Universal Scalable Firmware: Security Aspects of an Evolutionary Approach to System Firmware

Vincent Zimmer and Jiewen Yao (Intel)
UEFI 2023 Virtual Plugfest
Jiewen Yao

• **Jiewen Yao** is a principal engineer in the Intel Software and Advanced Technology Group. He has been engaged as a firmware developer for over 15 years. He is a member of the UEFI Security Sub Team, and co-chairing TCG PC Client Working Group and DMTF SPDM Code Task Force.
Vincent Zimmer

- **Vincent Zimmer** is a senior principal engineer in the Intel Software and Advanced Technology Group. He has been engaged w/ firmware for over 30 years and presently leads the UEFI Security sub team.
More Questions?

Following today’s webinar, join the live, interactive WebEx Q&A for the opportunity to chat with the presenters.

Visit this link to attend: https://bit.ly/3xkLPQR
Meeting number: 2554 924 4620
Password: UEFIForum (83343678 from phones and video systems)
Agenda

- Universal Scalable Firmware (USF) Overview
- Security Hardening
- OpenSSL 1.1 EOL Update
- Commercial National Security Algorithm (CNSA) Compliance
What is Universal Scalable Firmware (USF)?

- Multi-layer view of the firmware stack
  - Interfaces for boot environments (payload), platform code (EDKII, coreboot, slim bootloader, etc)
- Interfaces and infrastructure at different levels
- [https://github.com/universalscalablefirmware](https://github.com/universalscalablefirmware) for code and spec sources
- [https://universalscalablefirmware.groups.io/g/discussion](https://universalscalablefirmware.groups.io/g/discussion) for community discussions
- [https://www.youtube.com/watch?v=oEBtWsBZve4&list=PLehYIRQs6PR6J9Zf6CajwsFkAHedDXjLI&index=13](https://www.youtube.com/watch?v=oEBtWsBZve4&list=PLehYIRQs6PR6J9Zf6CajwsFkAHedDXjLI&index=13) for past meetings
- [https://universalscalablefirmware.github.io/documentation/](https://universalscalablefirmware.github.io/documentation/) for the ‘compiled’ specification
Today’s Talk – Security Impacts of USF to UEFI and EDKII ecosystem

5. Security

5.1. Security Overview

There are various security considerations for the various overall concerns and technology specific aspects.

5.1.1. Firmware Resiliency - Protection

5.1.1.1. Critical Resource Lock (hardware)

The platform shall always lock the important resource before it exits the platform manufacture phase.
USF Security Topic Areas

5. Security

5.1. Security Overview
- 5.1.1. Firmware Resiliency - Protection
- 5.1.2. Firmware Resiliency - Detection
- 5.1.3. Firmware Resiliency - Recovery
- 5.1.4. Measurement and Attestation
- 5.1.5. DMA Protection
- 5.1.6. Cryptography Agility

5.2. Vulnerability Mitigation Strategy
- 5.2.1. Eliminate Vulnerability
- 5.2.2. Break Exploitation
- 5.2.3. Contain Damage
- 5.2.4. Limit Attack Window

Reference: https://universalscalablefirmware.github.io/documentation/5_security.html
Continue Strengthening the Supply Chain


- Type-II-B indicates the one loaded from peripheral device, such as NIC, NVMe, Graphic Card.

For Type-I firmware, the component provider may provide a reference integrity manifest (RIM) for this specific component.

Intel FSP 2.x measurement and attestation defines a mechanism to report FSP manifest according to TCG PC Client Reference Integrity Manifest Specification. The RIM format could be SWID or CoSWID.

The universal payload should use SWID or CoSWID with below information:

<table>
<thead>
<tr>
<th>Element</th>
<th>Attribute</th>
<th>Required</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Identity</td>
<td>Name</td>
<td>Required</td>
<td>Name of the Universal payload</td>
</tr>
<tr>
<td></td>
<td>Version</td>
<td>Required</td>
<td>Version of the Universal payload</td>
</tr>
</tbody>
</table>
# Security Assurance

<table>
<thead>
<tr>
<th>Tactics</th>
<th>Method</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliminate Vulnerability</td>
<td>Reduce Attack Surface</td>
<td>• Remove Unnecessary Interface, e.g. SMI handler, private auth variable.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Adopt Firmware Security Best Practice (<a href="https://universalscalablefirmware.github.io/documentation/5_security.html">EDKII security docs</a>, <a href="https://universalscalablefirmware.github.io/documentation/5_security.html">OCP Secure Firmware Development Best Practices</a>)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Address Space Layout Randomization (ASLR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Non-executable Data Page. Read-only Code page.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Stack Cookie</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Intel Control Flow Enforcement Technology (CET) – Shadow Stack (SS), Indirect Branch Tracking (IBT).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ARM Pointer Authentication Code (PAC), Branch Target Identification (BTI).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ASLR in DXE/SMM</td>
</tr>
<tr>
<td>Break Exploitation</td>
<td>• Data Execution Prevention (DPE)</td>
<td>• Non-executable Data Page. Read-only Code page.</td>
</tr>
<tr>
<td></td>
<td>• Control Flow Guard (CFG)</td>
<td>• Stack Cookie</td>
</tr>
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</tr>
<tr>
<td>Contain Damage</td>
<td>Deprivilege</td>
<td>Ring-3 Third Party Option ROM. Ring-3 OEM SMM</td>
</tr>
<tr>
<td>Limit Attack Window</td>
<td></td>
<td>• Live Patching Runtime Component</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Firmware Vulnerability Scan</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Supply chain - firmware manifest (SBOM)</td>
</tr>
</tbody>
</table>

Reference: [https://universalscalablefirmware.github.io/documentation/5_security.html](https://universalscalablefirmware.github.io/documentation/5_security.html)
Possible Security Hardening

• Data Execution Protection (DEP) & Arbitrary Code Guard (ACG)
  • Image Protection
  • Non-Executable Memory protection
  • OS Loader Protection
  • SMM Code Access Check
• NULL pointer detection
• Address Space Layout Randomization (ASLR)
  • Data Buffer Shift
  • Image Shuffle

• Buffer Overflow Detection
  • Heap Guard
  • Stack Cookie
  • Address Sanitizer
• Misc Runtime Check
  • Undefined Behavior Sanitizer (Type Cast)
  • Memory Sanitizer (Uninitialized Access)
• Control Flow
  • Backward: CET Shadow Stack, ARM PAC
  • Forward: CET IBT, ARM BTI

Reference: https://github.com/jyao1/SecurityEx/blob/master/Summary.md
However ...

• UEFI / PI / APCI are interface specifications

• How do we let end users know what protection is available?
Example

- **Windows SMM Security Mitigation Table (WSMT)**
  - Allows system firmware to confirm to the operating system that certain security best practices have been implemented in SMM
  - [https://download.microsoft.com/download/1/8/a/18a21244-eb67-4538-baa2-1a54e0e490b6/wsmt.docx](https://download.microsoft.com/download/1/8/a/18a21244-eb67-4538-baa2-1a54e0e490b6/wsmt.docx)

- **Windows Hardware Security Test Interface (HSTI)**
  - Specifies a standard test interface for proprietary platform security technologies that enforce the Secure Boot promise

- **TCG Platform Firmware Integrity Measurement**
  - Platform Firmware Assertions can be reported in the platform certificate.
  - E.g. HardwareSRTM, SecureBoot, sp800-147, sp800-193, fwSetupAuthLocal, SMMProtection, fwKernelIDMAProtection, etc.
  - [https://trustedcomputinggroup.org/resource/tcg-pc-client-platform-firmware-integrity-measurement/](https://trustedcomputinggroup.org/resource/tcg-pc-client-platform-firmware-integrity-measurement/)
Request For Comment

• **Platform Integrity Mitigation Table (PIMT)**
  • Specifies the mitigation applied in the system firmware
    • DEP.CodeProtection, DEP.NonExecutableData, NULLPointerProtection, ASLR.BufferShift, ASLR.ImageShuffle, CFG.Backward, CFG.Forward
  • Could be ACPI table or GUIDed UEFI system table
    • ACPI better since all of ACPI most common across all platform implementations (slim, core, and EDKII)
Openssl 1.1 EOL

• Openssl 1.1 will be at EOL on September 2023
  • https://www.openssl.org/policies/releasestrat.html

• EDKII needs a replacement.
  • https://github.com/tianocore/edk2-staging/tree/OpenSSL11_EOL
Openssl 3.0 Design

Source: https://www.openssl.org/docs/OpenSSL300Design.html
Candidate - openssl 3.0

- Good option, but big
- Initial investigation shows size is doubled
- Will break the existing platform

- https://bugzilla.tianocore.org/show_bug.cgi?id=3466
- https://github.com/kraxel/edk2/tree/archive/openssl3-v1
- https://edk2.groups.io/g/devel/topic/87479913
Candidate - mbedtls

- Small, but missing features
- Missing SHA3 (Parallel Hash), SMx, etc.

- https://bugzilla.tianocore.org/show_bug.cgi?id=4177
Candidate - Other

- **Intel IPP**
  - no certificate support, no TLS

- **Libsodium**
  - [https://doc.libsodium.org/](https://doc.libsodium.org/)
  - no certificate support, no TLS

- **BoringSSL**
  - [https://github.com/google/boringssl](https://github.com/google/boringssl)
  - "We don't recommend that third parties depend upon it"

- **WolfSSL**
  - [https://www.wolfssl.com/](https://www.wolfssl.com/)
  - GPL license

- **BearSSL**
  - [https://bearssl.org/](https://bearssl.org/)
  - beta-quality software
## Latest Result – openssl 3.0

- [https://github.com/tianocore/edk2-staging/blob/OpenSSL11_EOL/CryptoPkg/Readme-OpenSSL3.0.md](https://github.com/tianocore/edk2-staging/blob/OpenSSL11_EOL/CryptoPkg/Readme-OpenSSL3.0.md)

### Acknowledgement

-- Gerd Hoffmann [kraxel@redhat.com](mailto:kraxel@redhat.com), Li, Yi1 [yi1.li@intel.com](mailto:yi1.li@intel.com), Ard Biesheuvel [ardb@kernel.org](mailto:ardb@kernel.org)

<table>
<thead>
<tr>
<th>Driver</th>
<th>1.1.1</th>
<th>3.0</th>
<th>percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>CryptoDxeFull</td>
<td>1014</td>
<td>1578</td>
<td>57%</td>
</tr>
<tr>
<td>CryptoPei</td>
<td>386</td>
<td>794</td>
<td>106%</td>
</tr>
<tr>
<td>CryptoPeiPreMem</td>
<td>31</td>
<td>417</td>
<td>1245%</td>
</tr>
<tr>
<td>CryptoDxe</td>
<td>804</td>
<td>1278</td>
<td>59%</td>
</tr>
<tr>
<td>CryptoSmm</td>
<td>558</td>
<td>986</td>
<td>77%</td>
</tr>
</tbody>
</table>

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<th>1.1.1</th>
<th>3.0</th>
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<tr>
<td>CryptoPei</td>
<td>386</td>
<td>398</td>
<td>3.1%</td>
</tr>
<tr>
<td>CryptoPeiPreMem</td>
<td>31</td>
<td>31</td>
<td>0%</td>
</tr>
<tr>
<td>CryptoDxeFull</td>
<td>1014</td>
<td>1031</td>
<td>1.7%</td>
</tr>
<tr>
<td>CryptoDxe</td>
<td>804</td>
<td>886</td>
<td>10.1%</td>
</tr>
<tr>
<td>CryptoSmm</td>
<td>558</td>
<td>604</td>
<td>8.2%</td>
</tr>
</tbody>
</table>
Latest Result – mbedtls 3.0

- [https://github.com/tianocore/edk2-staging/blob/OpenSSL11_EOL/CryptoPkg/ReadmeMbedtls.md](https://github.com/tianocore/edk2-staging/blob/OpenSSL11_EOL/CryptoPkg/ReadmeMbedtls.md)
- **PKCS7**: included in mbedtls 3.0.
- **SHA3**: under development - [https://github.com/Mbed-TLS/mbedtls/pull/5820](https://github.com/Mbed-TLS/mbedtls/pull/5820), [https://github.com/Mbed-TLS/mbedtls/pull/5822](https://github.com/Mbed-TLS/mbedtls/pull/5822)

<table>
<thead>
<tr>
<th>Driver</th>
<th>OpenSSL</th>
<th>MbedTLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEI</td>
<td>387Kb</td>
<td>162Kb</td>
</tr>
<tr>
<td>PeiPreMem</td>
<td>31Kb</td>
<td>58Kb</td>
</tr>
<tr>
<td>DXE</td>
<td>804Kb</td>
<td>457Kb</td>
</tr>
<tr>
<td>SMM</td>
<td>558Kb</td>
<td>444Kb</td>
</tr>
</tbody>
</table>

**Acknowledgement**

-- Hou, Wenxing [wenxing.hou@intel.com](mailto:wenxing.hou@intel.com), Marvin Häuser [mhaeuser@posteo.de](mailto:mhaeuser@posteo.de)
Request For Comment

• **Openssl 3.0**
  • Research on how to reduce size to make it fit to the firmware

• **Dual Mode**
  • EDKII supports both openssl 3.0 and mbedtls two instances
  • Platform chooses the library + feature based on the need
Commercial National Security Algorithm (CNSA) 1.0 Compliance

- **CNSA 1.0**
  - Sym: AES-256, SHA-384
  - Asym: ECDH/ECDSA-NIST-P384, RSA-3072 above
  - [https://media.defense.gov/2021/Sep/27/2002862527/-1/-1/0/CNSS%20WORKSHEET.PDF](https://media.defense.gov/2021/Sep/27/2002862527/-1/-1/0/CNSS%20WORKSHEET.PDF)

- **UEFI/EDKII – support crypto agility**
  - UEFI-2.10 defines Firmware/OS Crypto Algorithm Exchange.
  - Support new algorithms with compatibility consideration.
  - **CryptoIndications**: Allows the OS to request the crypto algorithm to BIOS.
  - **CryptoIndicationsSupported**: Allows the firmware to indicate supported crypto algorithm to OS.
  - **CryptoIndicationsActivated**: Allows the firmware to indicate activated crypto algorithm to OS.
CNSA 2.0 Guideline

Industry Preparation - PQC

- **Openssl 3.0**
  - Open Quantum Safe (OQS) project support openssl 3.0
    - [https://github.com/open-quantum-safe/openssl/tree/OQS-OpenSSL3](https://github.com/open-quantum-safe/openssl/tree/OQS-OpenSSL3)
    - OQS provider
      - [https://github.com/open-quantum-safe/oqs-provider](https://github.com/open-quantum-safe/oqs-provider)

- **MbedTls**
  - Future:
    - Post Quantum Crypto
CNSA 2.0 Compliance

- **CNSA 2.0 (Post Quantum Crypto)**
  - Firmware Image Signing/Verification: XMSS/LMS
  - General Signing/Verification: Dilithium
  - General Key Exchange: Kyber
  - [https://media.defense.gov/2022/Sep/07/2003071834/-1/-1/0/CSA_CNSA_2.0_ALGORITHMS_.PDF](https://media.defense.gov/2022/Sep/07/2003071834/-1/-1/0/CSA_CNSA_2.0_ALGORITHMS_.PDF)

- **UEFI/EDKII – Request For Comment**
  - Define more bit to support CNSA algorithm.
  - [https://bugzilla.tianocore.org/show_bug.cgi?id=4087](https://bugzilla.tianocore.org/show_bug.cgi?id=4087)
  - When to use XMSS/LMS?
  - When to use Dilithium?
# Asymmetric Cryptography in System Firmware

<table>
<thead>
<tr>
<th>Usage</th>
<th>Category</th>
<th>Feature</th>
<th>Standard</th>
<th>Algorithm</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code Signing Verification</td>
<td>Secure Boot</td>
<td><strong>UEFI Secure Boot</strong></td>
<td>UEFI</td>
<td>PKCS7(RSA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>PI Signed FV/Section</strong></td>
<td>UEFI PI</td>
<td>PKCS7(RSA) / RSA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intel Boot Guard (Verified Boot)</td>
<td></td>
<td>RSA / SM2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Platform Firmware Resilience (PFR)</td>
<td></td>
<td>RSA/ECDSA</td>
<td></td>
</tr>
<tr>
<td>Update</td>
<td></td>
<td><strong>UEFI FMP Capsule Update</strong></td>
<td>UEFI</td>
<td>PKCS7(RSA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intel BIOS Guard</td>
<td></td>
<td>RSA</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td></td>
<td>EDKII Signed Recovery with FMP Cap</td>
<td>EDKII</td>
<td>RSA</td>
<td></td>
</tr>
<tr>
<td>Data Signing Verification</td>
<td>Update</td>
<td><strong>UEFI Auth Variable Update</strong></td>
<td>UEFI</td>
<td>PKCS7(RSA)</td>
<td>Signed one time, when the data is created</td>
</tr>
<tr>
<td>Authentication</td>
<td>Device</td>
<td>SPDM Device Authentication</td>
<td>DMTF</td>
<td>RSA/ECDSA</td>
<td>Runtime Signing based upon challenge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPDM Device Measurement Verification</td>
<td>DMTF</td>
<td>RSA/ECDSA</td>
<td></td>
</tr>
<tr>
<td>Secure Session Establishment</td>
<td>Device</td>
<td>SPDM Session</td>
<td>DMTF</td>
<td>ECHDE</td>
<td>Key Exchange with SIGMA protocol</td>
</tr>
<tr>
<td></td>
<td>Network</td>
<td>HTTPS Boot (TLS)</td>
<td>IETF</td>
<td>ECDHE</td>
<td></td>
</tr>
</tbody>
</table>

Reference: [https://uefi.org/sites/default/files/resources/Post%20Quantum%20Webinar.pdf](https://uefi.org/sites/default/files/resources/Post%20Quantum%20Webinar.pdf)
Questions?
More Questions?

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