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Strategies for Stronger Software SMI Security in UEFI Firmware

Fall 2017 UEFI Seminar and Plugfest

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Agenda

- Management Mode Overview
- Implementing Software MMI Handlers Securely
- Call To Action & Resources

Management Mode* (MM) Overview

- UEFI PI-standard for creating a protected execution environment using hardware resources
  - Dedicated, protected memory space, entry point and hardware resources, such as timers and interrupt controllers
  - Implemented using SMM (on x86) or TrustZone (Arm)
  - Highest-privilege operating mode with greatest access to system memory and hardware resources

*Formerly known as SMM in the PI specification.

Software Management Mode Interrupts* (Software MMIs)

- Management Mode Interrupts generated by software synchronously are called Software MMIs
  - Generated using I/O resources or CPU instructions

- Used to provide firmware services to the
  - OS (ACPI, TPM)
  - OS drivers (device handoff, CPU management)
  - UEFI runtime support (variables, capsule, etc.)
  - BIOS vendor applications (flash utilities, setup access)
  - OEM/ODM applications

*Formerly known as SMIs in the PI specification.

Why Are Software MMI Vulnerabilities Dangerous?

- Software MMIs can be asked to perform privileged operations
  - Flash BIOS, flash EC, write to MMIO, write to MMRAM, etc.
- Software MMIs can be asked to overwrite OS code/data
- Software MMIs can be asked to copy protected OS data to another unprotected location
- Software MMIs can be asked to copy protected firmware data to another unprotected location
- Software MMIs can be asked to overwrite BIOS code/data

Assumptions For This Presentation…

- Memory protected by the OS cannot be snooped while in use by the OS application or OS driver
  - No protection from MM, VMs or hardware snooping
- Flash protected by hardware cannot be modified outside of MM after the end of DXE
  - Not worried about snooping since no secrets are stored in BIOS
  - Not worried about flash-altering hardware attacks
- Software MMIs cause CPUs to enter SMM in SMRAM at a fixed location
- MMRAM cannot be altered from outside SMM

Implementing Software MMI Handlers Securely

Implementing Software MMI Handlers Securely Overview

- #1: Allocate The Buffer In PEI/DXE
- #2: Never Trust That Pointers Point To The Buffer
- #3: Prohibit Input/Output Buffer Overlap
- #4: Don’t Trust Structure Sizes
- #5: Verify Variable-Length Data

#1: Allocate The Buffer In PEI/DXE

- Don’t use a buffer provided by the OS application or OS driver
  - Might point to SMRAM, MMIO, OS data, firmware data or generate an exception
- Allocate the buffer during DXE and pass the pointer to the buffer by a table (ACPI, System Configuration) or some other tamper resistant method
- Provide a library function that verifies if a range of bytes exists within the command buffer. Example:
  - **`BOOLEAN BufferInCmdBuffer(VOID *Ptr, UINTN Size);`**

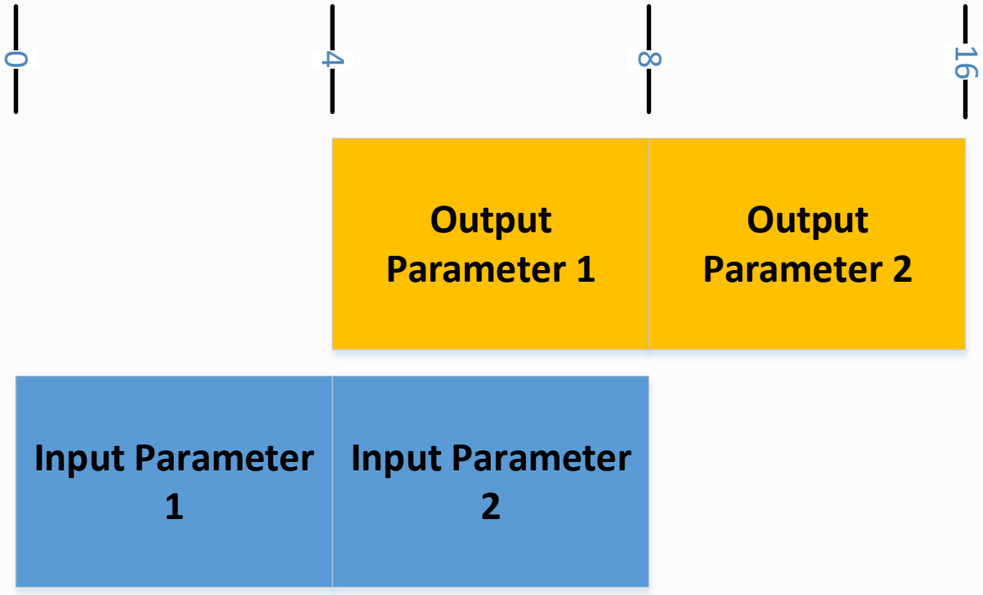
#2: Never Trust Pointers Point To The Buffer

- Provide a library function that verifies if a range of bytes exists within the buffer
- Must also test pointers to pointers
- Example:

```
BOOLEAN
BufferInCmdBuffer(
   IN CONST VOID *Ptr,
   IN UINTN      Size
   );
```

#3: Prohibit Input/Output Buffer Overlap

- If the pointers of input and output buffers overlap, then output data may overwrite input data **after** it has been validated, but **before** it has been used.
- Example:
  - Verify Input Parameter 1
  - Verify Input Parameter 2
  - Read Input Parameter 1
  - Write Output Parameter 1
    - Oops! Changes Input Parameter 2!
  - Read Input Parameter 2
  - Write Output Parameter 2



#3: Prohibit Input/Output Buffer Overlap Example

- Check for buffer-overlap when two buffers are passed in

```
// StructurePtr = pointer to 1st buffer.
// Structure2Ptr = pointer to 2nd buffer.
// StructureSize = size of 1st buffer.
// Structure2Size = size of 2nd buffer.

UINT8 *StructurePtrOffset = (UINT8 *) StructurePtr;
UINT8 *StructurePtr2Offset = (UINT8 *) StructurePtr2;

if (StructurePtrOffset+StructureSize >= StructurePtr2Offset &&
    StructurePtrOffset < StructurePtr2Offset+Structure2Size) {
  return SECUTIRY_ERROR;
}
```

#4: Don’t Trust Structure Sizes

- Verify that StructureSize member is actually in the Buffer!
  - Even if the start of the structure is in the Command Buffer, the Structure Size member might not be in the Buffer

```
StructurePtr = (STRUCTURE_NAME *)Register;
StructureSizeOffset = OFFSET_OF(STRUCTURE_NAME, StructureSize);
StructureSizeSize = sizeof(StructurePtr->StructureSize);
if (!BufferInCmdBuffer(
        (VOID *)StructurePtr,
        StructureSizeOffset + StructureSizeSize - 1)){
  return SECURITY_ERROR;
}
```

#4: Don’t Trust Structure Sizes

- Verify that StructureSize is at least the minimum size of the structure that contains it
  - Later code may assume that they are working on a specific structure, but need to verify the buffer can actually hold that structure

```
StructureSize = StructurePtr->StructureSize;
if (StructureSize < sizeof(STRUCTURE_NAME)) {
  return SECURITY_ERROR;
}
```

#5: Verify Variable-Length Data

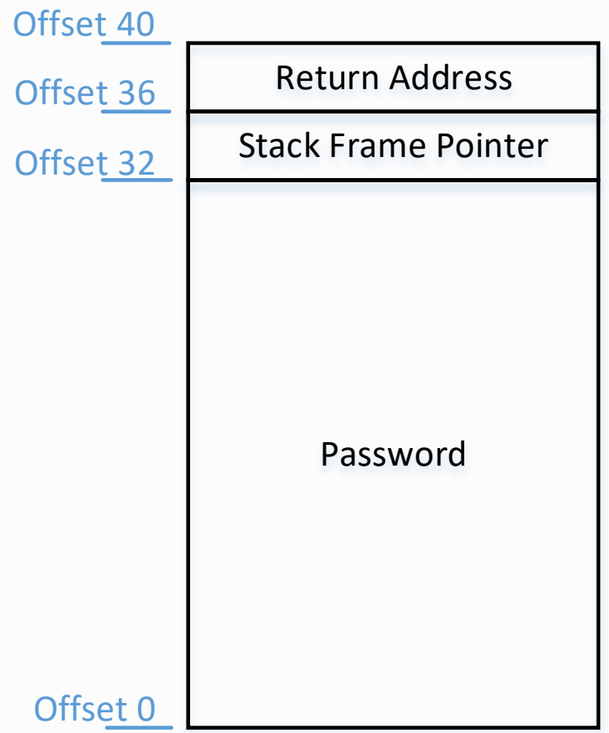
- While parsing variable length data, the software MMI handler must not go past the end of the input buffer or output buffer
  - When parsing variable-length structures
  - When handling null-terminated strings
  - When handling arrays with fixed or variable-sized entries

#5: Verify Null-Terminated Strings

- Missing null-terminators on strings can cause many functions (StrLen, StrCpy, StrCmp,AsciiStrToUnicodeS, etc.) to access data outside of the command buffer. Example:

```
CHAR16 Password[32];
StrCpy(Password, ptr);
```

If *ptr* points to a 40 byte string, then bytes 37-40 will be copied over the return address on the stack, causing the SMM function to return somewhere unplanned



- For strings, use **`StrnLenS()`** or **`AsciiStrnLenS()`** in **`MdePkg\Include\BaseLib.h`** to verify that the string does not extend past the end of the command buffer

```
str = pointer to string
Length= StrnLenS (ptr,(UINT8*)end-of-buffer-(UINT8*) str);
```

#5: Verify Variable-Length Arrays

- With variable length arrays, it is easy to accidentally read/write bytes outside of the buffer
  - Especially if each entry is also variable-length
- Verify that each entry does not extend past the end of the buffer
- Verify each entry header is in buffer before reading entry size

```
end-of-buffer = start-of-buffer + size-of-buffer.
do {
  if (!BufferInCmdBuffer(ptr, sizeof(header-struct) ||
      !BufferInCmdBuffer(ptr, ptr->StructureSize) {
    return SECURITY_ERROR;
  }
  switch(ptr->Type) {
    ..process structure..
  }
  ptr = (header-struct*)((UINT8*)ptr + ptr->StructureSize)
} while ((UINT8 *)ptr < end-of-buffer && ptr->Type!=0x00);
```

Call To Action

Call To Action

- Revise APIs to remove trust of the calling application
- Handle multi-stage operations with good security
- Revise handler buffer code to safely process variable-length data

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