FreeBSD SD/ MMC

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FreeBSD's SD/ MMC Implementation
Overview

- Background
- MMC / SD card survey
- Motivation
- Embedded
- Standard's Device Model
- MMC / SD hardware details
- FreeBSD Implementation
- To do list
Background

- **History**
  - MMCA (1997 Siemens AG, SanDisk)
  - SDCA (1999 as secure MMC Matsushita, Toshiba, SanDisk)
- **MMC Cards (1998)**
  - 16MB to 4GB
- **SD Cards (2000)**
  - 16MB to 2GB (or 4GB)
- **SDHC Cards (2006)**
  - 4GB-32GB, three speed classes
- **SDIO Cards (2006)**
MMC Cards

- MMCA (http://www.mmca.org/)
- Siemens AG and SanDisk 1997
- 1-bit 20MHz serial interface
- Multiple devices on bus
- Open standard, but expensive ($1k)
- RS-MMC
- Current Version 4.x
- Wikipedia article excellent: http://en.wikipedia.org/wiki/MultiMediaCard
MMC Cards (cont)

- MMC v1.0 (September 1996)
- MMC v2.11 (June 1999)
  - SD Card based on this standard
- MMC v3.31 (May 2003)
  - Dual Voltage Cards
- MMC v4.x (April 2005)
  - Smaller form factor
  - Larger bus (4 or 8 bits)
  - Faster bus (26MHz or 52MHz)
  - SecureMMC
  - MMCplus (> 4GB)
- eMMC (December 2006)
 MMC Cards (cont)

- Kinds of Cards
  - MMC / MMCplus
  - RS-MMC / MMCmobile
  - MMCmicro
  - eMMC
SD Cards

- SDCA (http://www.sdca.org/)
- Matsushita, Toshiba, SanDisk 1999
- MMC v 2.21
- 4bit Bus @ 25MHz
- Full Standard Closed
- Simplified Standard 1.01 and 2.0 (SDHC) freely available
SD Cards (cont)

- **SD 1.0 (October 2001)**
  - Complete Standard NDA & $$$
  - Simplified Standard released 2005
  - Based on MMC Standard
  - One device on bus
  - 4bit 25MHz bus (12.5MB/s)
  - Alternative SPI bus interface
  - 16MB-2GB (4GB available)

- **SD 2.0 (April 2006)**
  - SDHC (4GB-32GB)
  - Optional 8-bit bus
  - 3 speed classes (2MB/s, 4MB/s, 6MB/s)
SD Card Examples

- SDHC
- SD
- MiniSD
- MicroSD

Source: www.sdca.org
SD Card Caveats

• 4GB Card Issue

![CAUTION]

About SDHC Memory Card
- Look for the SDHC logo when purchasing SDHC Memory Cards.
- The SDHC Logo is used for cards 4GB or larger.
- SD Speed Class is mandatory for SDHC Memory Card. It also appears on the card.

* SD Logo is a trademark.
* SDHC Logo is a trademark.

• SD vs SDHC Compatibility

Source: www.sdca.org
**SDIO Card**

- **SDIO 1.0 (October 2006)**
  - I/O Cards for embedded/consumer platforms
  - Simplified Spec
  - Mostly wireless cards
  - Also modems, FM radios, Bluetooth

Source: www.sdca.org
Motivation / Background

- Timing Solutions' AT91RM9200 Product
- SD Cards cheaper than CF cards
- Other products FreeBSD based
- SD Cards cheap and ubiquitous
- No SDIO cards support in SoC
Embedded

- SD Cards popular in embedded devices
  - low pin count
  - low cost
  - MMC/SD dual solutions
  - SPI bus interconnect
- Each SoC has different SD/MMC host adapter interface
- Host adapters typically very simple
- Software architecture must facilitate
Idealized SD Device Model

- No MMC
- Standard SDHC not universally implemented
- Glosses over interaction with other OS subsystems

Source: www.sdca.org
**Idealized MMC Device Model**

- Multiple devices
- No standard HC
- No I/O cards
- No SD cards
- A block device

Source: Adapted from Hitachi MultiMediaCard User Manual
Real World Example

- Two different “slots”
- Signals shared between two buses

Source: Atmel AT91RM9200 User Manual
FreeBSD Device Tree

- at91_mci0 controller
- mmc0 and mmc1 are bus
- mmcsdX are MMC memory cards
- sath0 is SDIO hypothetical Atheros card
MMC: The details

- Pinout
- MMC Protocol
- MMC HC extensions
- SD Protocol
- SDHC extensions
- SDIO extensions
(A) MMC Mode

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Name</th>
<th>Type</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RSV</td>
<td>NC</td>
<td>Reserved pin</td>
</tr>
<tr>
<td>2</td>
<td>CMD</td>
<td>I/O, PP, OD</td>
<td>Command/response</td>
</tr>
<tr>
<td>3</td>
<td>V_{SS1}</td>
<td>S</td>
<td>GND</td>
</tr>
<tr>
<td>4</td>
<td>V_{DD1}</td>
<td>S</td>
<td>V_{CC}</td>
</tr>
<tr>
<td>5</td>
<td>CLK</td>
<td>I</td>
<td>Clock</td>
</tr>
<tr>
<td>6</td>
<td>V_{SS2}</td>
<td>S</td>
<td>GND</td>
</tr>
<tr>
<td>7</td>
<td>DAT</td>
<td>I/O, PP</td>
<td>Data input/output</td>
</tr>
</tbody>
</table>

(B) SPI Mode

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Name</th>
<th>Type</th>
<th>Pin Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CS</td>
<td>I</td>
<td>Chip select</td>
</tr>
<tr>
<td>2</td>
<td>DI</td>
<td>I</td>
<td>Data input</td>
</tr>
<tr>
<td>3</td>
<td>V_{SS}</td>
<td>S</td>
<td>GND</td>
</tr>
<tr>
<td>4</td>
<td>V_{DD}</td>
<td>S</td>
<td>V_{CC}</td>
</tr>
<tr>
<td>5</td>
<td>SCLK</td>
<td>I</td>
<td>Clock</td>
</tr>
<tr>
<td>6</td>
<td>V_{SS2}</td>
<td>S</td>
<td>GND</td>
</tr>
<tr>
<td>7</td>
<td>DO</td>
<td>O, PP</td>
<td>Data output</td>
</tr>
</tbody>
</table>

Note: S = Power supply
I = Input
O = Output
PP = Push pull
OD = Open drain
NC = Not connected

Figure 2.2 MultiMediaCard™ Pin Assignments
MMC Protocol

Figure 2.15  Examples of MMC Mode Read/Write Transfer

Source: Hitachi MultiMediaCard User Manual
MMC Replies

- R1 (8) Command Status
- R1b (8) R1 with Busy
- R2 (16) SEND_STATUS reply
- R3 (40) SEND_OCR (R1 + 32 bits of OCR)
- R4 & R5 SDIO replies
- R7 (40) SEND_IF_COND (SDHC ext)
MMC Bus Enumeration

- Send GO_IDLE_STATE (CMD0)
- Send SEND_OP_COND (CMD1) w/ vdd
- Send ALL_SEND_CID (CMD2)
  - one card wins and sends its CID
- Send SET_RELATIVE_ADDRESS (CMD3)
- Get the CSD for card size, etc
- Loop until no card wins
SD Extensions

- SD/ MMC coexist
- 4bit vs 1bit bus
- Broadcast vs singlecast
- Try SD first, fallback to MMC
- SDHC complication
- SDIO adds much complication

Source: SanDisk SD Card Product Manual v2.2
SDIO Extensions

- Additional ways to probe for SDIO cards
- SDIO cards have PCMCIA CIS for use in enumeration and configuration

Source: Simplified SDIO Card Specification v1.10
SDHC Extensions

- **SD/MMC read/write commands** byte based.
- **SDHC block (512 byte) based**
- **Different isolation sequence**

Source: SD Simplified Physical Specification v2.0
FreeBSD Overview

- HA -> MMC bus interface mmcbr_if.m
- MMC bus -> MMC/SD device (mmc_if.m)
- Why no port of OpenBSD mmc/sd code
- Design details
  - Simple
  - Linux-like and OpenBSD-like interfaces
- To Do list
mmcbr Interface

- update_ios
- request
- get_ro
- acquire_host
- release_host
mmcbrivars

- mmcbus sets/gets ivars from mmcbri
  - mmcbri_get_bus_mode
  - mmcbri_get_bus_width
  - mmcbri_get_chip_select
  - mmcbri_get_clock
  - mmcbri_get_f_min
  - mmcbri_get_f_max
  - mmcbri_get_host_ocr
  - mmcbri_get_mode
  - mmcbri_get_power_mode
  - mmcbri_get_ocr
  - mmcbri_get_vdd
mmcbus Interface

- mmc bus has two sides to its interface
  - HA <-> mmc bus callbacks from HA
  - mmcbus <-> mmc/sd device interface
- wait_for_request
- acquire_bus
- release_bus
- Needed: rescan_bus
mmcbus ivars

- mmcbus sets a common set of ivars in the devices can query
  - mmc_get_dsr_imp
    - Does this device implement SD's DSR register
  - mmc_get_media_size
    - Return the device's computed capacity
  - mmc_get_rca
    - Returns the 16-bit relative card address
  - mmc_get_sector_size
    - Sector size of the media (512)
  - mmc_get_tran_speed
    - Current bus clock rate
MMC Client Driver Interface

- `mmcsd` special for all memory cards
  - `mmcbus` needs to probe for what type
  - `mmcsd` handles all types
- SDIO cards need probe routine
  - Need implementation and cards
- MMC HC and SDHC cards
  - Need implementation and cards
- SDHC
- MMC cards (both HC and normal)
- SDIO
- Smarter transaction timeouts
- Improve mmcsd performance
- Add erase support
- More bridge/HA drivers
- Integrate or reject Andrea Bittau's sdh
- SPI mode support
- Other kinds of cards: MS, SM, xD, etc?