Intel and McAfee: Hardening and Harnessing the Secure Platform

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Agenda

• UEFI & PI Security Overview
• Hardening the Platform & Development Assurance Practices
• Introducing McAfee* Endpoint Encryption
• Value Proposition of a Secured Preboot
• Maintaining the Chain of Trust
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Pressure on BIOS

- Industry requirements (ex. UEFI 2.3.1+ Ch 27, TCG)
- Government requirements (ex: US NIST SP800-147)
- Product dvlp requirements (ex. SDL)
- Customers requiring security (ex. US DoD, Corporate IT)
- Malware (ex. Chernobyl, 2000 Bootkits, 2011 etc)
- Researchers (ex. Invisible Things Lab BMP attacks 2004)
What is UEFI? UEFI Platform Initialization Overview

- UEFI 2.3.1c specifies how firmware boots OS loader and drivers—3rd party extensible
- UEFI’s Platform Initialization (PI) 1.2.1
- Architecture specifies how Driver Execution Environment (DXE) Drivers and Pre-EFI Initialization (PEI) Modules (PEIMs) initialize Silicon and the platform
- DXE is preferred UEFI Implementation
- PEIMs, UEFI and DXE drivers implements networking, Update, other security features - Only Update by the OEM

Full system stack (user -> hardware)
Boot flow and Integrity

UEFI Protects through the Boot Flow
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Development Practices - Themes

• Practice defense in depth
  – Use several protection layers when designing and implementing security mechanisms
• Do not rely on security by obscurity
• Fail intelligently, Fail Safe
  – Fail secure – fail closed
    ▪ Robust crisis recovery, signed updates/signed recovery FV, etc.
  – Don’t provide hints to hackers (e.g., by disclosing information on failure).
  – Log errors and failures for auditing
    ▪ Trusted Computing Group (TCG) measured boot
• Check all return values
• Keep security critical code short and simple
Development Practices – Code Review

- Avoid unsafe calls (e.g., gets() equivalent)
- ASSERTs that should be error checking
- Check for valid input and reject everything else
- Perform sanity checks and bound checks – Check Type, Length, Range, Format
- Validate as much and as deep as possible to prevent unintended errors if code is changed; balance against coding time/performance
- Be careful of boundary conditions (e.g., off-by-one errors, array indices) and conditionals (e.g., reverse logic)
- Don’t implement your own crypto algorithms or protocols

Intel® UEFI Development Kit 2010 (Intel® UDK2010) uses OpenSSL* to meet the spirit of this

It’s not implementing the feature, but also how you write the code
Defensive Coding – Adding Robustness

• Validate input before using
  – Network packet
  – On-disk data structures/GPT
  – UEFI Variables
  – Device paths

• Storing secrets
  – Avoid if possible
  – Clear buffers to zero when done

• Key management
  – Access control storage to PI elements. SMM based authenticated variable driver in Intel® UDK2010.

• Fuzz testing
  – SCTS – positive testing “Does it work with expected input”?
  – Fuzzing is negative testing “What happens with unexpected input?”

It’s not just functional verification
Example of Safe Versus Unsafe Code

Example: Validate all input

```c
PartEntry = AllocatePool (PrimaryHeader->NumberOfPartitionEntries
* sizeof (EFI_PARTITION_ENTRY));
Status = DiskIo->ReadDisk ( DiskIo,
MediaId,
MultU64x32(PrimaryHeader->PartitionEntryLBA, BlockSize),
PrimaryHeader->NumberOfPartitionEntries * (PrimaryHeader->SizeOfPartitionEntry),
PartEntry);
```

Problem:
- The memory is allocated with A
- However, ReadDisk block is with B
- Buffer overflow occurs when the code reads a GPT with C

Fix:
```c
PartEntry = AllocatePool (PrimaryHeader->NumberOfPartitionEntries
* PrimaryHeader->SizeOfPartitionEntry);
```

Rationale for Input Validation

UDK2010 example:
## Technologies – Putting it Together

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<th>Reset</th>
<th>Assets</th>
<th>Threats</th>
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<td><strong>BIOS Flash</strong>&lt;br&gt;Hardware protection</td>
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<td><strong>System BIOS</strong>&lt;br&gt;-PEI recovery.&lt;br&gt;-SMM, UEFI Core.&lt;br&gt;-PK, KEK, CRTM</td>
<td>Erase flash part&lt;br&gt;Overwrite flash part</td>
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<td><strong>Option ROMs</strong>&lt;br&gt;UEFI drivers</td>
<td>Erase op ROM&lt;br&gt;Overwrite op ROM</td>
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<td><strong>Network Boot</strong>&lt;br&gt;IPv6 for the cloud</td>
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<td><strong>Pre-OS UEFI application</strong>&lt;br&gt;OS Boot loader, McAfee*&lt;br&gt;<strong>Endpoint Encryption</strong></td>
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**Different colors for different vendors**
Agenda

• UEFI & PI Security Overview
• Hardening the Platform & Development Assurance Practices

• Introducing McAfee* Endpoint Encryption
  – Product Overview
  – What is Full Disk Encryption?
  – UEFI Preboot Application
  – GPT Disks
  – Endpoint Encryption and the Boot process

• Value proposition of a Secured Preboot
• Maintaining the Chain of Trust
Product Overview

• McAfee endpoint encryption is a Full Disk Encryption product
  – Provides “data at rest” protection
  – Operating system data and user data is encrypted at the sector level

• Strong encryption algorithms protect data
  – Various methods of encrypting data are available
    ▪ Software based AES256 CBC
    ▪ Hardware accelerated AES256 CBC using AES-NI instructions
    ▪ Self encrypting disks
What is Full Disk Encryption?

- Full Disk Encryption encrypts data at the sector level
  - The product has no knowledge of directories or files
  - The encryption is completely transparent to the file system
  - A disk can be partially encrypted and still operate normally; this allows the system to be encrypted online
Endpoint Encryption Pre-Boot Application

• Encrypted disk data cannot be accessed until a user authenticates and the encryption key is obtained
• Operating system kernel and critical files lie within the encrypted data on disk
• A “Pre-Boot Application” (PBA) is required to authenticate and unlock the disk

• The McAfee* Endpoint Encryption PBA is a UEFI application
  – Started by the UEFI Boot Manager before the Windows* bootloader
  – Uses standard UEFI protocols for GUI implementation (Graphics Output Protocol, Simple Pointer Protocol, etc.)
  – Supports USB smartcard readers and tokens using standard USB protocol
McAfee* PBA: Unlocking Your Data

- Disk is unlocked by authenticating using McAfee* Endpoint Encryption Pre-Boot Application (PBA)
- User authenticates using token; password, smartcard, recovery process, etc.
- Once authenticated, the token releases the disk encryption key
- The disk encryption key is used to gain access to the encrypted data on disk
GPT Disks: What’s Encrypted?

- Some parts of the disk need to remain unencrypted
  - Endpoint Encryption PBA is not implemented in firmware
  - PBA needs to be loaded from disk by UEFI boot manager
  - Disk must be recognisable by UEFI partition and file system drivers in order to load PBA
GPT Disks: What’s Encrypted?

- Protective MBR, GPT Headers and Partition Tables cannot be encrypted
  - The data in these regions is required before the disk is unlocked
  - The disk would not be recognised as a valid GPT disk and the system would be unable to boot
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- EFI System Partition cannot be encrypted
  - Contains the executable McAfee* Endpoint Encryption preboot application image that is run by the UEFI Boot Manager
  - Also contains the Block I/O driver that performs the sector level encryption/decryption when authenticated
GPT Disks: What’s Encrypted?

- **PMBR**
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- **EFI System Partition**
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  - Also contains the Block I/O driver that performs the sector level encryption/decryption when authenticated

- **Endpoint Encryption Data Partition**
  - Contains themes and localisation data for PBA
  - Contains database of users and token data
  - All data is required by the PBA prior to the disk being unlocked
The Boot Process

**UEFI Boot Services**

- UEFI Boot Manager
- Endpoint Encryption PBA
- Windows Bootloader

**ExitBootServices()**

**Windows**

- Windows Kernel Startup
- Logon Screen
- Desktop/Windows 8

**Encryption**

- Encryption Block I/O Filter
- Encryption Disk Filter Driver

Start -> Read -> Start -> Read -> Load -> Write -> Read
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• Introducing McAfee* Endpoint Encryption

• Value proposition of a Secured Preboot
  – What does “Secure Platform” Mean for Endpoint Encryption?
  – Malware Threat for Endpoint Encryption preboot

• Maintaining the Chain of Trust
What does “Secure Platform” Mean?

• There are some considerations for deploying UEFI applications and drivers on a secure platform
  – All UEFI applications and drivers must be signed
  – The image hashes or signing certificate must be trusted by the platform
  – UEFI applications and drivers need to be careful not to execute untrusted code

• Secure Boot provides benefits to Endpoint Encryption
  – Without Secure Boot, the PBA is vulnerable to malware attacks; keyloggers, denial of service
  – Tamper-resistant PBA provides platform for checking integrity of configuration files – signed policies

Maintain the Chain of Trust!
Malware Threat: Keylogger

```c
BS->LocateHandleBuffer(ByProtocol, &simple_text_input_ex_protocol_guid, NULL, &num_handles, &handles);
for (i = 0; i < num_handles; ++i) {
    BS->OpenProtocol(handles[i], &simple_text_input_ex_protocol_guid, &st, ImageHandle, NULL, EFI_OPEN_PROTOCOL_GET_PROTOCOL);
    hooked_protocols[i].st = st;
    hooked_protocols[i].orig_read_key_ex = st->ReadKeyStrokeEx;
    st->ReadKeyStrokeEx = keylogger_read_keystroke_ex;
}

// Now chain load the original bootcode “EpeBoot.efi”
```

- All devices supporting EFI_SIMPLE_TEXT_INPUT_EX_PROTOCOL are enumerated representing keyboards and input devices at A.
- A pointer to each protocol is obtained at B.
- The function pointer that is used to obtain keystrokes is replaced with a function that logs the keystrokes and chains to the original at C.
- The keylogger application loads and executes the original subverted UEFI application at D.
Malware Threat: Keylogger Installation

- Original, uncompromised boot:

- Without Secure Boot, installation of the keylogger is simple:

  ```
  C:\> mountvol /s z:
  C:\> copy z:\EFI\McAfee\EpeBoot.efi z:\EFI\McAfee\EpeOrig.efi
  C:\> copy f:\keylogger.efi z:\EFI\McAfee\Epe\EpeBoot.efi
  ```

- Following a system reboot:
  - Without Secure Boot the keylogger is allowed to run
  - Endpoint Encryption PBA will execute but all keystrokes will be logged to disk
Malware Threat: Keylogger Installation

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  ```

- Following a system reboot:

  - Without Secure Boot the keylogger is allowed to run
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*With Secure Boot, execution of the keylogger is prevented*
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• Maintaining the Chain of Trust
  – Chain of Trust Considerations
  – What can go wrong?
  – Handling Loadable Modules/Data Files
  – Example Data File Breach
Chain of Trust: Considerations

• Why is the chain of trust important to Endpoint Encryption?
  – The chain of trust prevents malware from performing malicious actions such as keylogging or preventing the system from booting
  – Hardened boot process enables Endpoint Encryption PBA to validate configuration files – Trusted Data
    ▪ Policy files and other important configuration files can be signed using a certificate
    ▪ Certificate can be embedded in trusted UEFI application

• What needs to be considered?
  – Care must be taken to ensure the Chain of Trust can not be broken by unauthorised loadable modules or invalid data
What Can go Wrong?

- Even with Secure Boot the chain of trust can be broken if care is not taken

- Secure Boot ensures the Endpoint Encryption PBA and Windows* Bootloader are authentic
- PBA loads and executes Block I/O filter driver
- PBA loads and processes configuration and data files
- Careless coding may provide an exploitable bug to malware
Chain of Trust: Loadable Modules

• The Endpoint Encryption UEFI application allows for plugin modules
  – Used for adding support for USB smartcard readers

• This poses a risk to the chain of trust
  – It is the responsibility of the Endpoint Encryption UEFI application to ensure untrusted code cannot be executed

• The problem is easily solved:
  – Loadable modules are built as UEFI drivers
  – The modules are loaded using the Boot Services “LoadImage()” function
  – If the loadable module is not trusted by the platform, “LoadImage()” returns EFI_SECURITY_VIOLATION
  – The chain of trust is maintained!
Chain of Trust: Data Files

• Why are data files a threat to the Chain of Trust?
  – The McAfee* Endpoint Encryption PBA uses many configuration files
  – Malware may maliciously modify configuration files to attempt to crash the PBA
  – Modified configuration files can be engineered to execute malicious code
    ▪ Common exploits overflow stack variables to modify function return address to jump to unauthorised code
    ▪ *The chain of trust is broken!*

• How can this be prevented?
  – *All* buffers that are populated from disk are carefully checked to prevent overflow
  – Data file signing can be used to verify authenticity of files
Data File Threat

- Structure that mimics user file on disk is defined at A.
- Fixed length buffer assigned on stack at B.
- Memory copied from disk buffer to stack without validating input at C. Stack has been compromised.
- Return address D from function jumps to malicious code.
Example: Malicious Data

- Malicious data can be used to exploit poorly written code

Validate all configuration and input!
Summary

- Platform security is maintained by a combination of hardware and software using many technologies and specifications
- UEFI Secure Boot is a vital part of the chain that keeps the platform protected
- Malware infiltration during the boot process is prevented by the Chain of Trust
- McAfee* Endpoint Encryption adds data security to the hardened security provided by the Secure Boot process
- Precautions need to be taken when writing software to prevent the Chain of Trust from being breached
Get More Information

• Intel UEFI Community - [http://intel.com/udk](http://intel.com/udk)
• UEFI Forum Learning Center
• Use the TianoCore [edk2-devel mailing list](mailto:edk2-devel@lists.sourceforge.net) for support from other UEFI developers
• Read the “A Tour Beyond BIOS into UEFI Secure Boot” whitepaper at [tianocore.org](http://tianocore.org)

• Technical Showcase Booth #946
## Other UEFI Sessions @ IDF

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<td>Developing UEFI Support for Linux*</td>
<td>2008</td>
<td>Tue</td>
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<td>Using Wind River Simics* Virtual Platforms to Accelerate Firmware Development</td>
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