DECAF: Automatic, Adaptive De-bloating and Hardening of COTS Firmware

Supported by the Office of Naval Research

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Introduction

- Despite its privileged position, firmware is almost entirely opaque to the end-user
- The delivered blob is the result of a long chain (e.g. EDK II, American Megatrends, Dell)
- Code is of questionable quality
- Lots of code reuse leads to easily replicable attacks
  - Kovah & Kallenberg 2015
- Many (up to 69%) modules are unnecessary

Code Sample: Intel Galileo firmware

```
SerialNumStrLen = StrLen(SerialNumberPtr);
if (SerialNumStrLen >
SMBIOS_STRING_MAX_LENGTH)
{
  return EFI_UNSUPPORTED;
}
....
SKUNumStrLen = StrLen(SKUNumberPtr);
if (SerialNumStrLen >
SMBIOS_STRING_MAX_LENGTH)
{
  return EFI_UNSUPPORTED;
}
....
FamilyStrLen = StrLen(FamilyPtr);
if (SerialNumStrLen >
SMBIOS_STRING_MAX_LENGTH)
{
  return EFI_UNSUPPORTED;
}
```

Analysis courtesy Nikolaj Schlej
(https://www.viva64.com/en/b/0326/)

Introducing DECAF

- DECAF is an extensible platform for debloating commercial UEFI firmware
- Automatically prune up to 70% of an image!
- No source code needed
- Customizable functionality
- DECAFed firmware running in production data centers since mid-2017

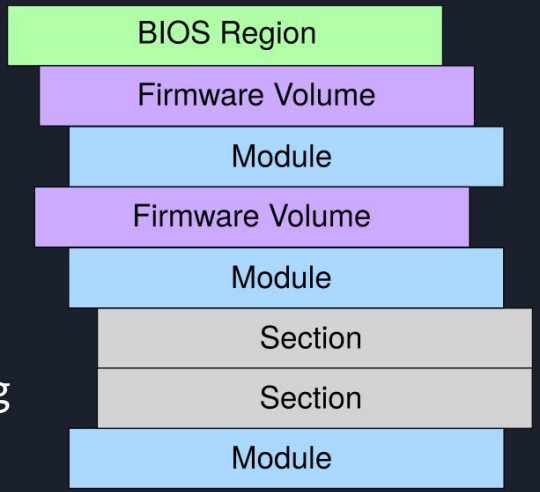
Benefits of pruning

- Remove potentially unknown vulnerabilities
- Removed code is NOT unused/unreachable
- Pruned firmware boots faster, and contains less potentially vulnerable code
- Features can be removed on demand, while retaining other functionality

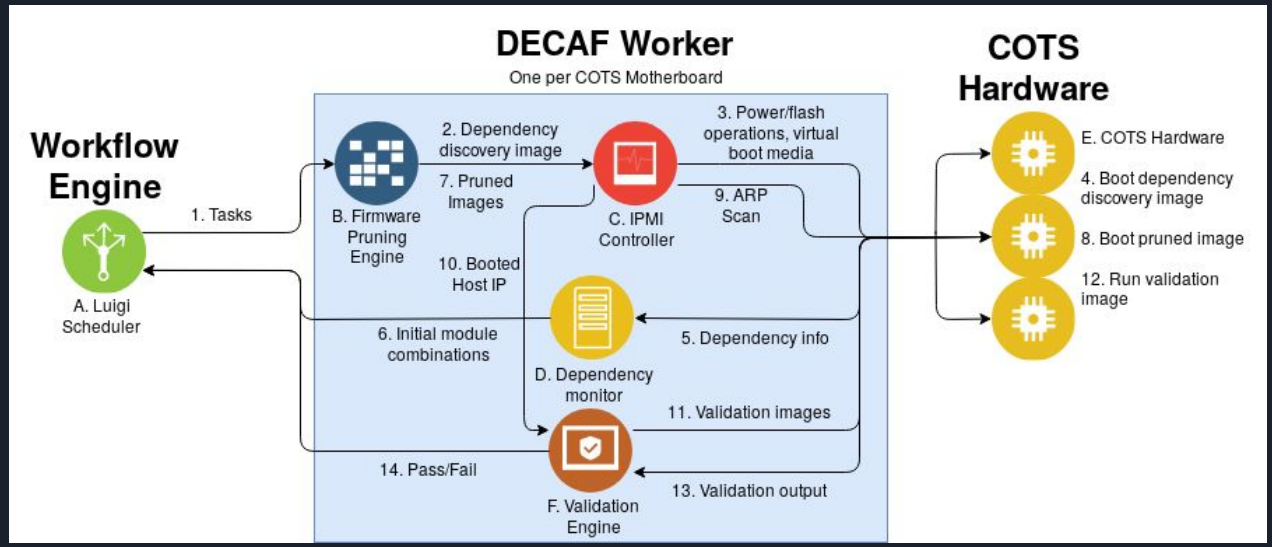
"Remove all other stuff you don't want or need, if the firmware can still boot your OS - it's fine to have that components removed"
- Nikolaj Schlej, Zero nights, 2015.

Background: UEFI Firmware

- Splits platform initialization into four phases
  - Security (SEC)
  - Pre-EFI Initialization (PEI)
  - Driver Execution Environment (DXE)
  - Boot Device Selection (BDS)
- Basic building unit is a module (generally containing a PE32 executable)
- Modules communicate via EFI protocols



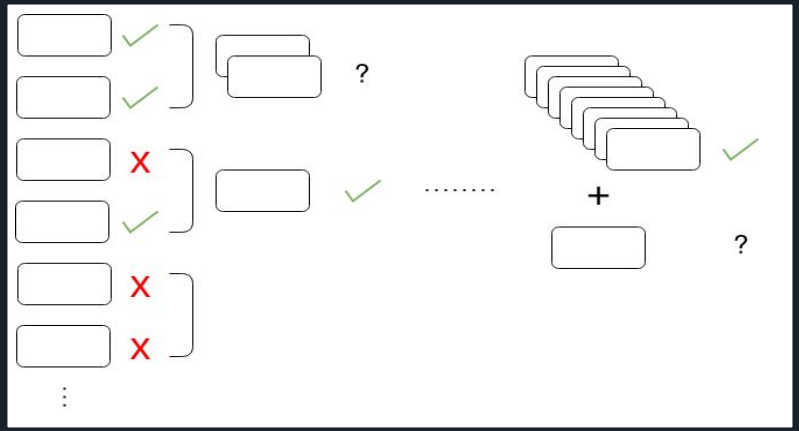
DECAF Pruning Overview



- Luigi workflow engine used for scheduling tasks (https://github.com/spotify/luigi)
- Python layer based on UEFITool used for modifying images (https://github.com/LongSoft/UEFITool)
- Python tools used to manage IPMI operations and collect info
- Docker images loaded onto booted images to validate the flashed firmware
- Custom dependency discovery modules written in C

Pruning Tasks and Phases

- Process can be parallelized on multiple boards
- Pruning happens in two phases: merge and hill climbing
  - Modules tried individually
  - Successfully removed groups are merged
  - Modules are then randomly selected and added to candidate solution



Dependency Discovery

- UEFI modules communicate with each other (using EFI protocols), creating dependencies
- Dependencies vary at runtime
- Module removal order becomes important!
- Solution: hijack the EFI protocol API and log active modules

Validation

DECAF employs several utilities to validate the pruned images:

- **dmidecode**
- **lspci**
- **/proc/acpi**
- **CHIPSEC**

CHIPSEC scans for known firmware vulnerabilities
- DECAF did not fix any CHIPSEC vulnerabilities

Results I

- Boot time reduction up to 24%
  - 55 to 44 seconds for SuperMicro
  - 34 to 27 seconds for Tyan
- DECAF can also selectively remove features
  - USB, network, VGA, etc
- Many common attacks on USB, network stack
  - BadUSB, Karsten Nohl and Jakob Lell, BlackHat 2014
- Example: 6/244 modules removed to disable USB on SuperMicro board

Results II

- DECAF can also selectively remove features
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Results II

Motherboard	Original modules	Remaining modules	Reduction	Original Gadgets	Remaining Gadgets	Reduction
SM A1SAi-2550F (V519)	244	90	63.11%	37846	14240	62.37%
Tyan 5533V101	194	60	69.07%	38776	20317	47.60%
HP DL380 Gen10	643	323	49.77%	183677	105116	42.77%
SM A1SAi-2550F (V827)	241	124	48.55%	37735	23055	38.90%
SM A2SDi-12C-HLN4F	313	194	38.02%	43593	31003	28.88%
SM A2SDi-H-TP4F	313	206	34.19%	44121	31024	29.68%
SM X10SDV-8C-TLN4F	316	286	9.49%	51534	45724	11.27%

*SM is short for SuperMicro

Thank you for your attention!

For further information and questions:

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