HPC I/O in the Data Center Workshop

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POSIX, and What Comes Next

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POSIX Is *Really Old*

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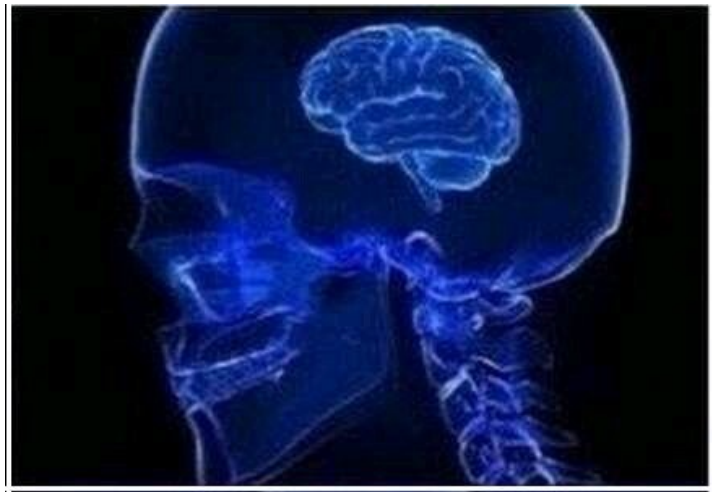

- Original interfaces developed with Unix in the 1970s
  - Fragmentation as Unix grew and changed in the 1980s
  - Needed a standard for interoperability during "Unix Wars"
- POSIX has been the standard IO interface for decades
  - Hasn't changed significantly in many years, but very widely available
  - Provides the lowest IO common denominator for apps and user tools
  - Consistent behavior means that applications can run everywhere
- Data portability for shared namespace via protocol export (Lustre, NFS, SMB, …)
  - Avoid data silos by exporting filesystem with (mostly) POSIX semantics to other nodes
  - "Mostly POSIX" can be important, but ***different*** parts of POSIX needed for different applications
- POSIX consistency can be a bottleneck for some workloads
  - Serialized directory operations, write/read ordering, etc. can slow down performance

Where Are We Now?

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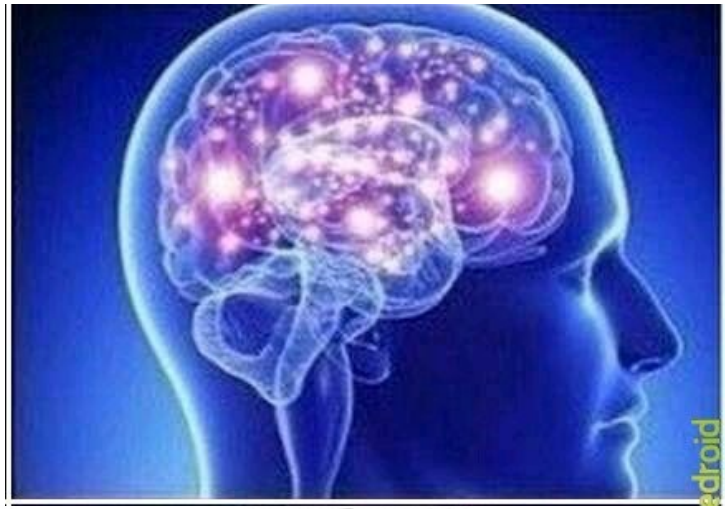
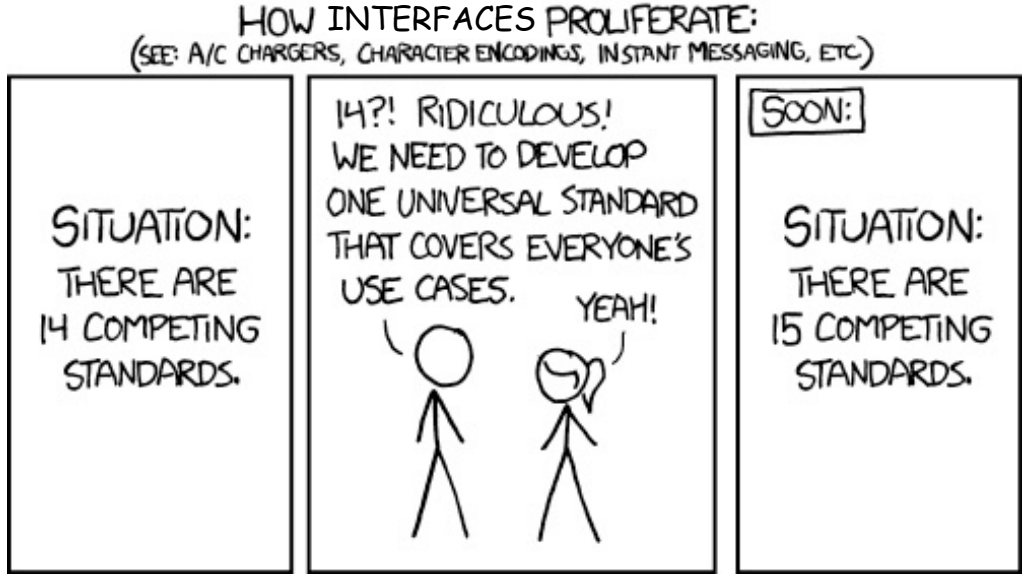
- An explosion of new IO interfaces for various special needs
  - New storage systems have their own IO APIs (HDFS, S3, DAOS, …)
  - Useful for some workloads, but needs significant application investment
  - Specialization ties applications to storage system, loses portability
  - Higher-level libraries abstract new interfaces, but also many libraries



- Leveraging hardware speedups needs optimization
  - Lower storage latency, higher bandwidth
  - Many cores, more and faster network interfaces
  - A rising hardware tide lifts all software, but not equally
    - Leaves "stranded" performance behind
  - Software needs to continually adapt to address bottlenecks
    - Finer-grained threading, locking, concurrency, new interfaces



How To Move Beyond Aging POSIX Standard?

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- Embrace and Extend
  - Some tries at HPC extensions (`stat_lite()`, `open_by_handle()`, …)
  - Didn't make it into official POSIX standard, but were added to Linux
- Linux provides de-facto standard for new interfaces
  - New IO interfaces are being added incrementally
  - Sometimes adopted from other OSes (BSD, Solaris, …)
  - `open_by_handle()`, `name_to_handle_at()`, `fallocate()`, `copy_file_range()`, `pwritev2()`
  - `*_at()`, `statx()`, `O_TMPFILE`, `FIEMAP`, `SEEK_HOLE/DATA`, …
- DAX for memory load-store access to persistent memory
  - Used by SPDK to provide access to NVRAM managed by ext4/XFS
- Asynchronous data AIO/DIO via `libaio`
  - Originally used by databases, but could be leveraged by any tools with a lot of concurrent IO
- Asynchronous data and metadata operations via `io_uring` with growing capabilities
  - Provides may POSIX syscall equivalents with completion callbacks, including some metadata syscalls

What Happens in the Future?

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- POSIX continues to be the common interface going forward
  - Important for interoperability during "IO Interface Wars"
  - Protects significant investment in developed applications and tools
  - By necessity, most storage systems must also provide a POSIX interface
- Sometimes bottleneck is in implementation, not POSIX
  - Serialized single directory operations is Linux VFS implementation limit
- API *extensions* for apps with special performance needs
  - Specialized interfaces ***opt-in*** when/where applications need it
  - Easier to relax strong POSIX semantics by request than miss them and cause corruption/bugs
  - Applications can leverage new APIs via common libraries or directly for performance reasons
  - Data continues to be accessible via standard POSIX APIs/tools after creation/processing

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