Evaluation of UBI and UBIFS

TOSHIBA CORPORATION
Core Technology Center
Embedded System Technology Development Dept.
UWATOKO Katsuki
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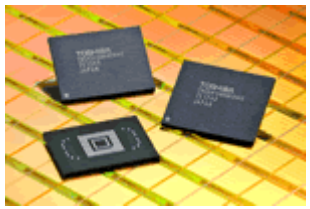
Agenda

- **Background**
- **Topic**
  1. **Boot time**
  2. **Flash space overhead**
  3. **UBI scrubbing on preempt kernel**
  4. **Sub-page write verify**
  5. **Error handling**
- **Summary**
- **References**

Background

- **Large size NAND flash memory is commonly used in embedded systems & Flash File systems for Larger size NAND are necessary.**

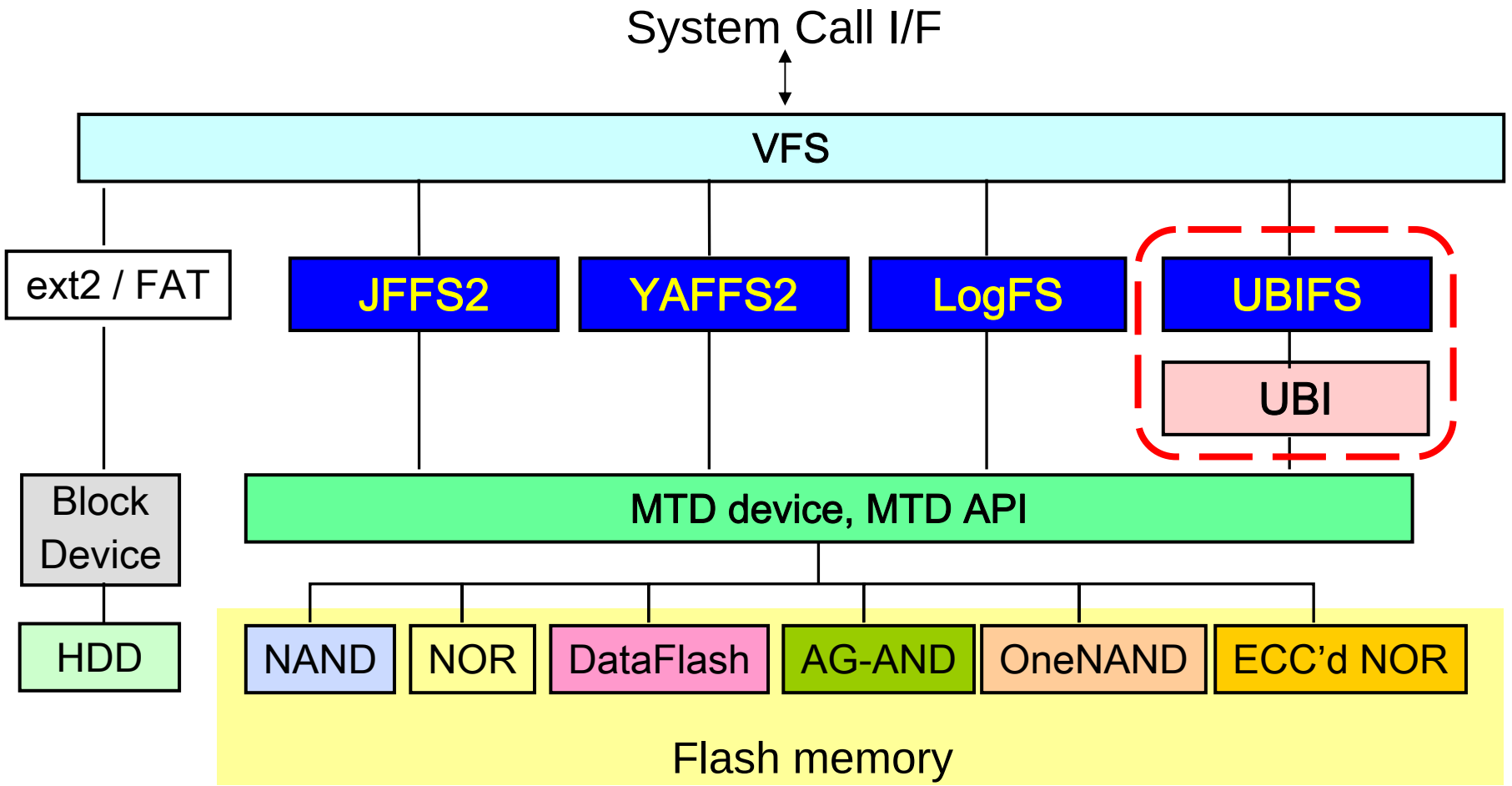


- **UBI : Unsorted Block Images**

  (Artem Bityutskiy, Adrian Hunter)
  - **Mainlined in 2.6.22 in Jul 2007.**
  - **Works on top of UBI volumes.**
  - **Write-back, Compression, Journal, …**
- **UBIFS : Unsorted Block Image File System** (Artem Bityutskiy)
  - **Mainlined in 2.6.27 in Oct 2008.**
  - **Works on top of MTD partition.**
  - **Logical Volume, Global Wear-leveling, Scrubbing, Journal, …**

⇒ UBI/UBIFS is one of the best file system. But one would run into some issues when evaluating it. This reports those issues.

Background

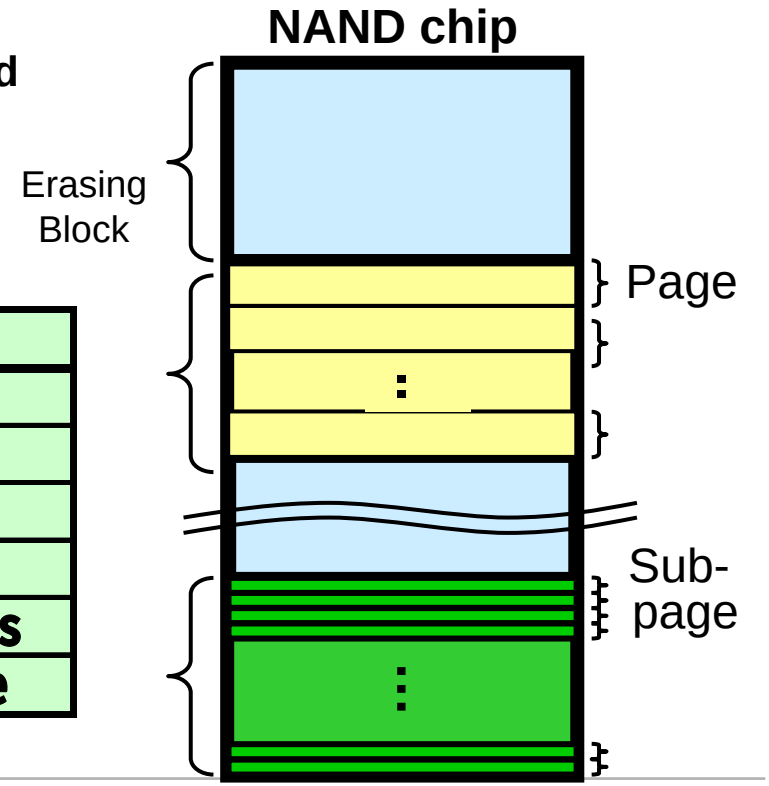


VFS: Virtual File System
MTD: Memory Technology Device

Background

- **Software**
  - **Linux kernel : Vanilla kernel 2.6.20.19 + Original patch for embedded systems**
  - **UBIFS / UBI : Vanilla kernel 2.6.30**
  - **MTD : Vanilla kernel 2.6.20.19**
  - **MTD NAND driver : txx9ndfmc (Original patch for the product's CPU)**
- **Hardware**
  - **Board : Digital product development board**
  - **CPU : MIPS 528 MHz (I$/D$: 64KB/64KB)**
  - **RAM(kernel) : 256 MB (64 MB)**
  - **NAND :**

		Toshiba	Hynix
Bus		8 bit	8 bit
Total Size	Data	64 MB	32 MB
	OOB	2 MB	1 MB
Erasing block		16 KB	16 KB
Page		512 bytes	512 bytes
Sub-page		256 byte	256 byte



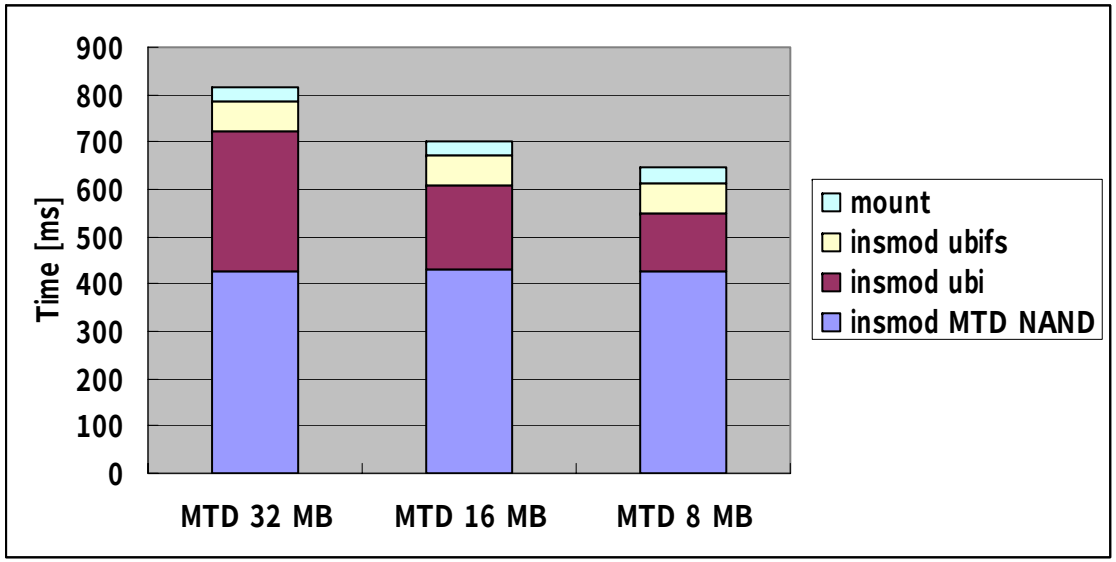
Topic 1 : Boot time

The correlation between the time and the size

MTD 32MB partition, UBI 1 volume (Toshiba NAND)

[ms]

Command	MTD 32 MB	MTD 16 MB	MTD 8 MB
insmod MTD NAND	428	429	428
insmod ubi	295	181	123
insmod ubifs	61	62	62
mount	30	30	32



Topic 1 : Boot time

The MTD NAND driver initialization is slow.

The time is not depend on the size of MTD partition,

is depend on the size of NAND chip.

- **Cause**

  The building BBT (Bad Block Table) is slow.

  - **Reading 1 OOB (16 Byte) per a EraseBlock**
  - **BBT of whole chips (MTD0) is build in the MTD NAND driver initialize.**

- **Ideas of an improvement**

  - **Building BBT per MTD partitions.**
  - **Using “BBT on Flash” - BBT is in a separate internal volume.**
  - **Using Large Page Size NAND**

Topic 1 : Boot time

The UBI initialization is slow.

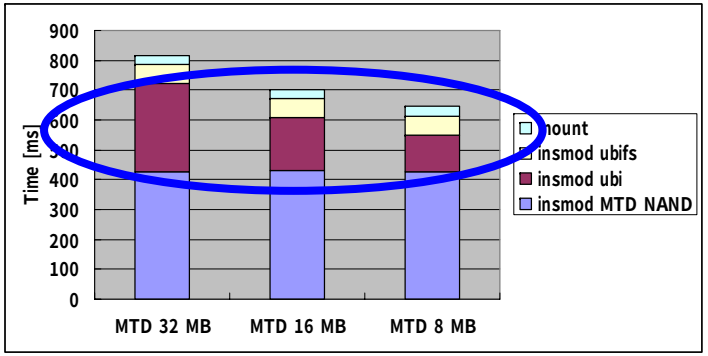
The time is depend on the size of MTD partition.

- **Cause**

  The reading of EC (Erase Counter) and VID (Volume Identifier) is slow.

  - **Reading 1 page (512 Byte) per a EraseBlock (2048 PEB * 512 = 1 MB)**
  - **BBT of whole chips (MTD0) is build in the MTD NAND driver initialize.**
  - **http://www.linux-mtd.infradead.org/doc/ubi.html#L_scalability**

    “Scalability issues”



- **The ideas of an improvement**
  - **Whole EC/VID are in a separate internal volume like “BBT on Flash”**
  - **http://www.linux-mtd.infradead.org/faq/ubi.html#L_attach_faster**

    “How do I speed up UBI initialization ”

Topic 2 : Flash space overhead

- **Problem**

  “df” command reports too few free space.

  The result of df on 32 MB (32768 1k-blocks) MTD partition...

```
~ $ df
Filesystem           1k-blocks      Used Available Use% Mounted on
ubi0_0                   22960        20     21468   0% /mnt/omote
```

- **Factors**

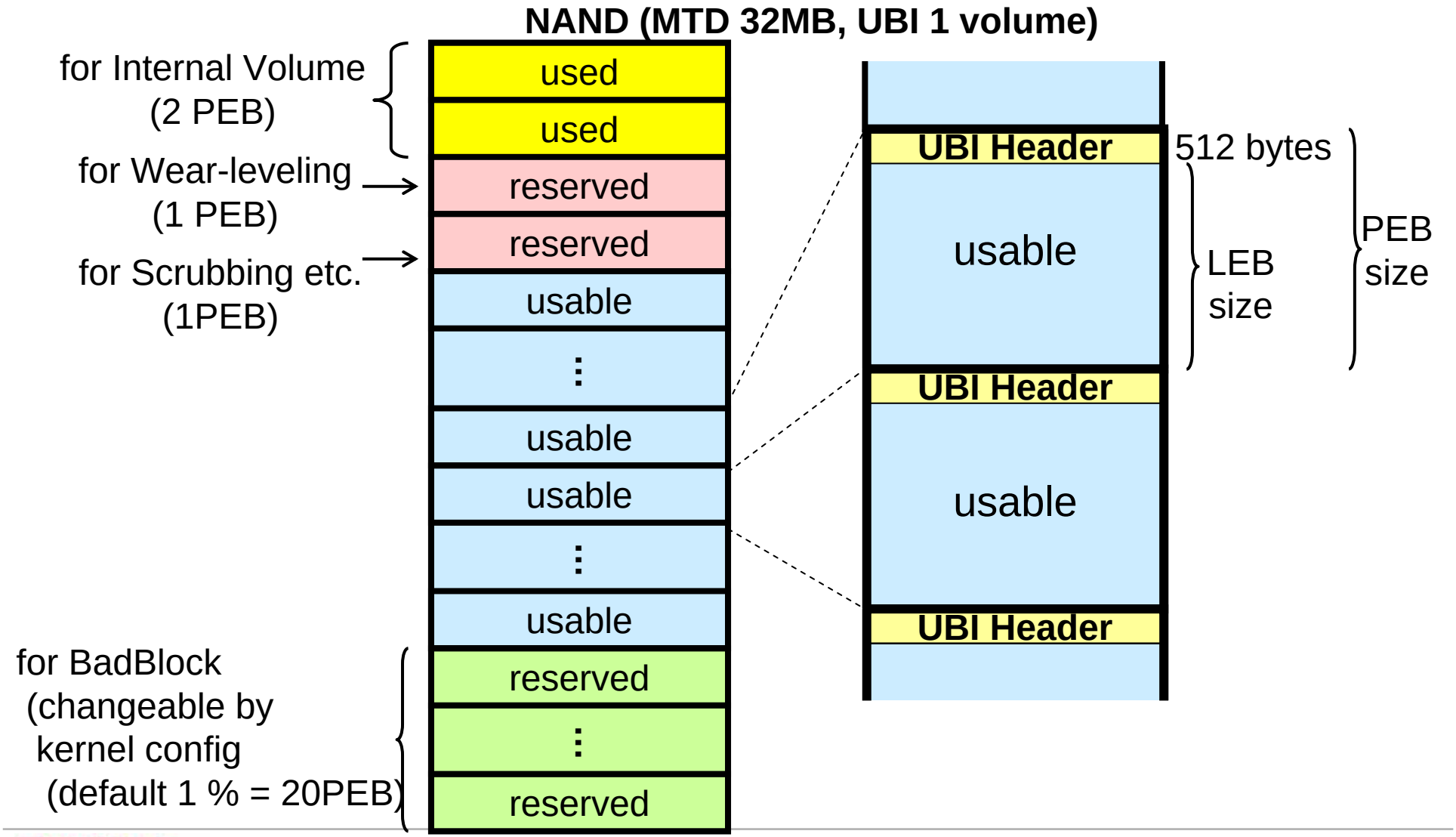
  “http://www.linux-mtd.infradead.org/faq/ubifs.html#L_df_report” describes the details.

  “Why df reports too few free space?”

  - compression
  - write-back
    - **→ The accurate size is unknown because the compression ratio depends on each file.**
  - space wastage at the end of logical eraseblock
    - **→ as more fully discussed herein after**
  - garbage-collection
    - **→ The accurate result of garbage-collection is not predictable.**

Topic 2 : Flash space overhead

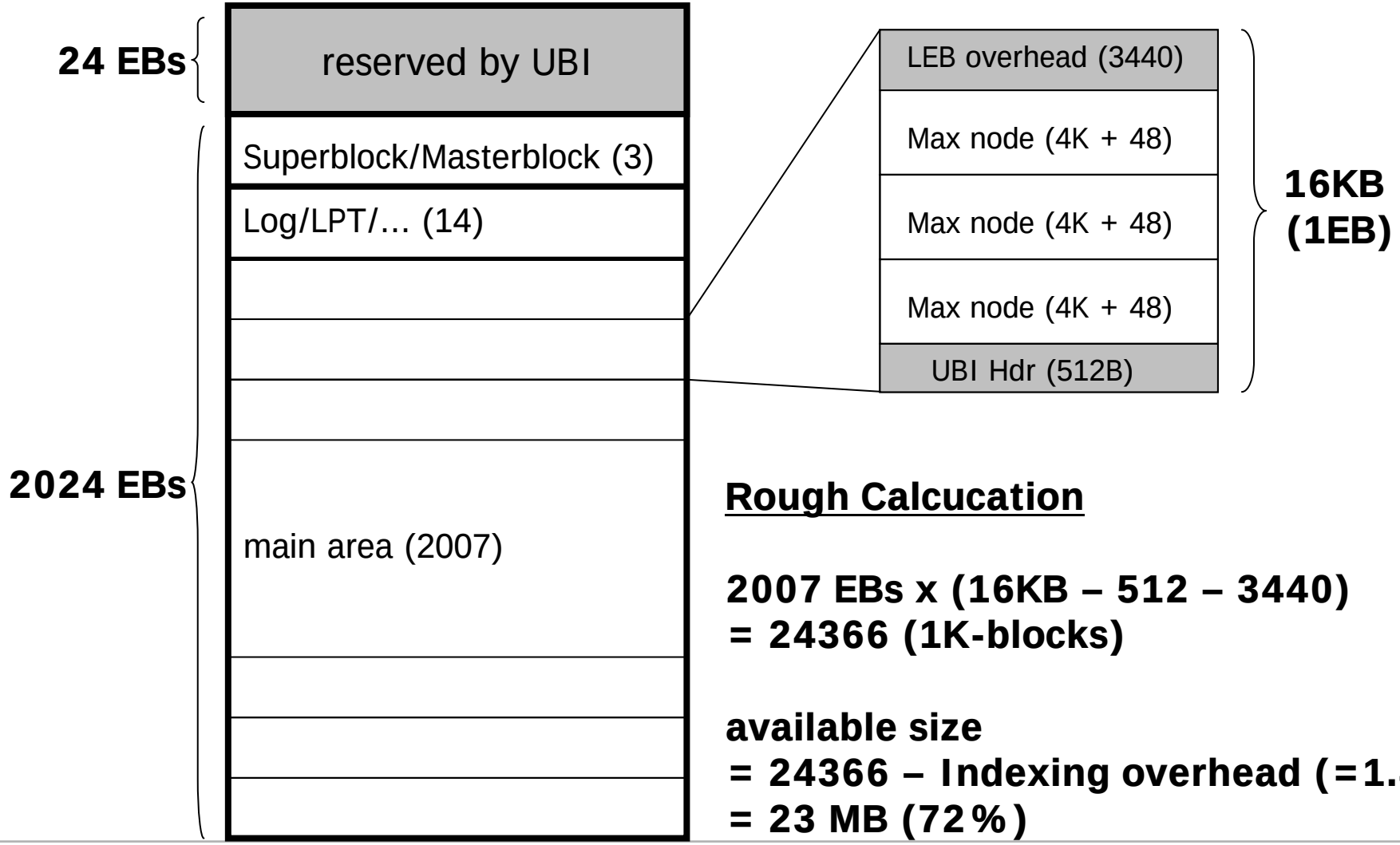
- **The factor of UBI**



Topic 2 : Flash space overhead

- **The factor of UBIFS**

NAND (MTD 32MB, UBI 1 volume)



Rough Calcucation

2007 EBs x (16KB – 512 – 3440)
= 24366 (1K-blocks)

available size
= 24366 – Indexing overhead (=1.4MB)
= 23 MB (72%)

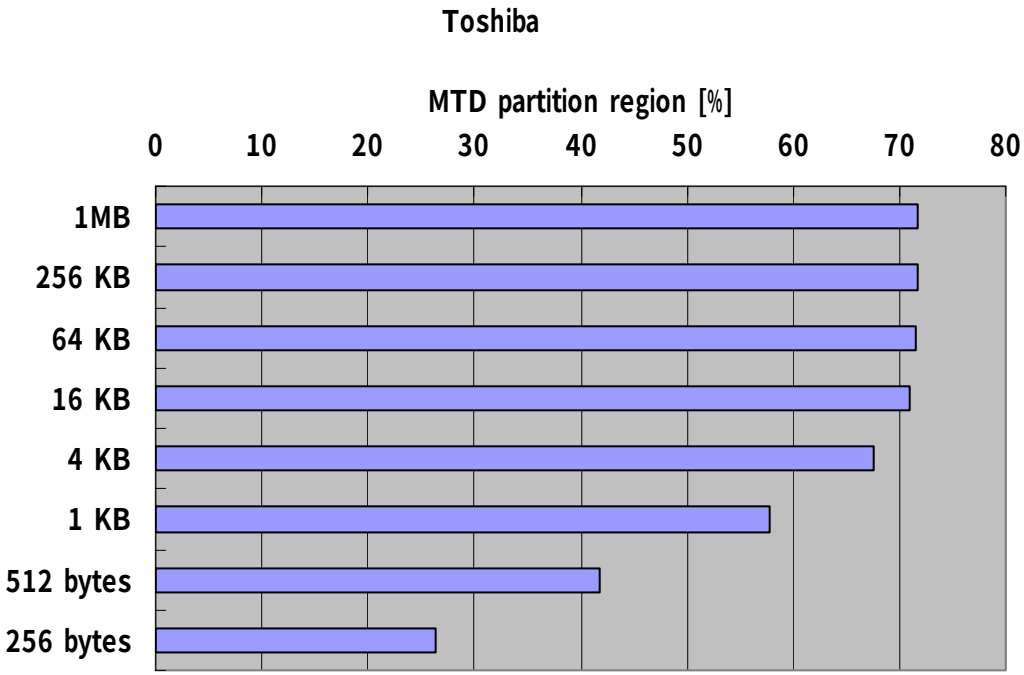
Topic 2 : Flash space overhead

- **The actual total size of user data**

Conditions:

- **MTD partition size: 32MB, UBI volume number: 1**
- **LZO compression enable**
- **Random Data Random Data (The compression rate is low)**
- **“df” command reports “available 22960 KB” when empty.**

	writable data [MB] (%)
file size	Toshiba (MTD 32MB)
1MB	23.5 (71.8)
256 KB	23.5 (71.8)
64 KB	23.4 (71.6)
16 KB	23.2 (70.9)
4 KB	22.1 (67.5)
1 KB	18.9 (57.8)
512 bytes	13.6 (41.7)
256 bytes	8.6 (26.3)



		Description	# of blocks
UBI (2048 EBs)		For Internal-Vol, Wearleveing, Scrubbing	4
		For Bad Block	20
UBIFS (2024 EBs)		Super Block/Master Block	3
		LOG/LPT..	14
	Main Area (2007 EBs)	Empty Block	24
		Index Block	19
		Data Block	1964

- **Typical Data Block**

  LEB 893 lprops: free 3072, dirty 368 (used 12432), flags 0x0

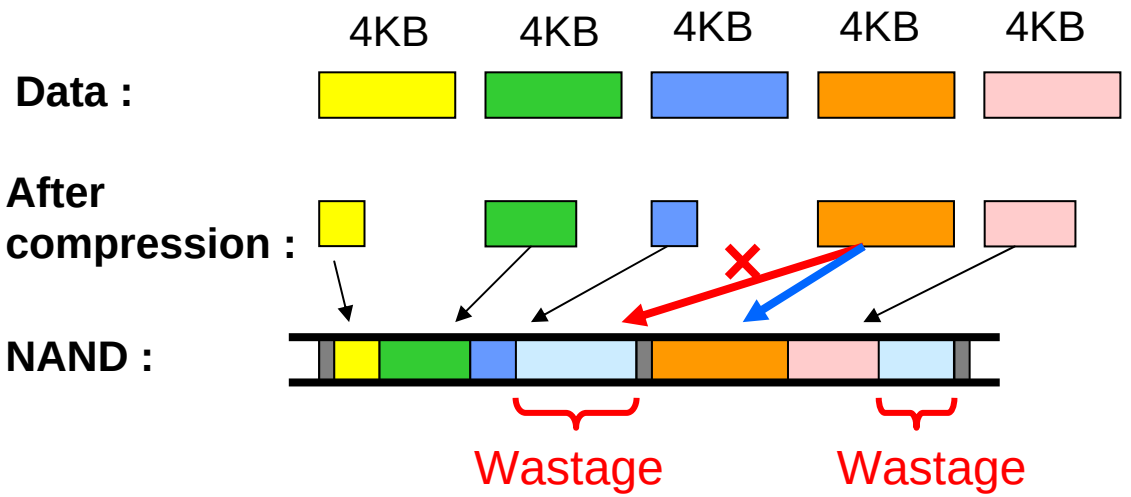
Topic 2 : Flash space overhead

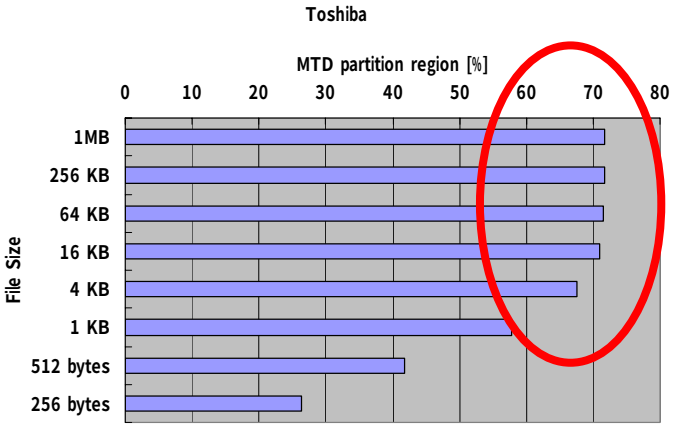
- **Cause**

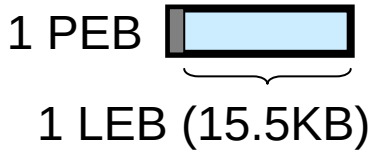
  Free space at the tail of PEB

  http://www.linux-mtd.infradead.org/doc/ubifs.html#L_spacea

  “Flash space accounting issues ” – “Wastage”







The ideas of an improvement

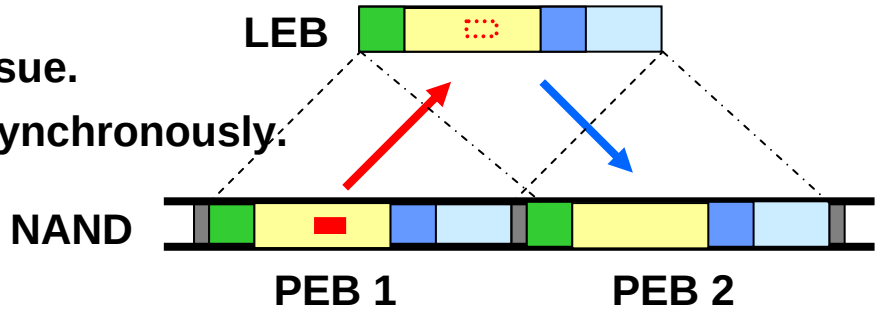
- **change the unit size (UBIFS_BLOCK_SIZE) of UBIFS to smaller (must be power of two)**

  → influence to the compression ratio and the performance

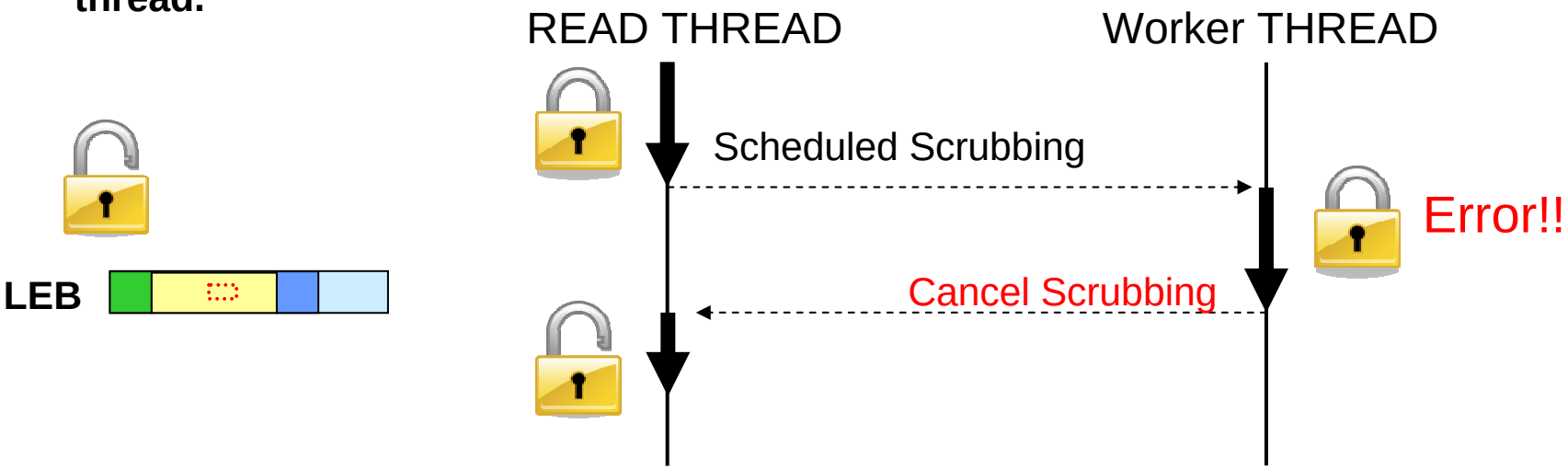
- **use Large Page size NAND**

Topic 3 : UBI scrubbing on preempt kernel

- **UBI “Scrubbing” function**
  - **When a bit-flip (ECC 1 bit error) is detected in a physical erase block, the block is move to other physical erase block.**
  - **It is beneficial for the “read disturb” issue.**
  - **Worker thread execute “scrubbing” asynchronously.**



- **Symptom**
  - **In the case of Preempt Kernel, the scrubbing could be canceled. Because the read thread holding the lock of LEB could be preempted by the wearleveing thread.**



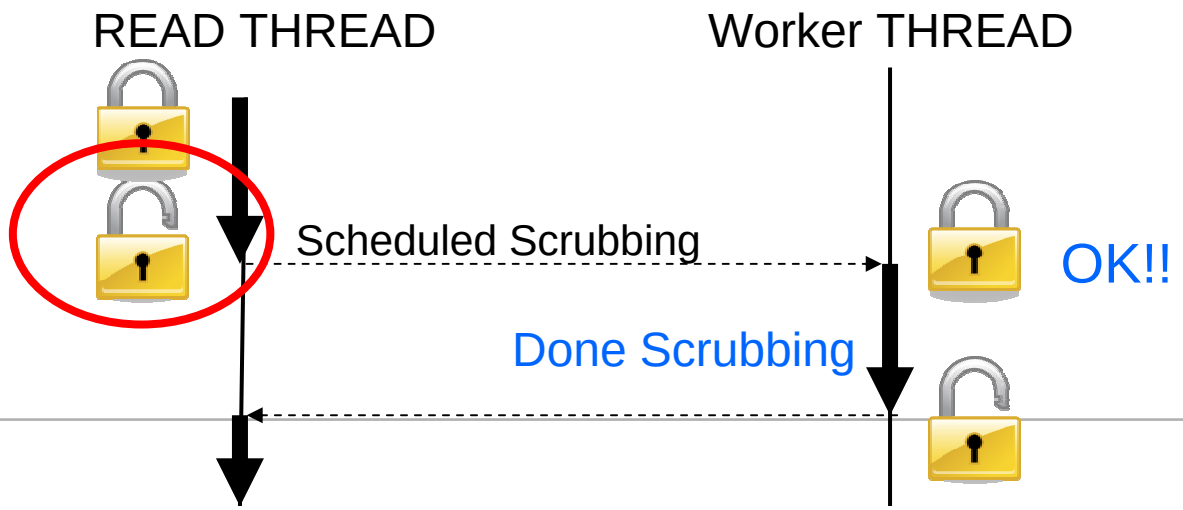
Topic 3 : UBI scrubbing on preempt kernel

- **Patch**
  - **The lock of LEB is released before queuing a scrubbing.**
  - **It is not necessary to hold the lock when queuing it.**
- **[drivers/mtd/ubi/eba.c]**

```
int ubi_eba_read_leb(struct ubi_device *ubi, struct ubi_volume *vol, int lnum,
                                                    void *buf, int offset, int len, int check)
{
   (中略)
+               leb_read_unlock(ubi, vol_id, lnum);

                if (scrub)
                                err = ubi_wl_scrub_peb(ubi, pnum);

-               leb_read_unlock(ubi, vol_id, lnum);
                return err;
```



Topic 4 : Sub-page write verify

- **MTD NAND “Verify NAND page writes” function**
  - **is the write verify function per a NAND physical page.**
  - **is implemented in MTD NAND driver.**

- **Symptom**
  - **does not support per a sub page.**

    the another sub page in the same page would not be managed properly.
  - **UBI uses a sub page write in writing VID header.**
  - http://www.linux-mtd.infradead.org/faq/ubi.html#L_subpage_verify_fail

    “I get "ubi_io_write: error -5 while writing 512 bytes to PEB 5:512“

    If you have a 2048 bytes per NAND page device, and have CONFIG_MTD_NAND_VERIFY_WRITE enabled in your kernel, you will need to turn it off. The code does not currently (as of 2.6.26) perform verification of sub-page writes correctly. As UBI is one of the few users of sub-page writes, not much else seems to be affected by this bug.

※ Not only “a 2048 bytes per NAND page device”.
(ex. This NAND. Page: 512 bytes, Sub-page: 256 bytes)

Topic 4 : Sub-page write verify

- **Patch**

  The function for write verifying with column (offset) and size is added to MTD NAND structure in MTD NAND driver.

[include/linux/mtd/nand.h]

```
struct nand_chip {
        void  __iomem           *IO_ADDR_R;
        void  __iomem           *IO_ADDR_W;

        uint8_t                 (*read_byte)(struct mtd_info *mtd);
        u16                     (*read_word)(struct mtd_info *mtd);
        void                    (*write_buf)(struct mtd_info *mtd, const uint8_t *buf, int len);
        void                    (*read_buf)(struct mtd_info *mtd, uint8_t *buf, int len);
        int                     (*verify_buf)(struct mtd_info *mtd, const uint8_t *buf, int len);
+ #ifdef CONFIG_MTD_NAND_VERIFY_WRITE_SUBPAGE
+       int                     (*verify_buf_column)(struct mtd_info *mtd, const uint8_t *buf, int len,
+                                                    int column, int verify_size);
+ #endif
        void                    (*select_chip)(struct mtd_info *mtd, int chip);
        int                     (*block_bad)(struct mtd_info *mtd, loff_t ofs, int getchip);
        int                     (*block_markbad)(struct mtd_info *mtd, loff_t ofs);
```

Topic 4 : Sub-page write verify

[drivers/mtd/mtd/nand/nand_base.c]

```
static int nand_do_write_ops(struct mtd_info *mtd, loff_t to,
                                        struct mtd_oob_ops *ops)
{
    (中略)
                        /* Partial page write ? */
                        if (unlikely(column || writelen < (mtd->writesize - 1))) {
                                cached = 0;
                                bytes = min_t(int, bytes - column, (int) writelen);
                                chip->pagebuf = -1;
                                memset(chip->buffers->databuf, 0xff, mtd->writesize);
                                memcpy(&chip->buffers->databuf[column], buf, bytes);
                                wbuf = chip->buffers->databuf;
                        }

                        if (unlikely(oob))
                                oob = nand_fill_oob(chip, oob, ops);

                        ret = chip->write_page(mtd, chip, wbuf, page, cached,
                                               (ops->mode == MTD_OOB_RAW));
                        if (ret)
                                break;

+ #if defined(CONFIG_MTD_NAND_VERIFY_WRITE_SUBPAGE) && !defined(CONFIG_MTD_NAND_VERIFY_WRITE)
+                       /* Send command to read back the data */
+                       chip->cmdfunc(mtd, NAND_CMD_READ0, 0, page);
+
+                       if (chip->verify_buf_column(mtd, wbuf, mtd->writesize, column, bytes))
+                               return -EIO;
+ #endif
```

Topic 5 : UBIFS/UBI error handling

- **UBIFS became read-only when an error occurs.**
  - **for protect data from any further corruption**
  - **http://www.linux-mtd.infradead.org/faq/ubifs.html#L_sudden_ro**

    “UBIFS suddenly became read-only – what is this?”
- **Problem**
  - **It is possible that NAND accesses (ex. read/write/erase..) will occur.**
  - **There could be no way to recover from R/O status after shipping.**

- **Current Status**
  - UBI: do not switch to R/O mode on read errors
    http://git.kernel.org/?p=linux/kernel/git/torvalds/linux-2.6.git;a=commitdiff;h=b86a2c56e512f46d140a4bcb4e35e8a7d4a99a4b

Summary

- **Boot Time**
  - The initializations time of MTD NAND driver and UBI depends on the size.
    - The optimization of building BBT in MTD driver and reading UBI information per erase block in UBI is effective for boot time.

      ex. “BBT on Flash”, “Large Page Size NAND”..

- **Flash Space Overhead**
  - The unit size (UBIFS_BLOCK_SIZE) is large for small page NAND (16KB).
    - Using Large Page Size NAND
    - change the size to smaller

- **We are preparing the patches in this to the community.**

References

- **MTD, JFFS2, UBIFS, UBI**

  http://www.linux-mtd.infradead.org/

- **YAFFS2**

  http://www.yaffs.net/

- **LogFS**

  http://www.logfs.com/logfs/

- **CE Linux Forum presentations**
  - Yutaka Araki, “Flash File system, current development status” http://www.celinuxforum.org/CelfPubWiki/JapanTechnicalJamboree20?action=AttachFile&do=view&target=celf_flashfs.pdf
  - Katsuki Uwatoko, “The comparison of Flash File system performance” http://www.celinuxforum.org/CelfPubWiki/JapanTechnicalJamboree19?action=AttachFile&do=view&target=celf_flash2.pdf
  - Keijiro Yano, “JFFS2 / YAFFS“ http://www.celinuxforum.org/CelfPubWiki/JapanTechnicalJamboree17?action=AttachFile&do=view&target=celf_flashfs.pdf
- **ELC 2009**
  - Toru Homma , “Evaluation of Flash File Systems for Large NAND Flash Memory” http://www.celinuxforum.org/CelfPubWiki/ELC2009Presentations?action=AttachFile&do=view&target=ELC2009-FlashFS-Toshiba.pdf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