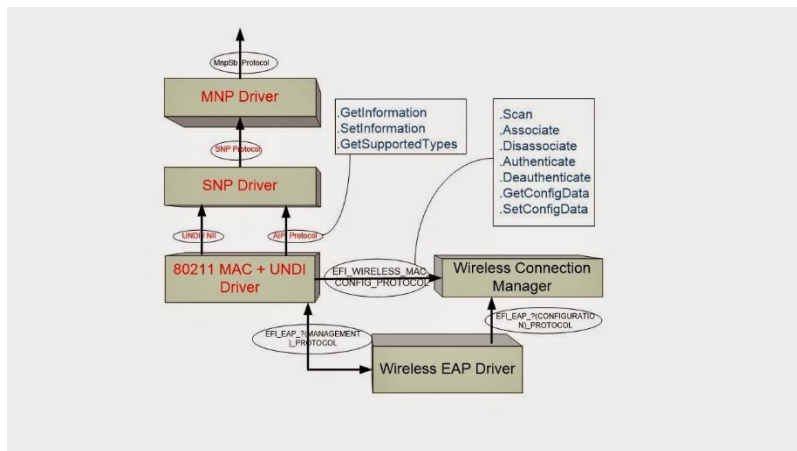
These specifications tie into the above discussion via a few threads. One thread is the need to evolve UEFI technology for the cloud, and to that end the boot-from-HTTP portion of the UEFI 2.5 specification squarely targets this space. Below shows schematically model of booting wherein TFTP (and thus UDP) based PXE can move to HTTP (and thus TCP) based booting. The move to a connection oriented protocol removes some of the chronic data center complaints, such as time-outs in "booting the Skynet" [SKYNET], or more formally, provisioning warehouse-scale computers [CLUSTER].



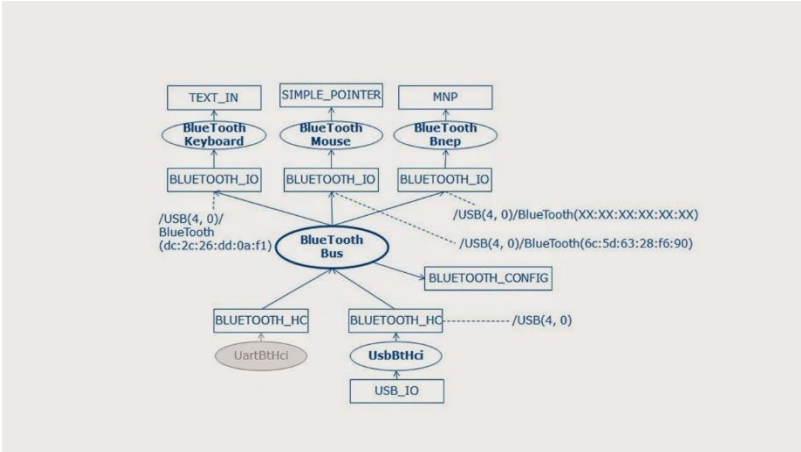
In addition to the wire protocols and DHCP extensions, additional API's for the network boot program were created, such as HTTP, DNS, and TLS. The latter allows for an optional boot-from-HTTP-s flow. This solution also allows for in-band and out-of-band RESTful [REST] messaging, such as required by emergent management interfaces [REDFISH]. Although many data centers use dark fibre and don't have threat models beyond the integrity concerns mitigated by UEFI Secure Boot [UEFI-ITJ], TLS allows for confidentiality cover where deemed necessary.



And TLS comes more into play in order to support another scenario enabled by the UEFI 2.5 specification, namely boot-from-wifi. Wi-Fi security requires a supplicant, which is typically EAP-TLS support. So the UEFI 2.5 specification updated EAP to work on concert with TLS for the WI-FI use case. Some of the WI-FI support is shown below.



In addition to WIFI, Bluetooth support was also added to the UEFI 2.5 specification. This allows for building IOT-style usages in UEFI, but more importantly works in tandem with WIFI above for the no-wires style usages found in today's phone, tablets, and slim laptops. Without this wireless evolution, UEFI and its wired networking support was becoming more of a server/datacenter technology and missing some of the prevailing client trends.



In order to support boot-from-HTTP, and other firmware network boot art, such as U-Boot, the [IANA] list has also evolved to support this boot usage:

Processor Architecture Types

Registration Procedure(s)

Expert Review

Expert(s)

Vincent Zimmer

Reference




[RFC5970]

Available Formats



CSV

Type	Architecture Name	Reference
0x00 0x00	x86 BIOS	[RFC5970] [RFC4578]
0x00 0x01	NEC/PC98 (DEPRECATED)	[RFC5970] [RFC4578]
0x00 0x02	Itanium	[RFC5970] [RFC4578]
0x00 0x03	DEC Alpha (DEPRECATED)	[RFC5970] [RFC4578]
0x00 0x04	Arc x86 (DEPRECATED)	[RFC5970] [RFC4578]

Type 	Architecture Name 	Reference 
0x00 0x05	Intel Lean Client (DEPRECATED)	[RFC5970] [RFC4578]
0x00 0x06	x86 UEFI	[RFC5970] [RFC4578]
0x00 0x07	x64 UEFI	[RFC5970] [RFC4578]
0x00 0x08	EFI Xscale (DEPRECATED)	[RFC5970] [RFC4578]
0x00 0x09	EBC	[RFC5970] [RFC4578]
0x00 0x0a	ARM 32-bit UEFI	[RFC5970]
0x00 0x0b	ARM 64-bit UEFI	[RFC5970]
0x00 0x0c	PowerPC Open Firmware	[Thomas Huth]
0x00 0x0d	PowerPC ePAPR	[Thomas Huth]
0x00 0x0e	POWER OPAL v3	[Jeremy Kerr]
0x00 0x0f	x86 uefi boot from http	[Samer El-Haj-Mahmoud]
0x00 0x10	x64 uefi boot from http	[Samer El-Haj-Mahmoud]
0x00 0x11	ebc boot from http	[Samer El-Haj-Mahmoud]
0x00 0x12	arm uefi 32 boot from http	[Samer El-Haj-Mahmoud]
0x00 0x13	arm uefi 64 boot from http	[Samer El-Haj-Mahmoud]
0x00 0x14	pc/at bios boot from http	[Samer El-Haj-Mahmoud]

Type ▾	Architecture Name ▾	Reference ▾
0x00 0x15	arm 32 uboot	[Joseph Shifflett]
0x00 0x16	arm 64 uboot	[Joseph Shifflett]
0x00 0x17	arm uboot 32 boot from http	[Joseph Shifflett]
0x00 0x18	arm uboot 64 boot from http	[Joseph Shifflett]
0x00 0x19-0xff 0xff	Unassigned	

In addition to boot-from-HTTP, DNS, TLS, wireless, Bluetooth, UEFI 2.5 also added REST support via a stylized API. REST can be built upon the new HTTP API for in-band networking usages, such as [REDFISH], or via out-of-band to a baseboard management controller (BMC), with the new BMC device path providing identity of the latter variant of the interface.

Summary

This section gives brief introduction UEFI and how it can help with provisioning.

This section provides an overview of platform security in UEFI.

Attack climate

The climate for platform attacks is ever increasing. As operating systems become successively more hardened, attacks have been migrating into the platform firmware. Below is a short example of some attacks against firmware, including 'boot kits', which are attacks on the first stage OS loader. UEFI Secure boot was primarily designed to combat this attack since the first stage loader and the platform firmware and a trust boundary between the system board OEM and OSV.

Attacks on Firmware

GrayFish boot steps

- Process Master Boot Record (MBR)
- Load Volume Boot Record (VBR)
- Load malicious VBR
- Patch Windows loader
- Load Windows kernel and boot drivers (up to Windows XP)
- Patch first loaded boot driver
- Load Windows Boot Manager (Windows Vista+)
- First loaded driver patcher

Hacking the Extensible Firmware Interface

John Heasman, Director of Research

Code Injection Attacks

- Important when firmware verifies digital signatures
 - Depends on implementation flaw in driver
 - e.g. stack overflow, heap overflow
 - or incorrect signature verification
- Plenty of targets:
 - File system drivers (e.g. FAT32, HFS+)
 - PE parsing code
 - Crypto code (Data in certs, ASN.1 decoding)
 - Network interaction (PXE)

DE MYSTERIIS DOM JOBSIVS: MAC EFI ROOTKITS

SHARE @ STSCAN SINGAPORE APRIL 2012

IN CONCLUSION... I HAD FUN.

So basically we're all screwed

- What should you do?
 - Glue all your ports shut
 - Use an EFI password to prevent basic local attacks
 - Stop using computers, go back to the abacus
- What should Apple do?
 - Implement UEFI Secure Boot (actually use the TPM)
 - Use the write-enabled pin on the firmware data flash properly
 - NB: They may do this on newer machines, just not my test one
 - Audit the device EFI code (see Heasman/ETL)
 - Secure the source, virgin

Network Nightmare

Ruling the nightlife between shutdown and boot with pxeexploit

Bootkits

Stoned Bootkit

Peter Kleissner

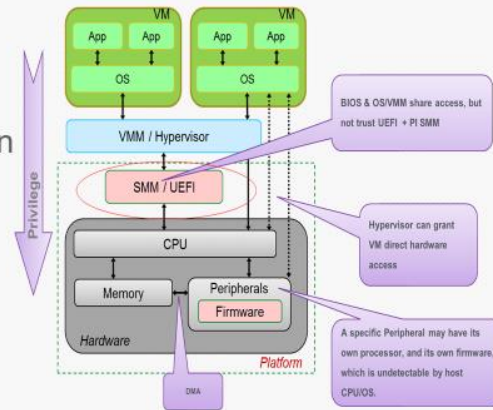
ENGINEERING WORKSHOP

The challenges in constructing the platform firmware for purposes of security are manifold. These include the fact that the platform firmware needs to correctly configure the system board hardware, discover and execute 3rd party code from HBA's, discovery and execute the operating system hand-off. In addition, portions of the firmware persist into the OS runtime via the UEFI runtime services or OS transparent execution modes like IA32/X64 System Management Mode (SMM). The OEM needs to protect the UEFI implementation from attacks since features like UEFI Secure boot are only of value if their controls and behaviors, as defined in the UEFI specification, are met by the implementation.

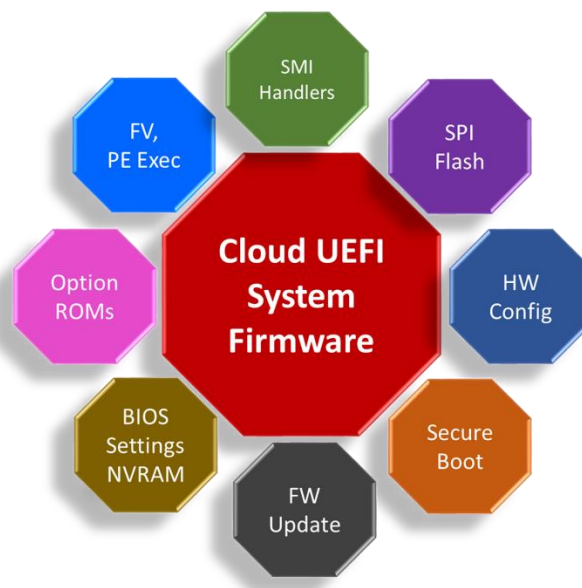
These security controls also need to scale in implementation and deployment. Any protection that needs local user access or cannot be scripted will inhibit deployment.

Security Challenges

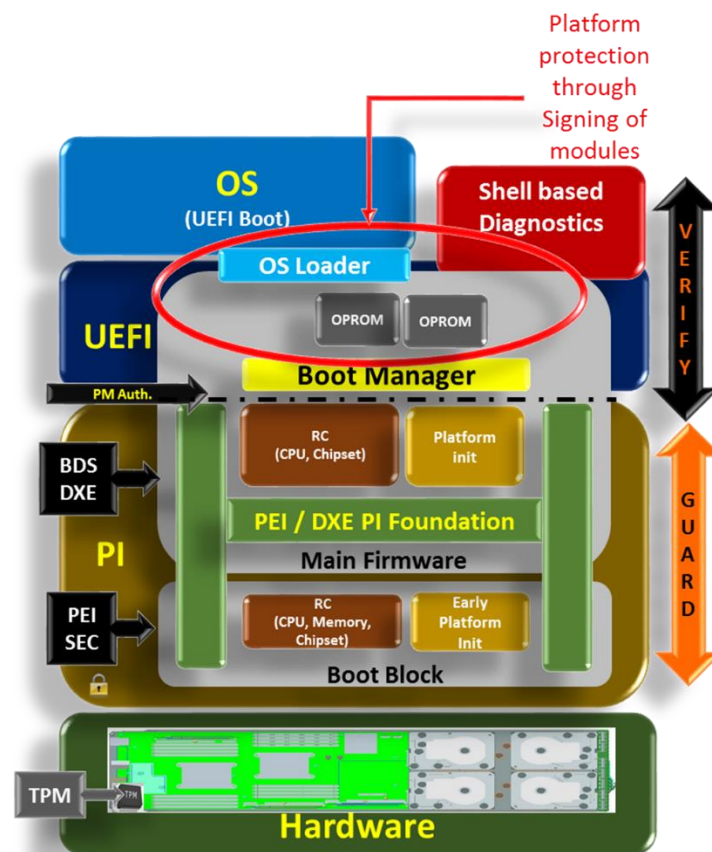
- Different elements in platform from many vendors
- How to establish trust anchor in the hardware
- How to protect elements
- How to protect the platform
- How to allow platform scaling



So in the context of platform security, UEFI brings many ingredients to the table as shown in below figure. These include a modular mechanism to load SMI handlers along with rules for their resource usage. In addition, UEFI provides mechanisms for exposing cryptographic hashing, secure boot of images, enveloping binary objects with cryptographic signatures, and authenticating the variables. The Trusted Computing Group (TCG) provides API's and guidance on how to integrate a Trusted Platform Module (TPM) in the platform. More information can be found at [UEFI-TRUST] , [UEFI-TRUST2] and [UEFI-TRUST3], too.

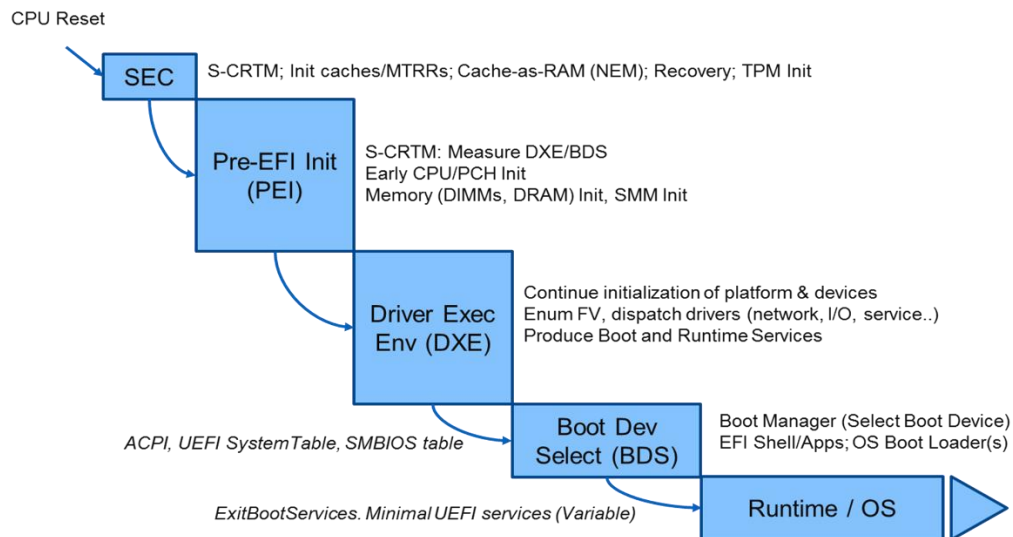


And when discussing security, you need to have a threat model in mind, including the assets in the platform and how they are to be protected. The presentation [UEFI-THREAT] describes a threat model for UEFI based systems. UEFI Secure Boot, as described in the UEFI 2.4b specification, is a critical capability in that it allows for protecting the underlying platform from possible pre-OS malware. In addition, the existence of the feature and a record of its usage in the TPM can inform the operating system or hypervisor that the machine was handed off in a trustworthy state. But as noted earlier, the implementation of the firmware and its protection from unwanted updates is imperative, and UEFI signed capsule updates and signed firmware images can help address that concern, including adherence to [NIST]. The figure below shows these protections in practice in a spatial, or layered view.



In addition to the spatial view shown above, a temporal view of platform security is in order. The figure below shows the UEFI Platform Initialization (PI) based boot flow. The SEC, PEI, and DXE are responsible for doing the basic platform initialization and germinating the UEFI services. In fact, you can think of DXE as the “UEFI Core”. All of these PI elements should be under the control of the platform supplier (PS) who will serve in the PS_Admin role. The Platform Owner (PO), who typically administers the operating system or hypervisor, services as the PO_Admin. For a vertically integrated supplier, the PS may be the same as the PO. After invoking BDS, the machine will admit 3rd party code. At this point, typically signaled by the End of Dxe Event, the DXE platform code should lock down the registers, flash parts, and any other elements that may be perturbed by untrusted third party code. The code prior to the BDS can be thought of as OEM-

extensible, and the latter to the right is third-party extensible. UEFI on the right provides for the rich interoperability between OEM, OSV, IHV, and ISV. To the left, the interoperability is typically between the CPU, SI component, board manufacturer, and the OEM. The latter extensibility should only be exposed in the factory or in the field view cryptographically signed updates, as described in the earlier firmware update chapter of this paper.



The latest UEFI specifications build upon this protection technology by making it more interoperable to have memory execution protection asserted. In addition, a new set of modes of the UEFI Secure Boot state machine, namely Audit Mode and Deployed Mode, have been introduced. This will allow for more options in provisioning UEFI Secure Boot from today's more rigid Setup Mode.

Finally, the above listed UEFI networking advances like "booting from a web server" can be combined by the OsRecoveryOrder variable to allow for more stylized support of operating system and OS loader recovery. Today recovery is ad hoc, with some vendors having a final boot option as the 'recovery agent,' or an OEM-specific flow invoked upon failure of the main boot paths. With the latest UEFI specification the recovery authorities and locations are explicitly exposed and hardened relative to today's boot options, which hearken back to 1998. Given the importance of up-time and robustness in the Cloud, the ability to recover in a more robust, interoperable fashion is another welcome addition of the UEFI2.5 into the Cloud deployments.

Summary

This section gives brief introduction of security for UEFI. This spans from the UEFI extensible environment down into the UEFI PI elements. Specific technologies and the intent of the specification, when reduced to practice, is also described.

Tools and Diagnostics

Introduction

Verifying compliance of a compute node to the underlying specifications before deployment is vital to commissioning of a datacenter. Also, any node / component failures during the operation of a datacenter must be identified in a timely manner before they can be repaired and restored to operation. Otherwise, there will be an impact to the overall capacity of the datacenter. Thus, one must invest in tools and diagnostics to address these issues.

Constructing platform as per well-defined specifications holds key to a viable story for developing tools and diagnostics (see below Figure).

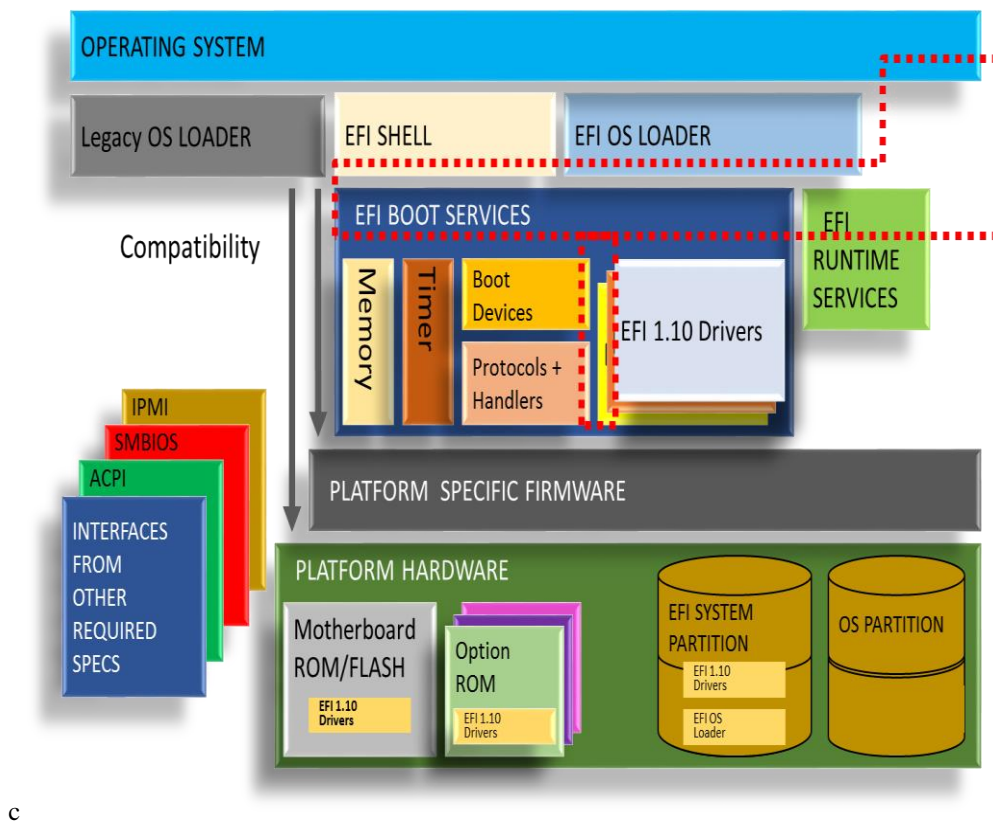


Figure: UEFI Stack overview

The UEFI specification provides a well-defined interactive execution environment for running tools and diagnostics by way of the UEFI Shell. The UEFI compliant BIOS can optionally include the UEFI shell. In addition, the shell comes with built-in commands for accessing memory, driver management, device access, and PCI configuration dump, file handling, etc. The UEFI also allows scripting, which can be used in automation.

```

EFI Shell version 2.00 [4096.1]
Current running mode 1.1.2
Device mapping table
fs0      :Removable HardDisk - Alias hd52g0b blk0
          Acpi (PNP0A03,0) /Pci (1D17) /Usb (6,0) /HD (Part1,Sig90909090)
blk0     :Removable HardDisk - Alias hd52g0b fs0
          Acpi (PNP0A03,0) /Pci (1D17) /Usb (6,0) /HD (Part1,Sig90909090)
blk1     :HardDisk - Alias (null)
          Acpi (PNP0A03,0) /Pci (1F12) /Ata (Primary,Master) /HD (Part1,SigD5BAE38B)
blk2     :HardDisk - Alias (null)
          Acpi (PNP0A03,0) /Pci (1F12) /Ata (Primary,Master) /HD (Part2,SigD5BAE38B)
blk3     :BlockDevice - Alias (null)
          Acpi (PNP0A03,0) /Pci (1F12) /Ata (Primary,Master)
blk4     :BlockDevice - Alias (null)
          Acpi (PNP0A03,0) /Pci (1F12) /Ata (Secondary,Master)
blk5     :Removable BlockDevice - Alias (null)
          Acpi (PNP0A03,0) /Pci (1D17) /Usb (6,0)

Press ESC in 1 seconds to skip startup.nsh, any other key to continue.
Shell> _

```

Figure: UEFI Shell command environment

Some of the tools that we can employ for specific

- UEFI SCT
- PI SCT
- ACPI Compliance
- SMBIOS Compliance

In addition, for the purposes of risk assessment, the chipsec [CHIPSEC] tool can be employed. This tool can be extended to meet specific platform concerns. The supported environments for this tool include Windows, Linux, and UEFI over Python.

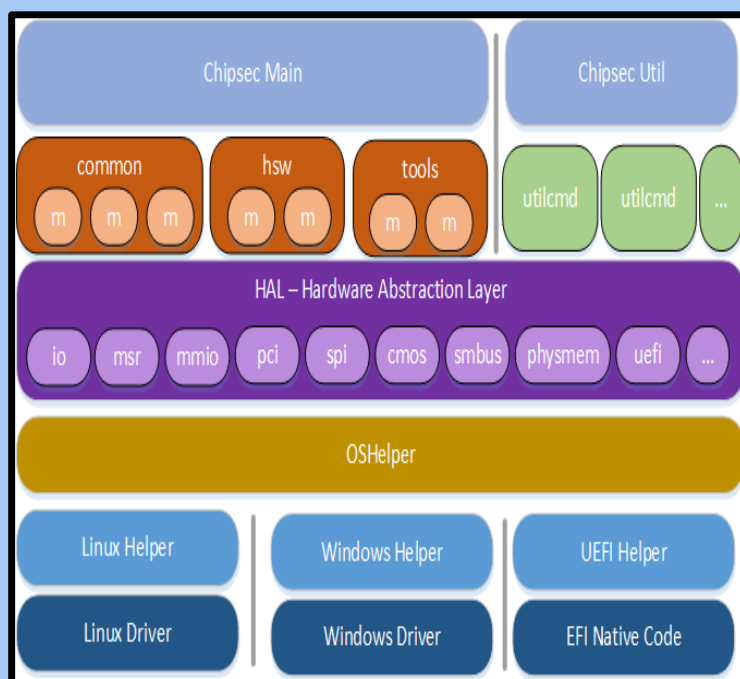


Figure: Chipsec tool architecture

The UEFI boot flow allows implementation of diagnostics OS (see Figure) as a last resort or terminal boot option. One instance of such a diagnostics operating system could be the Linux UEFI Validation environment that can either be hosted from service partition the local disk or over a network from a PXE service location.

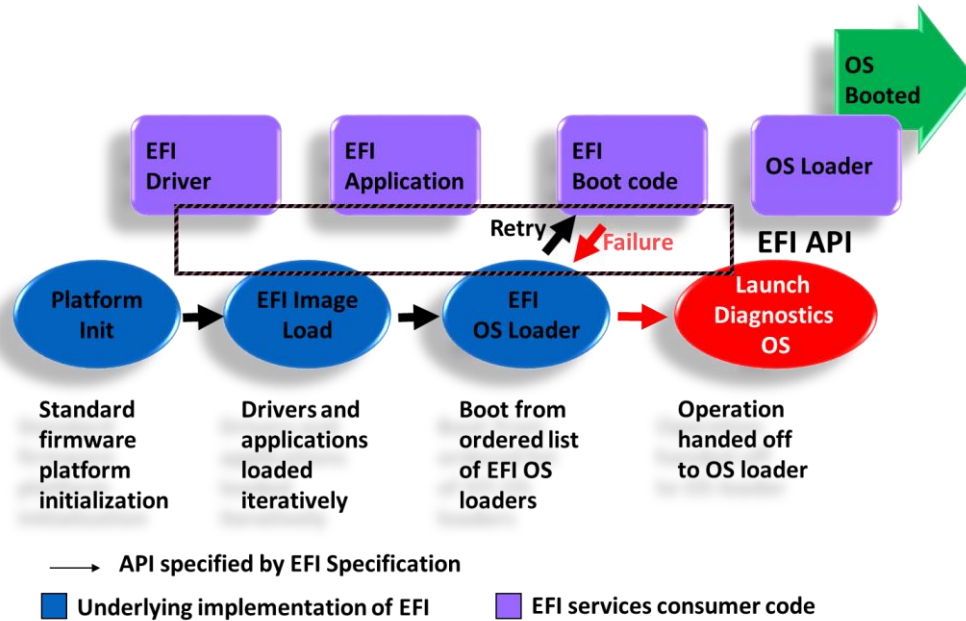


Figure: Example flow for launching diagnostics OS in UEFI

The platform BIOS can also use auxiliary processors such as BMC to log error records to SEL or report status codes using UEFI defined interfaces. This is one way a system can be diagnosed on a real-time basis. Optionally, the platform BIOS can implement BIOS Firmware Volume based logging to capture runtime errors. Tools can be easily developed to extract such errors to determine if a node needs to be serviced.

Conclusion

This paper has provided a brief overview the Cloud and the challenges that such scale-out environments pose. And it is in the face of such challenges that UEFI based technology could be brought to bear. These challenges and possible solutions include firmware update, diagnostics, provisioning, and security.

Glossary

ACPI – Advanced Configuration and Power Interface. The specification defines a new interface to the system board that enables the operating system to implement operating system-directed power management and system configuration. For more information on ACPI specification, visit <http://acpi.info/>

CHIPSEC: Platform Security Assessment Framework. The CHIPSEC is a framework for analyzing security of PC platforms including hardware, system firmware including BIOS/UEFI and the configuration of platform components. For more information on CHIPSEC, visit <https://github.com/chipsec/chipsec>

HECI – Host Embedded Controller Interface. The HECI is a technology used in Active Management Technology in Intel chipsets.

I2C - I2C is a serial protocol for two-wire interface to connect low-speed devices like microcontrollers, EEPROMs, A/D and D/A converters, I/O interfaces and other similar peripherals in embedded systems. For more information on I2C, visit <http://i2c.info/>

IPMI – Intelligent Platform Management Interface. The Intelligent Platform Management Interface (IPMI) defines common platform instrumentation to enable interoperability, extensibility, and scalability with intelligent hardware for enterprise-wide mission critical applications. For more information on IPMI, visit <http://www.intel.com/content/www/us/en/servers/ipmi/ipmi-home.html>

KCS – Keyboard Controller Style. The KCS is an interface used for communication between BMC and payload coprocessor in IPMI architecture.

OCP – Open Compute Project. The Open Compute Project Foundation is a community of engineers around the world whose mission is to design and enable the delivery of the most efficient server, storage and data center hardware designs for scalable computing. For more information on OCP, visit <http://www.opencompute.org/>

PCI – Peripheral Component Interconnect. The PCI bus is a local computer bus for attaching hardware devices in a computer. For more information on PCI, visit <https://www.pcisig.com/home>

PI – Platform Initialization. Volume 1-5 of the UEFI PI specifications. For more information on PI, visit <http://www.uefi.org/specifications>

SMBIOS – System Management BIOS. The System Management BIOS (SMBIOS) is the premier standard for delivering management information via system firmware. Since its release in 1995, the widely implemented SMBIOS standard has simplified the management of more than two billion client and server systems. For more information on SMBIOS, visit <http://www.dmtf.org/standards/smbios>

TPM – Trusted Platform Module. Trusted Platform Module (TPM) is an international standard for a secure crypto-processor, which is a dedicated microprocessor designed to secure hardware by integrating cryptographic keys into devices. For additional information on TPM, visit http://www.trustedcomputinggroup.org/developers/trusted_platform_module

UEFI – Unified Extensible Firmware Interface. Firmware interface between the platform and the operating system. Predominate interfaces are in the boot services (BS) or pre-OS. Few runtime (RT) services. For more information on UEFI, visit <http://uefi.org/>

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[OCP] Open Compute Project, <http://www.opencompute.org>

[PI1.4] UEFI PI 1.4 specification http://www.uefi.org/sites/default/files/resources/PI_release_1_4.zip

[REDFISH] Redfish Specification <http://www.redfishspecification.org/>

[REST] Representational State Transfer
http://en.wikipedia.org/wiki/Representational_state_transfer

[SKYNET] the Skynet computer http://en.wikipedia.org/wiki/Skynet_%28Terminator%29

[UEFI] Unified Extensible Firmware Interface (UEFI) Specification, Version 2.4.b
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