FUSE and beyond: bridging filesystems

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Goals

- Distributed file system beyond NFS
  - High availability, without SPOF
  - Storage clustering
  - Elasticity
  - POSIX semantics, with locking
  - Performances
  - Secure communications (crypto)

File systems

- Used to be implemented in kernel
  - Not easily portable
  - Long development cycles
- User space file systems
  - FS are Unix processes
  - Kernel is FS client
  - Microkernel-like approach

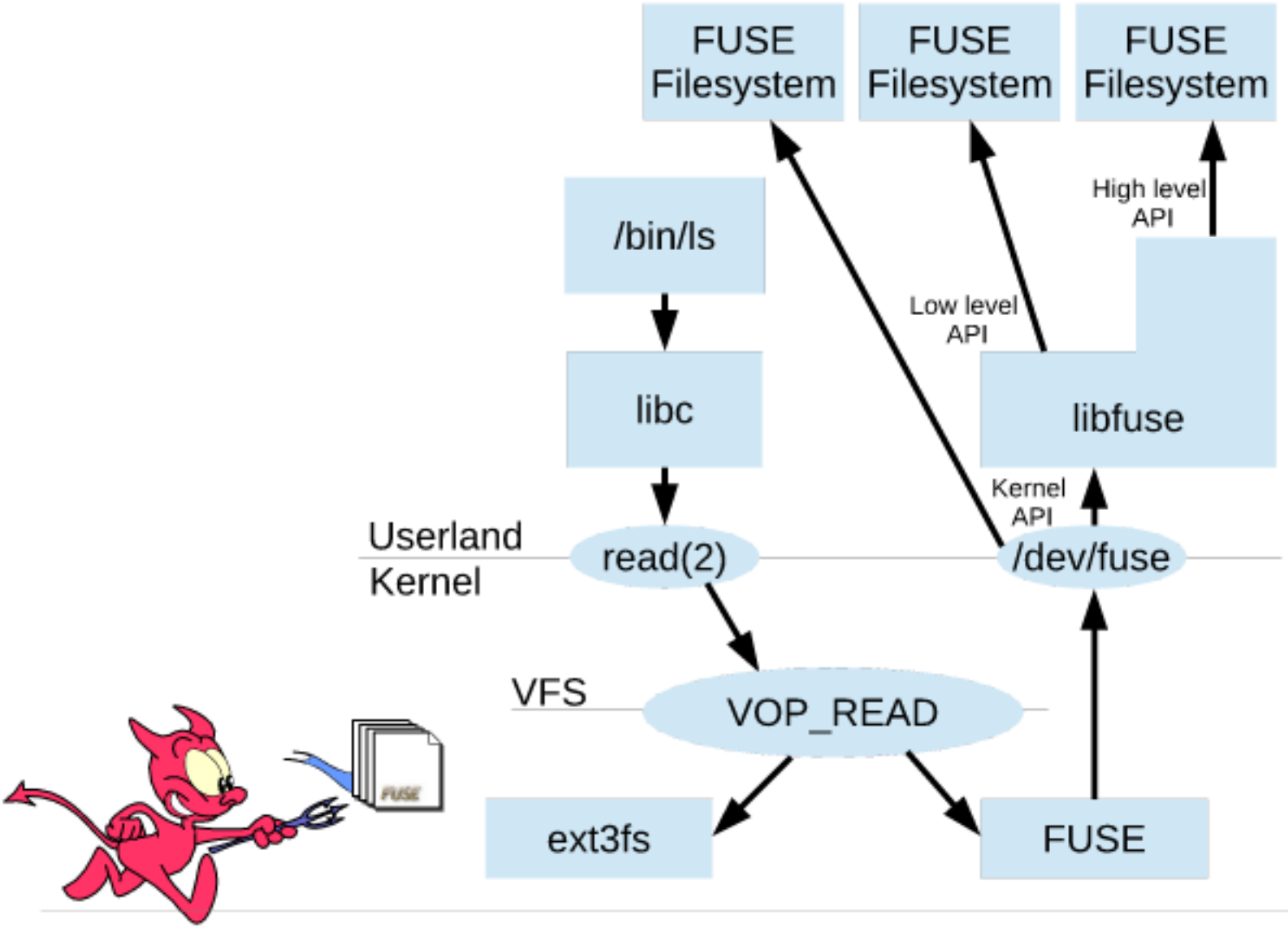
Many solutions

- Lustre Hadoop GlusterFS XtreemFS Ceph...
- Requirements to mount a FS
  - Kernel module (OS-dependent)
  - FUSE
    - Path of least resistance
    - Many FUSE FS available
- Goal : GlusterFS through FUSE

Implementations : FUSE (1)

- Used to be a Linux project
- *de facto* standard : FreeBSD, MacOS X
- Kernel is FUSE client
- Message-passing interface through /dev/fuse
- User level library : libfuse
- Three (!) API for FUSE file systems

Implementations : FUSE (2)



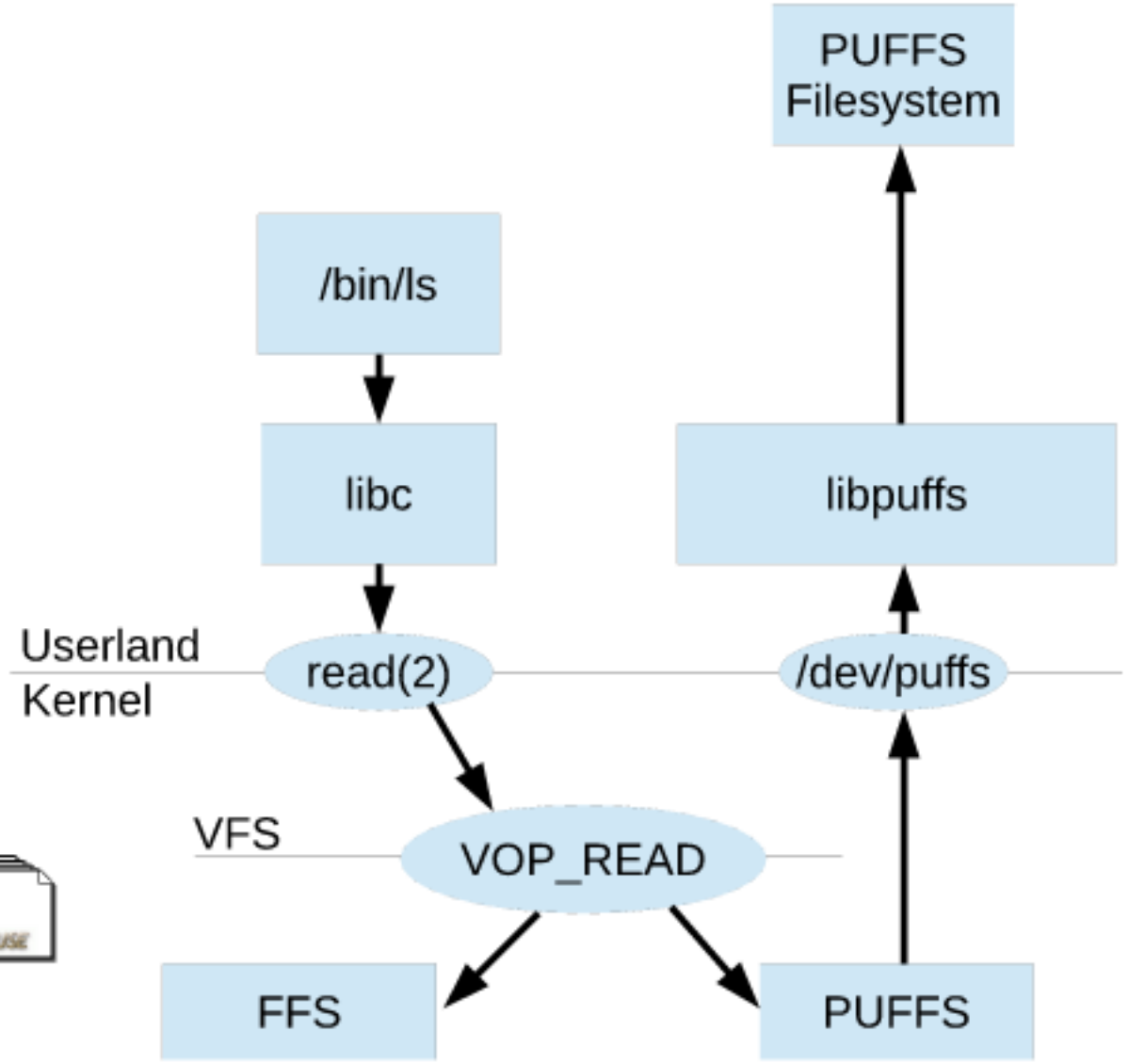
About VFS

- Virtual File System, introduced by Sun in 1985
- Multiplexer to mulitple FS (UFS and NFS)
- In-kernel VFS interface for all FS
- Code below VFS interface is FS-dependent
- Objects : mounts, vnode
- Methods: lookup, open, read, write...

Implementations : PUFFS (1)

- User space file systems for NetBSD
- Similar to FUSE, but not compatible
- Started when FUSE was no obvious standard
- Native interface still has merit today
  - Better fit native VFS
  - No roadblocks to adding new features

Implementation : PUFFS (2)



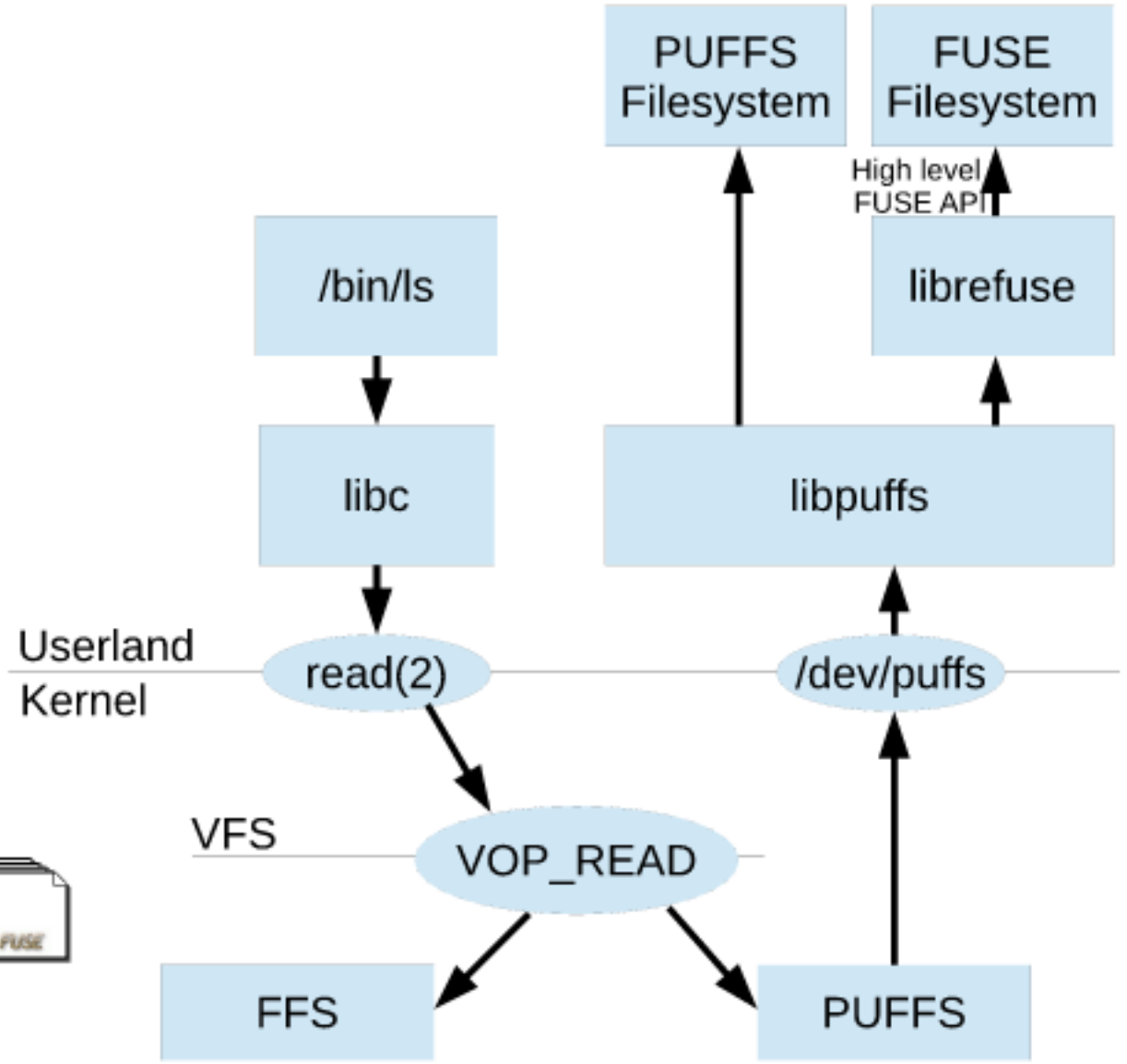
Implementation : PUFFS (3)

- PUFFS architecture looks a lot like FUSE...
  - /dev/puffs instead of /dev/fuse
  - libpuffs instead of libfuse
- ...but it is still different
  - Message-passing protocol is different
  - API is different (at least PUFFS has only one !)

FUSE over PUFFS : REFUSE (1)

- PUFFS has merits (native, not constrained)
- FUSE, is desirable as a *de facto* standard
- FUSE over PUFFS implementation : REFUSE

FUSE over PUFFS : REFUSE (2)



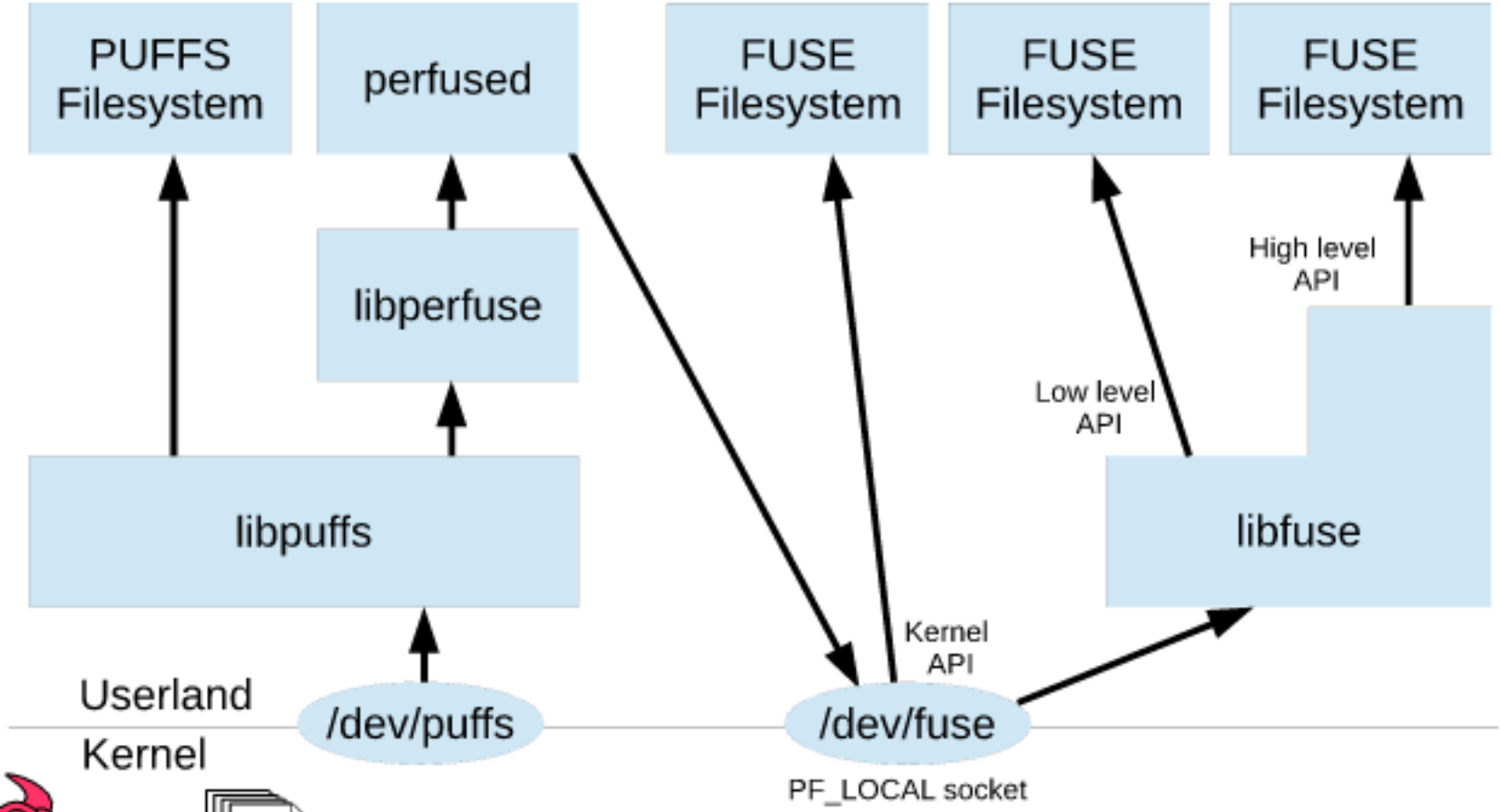
FUSE over PUFFS : REFUSE (3)

- Limitation: we only support FUSE high level API
- No support for FS using low level API
- No support for FS bypassing libfuse
  - GlusterFS directly uses /dev/fuse
- REFUSE is not enough

FUSE over PUFFS : PERFUSE (1)

- PERFUSE implements FUSE kernel API
  - But we do not want to work in kernel
  - perfused daemon, /dev/fuse socket
  - perfused translate PUFFS into FUSE
- Original libfuse is supported

FUSE over PUFFS : PERFUSE (2)



FUSE over PUFFS : PERFUSE (3)

- Special handling of /dev/fuse open & mount
  - /dev/fuse is a socket, open() & mount() will fail
  - perfuse_open() and perfuse_mount()
  - <perfuse.h> defines them as open() and mount()
  - Just use #include <perfuse.h> and -lperfuse
  - libfuse was modified upstream for that change
- /dev/fuse replaced by socketpair(2)

About VFS (1)

- VFS operations translated into PUFFS/FUSE
- Root node is obtained at mount time
- LOOKUP is used to find other nodes
  - Give a name, get a node (or an error)
- GETATTR, SETATTR for metadata
- OPEN, READ, WRITE, READDIR, etc...

About VFS (2)

mount("/gfs") => node1

node1.lookup("foo") => ENOENT

node1.loookup("bar") => node2

node2.getattr() => ino,uid,gid,mode,ctime...

node2.open() => 0

node2.read() => data

Node life cycle (1)

- Not obvious operations (NetBSD/PUFFS)
  - RELEASE : close() was called
  - INACTIVE : last reference is drop
  - RECLAIM : free and forget about a node
- Linux/FUSE :
  - RELEASE
  - FORGET

Node life cycle (2)

node2.release => 0

node2.read() => data

node2.inactive()=> 0

node1.inactive() => 0

node2.reclaim() => 0

node1.reclaim() => 0

Bugs and traps

- SOCK_SEQPACKET sockets
- Extended attributes
- Races in GETATTR
- dirname() thread-unsafety
- link() to a symlink
- pagedaemon has a nap

- swapcontext() swaps TLS

SOCK_SEQPACKET sockets

- /dev/fuse *vs* local socket semantics
  - /dev/fuse supports reliable atomic messages
  - Neither SOCK_STREAM, nor SOCK_DGRAM
  - We implemented SOCK_SEQPACKET

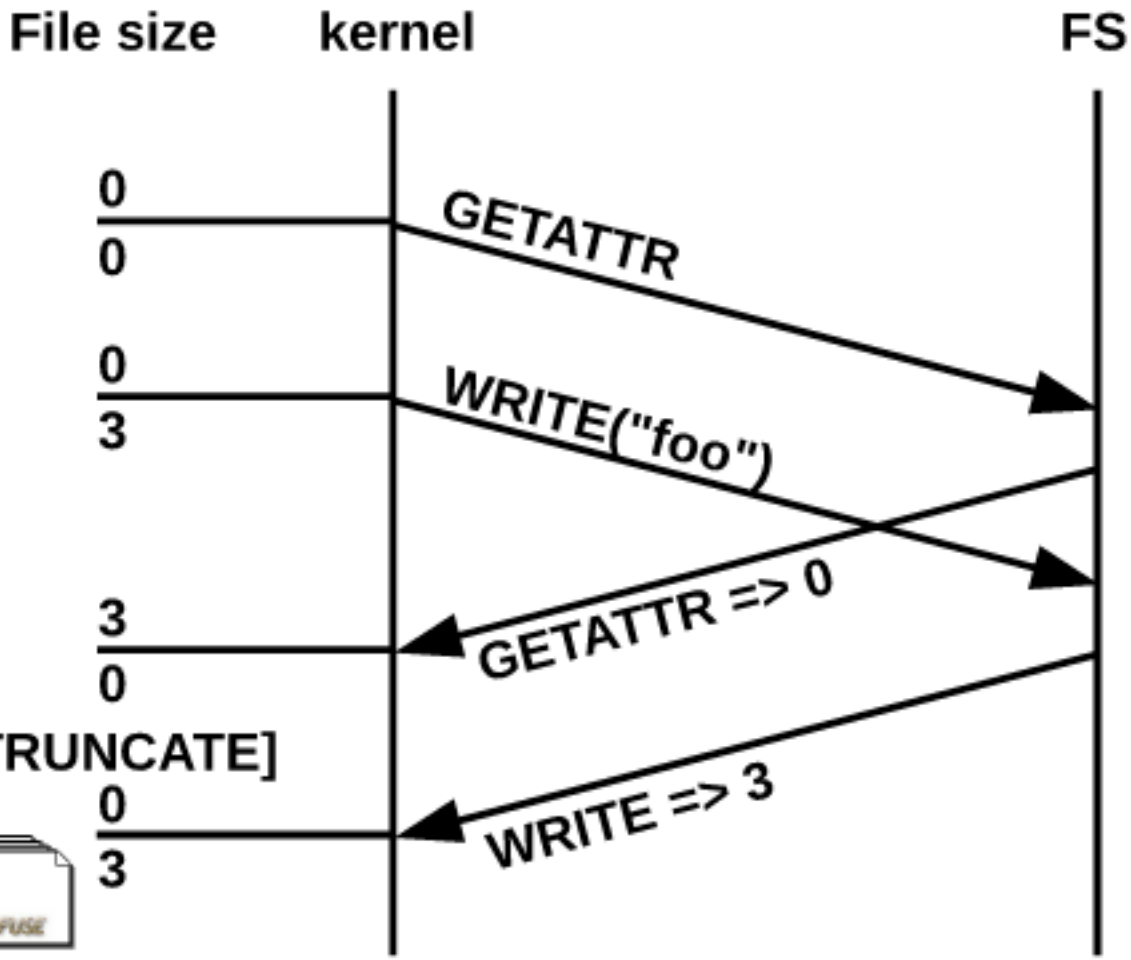
Extended attributes (1)

- Required for GlusterFS server component
- Bring back UFS1 extended attribute
  - Stored in a sparse file, just like quotas were
  - Autostart, backend autocreation
- Support in cp(1) and mv(1)
- Linux API vs FreeBSD API

Extended attributes (2)

- Must be added in various utilities
  - Critical for backups : pax(1), dump(8), restore(8)
  - Useful : scp(1), rsync(1)
  - May break standards : tar(1), cpio(1),
- Extended attributes storage improvment
  - Import support for UFS2 from FreeBSD
  - Native filesystem implementation *à la* QUOTA2

Races in GETATTR



- Mutex of size is required

dirname() thread-unsafety

- GNU dirname() vs BSD dirname()
  - Static buffer with const input vs modified input

```
printf("=> %s %s\n", dirname("/foo/a"), dirname("/bar/b"));
```

```
=> /bar /bar
```

- No consensus for dirname_r()
- Add GNU dirname() in GlusterFS contrib/

Link() to symlink (1)

- link() to symlink : symlink itself or target ?

  lrwxrwxrwx 1 manu manu 6 nov. 1 17:06 symlink -> target

  $ ln symlink link

[Linux]lrwxrwxrwx 2 manu manu 6 nov. 1 17:06 link -> target

[xBSD] lrwxrwxrwx 2 manu manu 6 nov. 1 17:06 link -> symlink

- Both behavior are standard-compliant !
- GlusterFS relies on Linux behavior

Link() to symlink (2)

- linkat() has a AT_NOFOLLOW option
- POSIX extended API set 2 implementation
  - Just a partial linkat(2) in netbsd-6 branch
  - Full set except fexecve(2) in netbsd-7 branch

Pagedaemon has a nap

- pagedaemon frees memory
- It may use PUTPAGE on a PUFFS vnode
- PUFFS message allocation : kmem_zalloc()
  - KM_NOSLEEP : fail if no memory available
  - KM_SLEEP : sleep if no memory available
- Pagedaemon must never sleep !

swapcontext() swaps TLS (1)

- GlusterFS uses swapcontext() *and* Pthreads
- Should swapcontext() swaps the TLS register?
  - Linux : TLS preserved, swapcontext(3) is thread-safe
  - NetBSD : machine-dependent behavior

swapcontext() swaps TLS (2)

```
[lwp1] getcontext(&nctx);
[lwp2] makecontext(&nctx, (void *)*swapfunc, 0);
[lwp2] swapcontext(&octx, &nctx);
[lwp2] printf("lwp2 self = %p\n", pthread_self());
[lwp1] printf("lwp1 self = %p\n", pthread_self());
```

lwp2 self = 0xbfa00000

lwp1 self = 0xbfa00000

swapcontext() swaps TLS (3)

- When should TLS register be preserved?
  - Only if linking with -lpthread
- _UC_TLSBASE option
  - Context option to control TLS register fate
  - libpthread overrides setcontext() stub

TODO

- Extended attributes for dump(8) and friends
- Extended attributes storage *à la* QUOTA2
- FUSE negative caching
- FUSE FS notifications to kernel
- CUSE (char device)