Lustre & Application I/O

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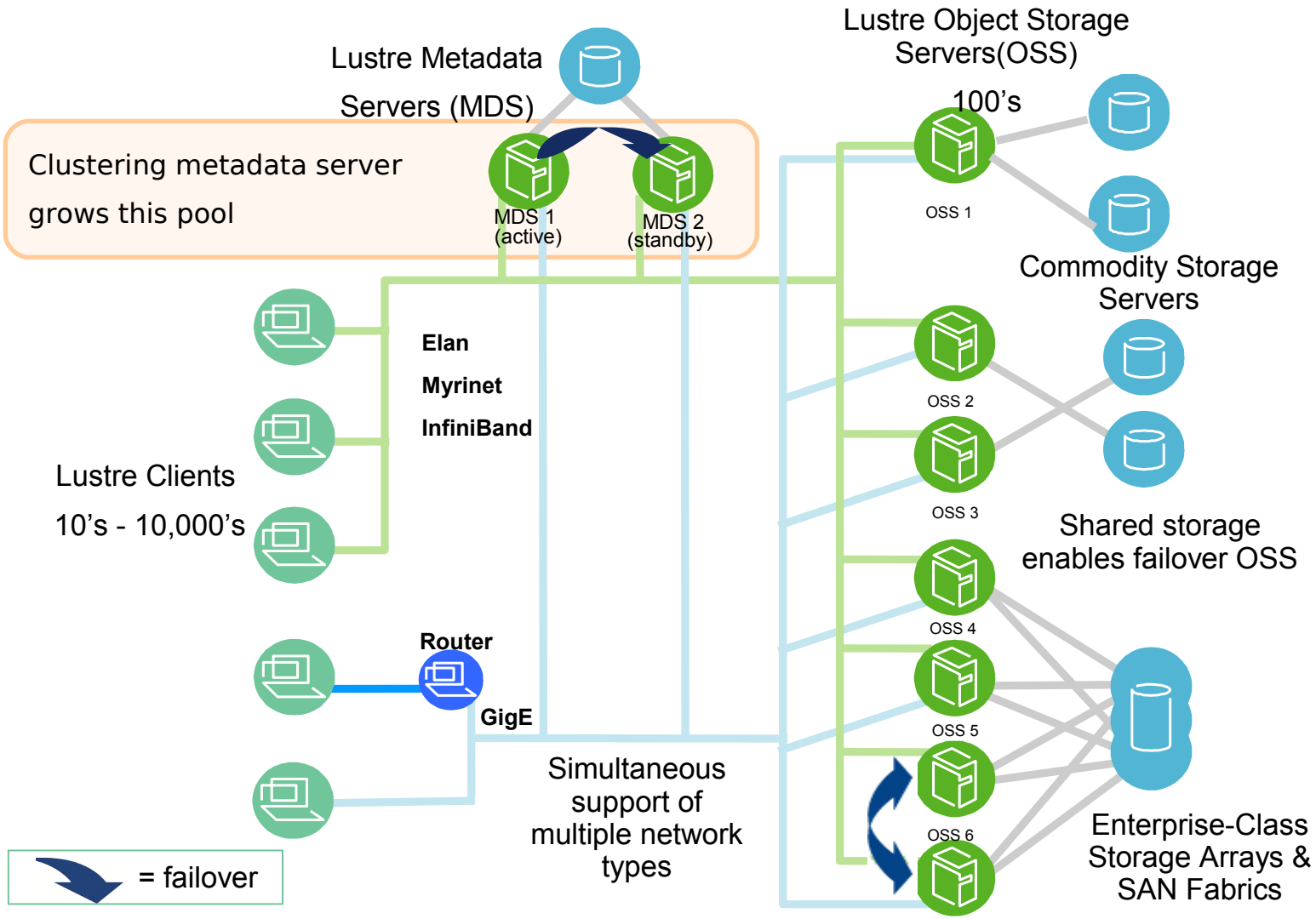
Agenda

- Lustre overview
- Lustre I/O
- Lustre Tuning
- Jaguar I/O pipeline
- Future improvements

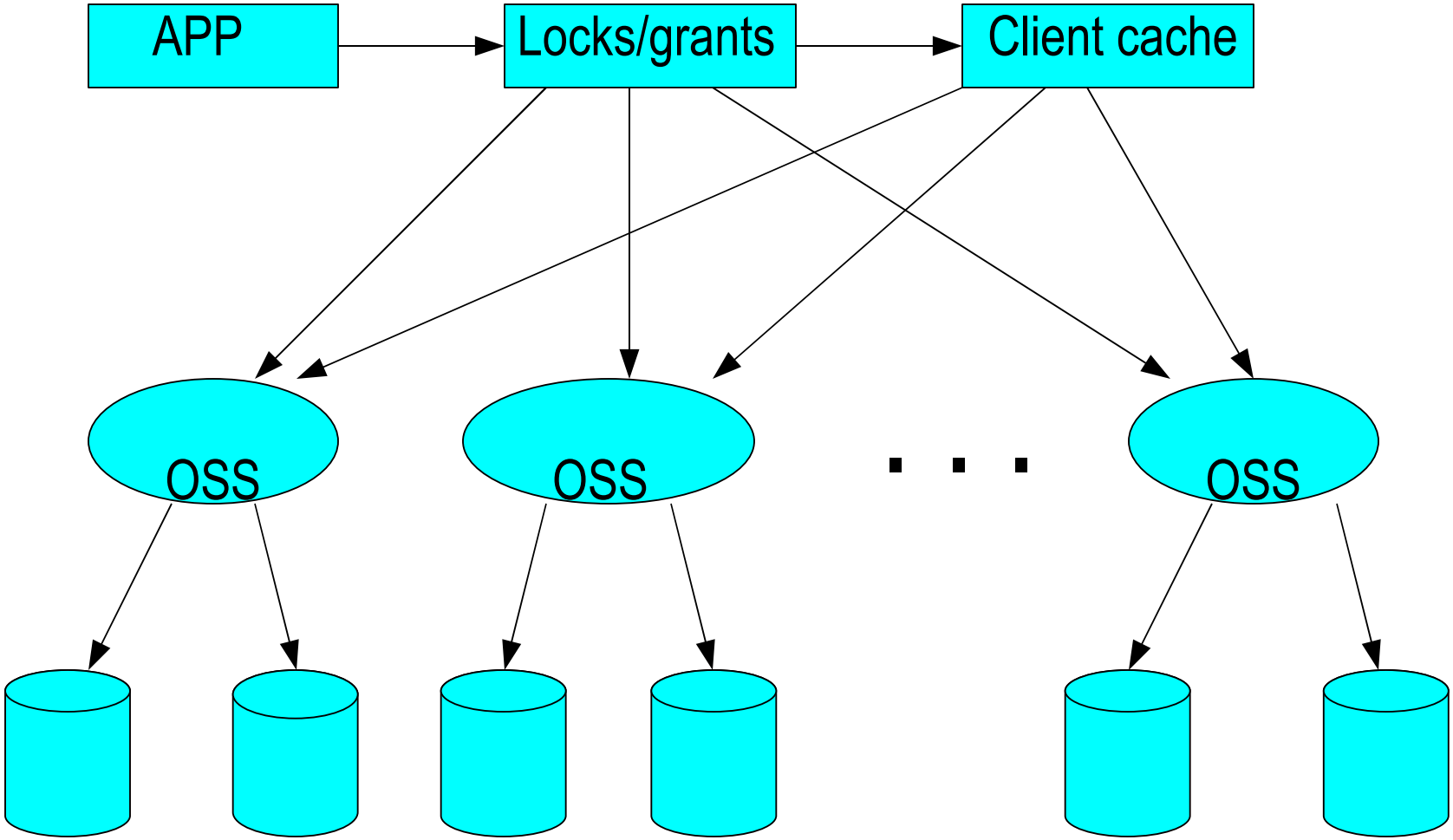
Lustre Architecture



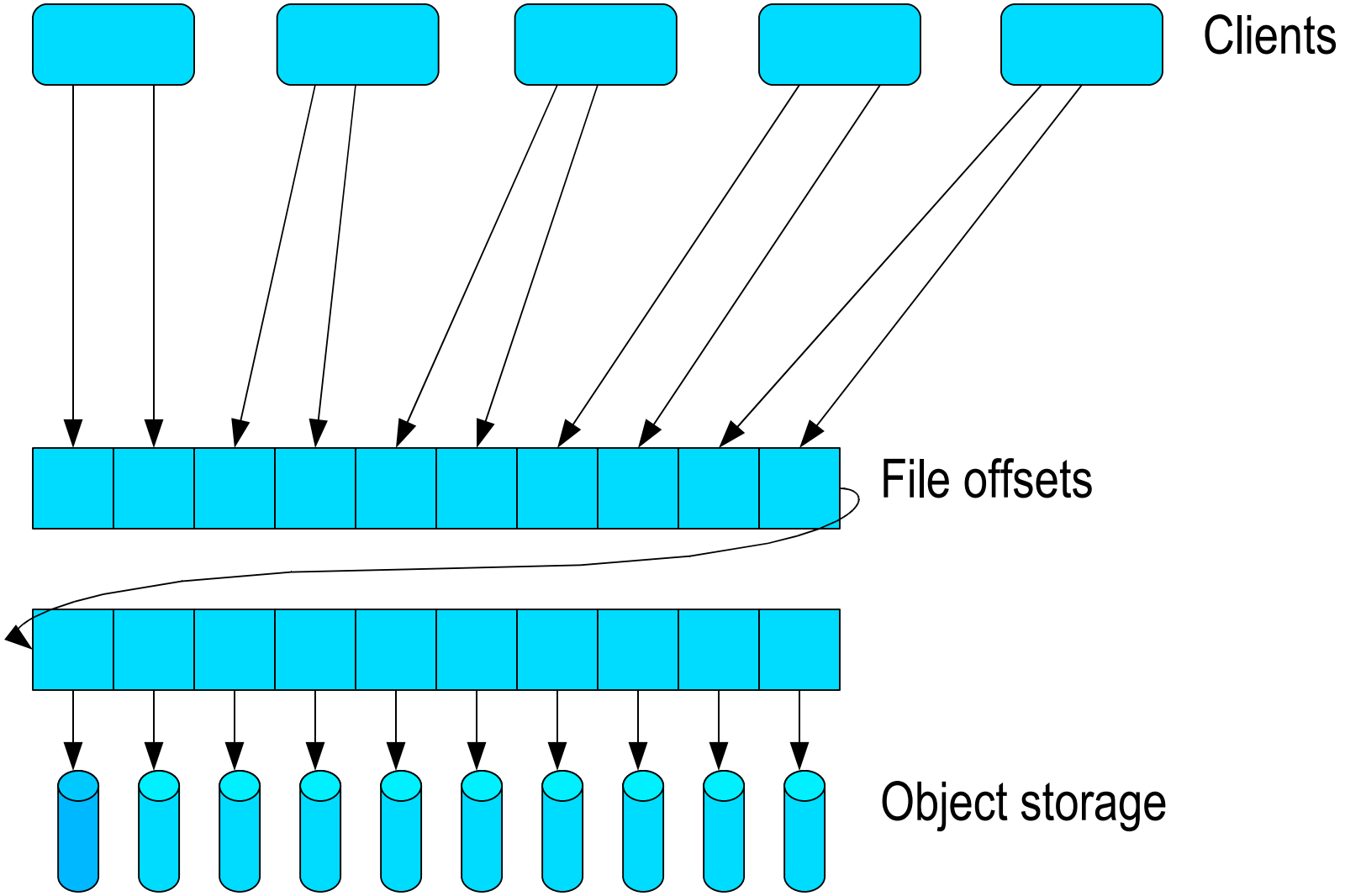
Why Lustre is fast

- No single point of contention on IO path, data is distributed across many storage servers
- Clients have data caches, could cache dirty data too, immediately know when caches are no longer valid
- Consistent POSIX-compliant view on entire FS from clients without any extra user-performed actions.

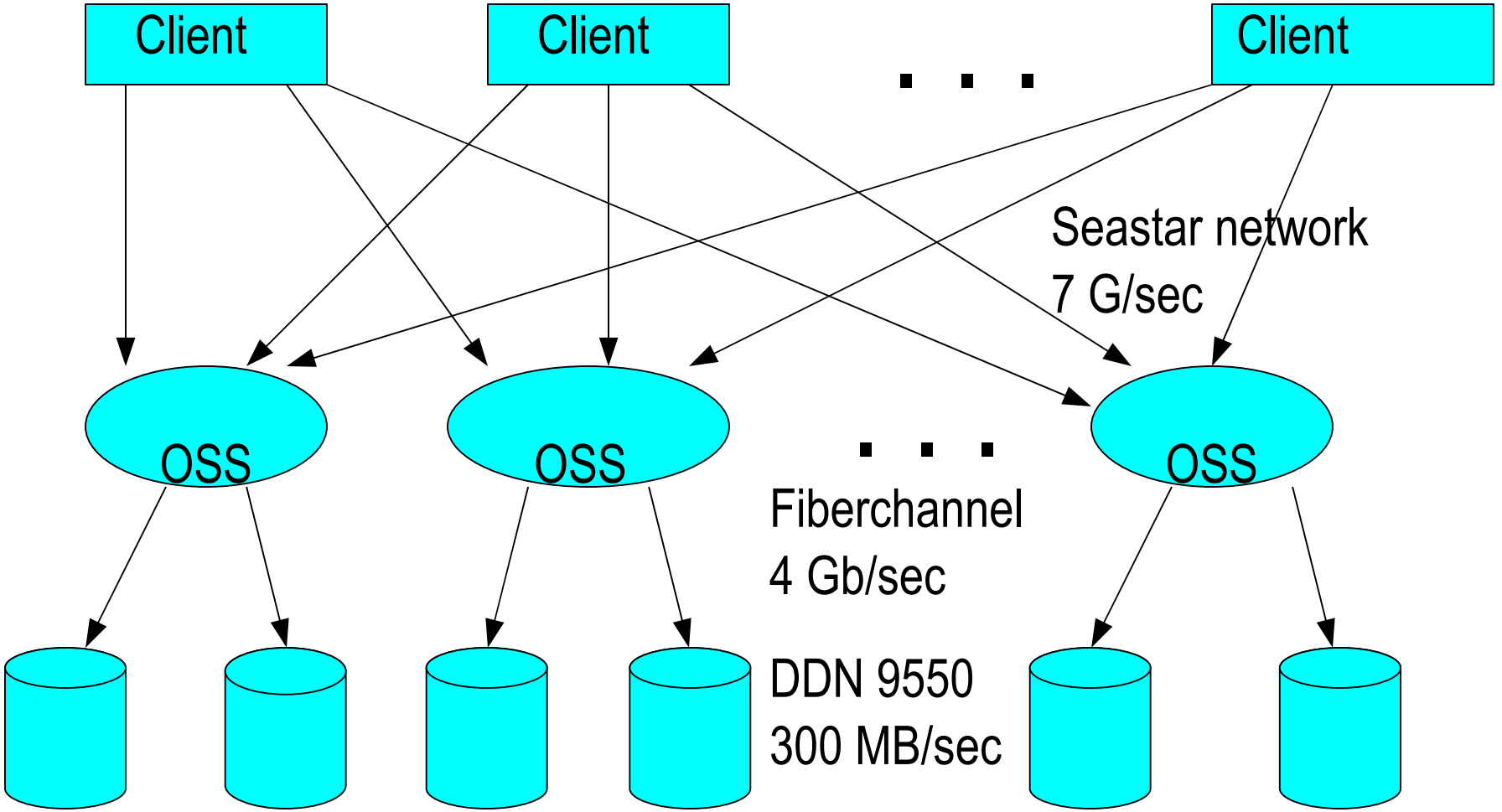
Client -> Server I/O in Lustre



Optimal file striping and IO



Jaguar I/O pipeline



Normal write path (client)

- A lock is obtained across entire write region (one lock per every stripe affected) - overhead
- Write is split across stripe boundaries and for every stripe we perform:
- For every new page of data a “grant of space” is consumed for proper OOS detection
- Data is copied to cache.
- Pages are put into a batch of dirty pages waiting to grow to RPC size (1M). Per-OST limit of dirty data in cache.

Normal Read path (client)

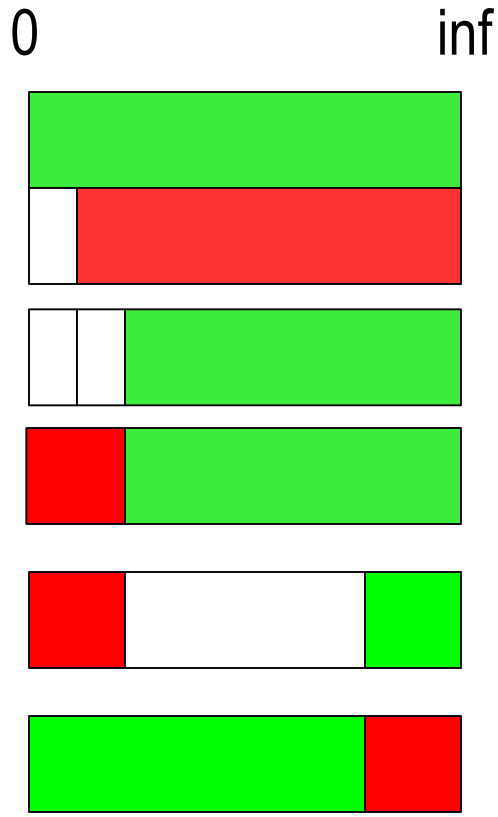
- For every I/O region a lock is obtained for consistency. One lock per stripe. - overhead
- For every stripe affected by read:
- Pages are added to a list of pages waiting to grow to RPC size (1M)
- Readahead can add more pages
- RPCs are sent (regardless of resulting RPC size)
- Data is copied from cache to userspace.

Locking (server)

- Lustre locks file data on a per-OST basis with “extent” locks.
- Locks could be of WRITE (exclusive) and READ (shared) type.
- Granularity is page size.
- Attempts to grant as big of a lock as possible without causing any conflicts.
- Notifies other lockholders in case of conflicts to release locks (and dirty data, sync) – expensive!
- No way to change existing locks at the moment

Locking example 1

- client 1 asks for WR [0;4096]
- client 2 asks for WR [4097;8192]
- client 1 asks for WR [8193;12288]
- client 2 asks for WR [0;4096]
- client 2 asks for WR [40960;45056]
- client 1 asks for WR [0;4096]



Locking (client)

- On clients locks are mostly used to guard caches
- Clients cache locks in LRU for later use
- When lock is revoked, all file data in the range is flushed out from that clients cache.
- Locks could be reused between different processes

Read/Write path (server)

- Request is accepted
- Pages are verified to be good (enough space, etc)
- Data is transferred to/from disk directly, bypassing any Linux caches.
- Replies are sent back.

Linux cache & Lustre

- Dirty cache
  - 32M (tunable) per OST on every client
  - When there is enough dirty data to fill entire RPC (1Mb), it is being written.
  - Sync or memory pressure can write dirty data in partial RPCs too
  - Lock revocation writes the data and clears the cache
- Read cache
  - Memory pressure can flush it
  - Lock revocation flushes it

Direct IO

- No page copying on clients
- No cache
- But still same locking as with normal i/o
- Not all workloads would benefit, consider with care.

MMAP I/O

- Lustre supports mmap that is also fully consistent
- It is much slower for writes.

Important conclusions

- Some local FS guidelines apply
  - Avoid partial page writes
- Lustre-unique hints
  - As few writers per stripe as possible (ideally only 1)
  - Stripe files widely for more throughput
  - Avoid i/o crossing stripe boundaries
  - Submit I/O in as big chunks as possible
  - Avoid repetitive actions from many clients (e.g. truncate shared file to zero from every client)
  - Reading same data from server always hits the disk

System tunables

- Lustre debug can be a performance hog
  - echo 0 >/proc/sys/lnet/debug
- LRU size adjustments (default is 100 locks/cpu)
  - Only makes sense on clients
  - /proc/fs/lustre/ldlm/namespaces/*/lru_size
- Number of RPCs in flight
  - /proc/fs/lustre/osc/*/max_rpcs_in_flight
- Max dirty cache per OST
  - /proc/fs/lustre/osc/*/max_dirty_mb

System tunables

- Readahead
  - /proc/fs/lustre/llite/*/max_read_ahead_mb
  - /proc/fs/lustre/llite/*/max_read_ahead_whole_mb
- Number of server IO threads
  - on OSS only
  - module parameter oss_num_threads to ost.ko

Future lustre improvements

- Less overhead on small i/o
- Cache on Object servers
- Dynamic LRU
- Dynamic number of server threads
- Even better overall scalability
- Bigger RPC sizes

Questions?