Developing FTLs on the Jasmine OpenSSD Platform

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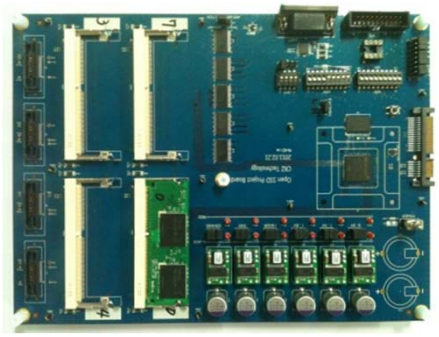
Outline

- Getting Started
- Building & Installing Firmware
- Greedy FTL Implementation & Development Guide
- Debugging Guide

Getting Started

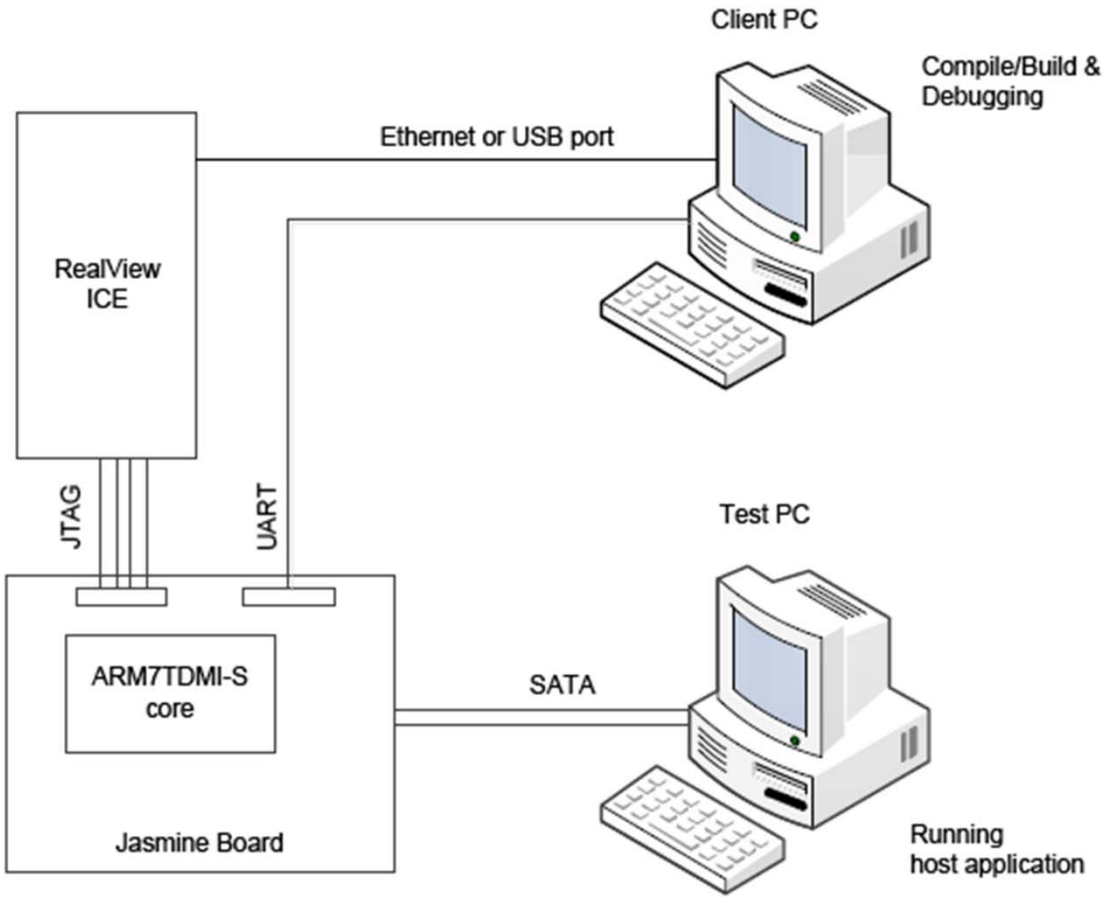
Development Setup: Hardware

- **Hardware Requirement**


  – For debugging (optional)

Development Setup: Hardware



Development Setup: Software

- **Jasmine Firmware**
  - Latest version: v1.0.3
  - Available from http://www.openssd-project.org/wiki/Downloads
- **RVDS(RealView Development Suite) 3.0 ↑ or Code Sourcery G++ Lite Edition for ARM (free)**
- **MS Visual Studio Express Free Edition 2010 (free)**

Development Setup: Software

- **Installing toolchain**
  - RVDS or Code Sourcery G++ Lite Edition for ARM
    - To build the firmware binary file (`firmware.bin`)
  - MS Visual Studio Express Free Edition 2010
    - To build the firmware installer (`install.exe`)
- **Serial communication**
  - Hyperterminal (BAUD_115200/8/N/1/X)
  - Configure on-board switches (SW 2,3,4)
    (please refer to Jasmine board schematics)

Building & Installing Firmware

Compile & Build Firmware

- **Setting compile options (`./include/jasmine.h`)**

```
OPTION_2_PLANE
OPTION_ENABLE_ASSERT
OPTION_FTL_TEST
OPTION_UART_DEBUG
OPTION_SLOW_SATA
OPTION_SUPPORT_NCQ
OPTION_REDUCED_CAPACITY
```

Compile & Build Firmware

- **Build the firmware**

```
> cd ./build_gnu
> build.bat
```

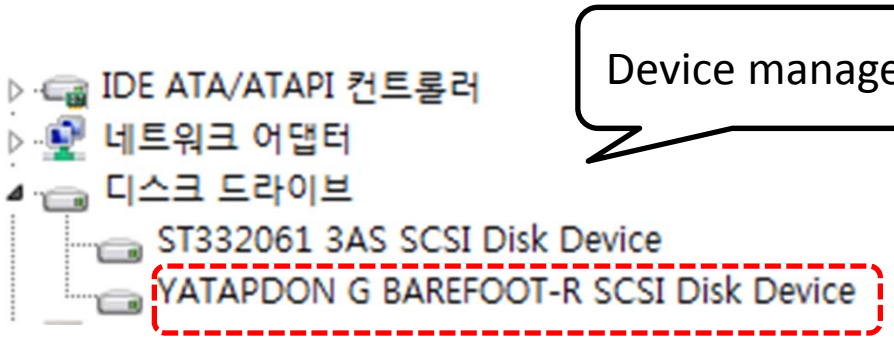
- **Compile the installer**
  - Open **`./installer/installer.sln`** & Build
  - Move **`./installer/install.exe`** to **`./build_gnu`**

Install Firmware to the Jasmine Board

- **Booting the Jasmine board as '*Factory mode*'**

Factory Mode

Normal Mode
(Default)



- **Install firmware**

```
> ./build_gnu/install.exe
```

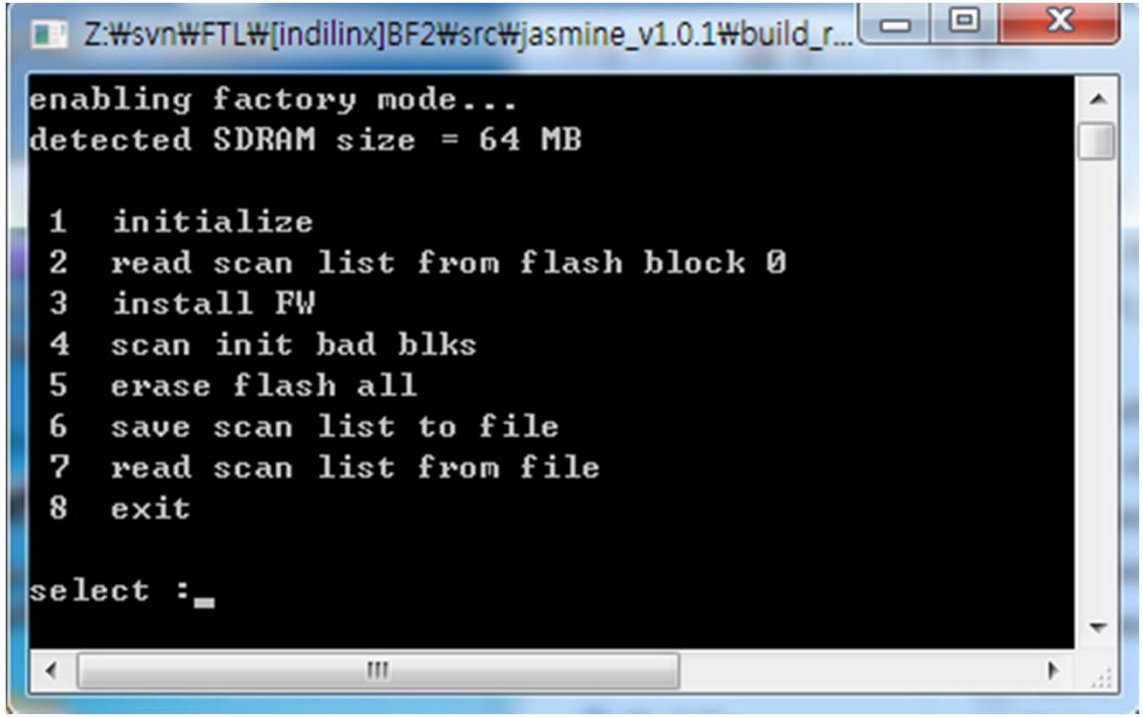
Install Firmware to the Jasmine Board

- **Install for the first time**

  1 – 2 – 6 – 3

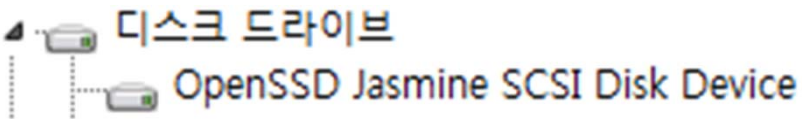
- **Reinstall**

  1 – 2 – 3



Run Firmware

- **Booting the Jasmine board as '*Normal mode*'**
  - Unplug SATA cable
    - Jasmine would be busy doing internal low-level format
  - Plug SATA cable when LED at D4 position is lit
- **Now Jasmine is ready to process SATA commands**



- **Try to send IO requests to Jasmine board!** ☺

Greedy FTL Implementation & FTL Development Guide

FTL Implementation

Source file	Function	Description
./installer/installer.c	ftl_install_mapping_table	FTL 초기 메타데이터를 NAND 플래시에 기록하는 연산 수행. 펌웨어 설치 시 함께 호출됨
./ftl_[scheme]/ftl.c	ftl_open	FTL 초기화 과정 수행 - NAND 플래시로부터 메타데이터 로드 및 초기화 - VBLK #0 에 포맷 마크가 기록되어 있지 않을 경우, format 함수 호출
	format	VBLK #0 와 FTL 메타 영역을 제외한 나머지 블록들을 삭제 - 포맷 마크 기록
	ftl_read	사용자 데이터 읽기 처리
	ftl_write	사용자 데이터 쓰기 처리
	ftl_flush	SATA idle/standby time 에 주기적으로 메타데이터를 flush 하는 연산 수행

Sample FTLs on the Jasmine Platform

- **Tutorial FTL** (developed by INDILINX)
  - Page-mapping FTL, but no garbage collection
- **Greedy FTL** (developed by SKKU VLDB Lab.)
  - Page-mapping FTL with simple garbage collection
  - Support Power-Off Recovery (*to appear*)
- **Dummy FTL**
  - Not a real FTL (*Not access NAND flash at all*)
  - For measuring SATA and DRAM speed

Greedy FTL: FTL Open

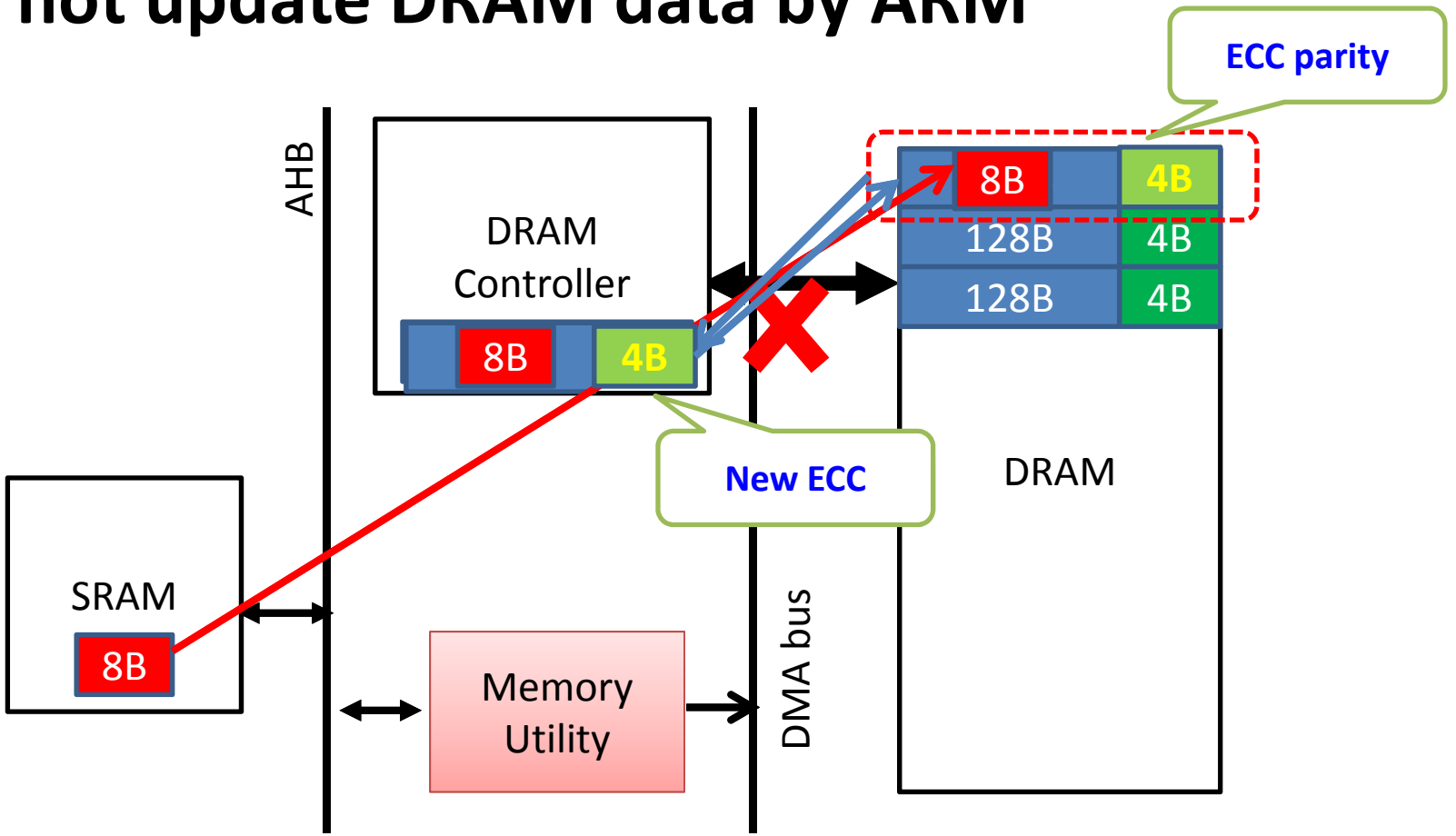
```
void ftl_open(void)
{
    // check DRAM footprint
    sanity_check();
    // build bitmap of bad blocks
    build_bad_blk_list();

    if (check_format_mark() == FALSE) {
        format();
    }
    // load FTL metadata
    else {
        // load FTL metadata in SRAM/DRAM from nand
        load_metadata();
    }
    // init FTL & SATA buffer pointer
    g_ftl_read_buf_id = 0;
    g_ftl_write_buf_id = 0;
}
```

Greedy FTL : FTL Metadata

- **DRAM metadata**
  - Page-level mapping table (PAGE_MAP)
    - For Logical-to-Physical page address mapping
  - Bad block bitmap table (BAD_BLK_BMP)
  - Block valid count information (VCOUNT)
    - For victim block selection
- **SRAM metadata**
  - Misc. information
    - Page index pointer of meta & user area
    - Remain free block count
    - Etc.

Guide #1 - Memory Utility

- **Do not update DRAM data by ARM**



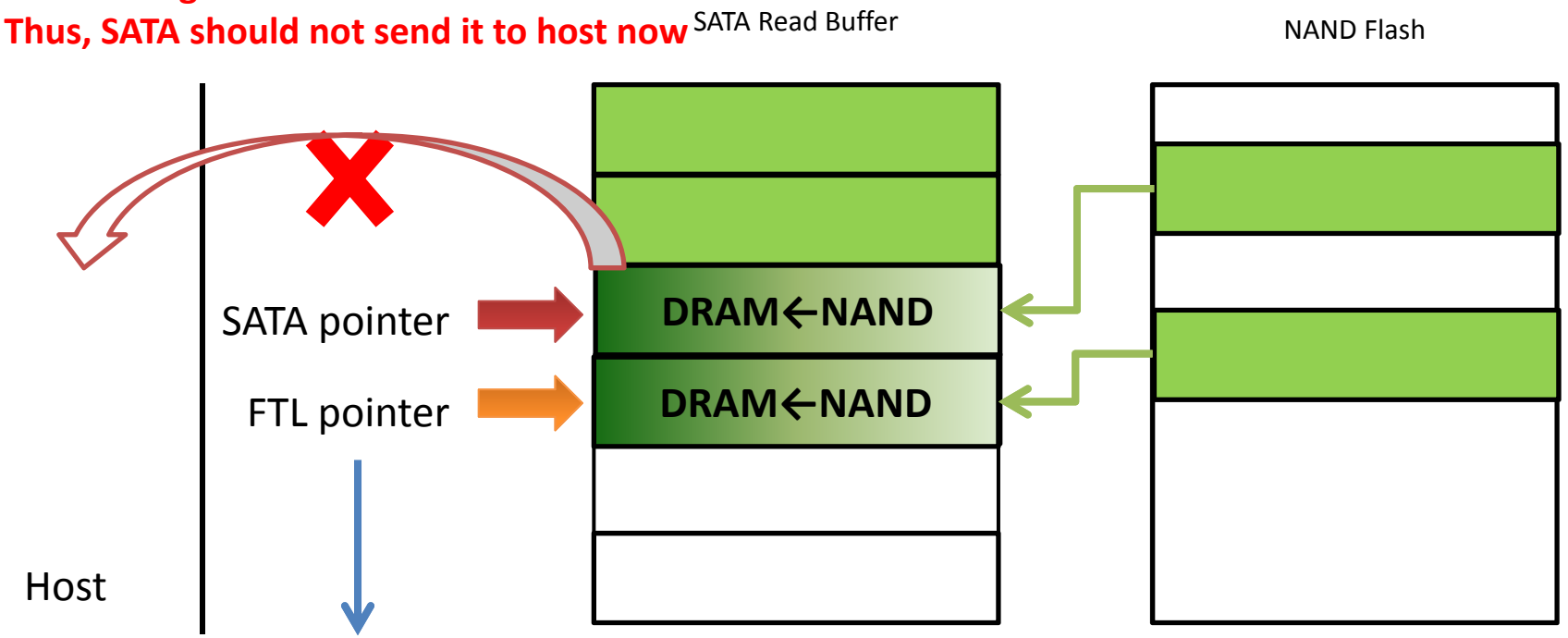
Guide #2 – DRAM Buffer Management

- **SATA read/write buffer**
  - Buffering the data to send to host or the data to program onto NAND
  - Circular FIFO
  - Controlled by **SATA**/**FTL**/**BM** buffer pointers
  - Why do we need a BM buffer pointer?
    - I/O Consistency issue
      - bandwidth gap between SATA and NAND
      - "SATA could send the wrong data to host"
      - "NAND could program the wrong host data"

Guide #2 – DRAM Buffer Management (contd.)

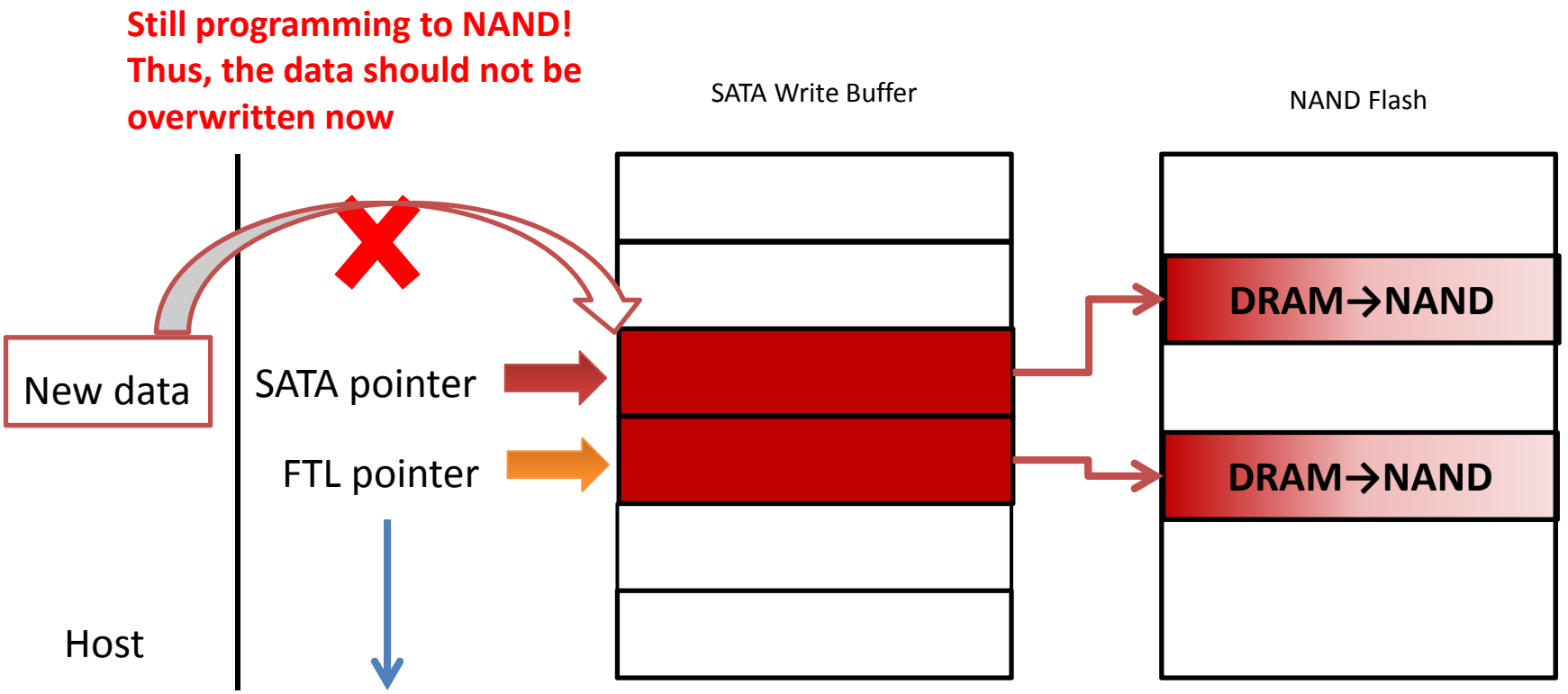
- **What if BM buffer pointer is not used?**

Still reading data from NAND!
Thus, SATA should not send it to host now



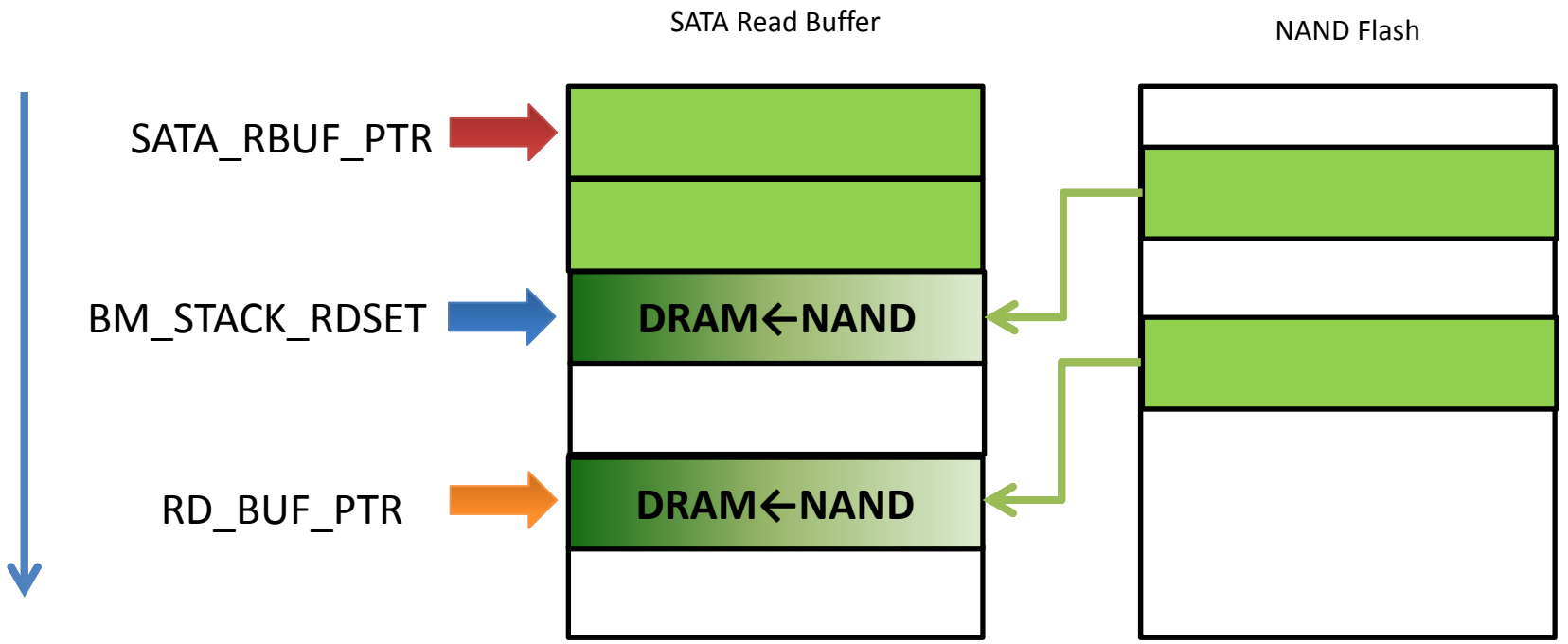
Guide #2 – DRAM Buffer Management (contd.)

- **What if BM buffer pointer is not used?**



Guide #2 – DRAM Buffer Management (contd.)

- **SATA read/write buffer**



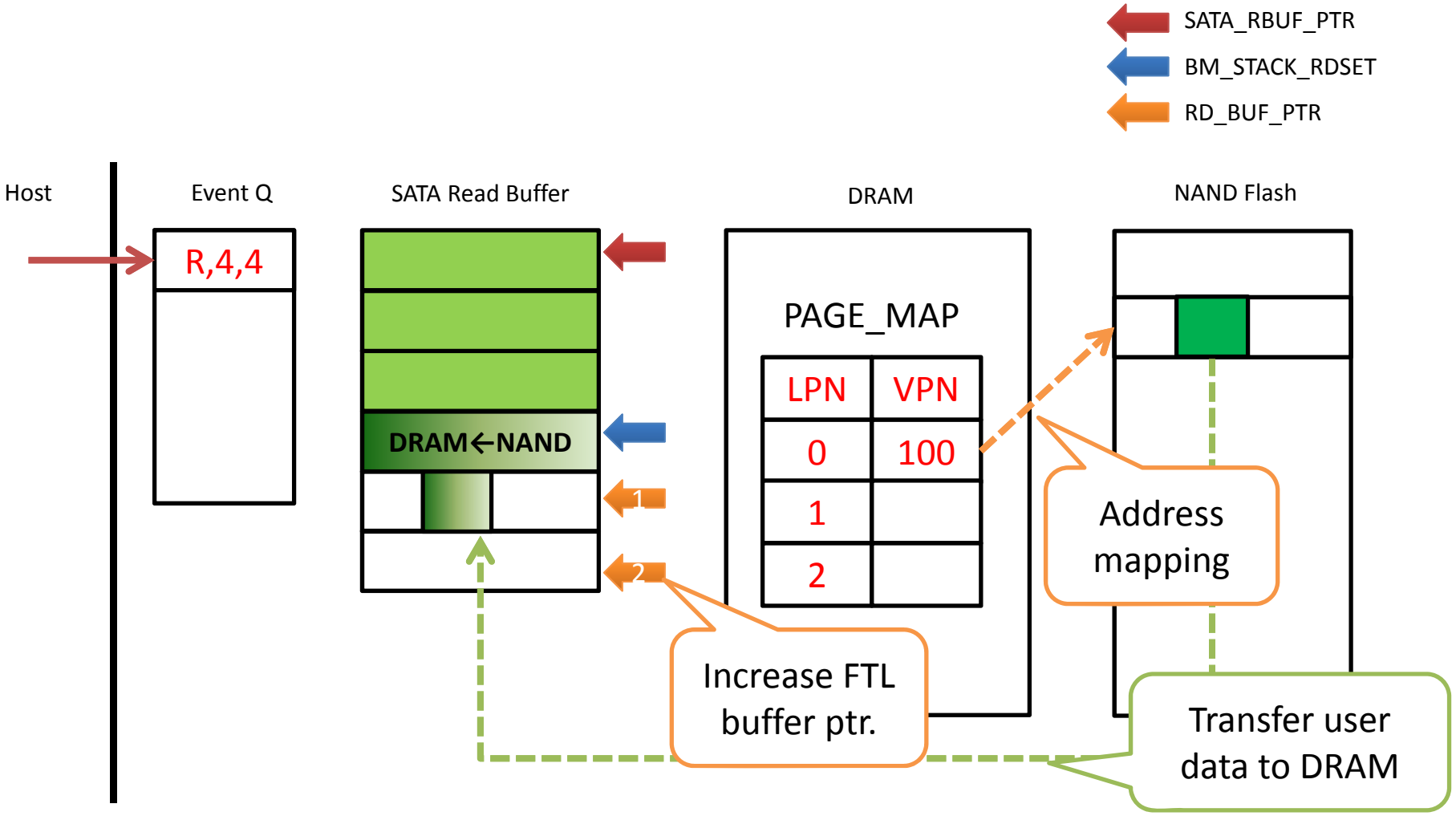
Greedy FTL : Read operation

```
void ftl_read(UINT32 const lba, UINT32 const num_sectors)
{
    lpn = lba / SECTORS_PER_PAGE;
    sect_offset  = lba % SECTORS_PER_PAGE;
    remain_sects = num_sectors;

    while (remain_sects != 0) {
        if ((sect_offset + remain_sects) < SECTORS_PER_PAGE) {
            num_sectors_to_read = remain_sects;
        }
        else {
            num_sectors_to_read = SECTORS_PER_PAGE - sect_offset;
        }
        bank = get_num_bank(lpn); // virtual page-level striping
        vpn  = get_vpn(lpn);      // address mapping
        ...
```

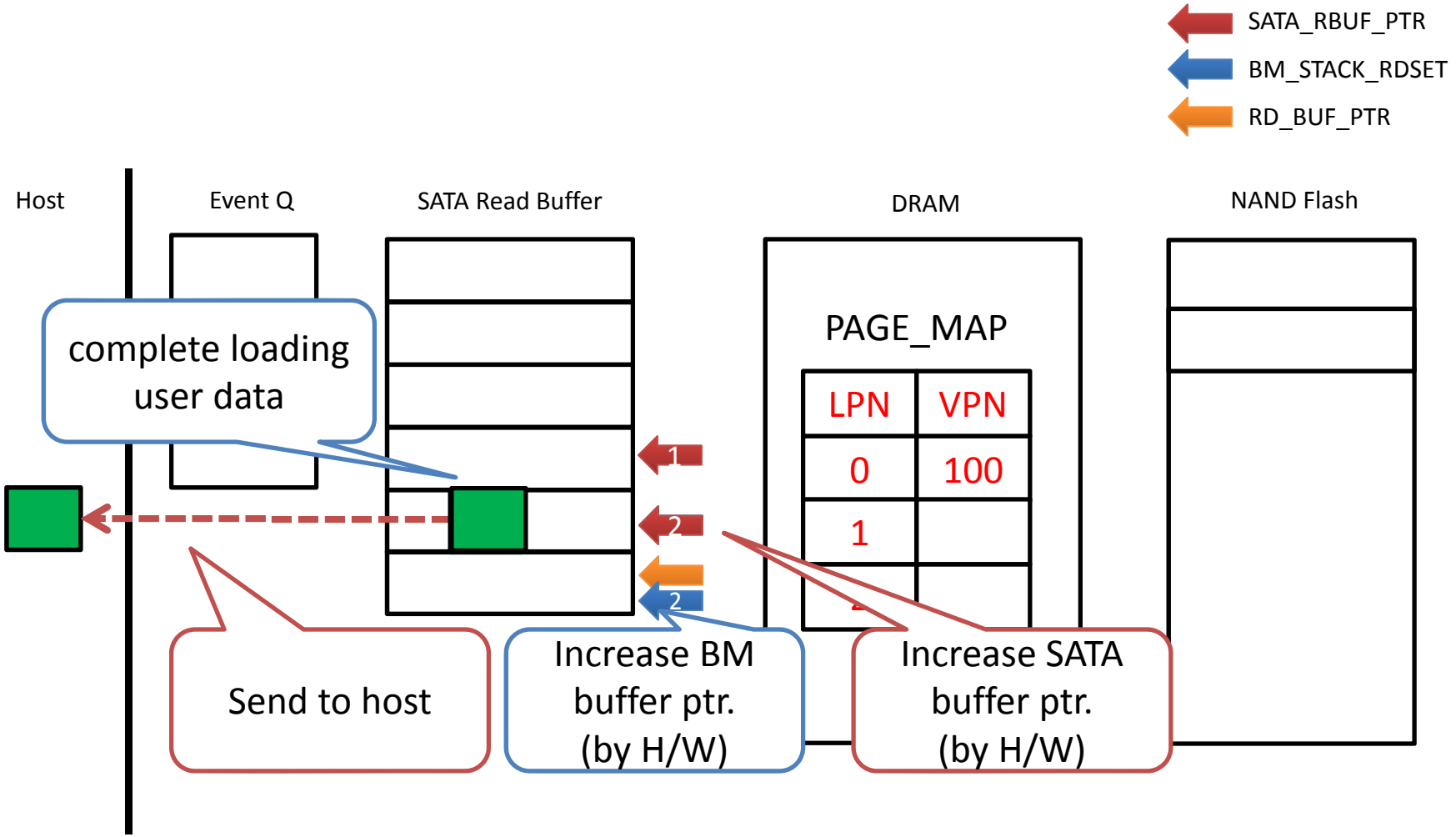
Greedy FTL : Read operation (contd.)

```
        ...
        // old data was already written
        if (vpn != NULL) {
            // send read request to nand flash
            nand_page_ptread_to_host(bank,
                                     vpn / PAGES_PER_BLK,
                                     vpn % PAGES_PER_BLK,
                                     sect_offset,
                                     num_sectors_to_read);
        }
        // The host is requesting to read a logical page that has never been written to.
        else {
                    // change Buffer Manager read limit pointer
                    // change FTL SATA read pointer
        }
        sect_offset   = 0;
        remain_sects -= num_sectors_to_read;
        lpn++;
} // end of ftl_read function
```

Greedy FTL : Read operation (contd.)



Greedy FTL : Read operation (contd.)



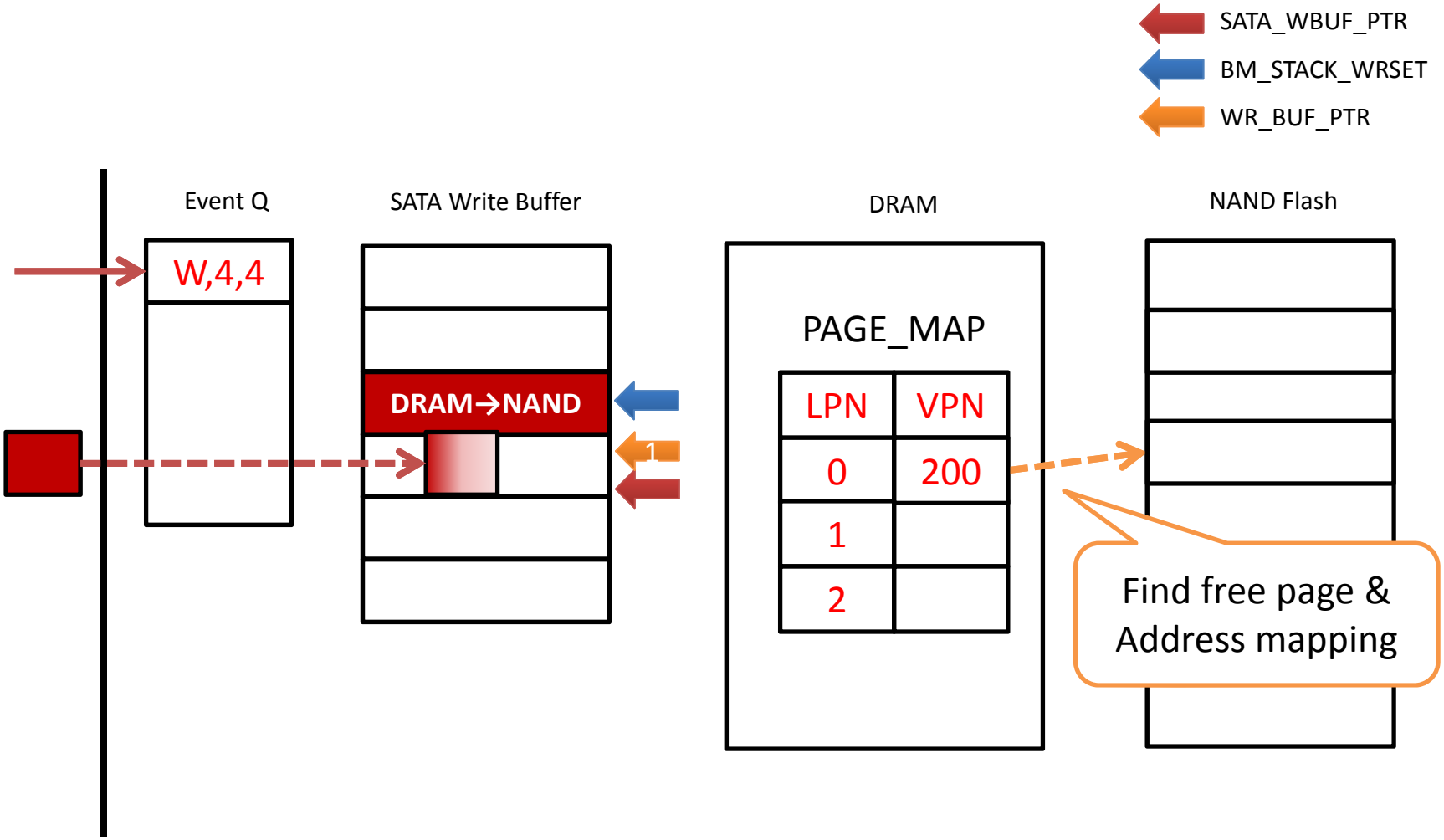
Greedy FTL : Write Operation

```
static void write_page(UINT32 const lpn, UINT32 const sect_offset,
UINT32 const num_sectors)
{
    bank        = get_num_bank(lpn);
    page_offset = sect_offset;
    column_cnt  = num_sectors;
    old_vpn  = get_vpn(lpn);        // address mapping
    new_vpn  = assign_new_write_vpn(bank); // get free vpage

    // if old data already exist,
    if (old_vpn != NULL) {
        // read 'left hole sectors'  [left*][new data][right]
        if (page_offset != 0)
            nand_page_ptread(..., RETURN_ON_ISSUE);
        // read `right hole sectors'  [left][new data][right*]
        if ((page_offset + column_cnt) < SECTORS_PER_PAGE)
            nand_page_ptread(..., RETURN_ON_ISSUE);
        // invalid old page (decrease vcount)
        set_vcount(bank, vblock, get_vcount(bank, vblock) - 1);
    }
    ...
```

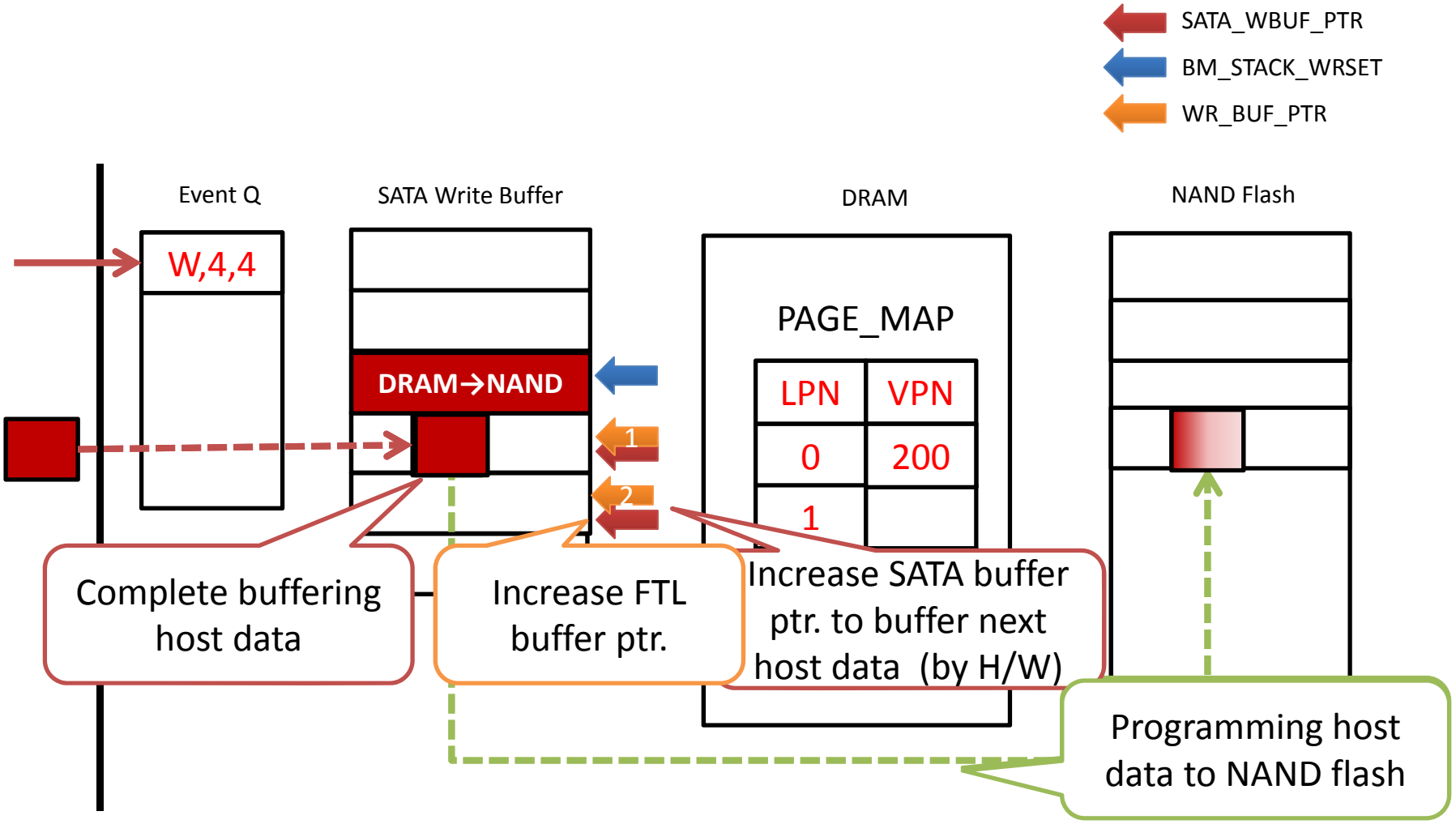
Greedy FTL : Write Operation (contd.)

```
    ...
    vblock   = new_vpn / PAGES_PER_BLK;
    page_num = new_vpn % PAGES_PER_BLK;

    // write new data (RETURN_ON_ISSUE)
    nand_page_ptprogram_from_host(bank,
                                  vblock,
                                  page_num,
                                  page_offset,
                                  column_cnt);
    /* update metadata */
    set_lpn(bank, page_num, lpn); // maintain lpn list for GC
    set_vpn(lpn, new_vpn);        // address mapping table
    // increase block valid page count
    set_vcount(bank, vblock, get_vcount(bank, vblock) + 1);

} // end of write_page function (caller: ftl_write)
```

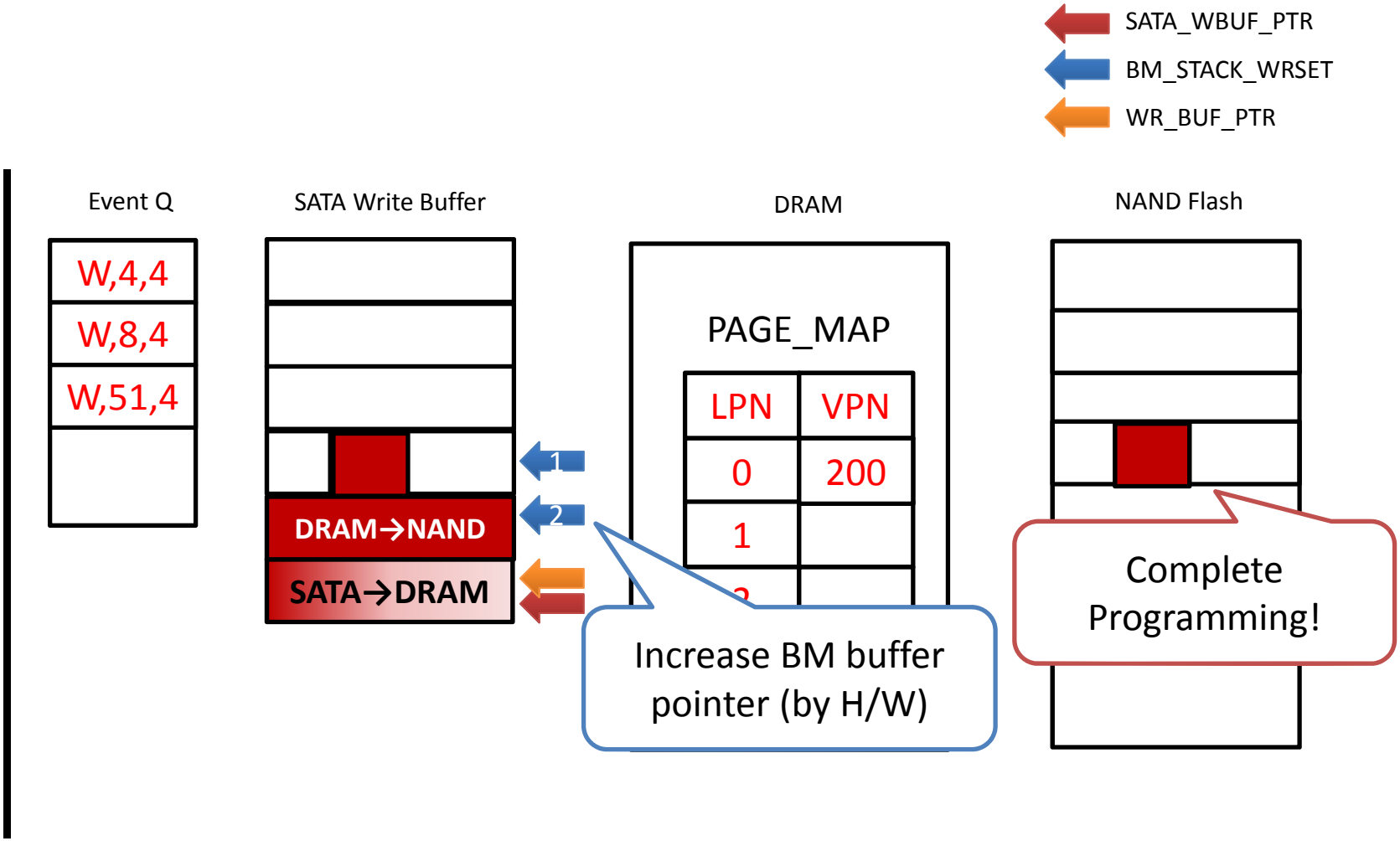
Greedy FTL : Write Operation (contd.)



Greedy FTL : Write Operation (contd.)



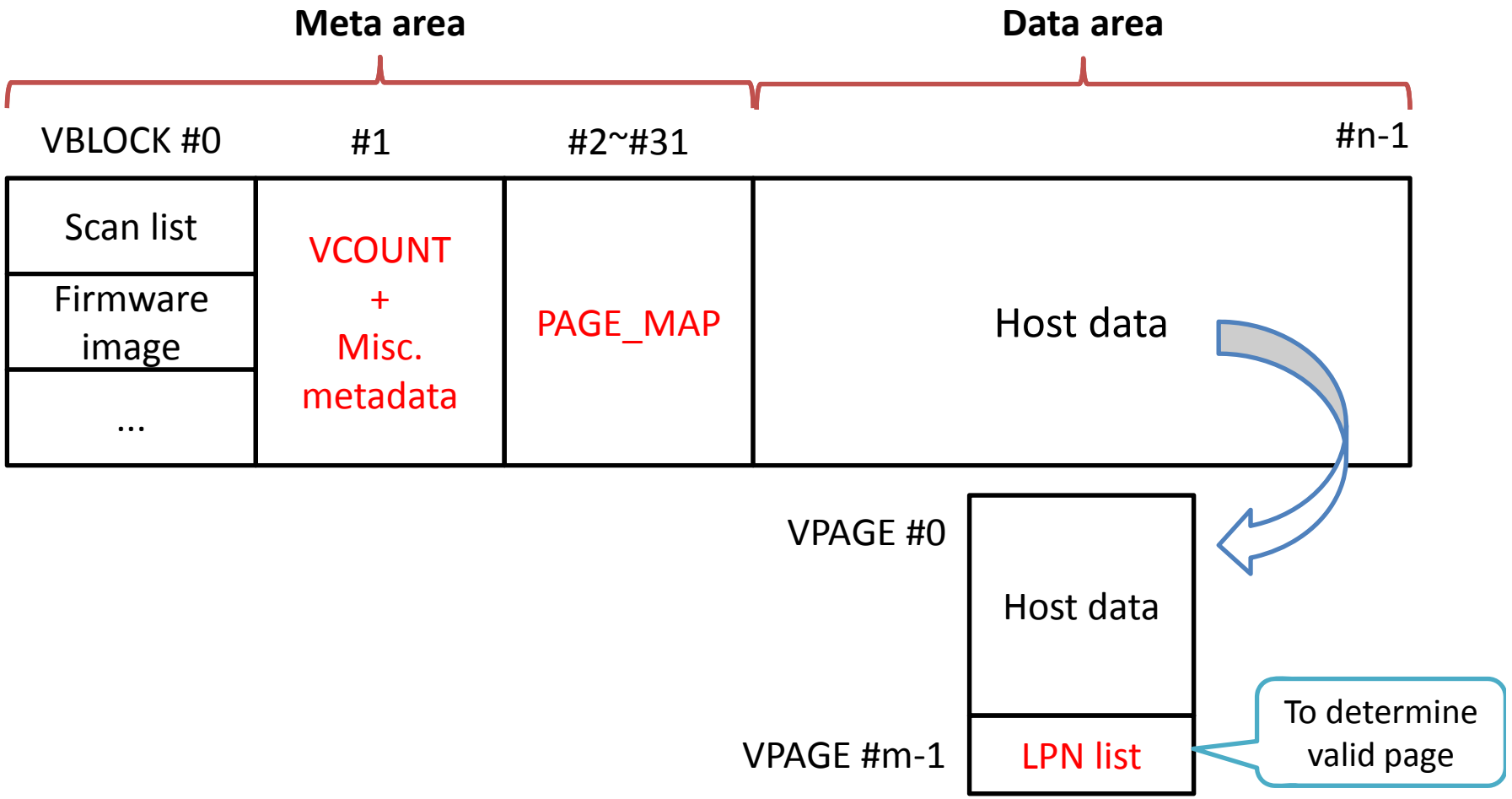
Greedy FTL : Write Operation (contd.)



Guide #3 – Flash Command

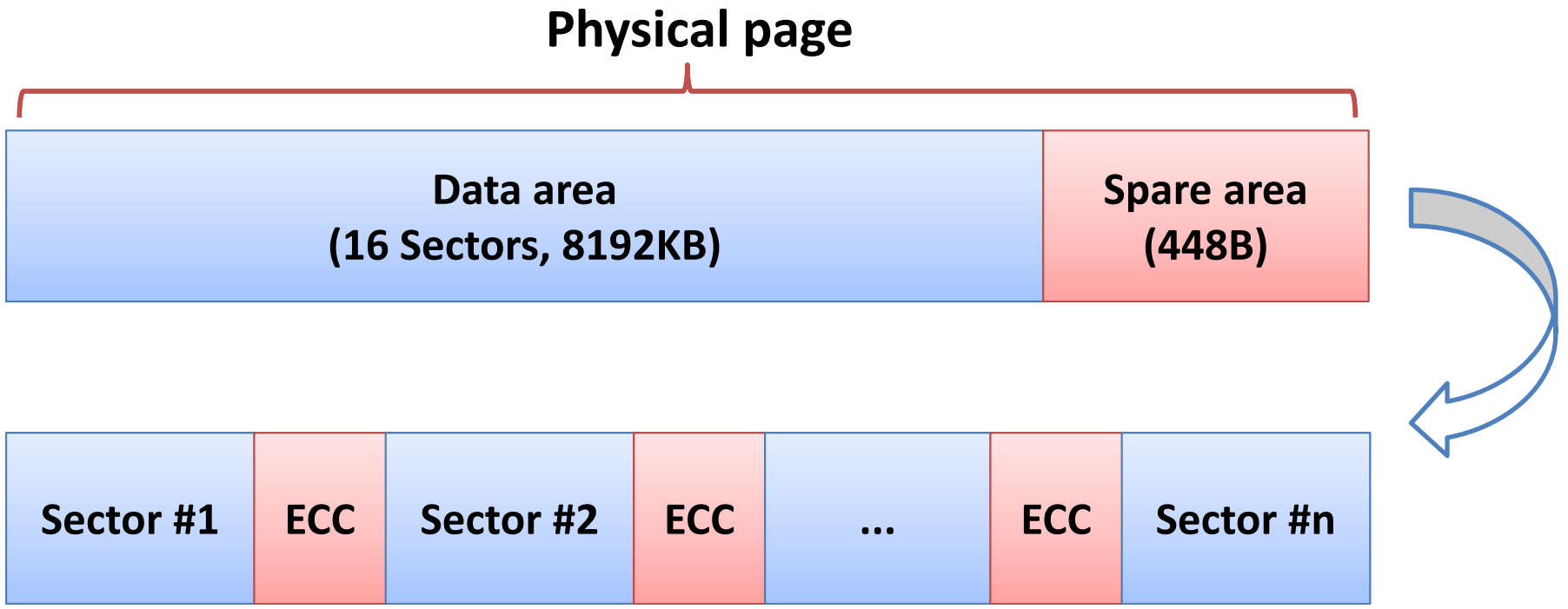
- **To send I/O command to NAND flash**
  - ① Programming FCP command manually
    - See tutorial FTL code (`./ftl_tutorial/ftl.c`)
  - ② Use LLD interface (`./target_spw/flash_wrapper.c`)
    - Easiest way to implement an FTL
    - If you want to make a high performance FTL, the first option is recommended

Greedy FTL : NAND Configuration



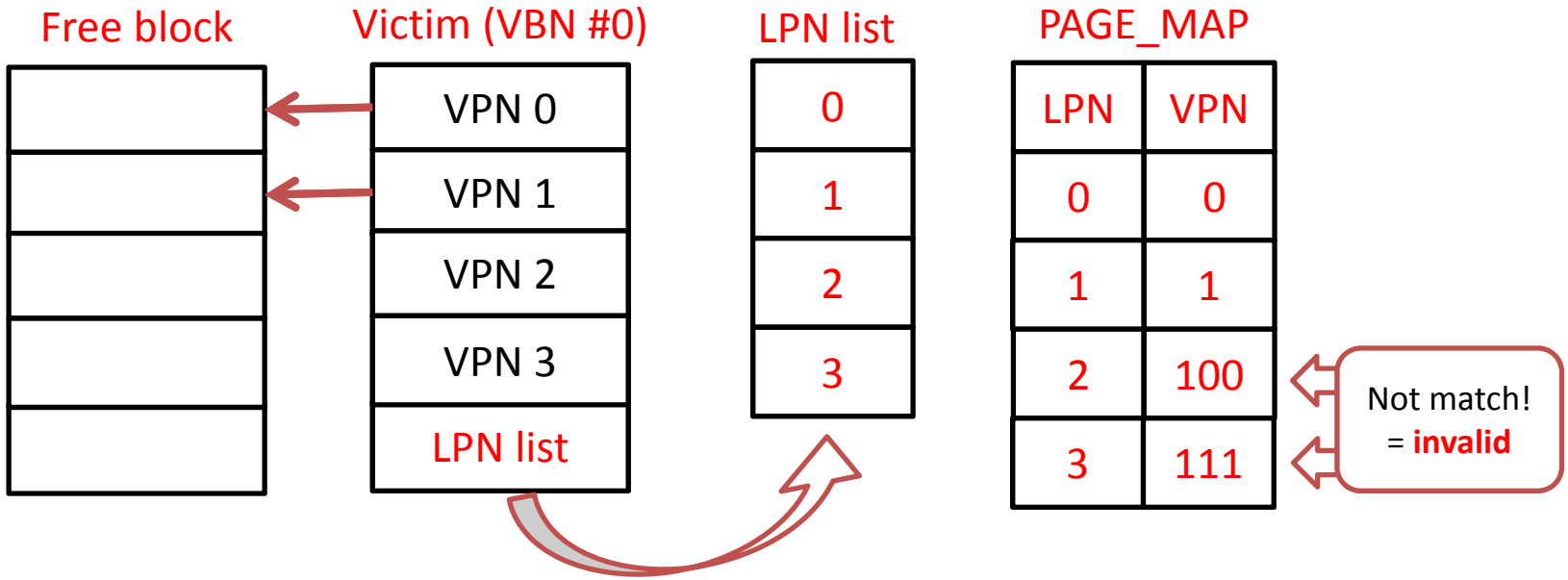
Guide #4 - Restriction of Accessing NAND

- **No support for accessing 'spare area'**



Greedy FTL : Garbage Collection

- **If free blocks run out, a victim block is chosen based on the 'greedy policy'**
  - i.e., select the block containing min. valid pages



Greedy FTL : POR(Power-Off Recovery)

- **Metadata logging**
  - Flush all metadata instantly (by **`ftl_flush`**)
  - @ SATA ready/idle/standby time

Block #0

<table>
<tr><td>Scan list</td><td rowspan="3">VCOUNT
+
Misc.
metadata</td><td rowspan="3">PAGE_MAP</td><td rowspan="3">User space</td></tr>
<tr><td>Firmware image</td></tr>
<tr><td>…</td></tr>
</table>

Guide #5 – BSP interrupt

- **Check `BSP_INTR` register (`ftl_isr`)**

```
FIRQ_CORRECTED    FIRQ_CRC_FAIL    FIRQ_MISMATCH
FIRQ_BADBLK_L     FIRQ_BADBLK_H    FIRQ_ALL_FF
FIRQ_ECC_FAIL     FIRQ_DATA_CORRUPT
```

- **BSP contains the flash command which was last issued for debugging**

Debugging Guide

Ways to Debug Your Code

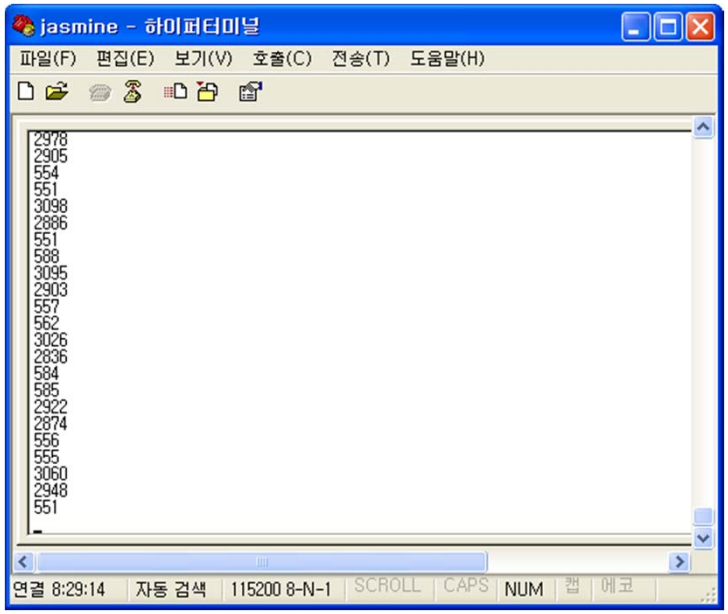
① Serial communication (UART interface)

② ICE + RVD (JTAG interface)

③ On-board indicator (LED on Position D4)

UART Debugging

- **Memory/Register dump message**
- **You also can measure I/O response time using Timer function (`./target_spw/misc.c`)**



Debugging using ICE + RVD

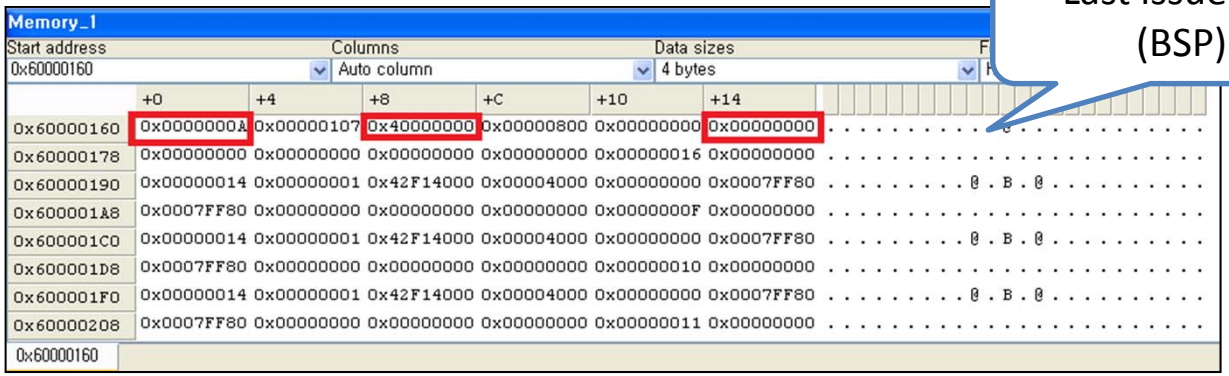
- **Line-by-line debugging**

```
g_barrier = 0;
while (g_barrier == 0);
```

To stop the firmware execution

- **Check controller registers**

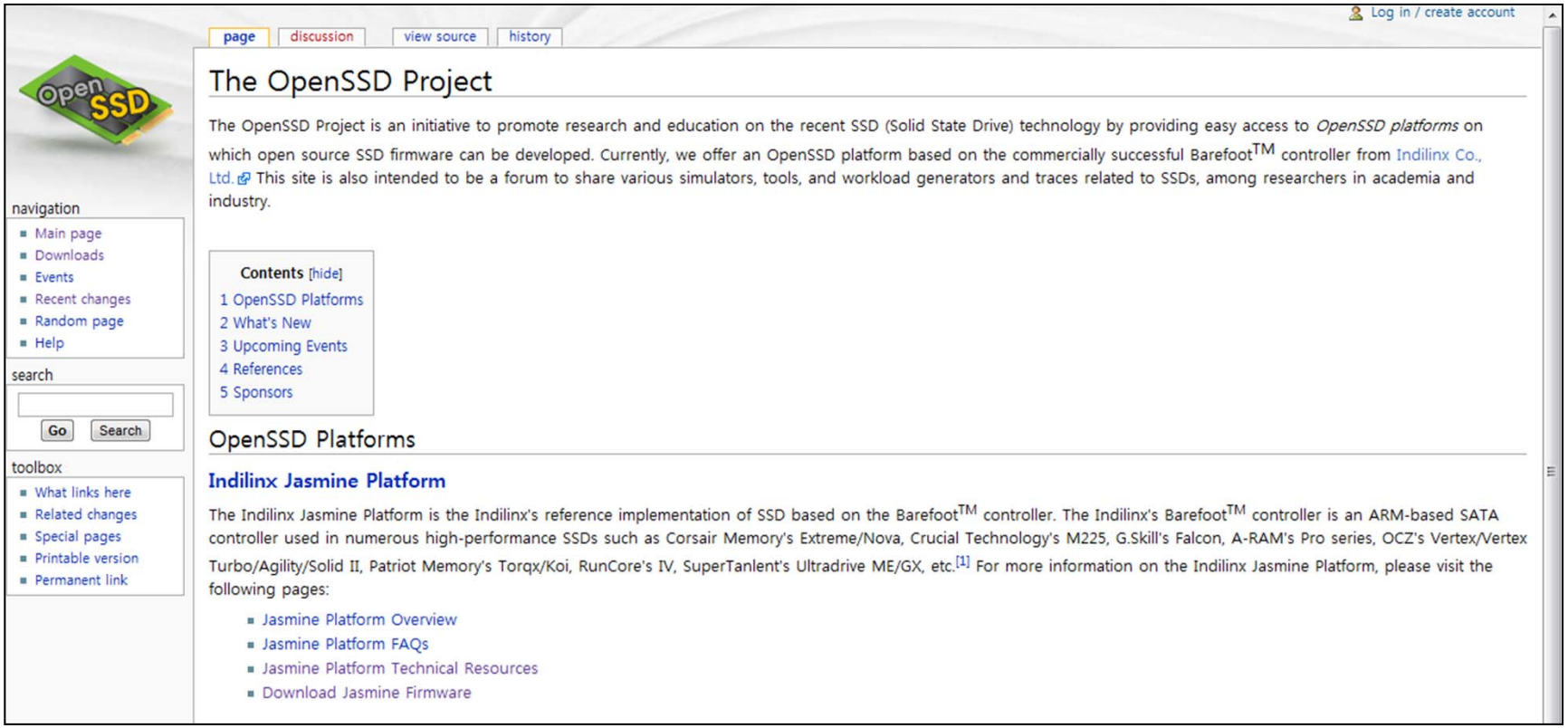
Last issued FC (BSP)



Jasmine Technical Document

- **You can download them from the OpenSSD Project homepage**
  - http://www.openssd-project.org
- **Technical Reference Manual**
  - Jasmine Board Schematics
  - INDILINX Barefoot™ SSD Controller Specification
  - Jasmine Firmware Architecture
  - Jasmine Firmware Software Specification
- **FTL Developer's Guide**
  - FTL Porting Guide
  - Compile, Build & Install Firmware
  - Debugging Tips

Participate in Our OpenSSD Activities!



Thank you !