filemon2 Manual

dentry-based persistent filesystem notifications

Thomas Schöbel-Theuer (tst@schoebel-theuer.de)

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Abstract

`filemon2` differs from `inotify` / `dnotify` / `fsnotify` in several respects: (a) persistent event recording by a kernel thread even when no consumers are present at the moment (thus completeness / contiguity can be guaranteed), (b) ability to serve an arbitrary number of consumers in parallel with an arbitrary lag-behind (only limited by filesystem space, even several days of lag-behind are possible), and (c) use of relative paths inside of *physical* filesystems, independently from ambiguous logical paths caused by bind mounts / namespaces / containers etc. In contrast to `inotify` and friends which can lead to "leaks of watches" and other kernel memory leaks, no additional kernel memory is allocated at all during transient states, by directly placing the `filemon2` event information into already pre-existing `struct dentry`.

Contents

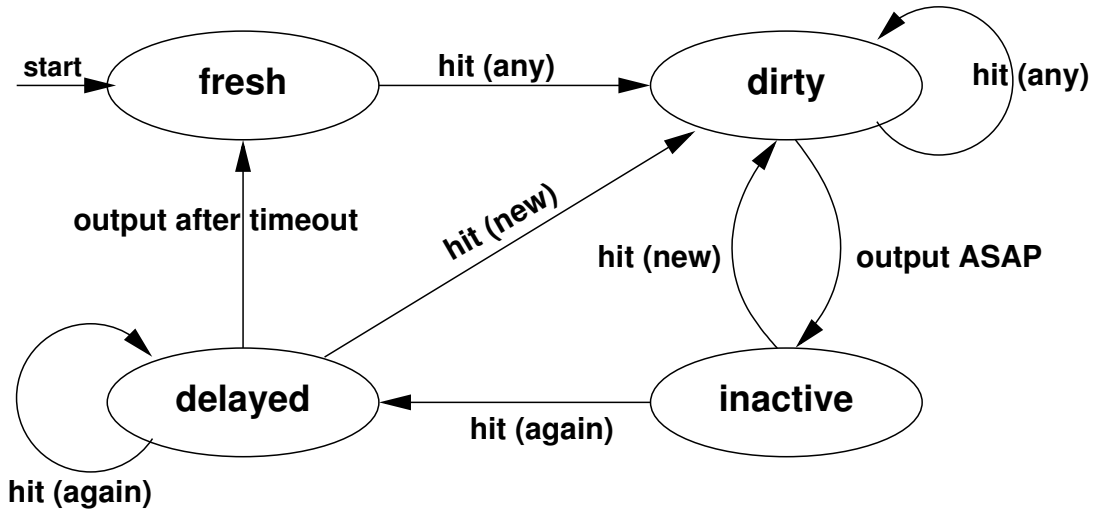
1 Operating Principle

1.1 General Operating Principle

Event logging is *sequential* in nature, while event generation is *parallel* in nature.

Think of rain drops pouring down from the sky in parallel, while the gully has only a limited capacity.

Filemon2 uses dentries for *transient* event accumulation during such phases where the gully cannot catch with some short load peaks. Here is the state transition diagram of one `dentry` ("again", "new" and "any" relates to arrival of event types):



On a big server (e.g. 40-core machine), the `dentry` cache of the kernel (and in turn the corresponding `inodes`) can be dirtified much faster than *any*[1] output mechanism can cope with.

Example: `for i in {1..40}; do while true; do touch /tmp/xxx.$i; done & done`

Therefore, `filemon2` (shortly called `fm2`) is recording all events belonging to the *same* `dentry` instance in a bitmask, called event bitmask `fm2_events`. Whenever an event bit is set much faster than the output thread can cope with, a counter `fm2_repeat` is incremented. The latter can serve as a *hint* that *some* event types have occurred multiple times.

In order to not flood the eventlog with repetitions of the *same* event type, the following strategy is used:

- whenever a *new* event type occurs since the `dentry` had been fresh or logged for the last time, logging is always done ASAP (state transition from `dirty` to `inactive` without unnecessary delay).
- otherwise, repetition of the *same* event type (already occurred since the dentry was `fresh`) does nothing but (re)starting a timeout timer in state `delayed`. Only when the timeout (default 60s) has occurred, the event is logged *again* (state transition from `delayed` to `fresh`).

1.2 The `fm2` Epoch Timestamp

`fm2` tries to ensure as best as it can that **no events are lost in an unnoticed way**.

Therefore, the persistent eventlog is written by a kernel thread which cannot be `kill(1)`ed or otherwise destroyed by userspace actions. The kernel thread is automatically started during the `mount(2)` syscall, and automatically stopped as a last action during `umount(2)`.

[1] This argument is independent from the logging mechanism. It also applies to userspace logging daemons.

Hint: other solutions (including the old `filemonitor1` in combination with the old `fsmd1` userspace daemon) were trying to solve this via a userspace daemon reading events from a non-persistent `/proc/` interface from the kernel. This led to several problems. In particular, race conditions or wrong `systemd` configs could influence the startup / shutdown order of services, such that events could get lost. More generally, it is a hard problem to run multiple such daemon instances inside of multiple LXC containers which can be started / stopped indepently from each other, and/or when access to the container filesystem is also possible from outside (bypassing the container) and/or when bind mounts are leading to ambiguities in the path names.

`fm2` solves this by keeping the so-called `fm2` **epoch timestamp**. It shows the Unix time (seconds since 1970) since when the `fm2` events were recorded contiguously.

The fm2 epoch timestamp can be easily seen when looking into the first (or any other) global record at each `.filemon2/eventlog-????????.log` logfile (see section 4.1 below).

The `fm2` epoch timestamp is automatically recorded in the filesystem during `umount(2)`, and automatically restored followed by deletion at the next `mount(2)`.

When the system crashes during operation, no recorded timestamp will exist at remount time. This indicates that the epoch was interrupted, because some old events might have been missed.

The current version of `fm2` does not (yet) notice when the filesystem is mounted at a different kernel not containing the filemonitor2 kernel patch. In such a case, events may get lost. Later versions of fm2 are planned to detect this special case as best as possible.

The `fm2` epoch timestamp is reset in the following situations:

- when there exists no recorded old epoch timestamp (e.g. fresh filesystem, or information has been lost by crashes etc).
- when an overflow is explicitly triggered during runtime via `extra-overflow-fm2.cmd`.
- when the filesystem is almost full (`free-space-min-fm2.conf` has been undershot).

Notice that the sequence of event logs does not only contain a *history* of events, but also a history of `fm2` epoches. Notice that each eventlog may have its own instance of the `fm2` epoch, because interruptions of the contiguity of events might have occurred *multiple* times. Correctness of interpretation of the *meaning* of the `fm2` epoch timestamps is the task of each consumer application.

2 Activation and Config of fm2

2.1 Activation and File Formats

The basic unit of fm2 is a **filesystem instance** as occurring on a disk media. Only *relative* paths as present at the media are recorded. Runtime presentations like bind mounts or namespaces are ignored by fm2.

If a filesystem has a subdirectoy .filemon2/ directly below its filesystem root, it will be automatically monitored by fm2 after it has been mount(2)ed. Any filesystem which does not have such a reserved subdirectory is completely ignored by fm2.

Notice: after creation of the .filemon2/ subdirectoy (e.g. after a fresh mkfs), the current version of the kernel patch requires you to first umount(2) the filesystem followed by a re-mount(2) in order to activate fm2. This might change in a later version of fm2.

Inside of .filemon2/ the following **naming conventions** must be obeyed by multiple consumer applications:

- different consumer applications $app1 and $app2 must use the general filename pattern .filemon2/*$something*-$app1.* and .filemon2/*$something*-$app2.* in order to avoid any name clashes. Applications are allowed to place their own private information inside of .filemon2/ provided that the naming conventions are met.
- the special application name fm2 is reserved for filemon2.
- the suffix *.conf is reserved for configuration information.
- the suffix *.private is reserved for *internal* state information.
- the suffix *.status is reserved for *public* status information.
- in particular, position-*$appname*.status **must be used** by any consumer application to indicate the current eventlog number which has *not yet* been consumed. Consumer applications are responsible for maintaining this correctly and timely. Notice that fm2adm logdelete will later delete any logfile which has a lower number than indicated here, by the minimum position indicated by all consumers.
- eventlog-000000001-fm2.log (and further 9-digit numbers) are written by the internal kernel thread of fm2 and can be read by any consumer application. Consumers should regularly check the .filemon2/ directory for new event logfiles to appear.

2.2 Parameterization

For basic operation of fm2, the pure existence of the .filemon2/ directory is sufficient. The following is only necessary in order to deviate from defaults.

It is useful to parameterize the operation of fm2 via the following reserved files inside of .filemon2/ each containing a single ASCII line with a number, possibly prefixed by 0x to indicate a hex-coded number:

enabled-mask-fm2.conf This file should not be directly overwritten by any single consumer application. Instead, each consumer application *$applicationname* should write the event types it wants to watch into another file enabled-mask-*$applicationname*.conf in hex format. Upon the next fm2adm log-delete operation (as typically triggered from a cron job for freespace management), all enabled-mask-*$applicationname*.conf files will be logically or'ed together to form the new enabled-mask-fm2.conf config file. This way,

multiple co-existing applications may request different event types. Applications **must** be programmed in such a way that they have to ignore any additional event types they are not currently interested in.
The event type bits and their meaning are documented in `include/uapi/linux/filemon2.h` in the kernel patch. Later versions of the kernel patch may define further bits. Applications **must** be programmed in such a way that arbitrary new bit definitions appearing in future versions of `include/uapi/linux/filemon2.h` **must not disturb** them.

`rot-time-fm2.conf` This number is intended for sysadmin tuning of the event logfile rotation (default 600s). It must not be touched by consumer applications.

`repeat-timeout-fm2.conf` This number is also intended for sysadmin tuning of the timeout for the `delayed`→`fresh` transition (default 60s). It must not be touched by consumer applications.

`free-space-min-fm2.conf` Sysadmins can tune this number to the free space on the filesystem in GiB which must be present for ordinary operation (default 1 GiB). When the free space on the filesystem drops below this limit, **fm2** will automatically stop event logging immediately after writing a `DISK_FULL` record into the eventlog. This value must not be touched by consumer applications.

`free-space-max-fm2.conf` This is the reverse of `free-space-min-fm2`.conf (default 2 GiB): it denotes the point where event logging is automatically resumed after a `DISK_FULL`. This value must not be touched by consumer applications.

All `*-fm2.conf` files are re-read during log-rotation. As a consequence, it is possible to change masks etc during runtime with logfile granularity.

2.3 Runtime Commands

Communication to the kernel thread is possible by spontaneous creation of some tiny files. The files are removed by the kernel thread once the command has been executed. Not only sysadmins, but also consumer applications may request them.

Please prefer the corresponding `fm2adm` commands (see chapter 3) in front of this. This is only documented here for completeness.

`extra-logrot-fm2.cmd` When containing a value >0, this will start an immediate eventlog rotation even when the ordinary logrotate intervall has not yet occurred.

`extra-overflow-fm2.cmd` When containing a value >0, this will write an `OVERFLOW` record into the eventlog, and reset the epoch timestamp to the current time, similar to a real space overflow. Similar to a real `SPACE_FULL` event, the following logfile will later start with a `RESUME` event (see table in section 4.1).

Please be aware that a real `SPACE_FULL` situation may last for several hours or days, while an `extra-overflow` is typically much shorter. Testers should not rely on these differences in timing. Always assume that after an `OVERFLOW` or `SPACE_FULL` the next logfile show up after an *arbitrary* pause.

`extra-timeout-fm2.cmd` When containing a value >0, this will flush all `delayed` dentries to the eventlog and bring them to state `fresh` again.

3 Userspace Admin Command `fm2adm`

`fm2adm` usually takes one sub-command as an argument. When no further arguments are given, all mountpoints from `/proc/mounts` are scanned for a `.filemon2/` subdirectory where `fm2` is currently running; these are taken as `fm2` resource arguments. Alternatively, an explicit list of mountpoints (denoting `fm2` resources) may be given as further arguments.

Currently, the following sub-commands are supported (to be extended in future):

help Show a short usage info.

status Show a short info on each resource.

logdelete After updating `enabled-mask-fm2.conf`, delete all currently unreferenced logfiles which are not referenced by some `.filemon2/position-`*`$appname`*`.status` file. This should be called regularly by a cron job in order to maintain free space on each `fm2` filesystem.

extra-logrot After updating `enabled-mask-fm2.conf`, cause some extraordinary logfile rotation.

extra-overflow After updating `enabled-mask-fm2.conf`, cause a reset of the epoch timestamp, followed by a logfile rotation.

extra-timeout After updating `enabled-mask-fm2.conf`, cause an extraordinary flush of all `delayed` dentries.

Hint: updating `enabled-mask-fm2.conf` means that `fm2adm` will look for any *other* application masks `enabled-mask-*.conf` and to compute the logical OR of their bits. When no *other* application masks exist, `enabled-mask-fm2.conf` will be deleted in order to urge the kernel to work with some built-in default mask (similar to startup with an empty `.filemon2/` directory). Notice that this built-in default may change in future versions of `fm2`. If you want to control your masks in exactly your way, please do so by providing `enabled-mask-*.conf` files for *all* of your consumer applications.

In particular, package maintainers of `*.deb` or `*.rpm` packages are requested to provide some reasonable default masks for their application in `/etc/defaults/fm2/` and some way of copying or symlinking them to all `.filemon2/` directories once they are created later and *activated*. Doing this is outside the scope of both the `filemon2` kernel patch and the `fm2adm` utility. In particular, activation / deactivation of a particular consumer application should be possible *individually* for each `fm2` resource, e.g. by creating / removing / renaming their respective `enabled-mask-*.conf`. Alternatively, this might be delegated to some `systemd` units, and/or to configuration management tools like Puppet or Chef or Ansible. Suchalike is clearly outside the scope of a *generic* tool like `filemonitor2`.

Please construct your consumer applications, as well as their packaging and their configuration management, in such a way that **friendly co-existence** with other applications is the headline. OpenSource communities should obey this anyway. Anyone who willingly sacrifices this general rule, will run the considerable risk of being blamed in public.

Hint: *temporary* deactivation of `fm2` is possible by writing 0 directly into `.filemon2/enabled-mask-fm2.co` and to set `chattr +i` on it. This will also reset the epoch timestamp. Please use this only as a workaround for maintainance.

4 Eventlog Format

Basically, event logfiles are in human-readable **CSV format** with blanks as delimiters. They should be easily processable with standard Unix pipes-and-filters tools like `grep` and `awk`.

Interspersed are **global records** and **variable records** having a different format, starting with comment symbols `#`. Thus it should be easy to filter out these comment lines with filters like `grep -v '^#'` or similar.

Each eventlog .filemon2/eventlog-?????????.log starts with a textual CSV header denoting the column names of the CSV parts. Following are three types of records, each terminated by a newline character:

1. Global Record Format (is a fixed width format)
2. Variable Value Format (is a variable width format)
3. CSV Record Format (is a variable width format)

4.1 Global Record Format

Typically, the next line after the header is a comment line showing the reason why this logfile was started. Here is a list of global record names:

Field	Purpose
`# MOUNT`	Filesystem was freshly mounted
`# UMOUNT`	Filesystem is being umounted.
`# OVERFLOW`	`extra-overflow-fm2.cmd` has been triggered (resets epoch).
`# SPACE_FULL`	Filesystem has less than `free-space-min-fm2.conf` GiB (resets epoch)
`# RESUME`	`OVERFLOW` or `DISK_FULL` now finished; now resuming.
`# LOGROT_BEGIN`	Logfile rotation started.
`# LOGROT_END`	Logfile rotation finished.
`# TIMEOUT_BEGIN`	extra-timeout operation has started.
`# TIMEOUT_END`	extra-timeout operation has finished.
`# BAD_FORMAT`	(internal error) An output record could not be formatted (resets epoch).

Further global record types may be defined in future versions of `fm2`. Consumer applications must ignore them if they cannot interpret them (yet).

The general global record format in C `printf()` notation is as follows: ‘‘`# %-19s %10ld.%09ld %10ld.%09ld\n`’’. This is a fixed-record format having exactly a lenght of 64 bytes, including the final newline character. The length is guaranteed to not change in future. Following the record type string, there are two timestamps in Unix format:

1. The `fm2` epoch timestamp.
2. The current timestamp when the global record was created.

Notice that the last record of each ordinarily closed event logfile is always a global record. Therefore, it is possible to use `lseek64(fd, -64, SEEK_END)` in a C program to find this record without scanning for it eagerly. However, when the system has crashed during operation, then this record will *not* exist after the system has rebooted and the filesystem has been remounted. This may be exploited for detection of such interruptions.


Also notice that upon such crashes, the `fm2` epoch timestamp will be reset to the mount time because the old internal epoch timestamp status had not been saved due to the missing `umount`.

4.2 Variable Record Format

Records of this type are supposed to occur only rarely (not for mass data, but only for some config changes or for rarely occurring extraordinary global events). The format is **`‘## VARNAME=VALUE\n’`**.


New varnames may be added at future versions of `fm2`. Applications are required to ignore any unknown variables and their values.

4.3 CSV Record Format

CSV records can be detected by the *absence* of a leading hash symbol `#`.

The format is **extensible**: new columns may be added at any new eventlog instance, provided that the number of colums is the same for the headline and for all following CSV value lines.

Consumer applications **must** deal with any additions of new columns at any place.

Currently the following columns are defined:

CSV name		Description
`event_stamp`		Timestamp when some event has last occurred (retriggerable)
`now_stamp`		Timestamp when this CSV record has been written
`events_new`		(hex-coded) Event bits newly hit since the last record has been written
`events_cumul`		(hex-coded) Event bits cumulated since this dentry had been fresh
`repeated`		Number of events since the last record has been written
`i_ino`		Inode number of the corresponding inode (if existing)
`i_generation`		Inode generation number (if existing)
`pid`		PID of the last process causing some event
`path`		Relative pathname associated with this dentry, encoded like RFC2396.

The event bits are documented at `include/uapi/linux/filemon2.h`. The pathname is decodeable via `curl_easy_unescape(3)`.

Hint: `rename()` operations will lead to *two* events: `FM2_EV_MOVE_FROM` and `FM2_EV_MOVE_TO` showing the old and the new path of the dentry before and after the rename operation.

Notice that it is up to the consumer application to deal with any races which are *intrinsic*(!) to the POSIX filesystem standards.

Example: according to POSIX and other Unix standards, it is possible to `unlink()` a file while some filehandles to it remain open. Afterwards, even some data can be written. Similar effects can occur on hardlinks. Also, `rename()`s won’t affect any filehandles which were already open before.

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