JFFS : The Journalling Flash File System

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Outline

- Flash
  - NOR, NAND
- Using Flash
  - Emulating block-devices
    - Direct mapping
    - FTL
  - Efficient FS
    - JFFS
    - JFFS2
- Future development

Flash

- Solid state, non-volatile storage
  - Reliable, High speed, Relatively low cost
- Two types: NOR and NAND
  - Block structure („erase blocks“)
    - 128 KB block on NOR flash
    - 8 KB block on NAND flash
  - Erasing by blocks only!
  - Limited lifetime
    - Endurance ~ 10-100 k erases per block
    - „Wear levelling“ needed

Flash for File Storage

- Conventional approach

  Many „standard“ file systems exist

  Why not use one of them?

  - Simplest method – direct 1:1 mapping
    - Good for read-only operations
    - No wear levelling
    - Very unsafe (on power loss)
  - Flash Translation Layer – keep track of „sectors“
    - Suitable for a writable FS
    - Wear levelling, Reliable operation; **BUT**
    - One journalling FS on top of the other

Flash for File Storage

- Efficient approach
  - Design an FS specifically for flash
    - Built-in wear levelling
    - No extra translation layers
    - Reliable operation

Flash for File Storage

- Efficient approach
  - JFFS
    - Log-structured FS
    - Only one type of node in the log
    - Direct operation without Translation Layers

JFFS: Log-structured

- No file has a fixed location
- Nodes (packets of data) are stored sequentially in flash, as in a log
  - Wear Levelling!
- Each node:
  - Is associated with a file (filename, link to parent)
  - Has a unique Version number (among file's nodes)
  - Contains latest metadata (timestamp, permissions)
  - (Optionally) Contains some of the file's data and offset at which those data reside in the file

JFFS: Operation: Writing

User action	What is written
Write 200 bytes D at offset 0 in a file	Version: 1 Offset: 0 Length: 200 Data: DDDDD.....D
Write 200 bytes 'C' at offset 200 in file	Version: 2 Offset: 200 Length: 200 Data: CCCCC.....C
Write 100 bytes 'A' at offset 120 in file	Version: 3 Offset: 20 Length: 100 Data: AAA.....A

JFFS: Operation: Reading the FS

The log nodes are „played back“
in version order, to recreate a map of where each range of data is located on the flash

Node version 1
200 bytes at 0

0-200: node v1 address

Node version 2
200 bytes at 200

0-200: node v1 address
200-400: node v2 address

Node version 3
100 bytes at 120

0-120: node v1 address
120-220: node v3 address
220-400: node v2 address

JFFS: Obsoleted nodes

- A node is obsolete if some latter node(s) has new data for the same location in file

- Nodes can also be obsoleted when the user deletes a file
  - New node is written to the log, with a **`deleted`** flag set in the metadata
  - All following nodes are marked
  - After the last file handle is closed, all nodes from this file become obsolete

- Node data physically stays on flash (dirty space)

JFFS: Garbage collection

Nothing is erased, so sooner or later we will start to run out of space. We need to reclaim the „dirty space.“

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JFFS: Implementation flaws

- Garbage collection
  - Rewriting even the „clean“ nodes

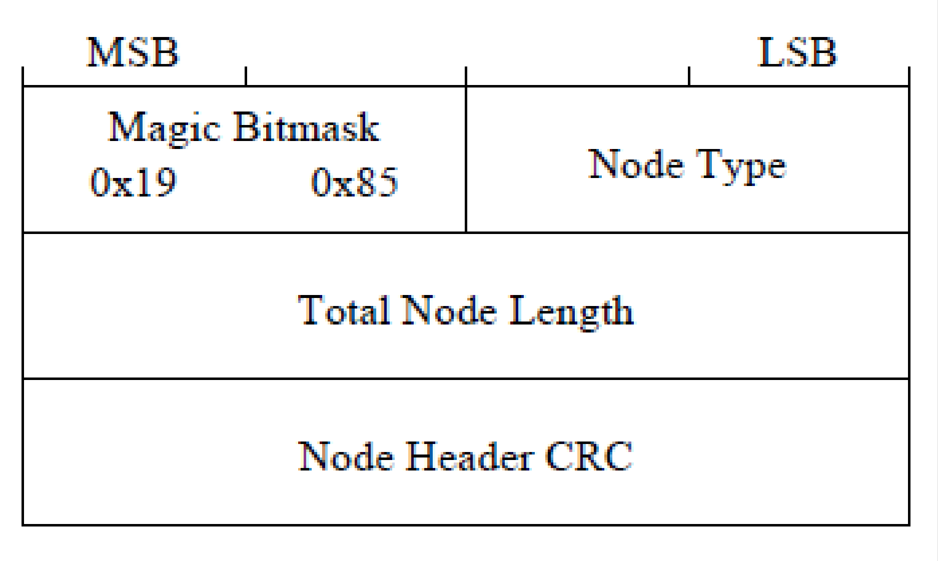
  - Perfect „wear levelling“;
    however, too frequent erasures
- Compression not supported
  - Too bad, was a very important feature at that time
- Filenames and metadata stored in each node
  - Waste of space

JFFS2

- Compression
- New node types
  - Inode, DirEnt, CleanMarker
- Non-sequential structure
  - Erase blocks treated individually
- Better memory economy

JFFS2: Node format

- Different node types for the log entries
  - JFFS used one type of node
- Common node layout
  - Backwards compatibility



JFFS2: Compatibility

- JFFS2_FEATURE_INCOMPAT
  - Refuse to mount the FS
- JFFS2_FEATURE_ROCOMPAT
  - Read-only FS
- JFFS2_FEATURE_RWCOMPAT_DELETE
  - Delete on Garbage Collection
- JFFS2_FEATURE_RWCOMPAT_COPY
  - Copy on GC

JFFS2: Node types

- Inode data node (file data)
  - Similar to JFFS node
    - Size
    - Metadata
    - Offset + data (optionally)
  - No filename or links to parent
  - Data may be compressed
    - „None“
    - „Zero“
    - Zlib compressed
  - No more than 1 page of data

JFFS2: Node types

- Directory Entry node
  - Link to Parent (directory inode number)
  - Link to File itself (inode number)
    - Inode num = 0 to unlink the file
  - Name
  - Version

Renaming done in two stages

- Write new DirEnt with the new name
- Write DirEnt with original name and inode num=0

JFFS2: Node types

- Clean Block marker node
  - Written to the cleanly erased block
  - Used to deal with partially erased blocks
    (Not fully erased due to power loss during an erase cycle)

JFFS2: Log structure

- Erase blocks are treated individually
- Several lists to store references to them:
  - clean_list – blocks containing only valid nodes
  - dirty_list – blocks containing some dirty nodes
  - free_list – erased blocks ready to be written to
    - Contain one node – Clean Block Marker

JFFS2: Operation: Writing

- Similar to JFFS
  - Write nodes sequentially until a block is filled
- Take a new block from the free_list and continue
- When free_list's size reaches a threshold
  - Garbage collection to reclaim blocks

JFFS2: Garbage Collection

- Pick a block from dirty_list, write out all its clean nodes, and erase the block
  - 99 times in 100
- 1 time in 100, pick a block from the clean_list to ensure wear is levelled

JFFS2: Mounting

- Physical scan, data structures allocation, node information caching
- Pass 1: data maps built for each file,
  nlink calculated for each file
- Pass 2: files with nlnks=0 are deleted
- Pass 3: temporarily cached information freed

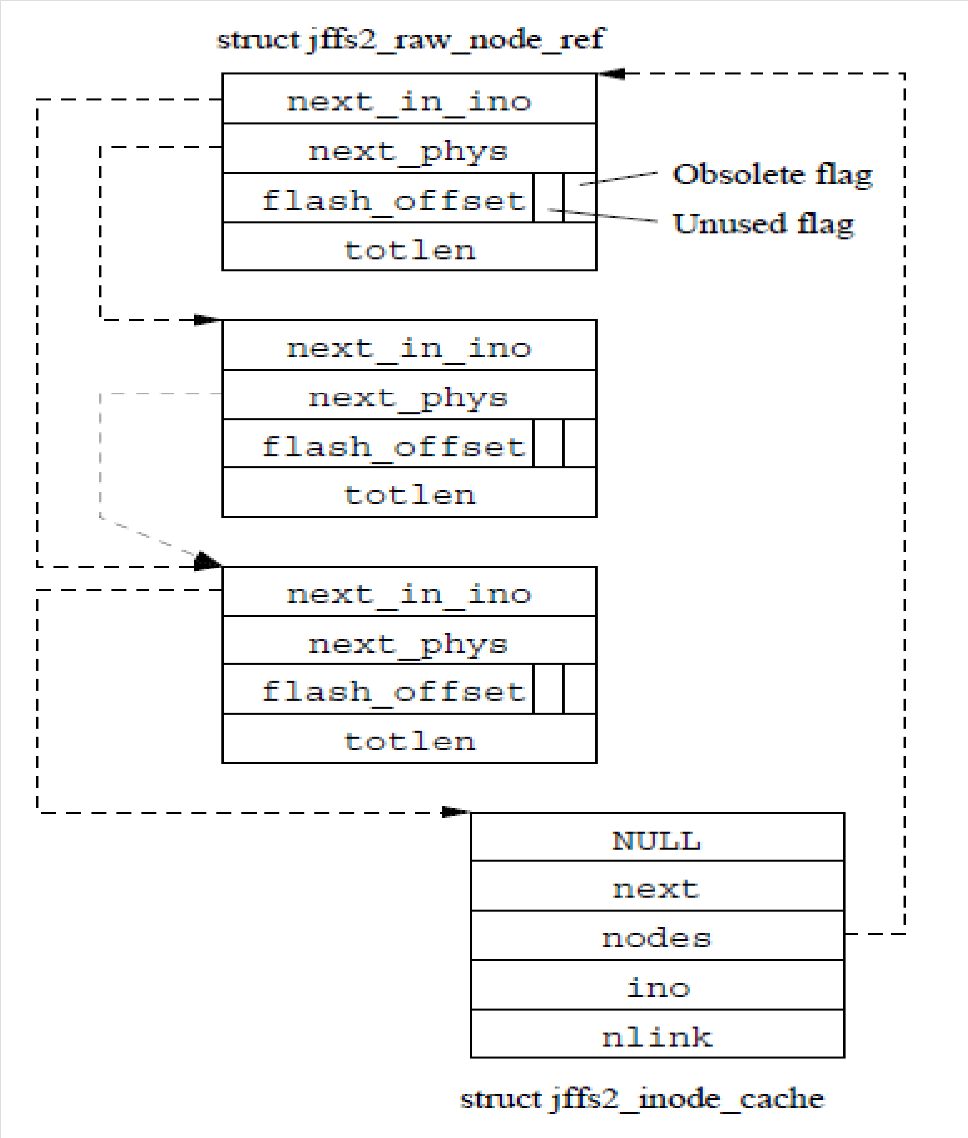
JFFS2: Operation: Data structures

What is kept in memory:

- For each inode
  - inode_cache

- For each node
  - raw_node_ref

Full map of data regions is built only on file access



Future development

- Improved fault tolerance
  - Error correction
  - Lists of bad blocks
- Lower Garbage Collection overhead
  - Currently minimum 5 free blocks
  - Possible to reduce to 1-2 blocks
- Database support
  - Exposing transactions to userspace

Thank you!