Understanding UFFS

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Why UFFS ?

- JFFS/JFFS2
  - Can't go out of Linux/MTD
  - Memory monster
- YAFFS/YAFFS2 still consumes too much RAM
  - 64M FLASH, 500 files ==> 410K RAM
- No YAYAFFS exists yet

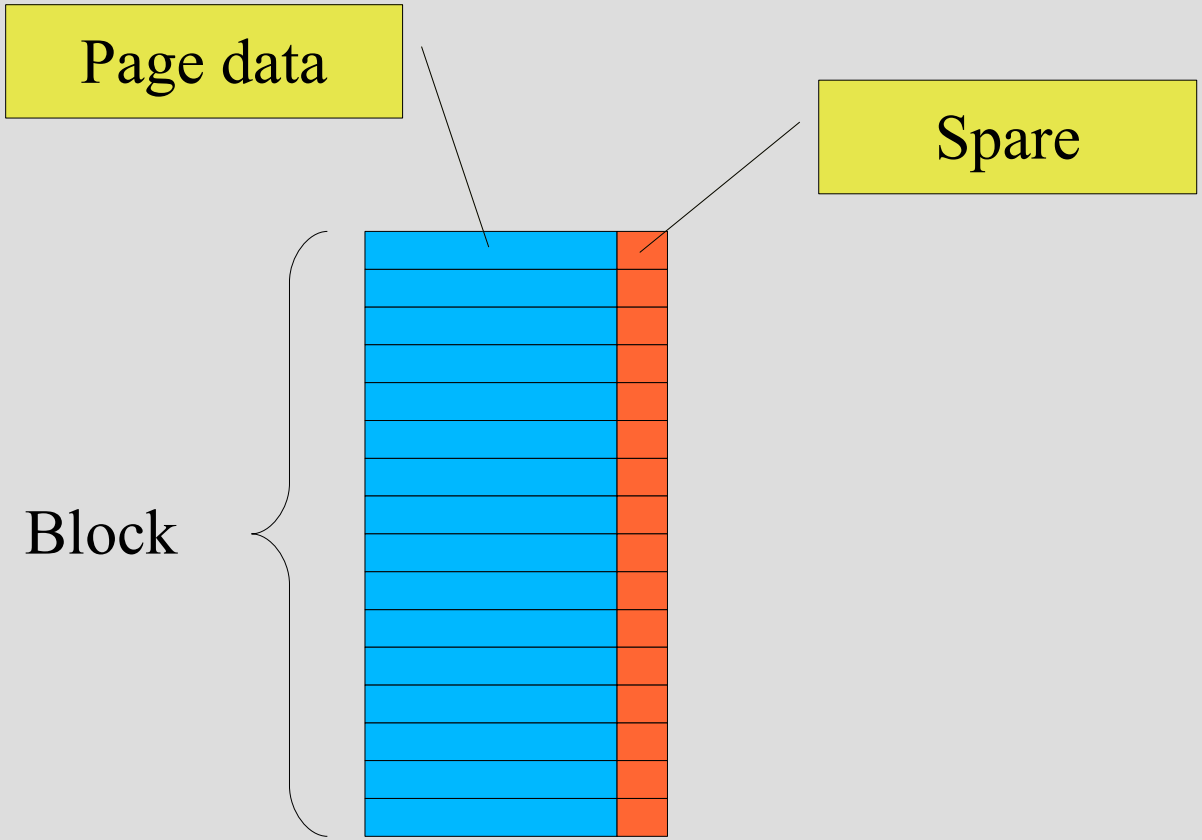
UFFS design goal

- Ultra low cost
  - Low memory cost
  - Fast booting
- Superb Stability
  - Guaranteed integrity across unexpected power losses
  - Bad block tolerant, ECC and ware leveling
- NAND flash friendly
  - Support variety NAND flash(page size 512, 1K or 2K, ...)
  - Direct flash interface

Flash: NOR vs NAND

- NOR:
  - Random access for read
  - Big block (minimal erase unit)
  - Byte programing
  - Slow erasing/programing
- NAND:
  - Page/spare access for read
  - Small block
  - Page/spare programing (with limited splits/Restricted rewrite)
  - Fast erasing/programing
  - Delivered with bad blocks

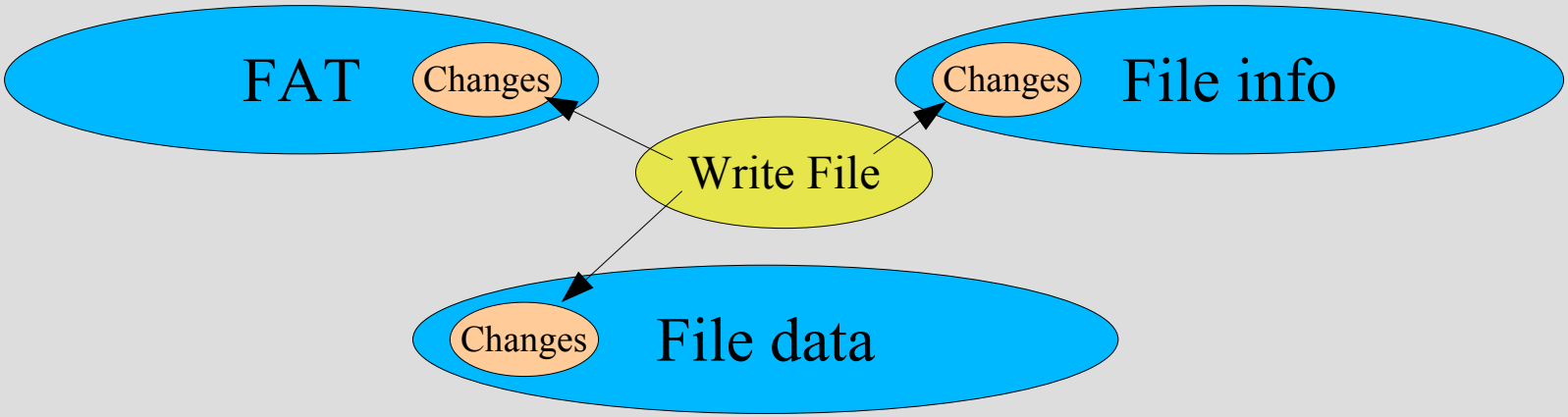
NAND Flash Basic



Erase: '0'->'1', Write/Program: '1'->'0'

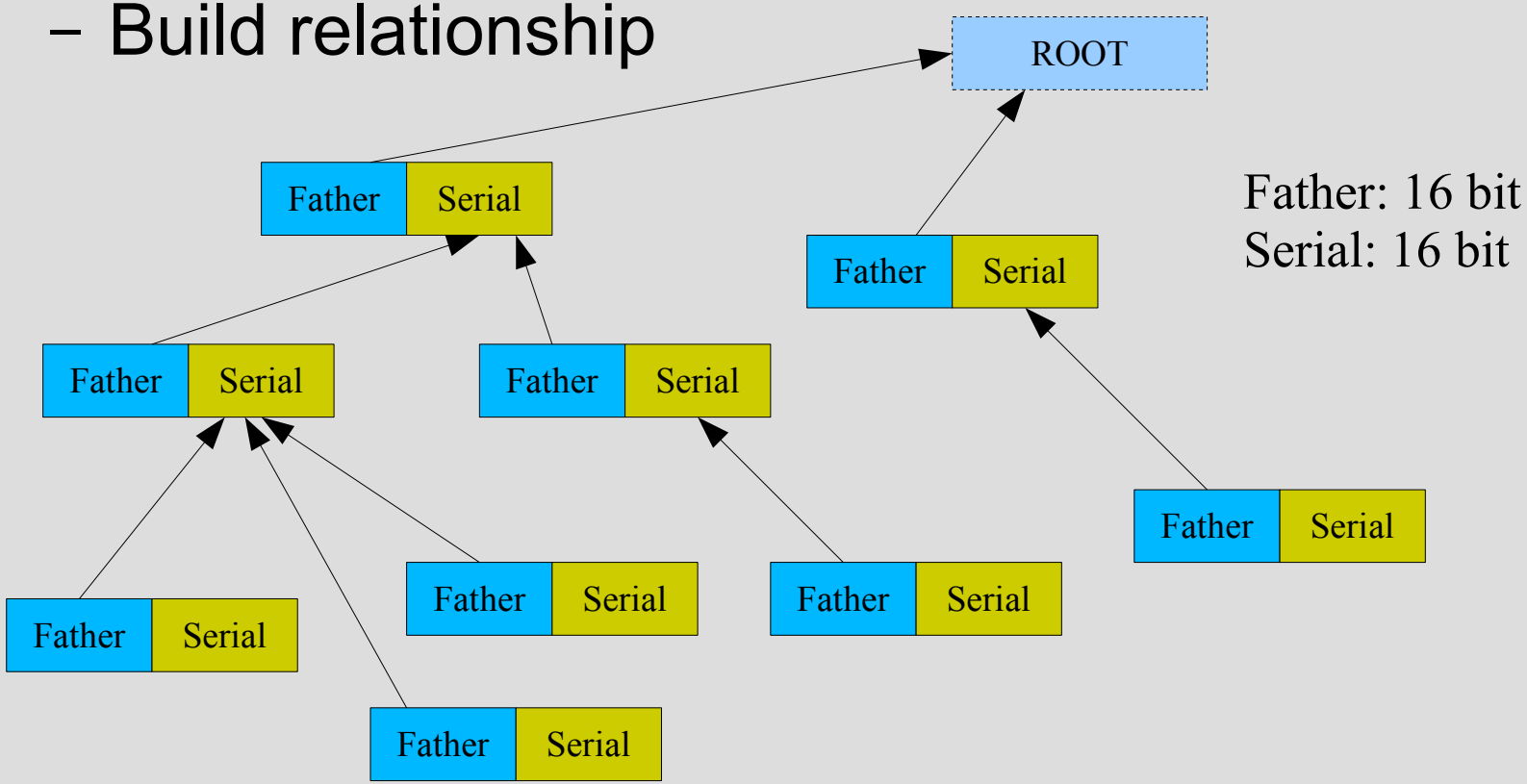
What's wrong with FAT

- Need FTL (which may cost many RAM)
- Big FAT table,slow down the whole system
- Vulnerable when unexpectedly interrupted while updating FAT or File info



UFFS basic idea(1)

- Use unique father/serial number pair to:
  - Identify blocks
  - Build relationship



UFFS basic idea(2)

- Build the relationship tree in memory when mounting UFFS:
  - Erased blocks
  - Bad blocks
  - Hash tables (serial number as key)
    - Dir table
    - File table
    - File data table
- Tree node size: 16 bytes
  - Memory cost: 16 * total_blocks

UFFS basic idea(3)

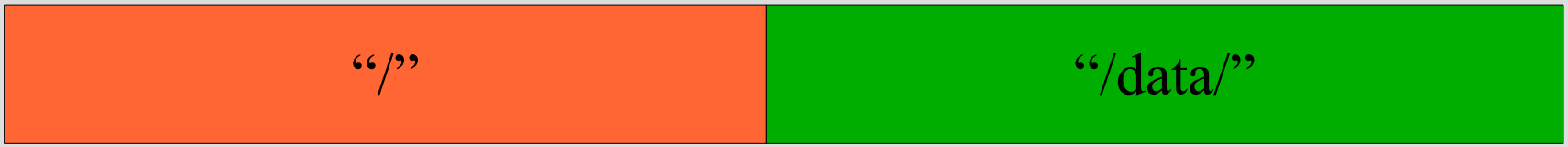
- Journalizing
  - Write to a new block/page instead of modify the old one.
  - Use circular time stamp: 00->01->11->00>...
  - Check and correct conflicting while mounting UFFS

UFFS Device

- UFFS Device & Mount Point

```
extern uffs_Device uffs_rootDev;
extern uffs_Device uffs_dataDev;

static struct uffs_mountTableSt
femu_MountTbl[] = {
    {&uffs_rootDev, 0, 200, "/"},
    {&uffs_dataDev, 201, -1, "/data/"},
    {NULL, 0, 0, NULL},
};
```

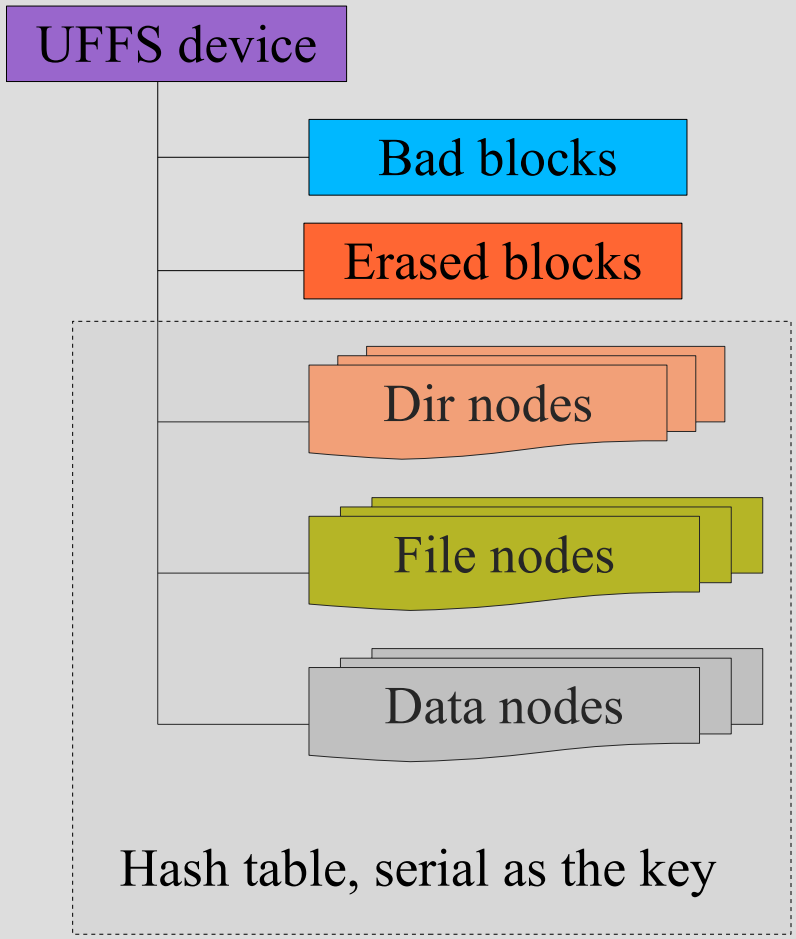


UFFS Device ===> Partition

UFFS Device: individual flash ops, cache/buffer, tree nodes ...

UFFS node tree

- UFFS nodes tree



block,next

block,next

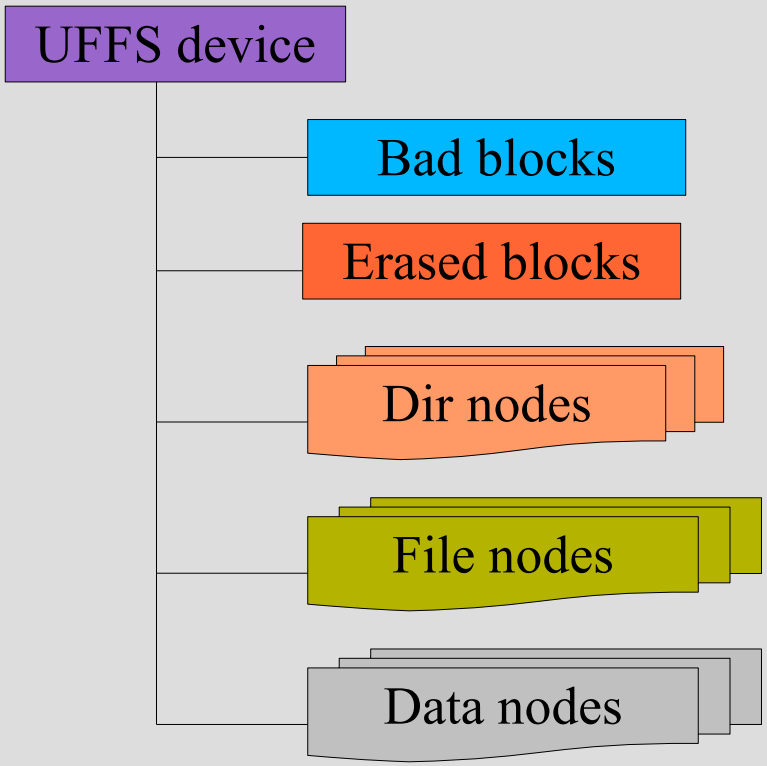
block,farther,serial,sum,next

block,father,serial,sum,length(32),next

block,father,serial,length(16),next

sizeof(TreeNode) = 16

UFFS Mounting



- Mounting UFFS

Step 1:
  - Scan page spares*, classify DIR/FILE/DATA nodes
  - Check bad block
  - Check uncompleted recovering

Step 2:
  - Randomize erased blocks

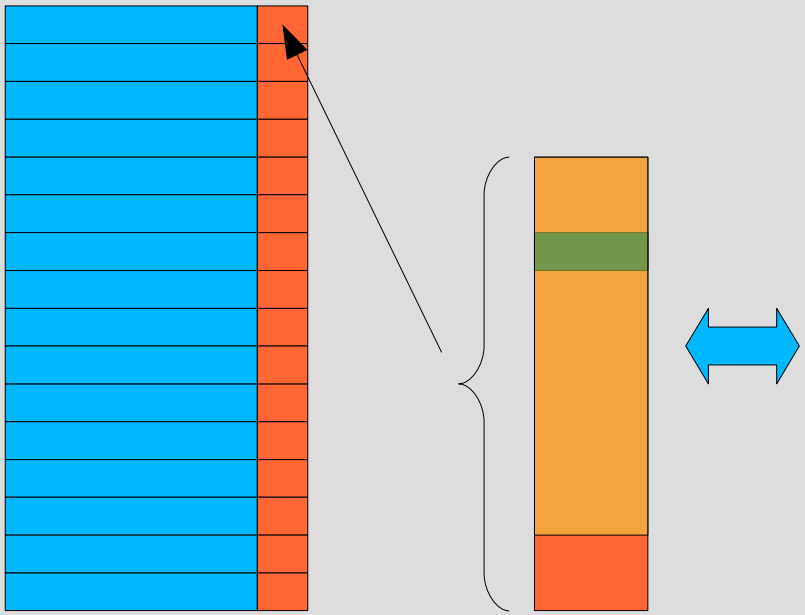
Step3:
  - Check DATA nodes,take care orphan nodes

Super fast !

** Unlike YAFFS, UFFS only need to read one spare from each block rather then read all spares !!*

UFFS tags

- Page spare/UFFS tags

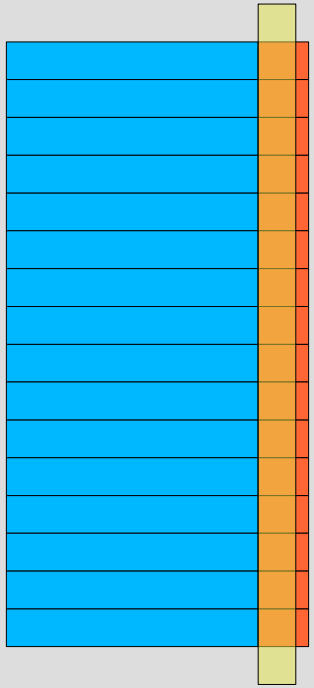


```
struct uffs_TagsSt {
        u8 dirty:1;
        u8 valid:1;
        u8 type:4;
        u8 blockTimeStamp:2;
        u8 pageID;
        u16 father;
        u16 serial;
        u16 dataLength;
        u16 dataSum;
        u8 checkSum;
        u8 blockStatus;
};
```

sizeof(struct uffs_TagsSt) = 12

UFFS block info cache

- UFFS block info cache



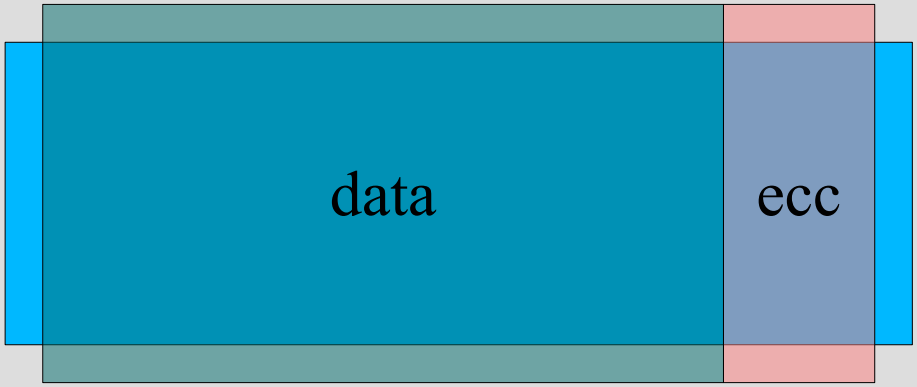
```
struct uffs_pageSpareSt {
        u8 expired:1;
        u8 checkOk:1;
        u8 blockStatus:1;
        uffs_Tags tag;
};
struct uffs_blockInfoSt {
        struct uffs_blockInfoSt *next;
        struct uffs_blockInfoSt *prev;
        u16 blockNum;
        struct uffs_pageSpareSt *spares;
        int expiredCount;
        int refCount;
};
```

uffs_config.h:
MAX_CACHED_BLOCK_INFO(5 ~10)

Memory: 40 bytes for each cached info

UFFS page buffer

- UFFS page buffer



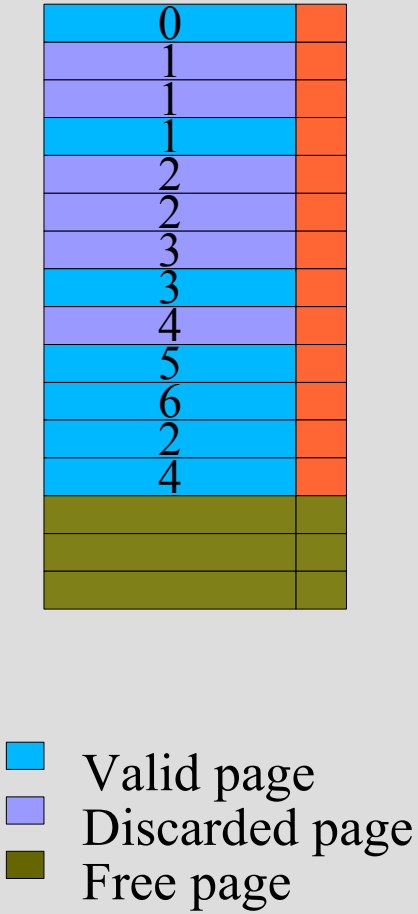

```
struct uffs_BufSt{
        struct uffs_BufSt *next;
        struct uffs_BufSt *prev;
        struct uffs_BufSt *nextDirty;
        struct uffs_BufSt *prevDirty;
        u8 type;
        u16 father;
        u16 serial;
        u16 pageID;
        u16 mark;
        u16 refCount;
        u16 dataLen;
        u8 * data;
        u8 * ecc;
};
```

uffs_config.h:
MAX_PAGE_BUFFERS (10 ~ 40)
Memory: (36 + page_size) each buffer

Note: UFFS ECC is on page data area.

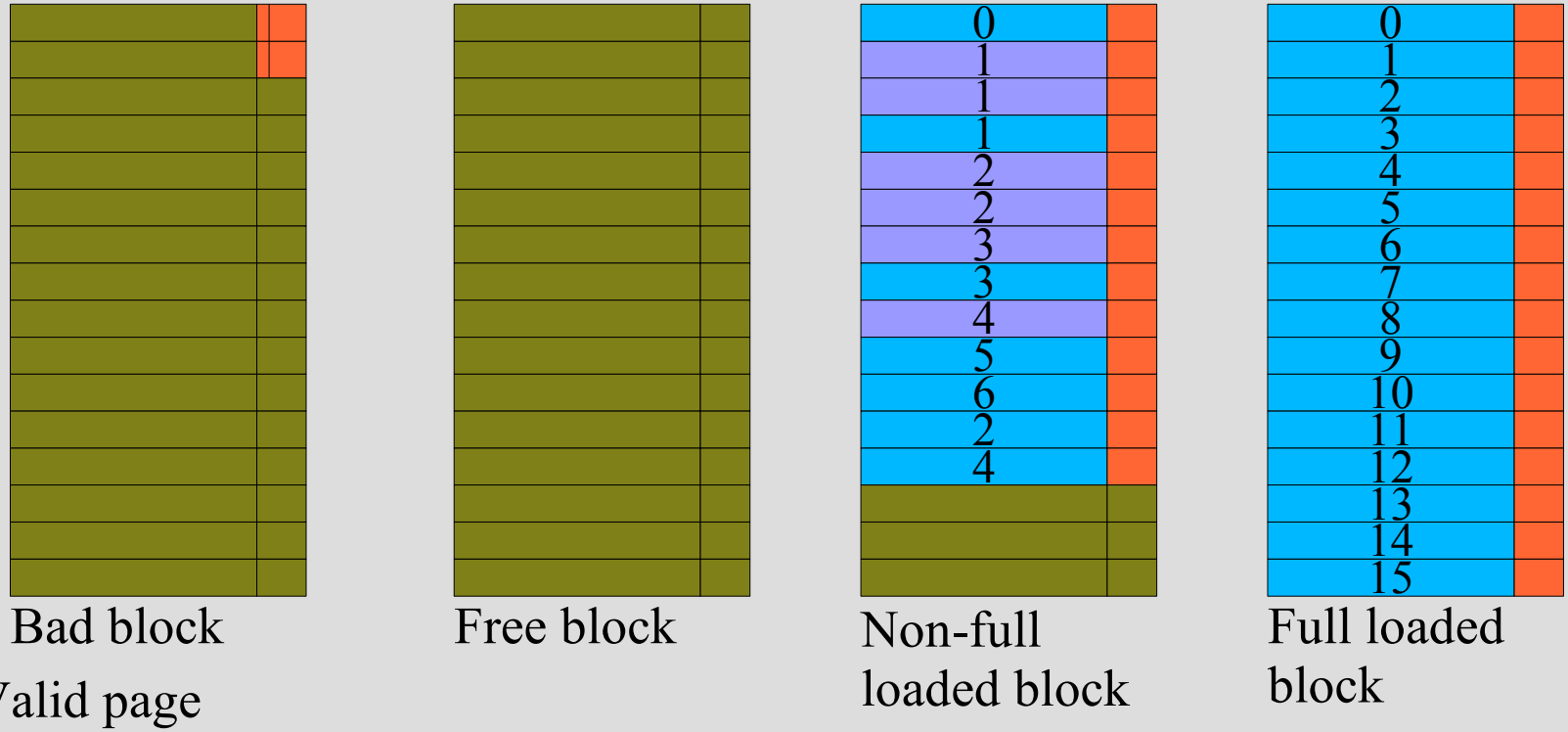
UFFS page status

- Free page: no page id assigned yet. Free pages are always on the bottom.
- Valid page: the page with a id and have max page offset
- Discarded page: the page with page id, there are one or more pages have the same id and bigger page offset.
- Unknown status: interrupted while writing a page.



UFFS block status

- Bad block
- Free/Erased block
- Non-full loaded block (have one or more free pages)
- Full loaded block (no free page, page id = physical page offset)

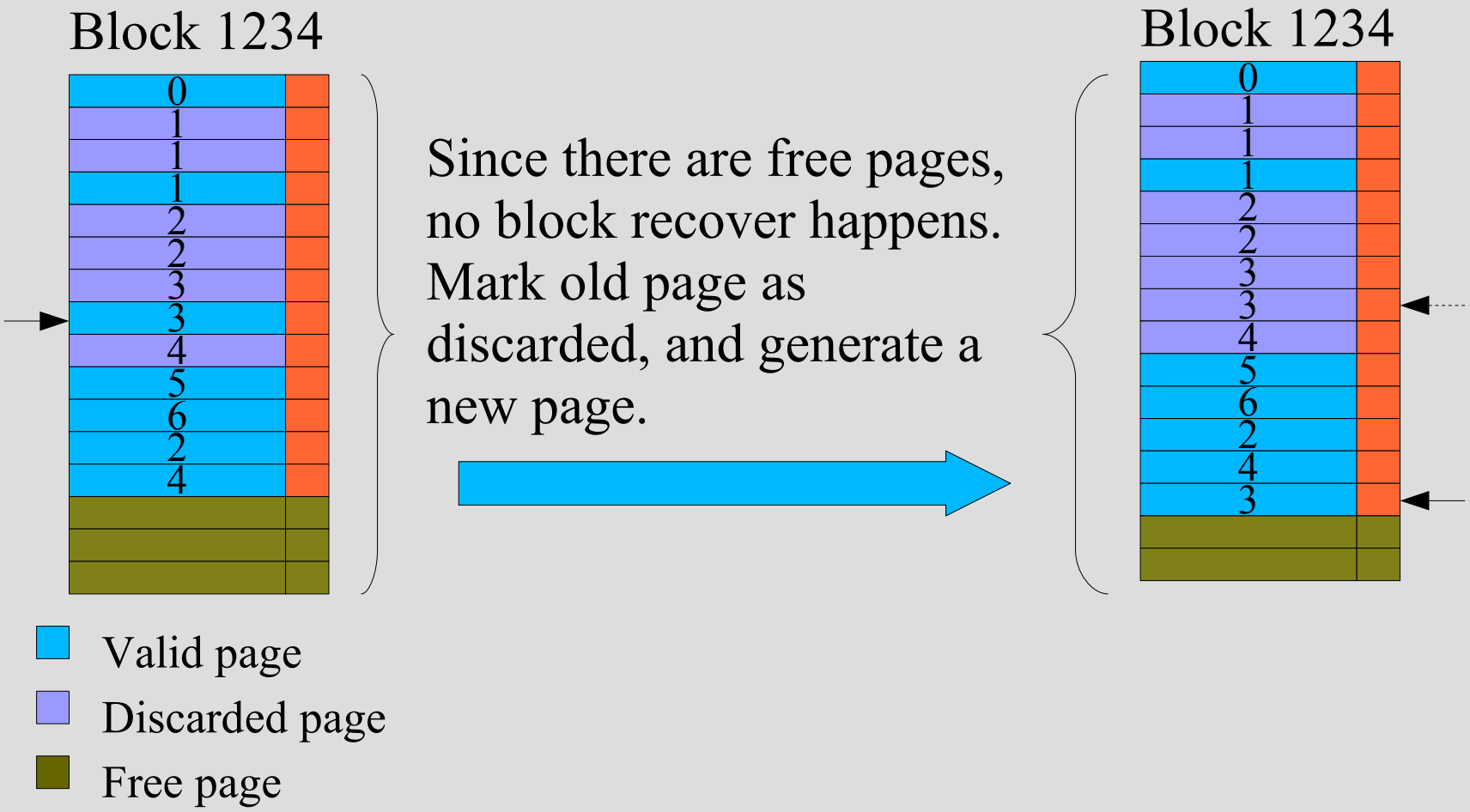


UFFS block recover(1)

- Block recover happens when:
  - No more free pages available inside the block and
  - Data were modified and/or
  - Flush the buffer
- Block recover steps:
  - (1)Get a free/erased block from erased block list
  - (2)Copy pages from old block, write to new block with newer timestamps
  - (3)Erase the old block
  - (4)Put the old block to erased block list
  - Note: (1) and (4) are operating in memory. (2) and (3) identified by timestamps, so there are all interruptible! (Guaranteed integrity across unexpected power losses)

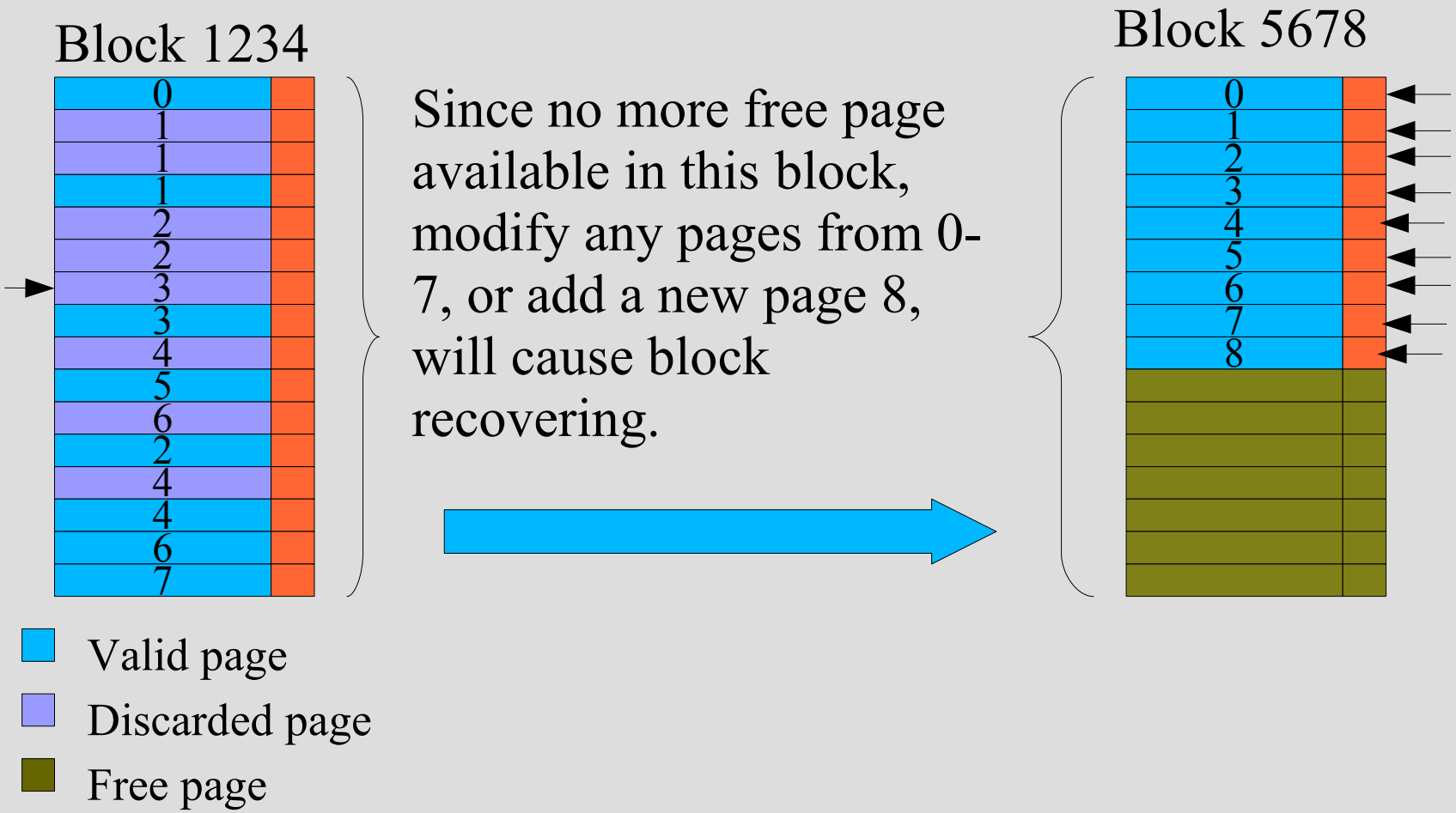
UFFS block recover(2)

- No block recover if there have enough free pages



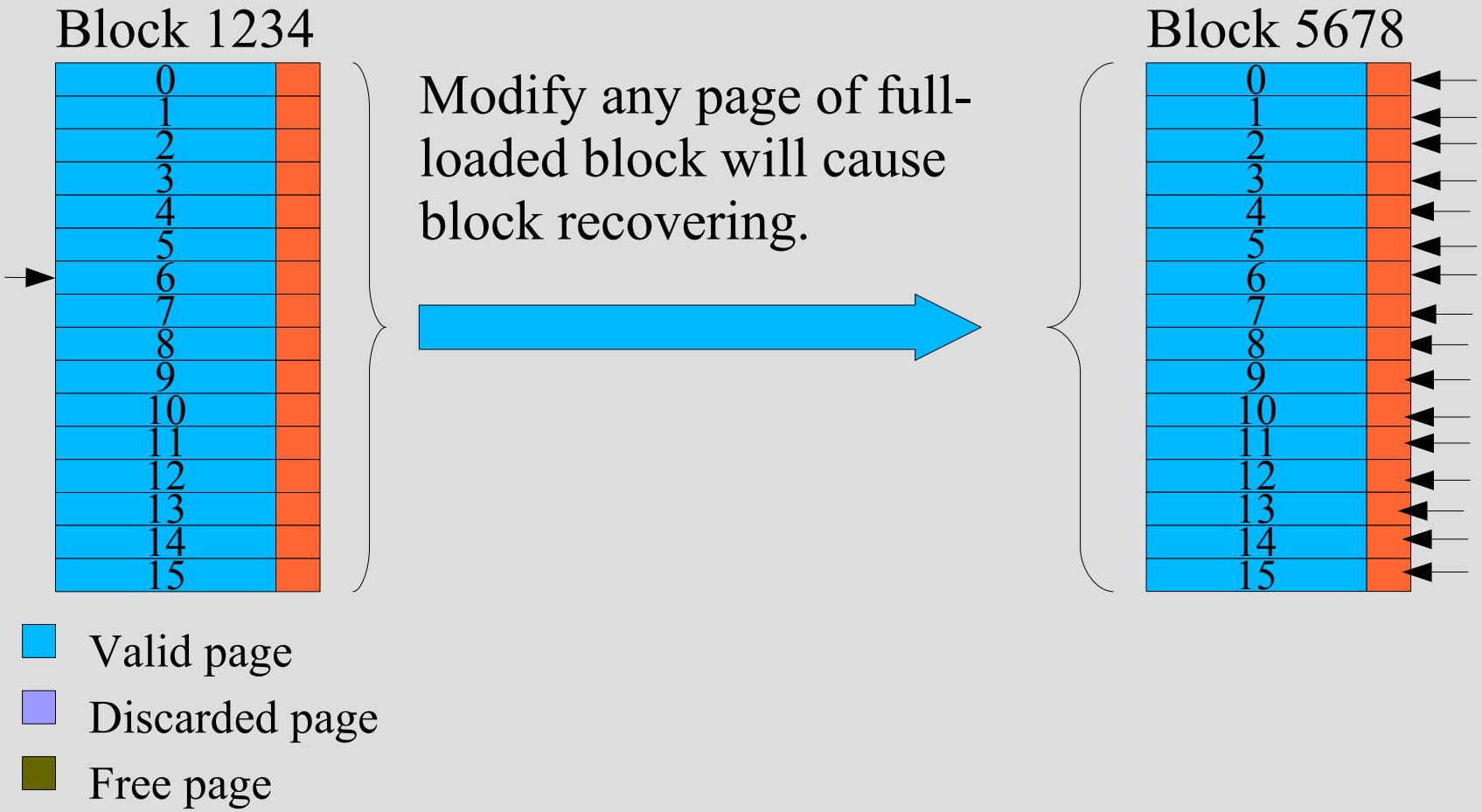
UFFS block recover(3)

- Recover a non-full loaded block



UFFS block recover(4)

- Recover a full-loaded block



UFFS bad block management

- Bad block discover when mounting UFFS
- Bad block discover when read/write
  - Try ECC error correct
  - If ECC fail, there is no way get valid data
  - Do not process bad block immediately, leave it at the end of Read/Write operation.
  - Only handle one bad block during the read/write operation.
- Check bad block when formating UFFS

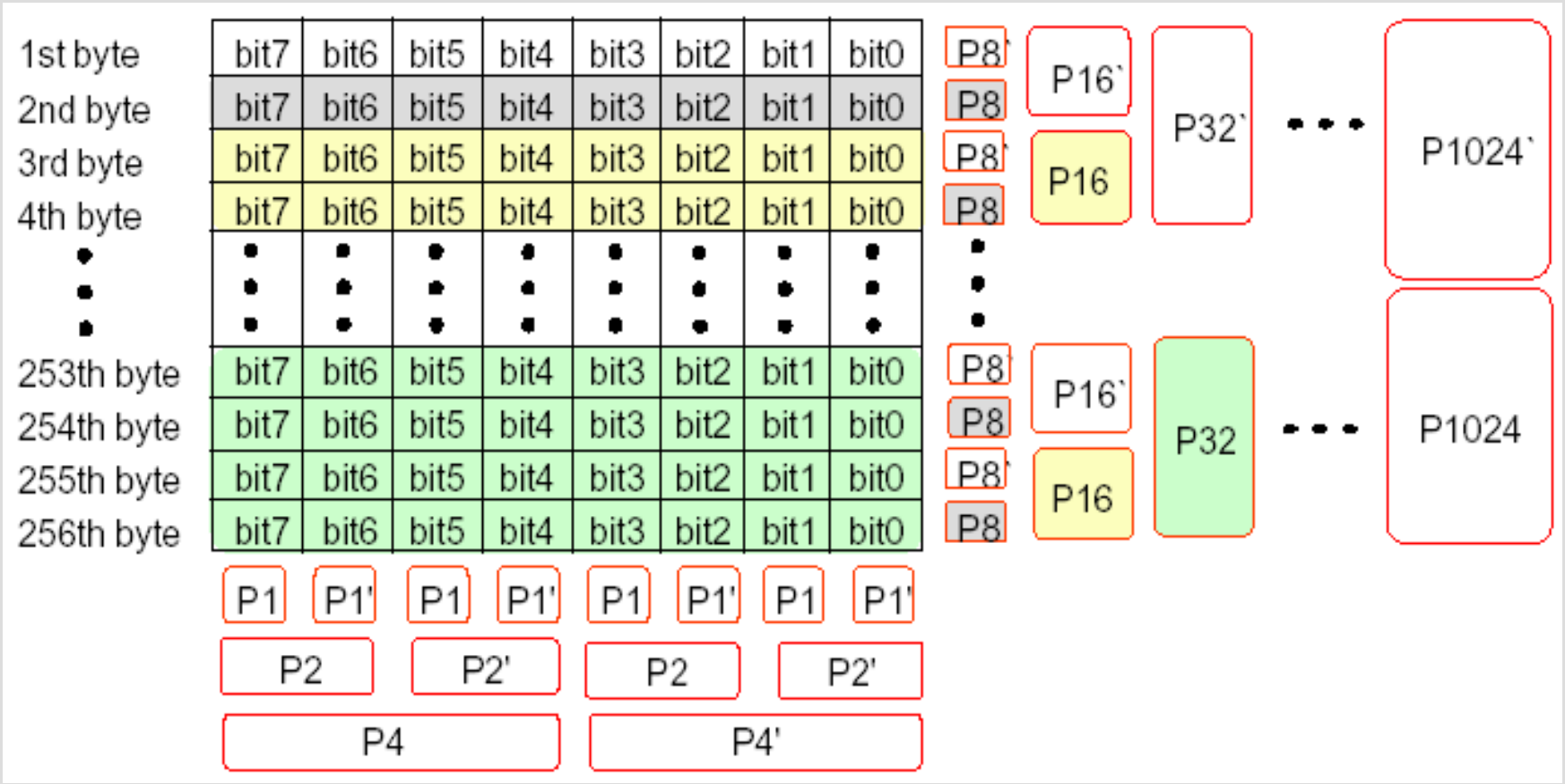
How ECC works ? (1)

- XOR: A ^ B = C
  - 0 ^ 0 = 0
  - 1 ^ 0 = 1
  - 0 ^ 1 = 1
  - 1 ^ 1 = 0
- Knowing any two of A, B and C, will know the rest one.
- UFFS ECC: 3 bytes ECC for 256 bytes data
  - 256 Bytes ==> 2048 Bits ===> 256(row) X 8(col)

How ECC works ? (2)

I/O 7	I/O 6	I/O 5	I/O 4	I/O 3	I/O 2	I/O 1	I/O 0
P64	P64`	**P32**	P32`	**P16**	P16`	**P8**	P8`
P1024	P1024`	**P512**	P512`	**P256**	P256`	**P128**	P128`
P4	P4`	**P2**	P2`	**P1**	P1`	1	1

P8 ~ P1024 : Line parity
P1 ~ P4 : Column parity



UFFS Flash Interface

- struct uffs_FlashOpsSt:
  - Flash database (id table)
  - UFFS tags <==> Flash page spare
  - Bad block information (using Block info cache)
  - Chose ECC algorithm
- struct uffs_DeviceOpsSt:
  - Read chip information
  - Low level Flash read/write/erase operations

Need to implement all members of uffs_DeviceOps in terms of your hardware specification.

UFFS Limitations

- ~~Block size < 64K~~ No 64K block size limitation anymore from V1.1.0
- Only one file/dir on one block

The next: UFFS2 ?

- Smaller Tree Node (12 bytes), save 25% RAM
- Multiple files/dirs on one block
- Symbol link, special file
- ECC on Page or Spare
- NOR flash support ? Other media (SD card) ? Maybe ...

The End