Best Technical Methods for Unified Extensible Firmware Interface (UEFI) Development

Reducing Platform Boot Times
Michael A. Rothman, Intel

Firmware Debugging: UEFI and USB for Platform Forensics
Brian Richardson, AMI

EFIS003
Reducing Platform Boot Times

Michael A. Rothman
Senior Staff Software Engineer

EFIS003
Background Information

Factors in performance

Things to note

Key Learnings
UEFI Phase Transitions

Power on

[ . . . Platform initialization . . . ]

[ . . . . OS boot . . . . ]

Shutdown
**PEI to DXE Transition**

**PEI**

- Pre-Memory

**DXE**

- Dispatcher

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**Memory**

- Memory Initialized

**HOB List**

- Termination
- Firmware Volume
- Physical Memory
- PHIT

**DXE Main**

- EFI System Table
- EFI Boot Services Table
- Memory Only Boot Services

**DXE IPL**

**Last PEIM**

**Termination**

**PHIT – PEI Handoff Information Table**

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*
Boot Device Selection

- Invoked after DXE Dispatcher is Complete
- Implemented as a driver
- Connects EFI drivers as required
  - Establishes Consoles (Keyboard, Video)
  - Processes EFI Boot Options (Boots O/S)
What is a Boot Target?

- A boot target is described through an EFI Device Path.
  - A binary description of the physical location of a particular target.
O/S Target and Attributes

- What are the target Operating Systems?
  - Legacy Boot Support Required?
  - What data does the O/S require from the BIOS?
- Some tables may not be required for certain targets.
Platform Specific Expectations/Behavior

• What are the platform policies?
  – Expect to interact with user during the pre-boot?

  – What type of hardware are we required to initialize prior to launching the O/S?

Platform Policy choices affect boot times
**Peripherals Affect Performance**

- Can we avoid slow hardware?
  - Use of an SSD boot device in lieu of rotating media can save seconds in the boot time.

<table>
<thead>
<tr>
<th>Values</th>
<th>DRAM</th>
<th>SSD (34nm)</th>
<th>EIDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Read Latency</td>
<td>~30 ns</td>
<td>65 µs</td>
<td>8.5 ms</td>
</tr>
<tr>
<td>Read BW (MB/s)</td>
<td>1800</td>
<td>250</td>
<td>120</td>
</tr>
<tr>
<td>Write Latency</td>
<td>~30 ns</td>
<td>85 µs</td>
<td>10 ms</td>
</tr>
<tr>
<td>Write BW (MB/s)</td>
<td>1800</td>
<td>70</td>
<td>120</td>
</tr>
<tr>
<td>Spin-up/down time</td>
<td>N/A</td>
<td>N/A</td>
<td>1-2s++</td>
</tr>
</tbody>
</table>

*Higher the RPM longer the time*

**Boot hardware can affect times tremendously**
Background Information

Factors in performance

Things to note

Key Learnings
Size and Organization matters!

• The less you have to read from FLASH the better.
  – It is possible to organize the FLASH layout so that you never search firmware volumes which contain nothing of interest for that configuration.
Where to Optimize?

• Try to avoid slowing down the boot process for to accommodate the case which almost never happens.
  – Pausing for a keystroke in the anticipation that someone might interrupt the boot process.
  – Initializing and reading from alternate recovery devices when in almost all cases, we aren’t going to be asked to recover the platform.

Platform behavior requirements often dictate where certain optimizations can occur.
Functional Optimization

• Note that depending on platform needs, we may very well do different things....

For a normal boot, the figure on the left illustrates a common set of operations during the boot. The figure above shows an optimized boot. Both are accomplishing the same basic goal - launching the boot target.

BIOS functionality can and will vary
Maintain Architectural Design

- Performance Optimization doesn’t mean we lose UEFI compatibility

[Diagram showing the boot phases and decision processes for Normal Boot and Optimized Boot]

**Optimize without losing UEFI compatibility**
Background Information

Factors in performance

Things to note

Key Learnings
## Demo Video

![Intel Logo]

### Normal Boot

<table>
<thead>
<tr>
<th>Phase</th>
<th>Duration</th>
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</thead>
<tbody>
<tr>
<td>SEC</td>
<td>2,634 (us)</td>
</tr>
<tr>
<td>PEI</td>
<td>123,090 (us)</td>
</tr>
<tr>
<td>DXE</td>
<td>9,982 (us)</td>
</tr>
<tr>
<td>BDS</td>
<td>73,960 (us)</td>
</tr>
<tr>
<td>Total</td>
<td>9,651 (s)</td>
</tr>
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</table>

### Optimized Boot

<table>
<thead>
<tr>
<th>Phase</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEC</td>
<td>2,641 (us)</td>
</tr>
<tr>
<td>PEI</td>
<td>76,331 (us)</td>
</tr>
<tr>
<td>DXE</td>
<td>4,430 (us)</td>
</tr>
<tr>
<td>BDS</td>
<td>76,678 (us)</td>
</tr>
<tr>
<td>Total</td>
<td>1,999 (s)</td>
</tr>
</tbody>
</table>
Key Learnings

• Performance can be greatly affected by Platform Policy and Hardware Configurations
  – Firmware engineers get involved early in the platform design

• BIOS Design Elements Can Improve Performance
  – A variety of software optimization techniques exist within the BIOS

• Performance Optimization does not mean a lack of compatibility

• See the published whitepaper for more details:
  http://edc.intel.com/Link.aspx?id=2355
Firmware Debugging: UEFI and USB for Platform Forensics

Brian Richardson - American Megatrends, Inc.
Senior Technical Marketing Engineer
Agenda

- Limitations for UEFI Debugging
- Utilizing USB Debug Solutions
- Extending UEFI Debugging Concepts
- Using USB Debugging in the Field
Limitations for UEFI Debugging

- Moving to UEFI introduced new debug tools
  - Debug Strings, Status Codes, C-style debugging
  - Problem: these tools are for developers, not users

- Tools from “the BIOS days” are disappearing

- “No user-serviceable parts inside”
  - Thin & light systems
  - Netbook, nettop, embedded
  - No expansion slots
Firmware Debug Tool Wishlist

Common ground between developers & field technicians

The Developer
- Use standalone or with another PC
- Use w/o opening case
- View checkpoints
- Store data for analysis
- Use on production HW
- View debug strings
- Source-level debug

The Field Technician
- Use standalone or with another PC
- Use w/o opening case
- View checkpoints
- Store data for analysis
- Use on production HW
- No proprietary ports

New Platform Designs Demand New Debug Tools
Agenda

Limitations for UEFI Debugging

Utilizing USB Debug Solutions

Extending UEFI Debugging Concepts

Using USB Debugging in the Field
Utilizing USB Debug Solutions

Why USB?
• USB is Ubiquitous
• Externally Accessible, Screwdriver Free
• USB 2.0 Enables Early Debugging via the EHCI debug port
• Same port works with debug devices or standard USB devices

What’s a “debug port”
• One USB port supporting a simplified USB protocol
  – Fast protocol
  – Does not require full memory stack
  – Works only with “debug descriptor” device
• Supported by Intel ICH/SCH with USB 2.0
Today’s Uses in Source Debugging

- USB Debug Port works as a “transport layer”
  - UEFI Debug Protocol
  - Requires host-to-host bridge
- Shown previously at IDF
- Example: AMI Debug
  - Source-level debug
  - DXE, PEI and UEFI Shell
  - Add breakpoints
  - Read & write mem/IO/PCI
  - Redirect debug messages
  - Redirect remote console

**USB Debug Port Is Already Available & Used by IBVs**
Agenda

Limitations for UEFI Debugging

Utilizing USB Debug Solutions

Extending UEFI Debugging Concepts

Using USB Debugging in the Field
Extending UEFI Debugging Concepts

Field Technicians
- Diagnose systems using checkpoints or status codes.
- Translate “hexadecimal nerd nonsense” into usable data.

Quality Assurance
- Measure boot performance using checkpoint timing
- Record data for test reports
- Easily pinpoint hangs

BIOS/UEFI Developers
- Read checkpoints
- Optimize boot performance using checkpoint timing
- Enable source-level debug
Extending UEFI Debugging Concepts

For years, the focus has been on fixing problems for BIOS developers.

There are new product opportunities solving the same set of problems for QA & field technicians.

New Tools in UEFI Can Go Beyond Traditional BIOS Debugging
Agenda

Limitations for UEFI Debugging

Utilizing USB Debug Solutions

Extending UEFI Debugging Concepts

Using USB Debugging in the Field
Using USB Debugging in the Field
An Example Based on Today’s Tools from AMI

• Stand-Alone Operation
  – Read & store checkpoints
  – Store UEFI debug strings
  – Replace cryptic hex values with text descriptions
  – Measure boot timing

• Use with Another PC
  – Stream UEFI debug strings live to a console
  – Enable source-level debug
  – Access stored sessions
  – Enabled in firmware by drop-in modules
Enhanced Features in USB Debug

- **UEFI Debug Strings**
  - Used when BIOS is compiled in “debug mode”
  - Pass strings in DEBUG() & ASSERT() macros
  - Better information than just checkpoints
  - Redirected to AMI Debug Rx & USB Debug Port

```
[AmiDbg]Register PPI Notify: f894643d-c449-42d1-8ea8-85bdd8c65bde
[AmiDbg]Register PPI Notify: 605ea650-c65c-42e1-ba80-91a52ab618c6
[AmiDbg]CpuPeiBeforeMem.Entry(FFFFECB85)
[AmiDbg]NBPEI.Entry(FFFF495B)
[AmiDbg]SBPEI.Entry(FFFF1AED)
[AmiDbg]>>> PM Registers Before GPIO Init <<<

[AmiDbg] +================================== PM Registers dump ==============================+
[AmiDbg]  PM1a_EVT_BLK.PM1_STS       : Addr = 0400 => Val = 0001
[AmiDbg]  PM1a_EVT_BLK.PM1_EN        : Addr = 0402 => Val = 0000
```
Enhanced Features in USB Debug

- **Boot Time Analysis**
  - Used on any BIOS with AMI Debug Rx support
  - Based on device’s internal timer
  - Total boot time or time between checkpoints

```
<table>
<thead>
<tr>
<th>Num</th>
<th>CP</th>
<th>Time (ms)</th>
<th>String</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0x0011</td>
<td>1,372ms</td>
<td>PRE-MEM CPU INIT</td>
</tr>
<tr>
<td>2</td>
<td>0x0015</td>
<td>1,513ms</td>
<td>PRE-MEM NB INIT</td>
</tr>
<tr>
<td>3</td>
<td>0x0019</td>
<td>1,883ms</td>
<td>PRE-MEM SB INIT</td>
</tr>
<tr>
<td>4</td>
<td>0x002B</td>
<td>8,674ms</td>
<td>MEM INIT. SPD READ</td>
</tr>
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</table>
```

**Session Start Time**: 06/10/2009 15:16:44
**Total Checkpoints**: 52
**Duration of last boot**: 23,703ms
**BIOS Tag**: 0ABFL032
**BIOS Type**: Aptio 4.x
**BIOS Build Time**: 05/11/2009 17:00:07
Demo

AMI Debug Rx in use ...

- Capture Checkpoints
- Retrieve Stored Checkpoint Session
- Boot Time Analysis
- Store UEFI Debug Strings
Problems Solved w/AMI Debug Rx

Works with any System Form Factor

- No PCI slot or LPC header
- Externally accessible
- Uses commodity USB port
- Utilizes existing technology in today’s USB 2.0 EHCI controllers

Single Solution for Multiple Applications

- Standalone or with another PC
- Field Debug & Quality Assurance
- Measure boot performance
- Enable source-level debugging

IBV Debug Tools Can Support Products From Development to Deployment
Key Learnings

- New Platform Designs Demand New Debug Tools

- USB Debug Port Is Already Available & Used by IBVs

- New Tools in UEFI Can Go Beyond Traditional BIOS Debugging

- IBV Debug Tools Can Support Products From Development to Deployment
Next Steps –
Best Technical Methods for UEFI Development

• UEFI is a rich environment visit the UEFI web site
  – Learning center on UEFI web site
• Down load the white papers
• Work with your IBVs for the latest innovation tools
Additional resources on UEFI:

• Demos in the Showcase
  – UEFI Booth #136
  – American Megatrends Inc #429

• Talk to other UEFI members in the showcase

• Other information on the web
  – “Improving BIOS Debugging Using USB 2.0 Methods” Whitepaper available at www.ami.com
  – AMI Debug Rx product information at www.ami.com/amidebugrx
  – “USB2 Debug Device Functional Specification, Revision 0.90” available at www.intel.com

• Technical book from Intel Press:
## IDF 2009 UEFI Sessions

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<tr>
<th>EFI#</th>
<th>Company</th>
<th>Description</th>
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<th>RM</th>
<th>D</th>
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<td>Dell, HP, IBM, Intel, Microsoft</td>
<td>Using UEFI as the Foundation for Innovation</td>
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<td>2005</td>
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<td>Phoenix, Intel</td>
<td>Transitioning the Plug-In Industry from Legacy to UEFI: Real World Cases</td>
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<td>2002</td>
<td>Th</td>
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<td>Q001</td>
<td>Intel, All</td>
<td>UEFI Q &amp; A session</td>
<td>15:40</td>
<td>2002</td>
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