whamcloud

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Lustre Metadata Performance Improvements

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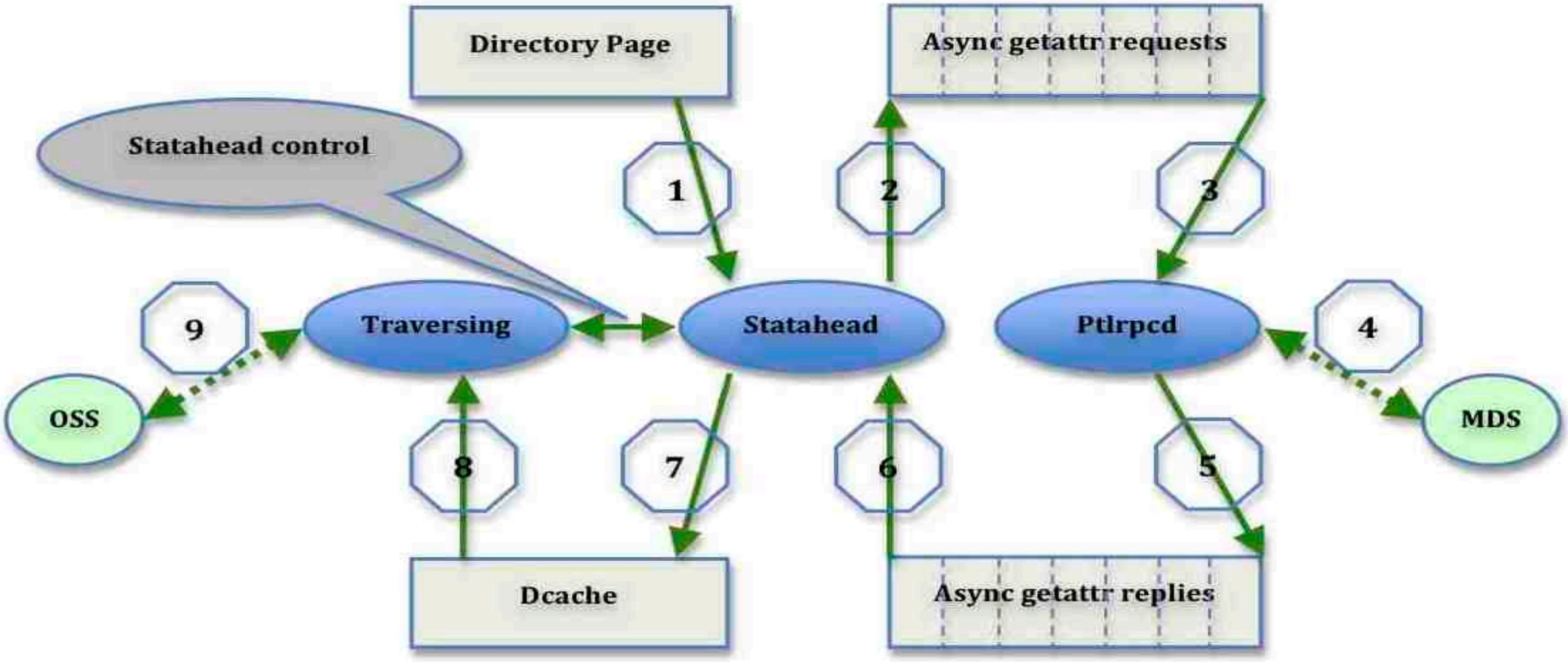
Overview

- What we focused on
  - Sequential traversing large directory on single client: ls/du/find
  - Metadata performance SMP scaling: opencreate/unlink
- Accelerate sequential traversing directory
  - Asynchronous glimpse lock
  - Statahead load balance
  - Aggregate attributes to save RPCs
  - Efficient ldlm/object hash
- New progress on Lustre SMP scalability
  - Flexible RPC scheduler
  - Parallel directory operations

Accelerate traversing directory (prolog)

- Existing statahead
  - Only prefetch attributes from MDS
  - Single pipeline for async getattr



Asynchronous glimpse lock

- Prefetch glimpse lock from OST
  - Async RPC without waiting
  - Cache file size/blocks if AGL granted
  - No glimpse callback if OST can't grant AGL
  - Re-enqueued by traversing thread if AGL non-granted/cancelled

May cause additional RPCs if someone held conflicting locks on some items, but it works well for large directories, since stat/read cases are more common than writes.

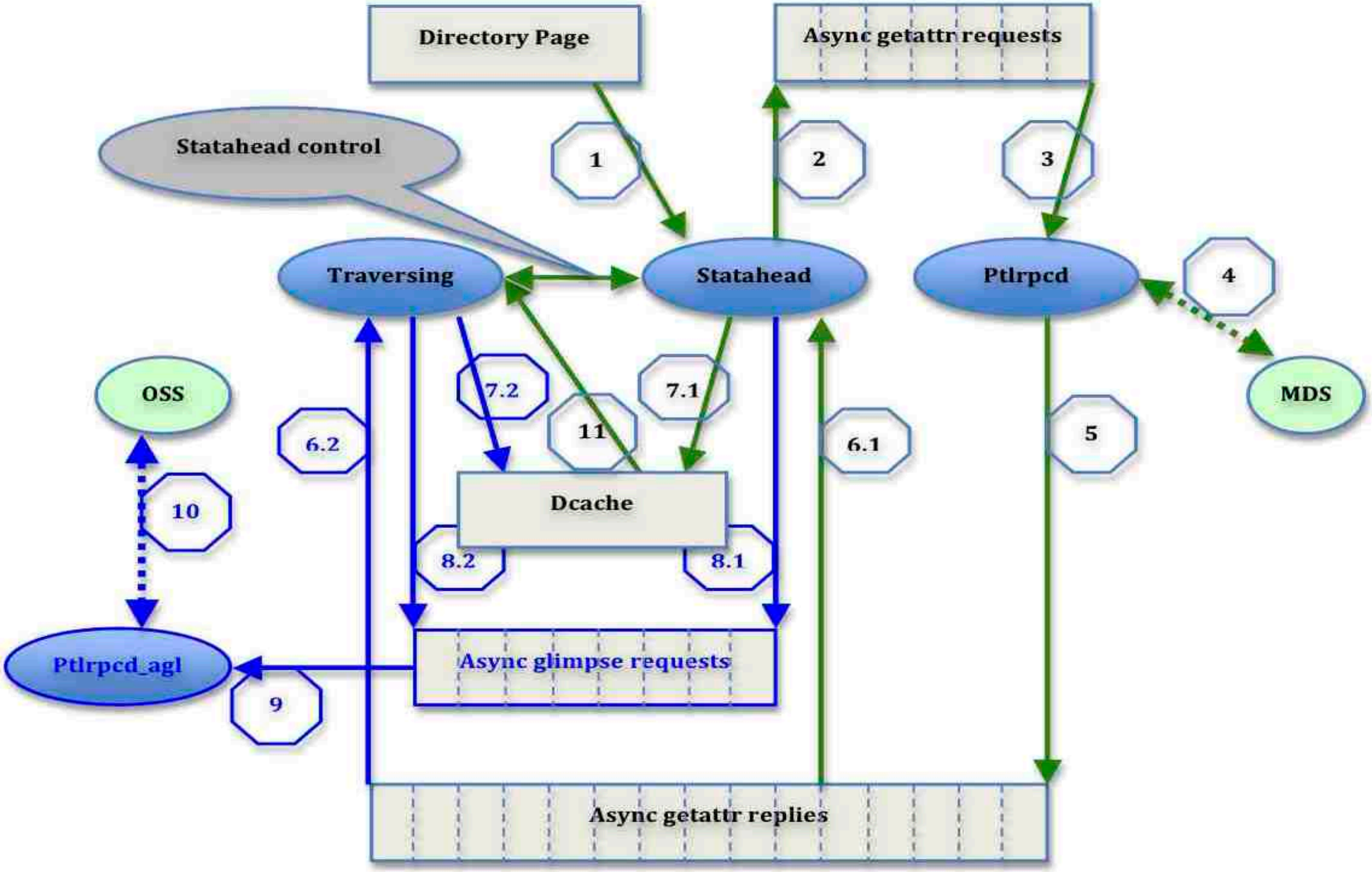
Statahead load balance (1/2)

- Independent portal RPC service (ptlrpcd_agl)
  - Dedicated to processing AGL RPC
    - Single ptlrpcd on client may be overloaded to process all non-I/O async RPCs when traversing large directory
    - Unbalanced load, other CPU(s) on the same client maybe idle
  - Separate pipelines for async getattr and AGL
    - Async RPCs for getattr and glimpse can be processed in parallel, no contention between ptlrpcd and ptlrpcd_agl
    - Decrease the unnecessary dependence between MDS-side RPC and OSS-side RPC

Statahead load balance (2/2)

- Unbalanced load between statahead and traversing
  - Statahead thread is so slow that RPC processing time can’t be hidden
  - Statahead thread
    - Async getattr pipeline Input & Output
    - AGL pipeline Input
  - Traversing thread
    - AGL pipeline Output

- Pool for async getattr replies to be interpreted
  - Traversing thread helps to process async getattr replies
  - Statahead thread
    - Async getattr pipeline Input & Output
    - AGL pipeline Input
  - Traversing thread
    - Async getattr pipeline Output
    - AGL pipeline Input & Output


Directory Page
Async getattr requests
Statahead control
1
2
3
Traversing
Statahead
Ptlrpcd
4
MDS
OSS
6.2
7.2
11
7.1
6.1
5
10
Dcache
8.2
8.1
Ptlrpcd_agl
Async glimpse requests
9
Async getattr replies

Aggregate attributes to save RPCs

- MDS-side attributes for traversing directory:
  1) Basic attributes, like mode/owner/flags
  2) Stripe information
  3) Access Control List
  4) Default ACL for directory

  Currently, 1) & 2) & 3) can be obtained through single RPC; and further combining 4) can save about 50% RPC for the best cases.

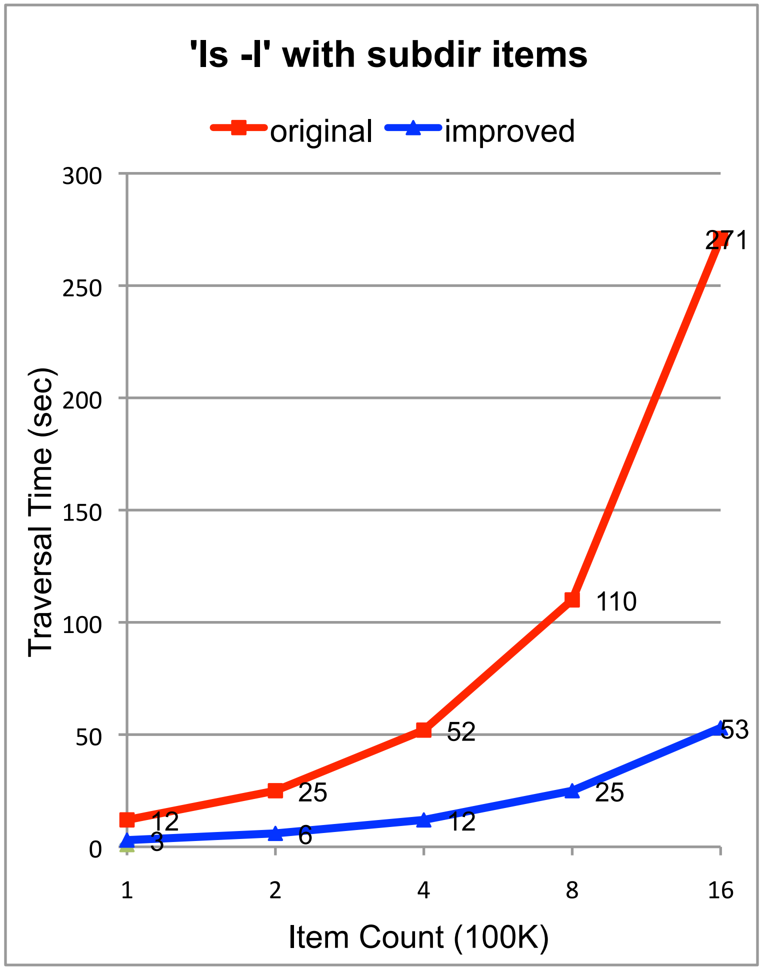
  – Maybe more in future

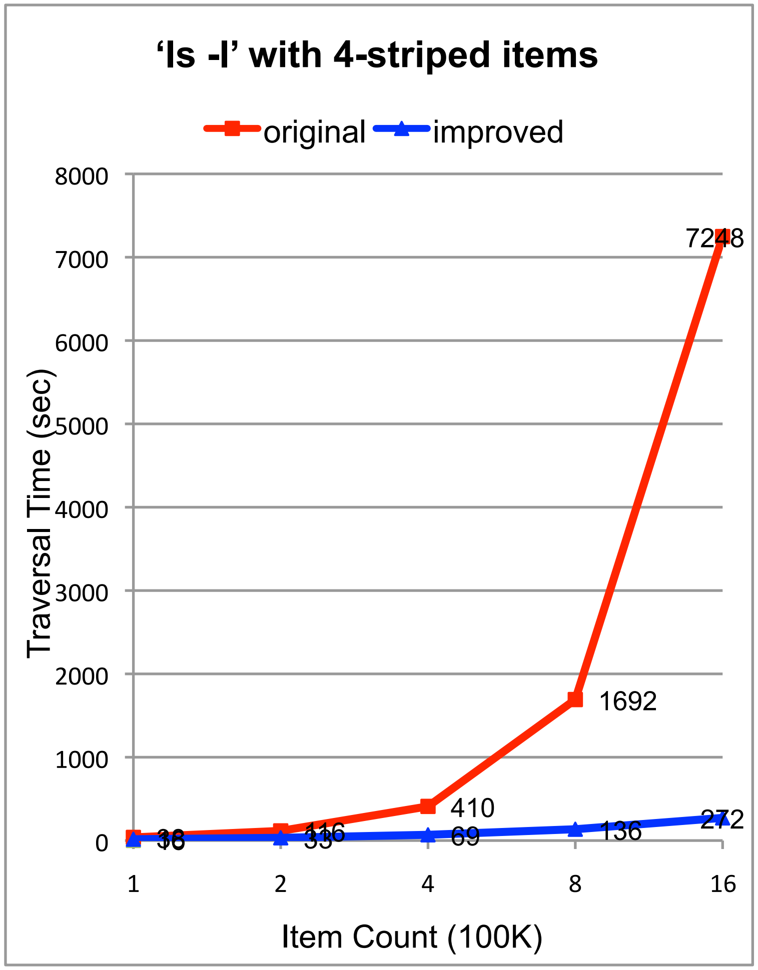
Efficient ldlm/object hash

- Hash greatly affects traversing performance
  - MDS: object hash & ldlm hash
  - OSS: ldlm hash
  - Client: object hash & ldlm hash

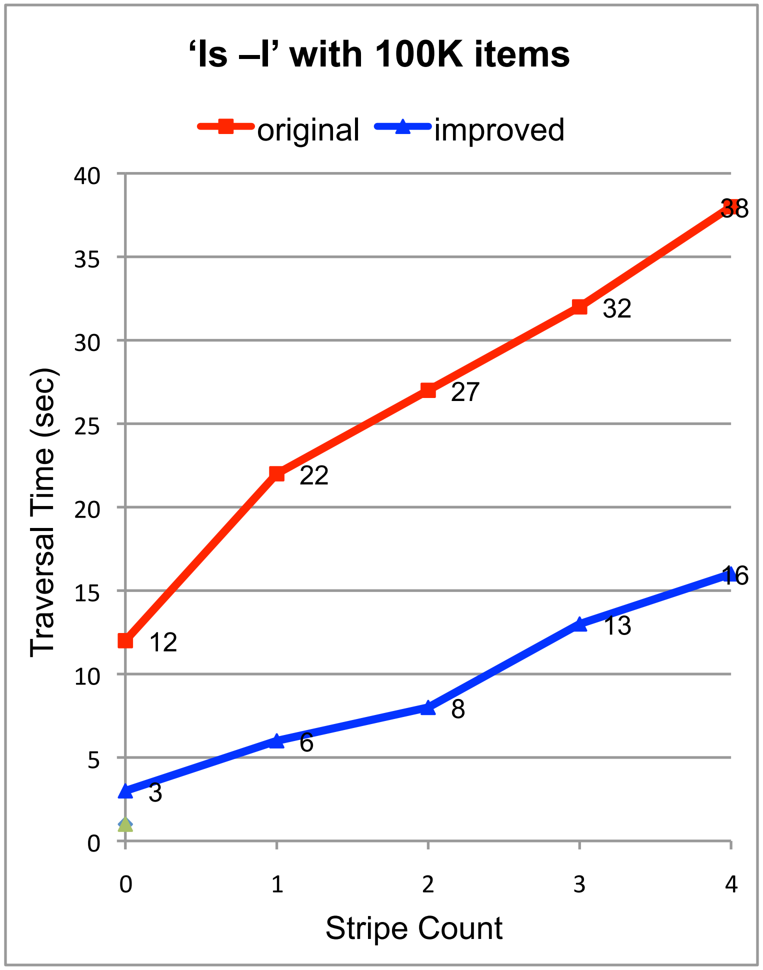
- Hash bucket depth is quite important
  - Basically depends on hash function
    - Scatter ldlms/objects throughout buckets as evenly as possible
  - RAM size and filesystem size are associated
  - Experience: Max depth for millions of ldlms/objects hash
    - lustre-2.0 approaches 3K
    - no more than 50 is expected

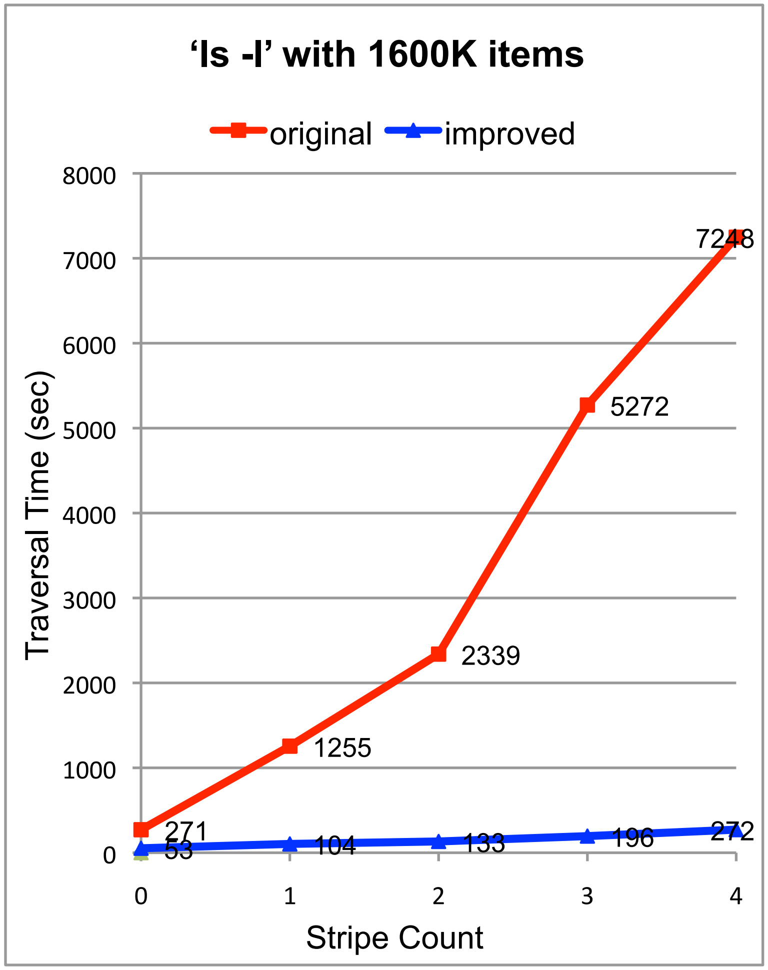
‘ls –l’ on single client (1/2)





‘ls –l’ on single client (2/2)

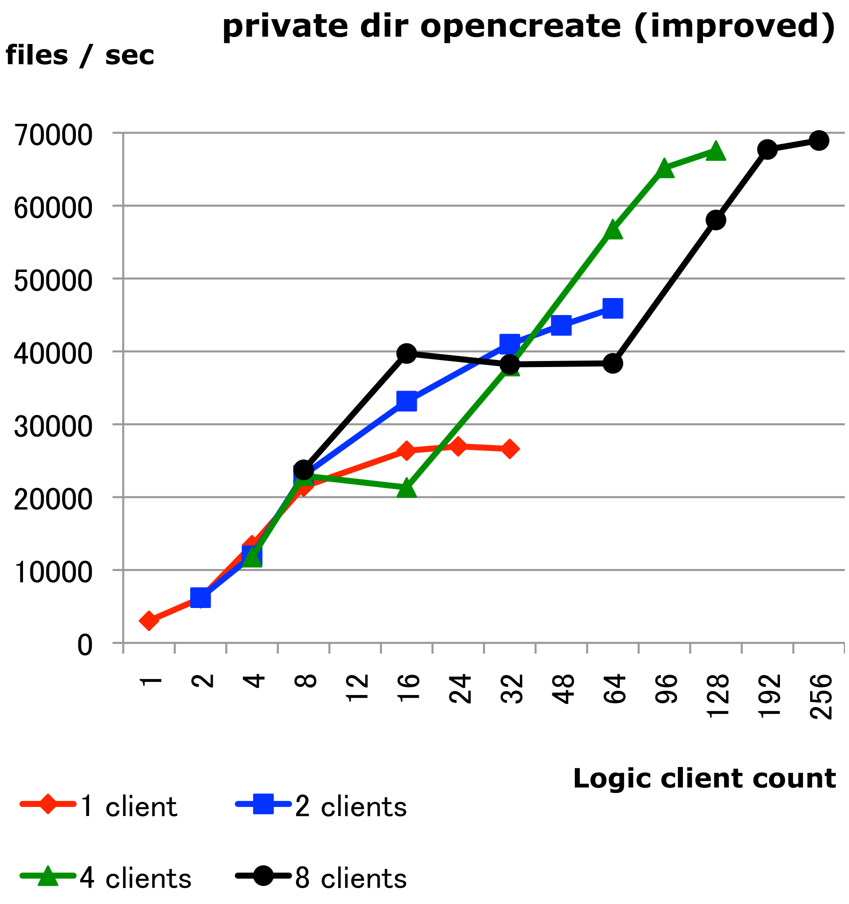


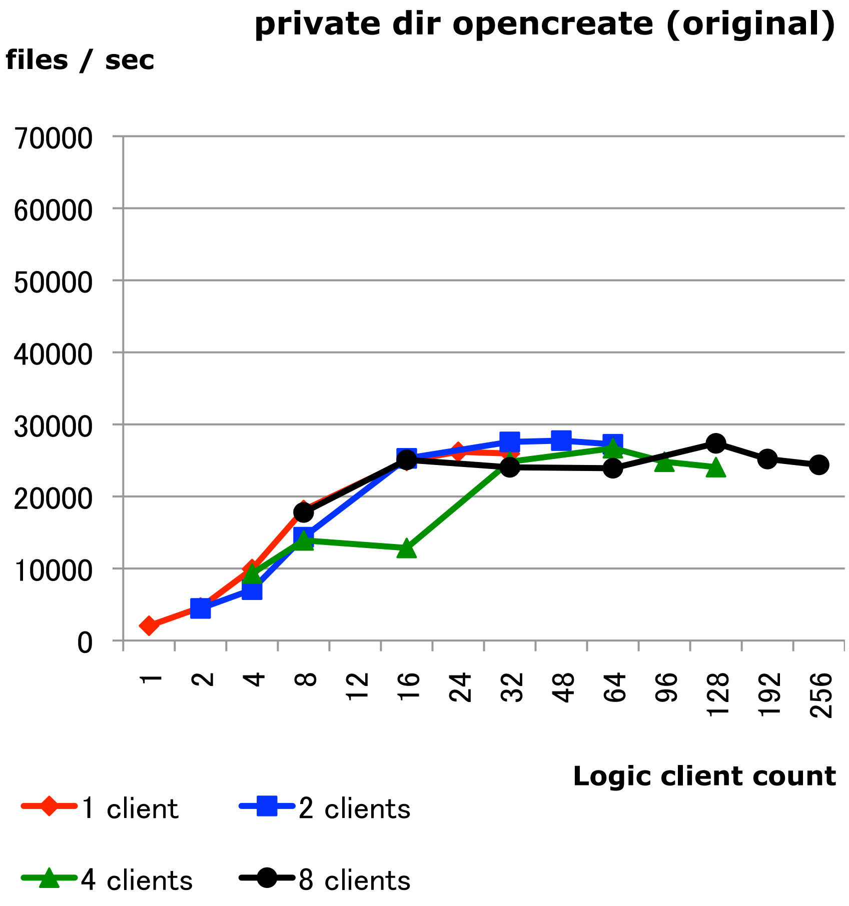


Flexible RPC scheduler – SMP scaling

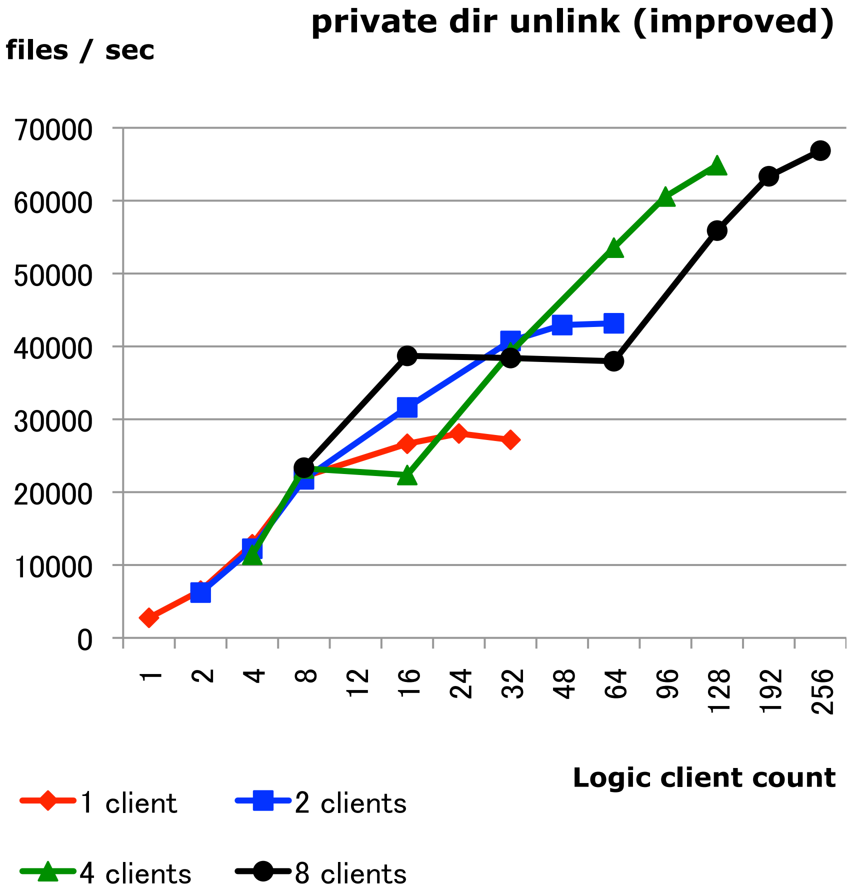
- Metadata performance is CPU bound for scaling
- Localize lifecycle of RPC request/reply on the same CPU unit all along
  - CPU unit: socket, core, processor (hyper-thread)
  - Separate RPC queue for each CPU unit
  - General optimization for service side RPC processing
    - RPC queue lock contention within CPU unit
    - No data migration between CPU units
  - Little help for shared directory operations
    - High contention on operation target(s)

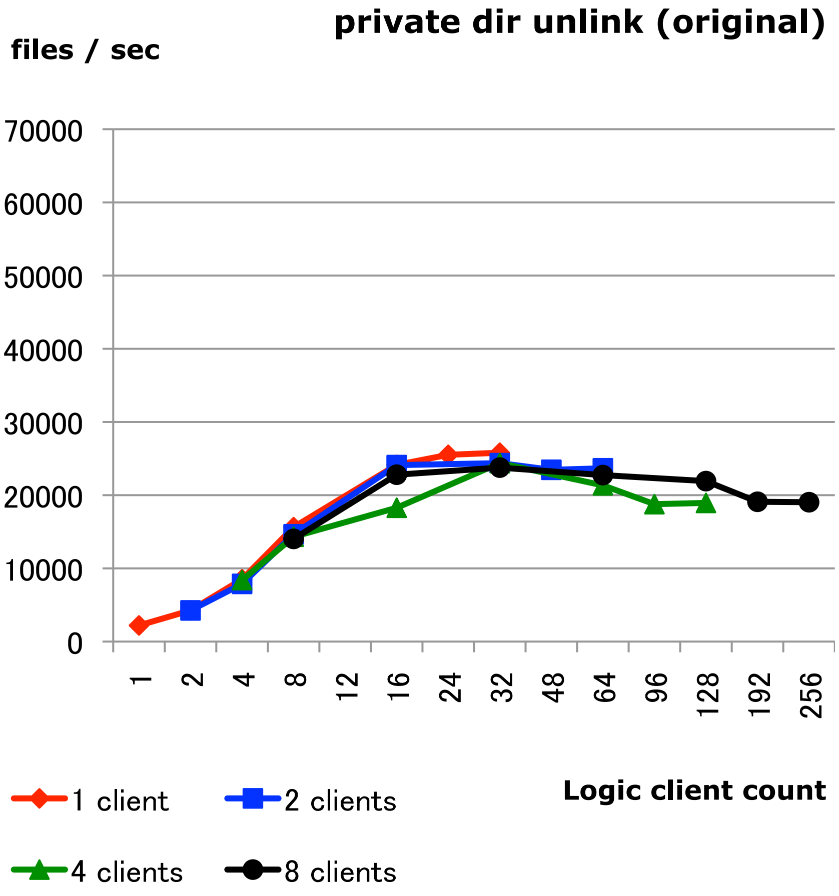
Opencreate under private dir





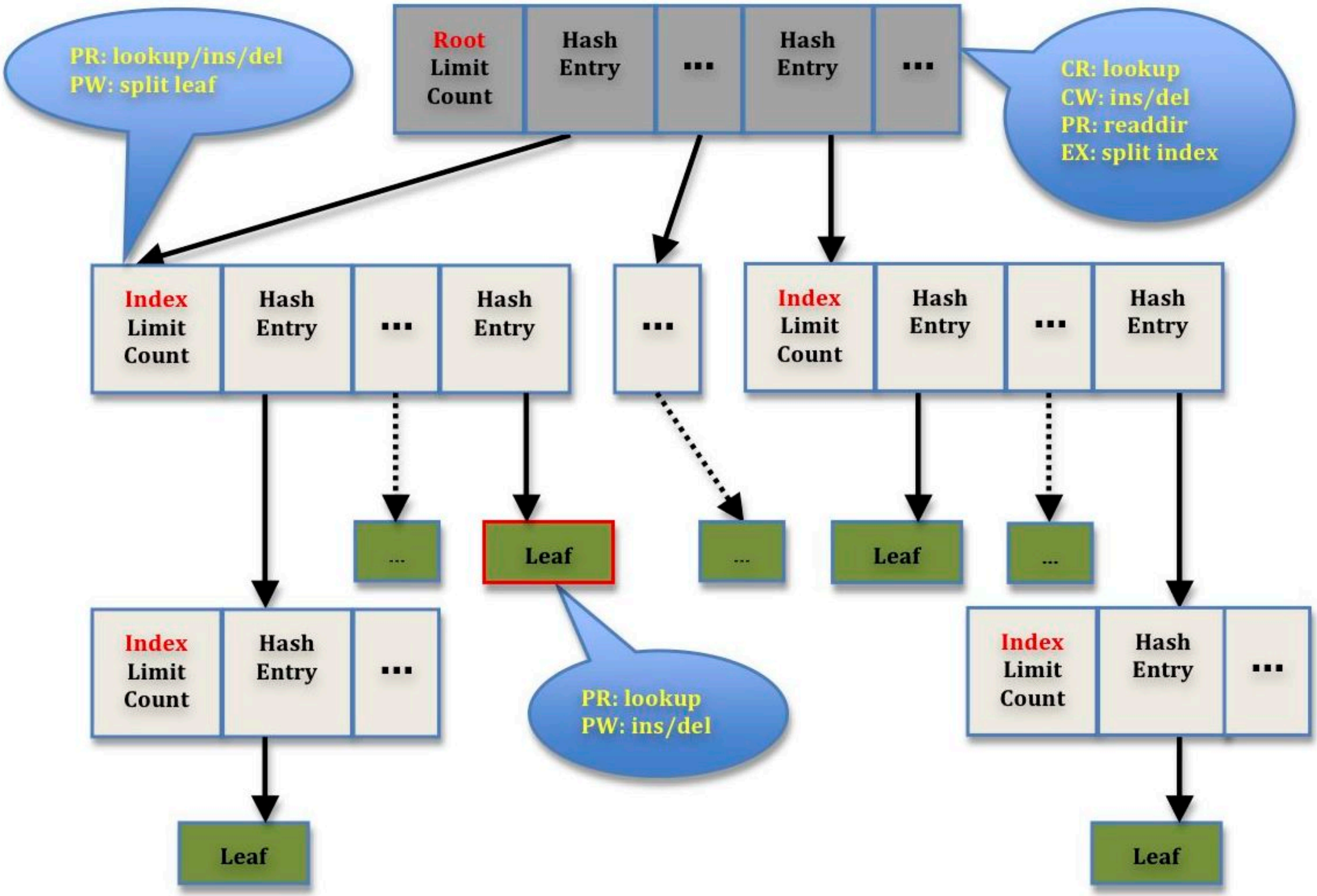
Unlink under private dir


private dir unlink (improved)

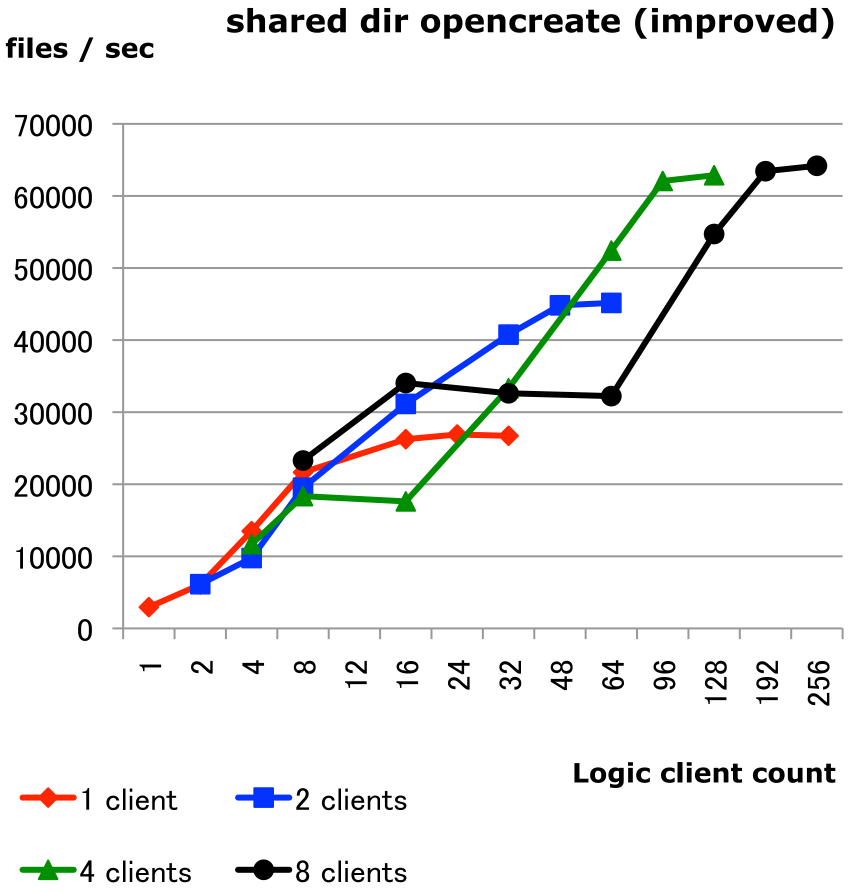

private dir unlink (original)

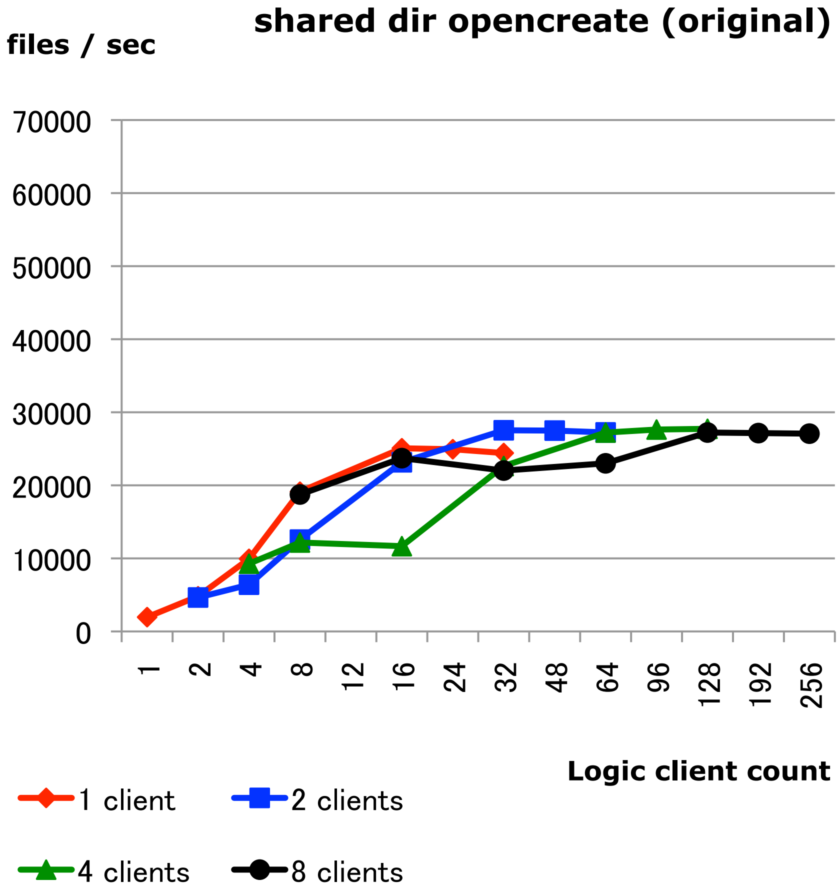
Parallel directory operations

- Policy: reduce contention range as far as possible
  - At least two levels contention: ldlm & ldiskfs
  - Already support ldlm level PDO
- IAM (Index Access Module) based ldiskfs
  - Contain ldiskfs level PDO control
  - Incompatible disk format with lustre-1.8
- EXT3/EXT4 based ldiskfs
  - Bottleneck: single read-write semaphore protects whole parent htree
    - Most concurrent operations at ldlm level are serialized here
  - Improvement:
    - Only lock leaf node if non-split
    - Backtrack to lock index node(s) when split
    - Local lock hash

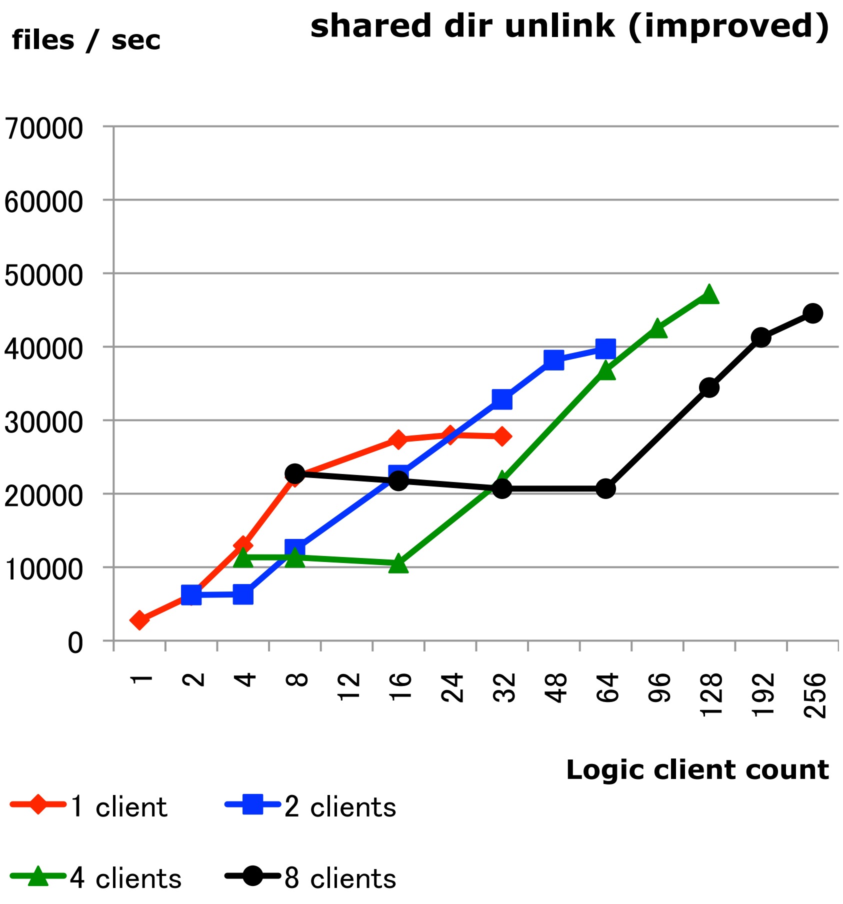

Root
Limit
Count
Hash
Entry
...
Hash
Entry
...
CR: lookup
CW: ins/del
PR: readdir
EX: split index
PR: lookup/ins/del
PW: split leaf
Index
Limit
Count
Hash
Entry
...
Hash
Entry
...
Index
Limit
Count
Hash
Entry
...
Hash
Entry
...
Leaf
...
Leaf
...
Index
Limit
Count
Hash
Entry
...
PR: lookup
PW: ins/del
Index
Limit
Count
Hash
Entry
...
Leaf
Leaf

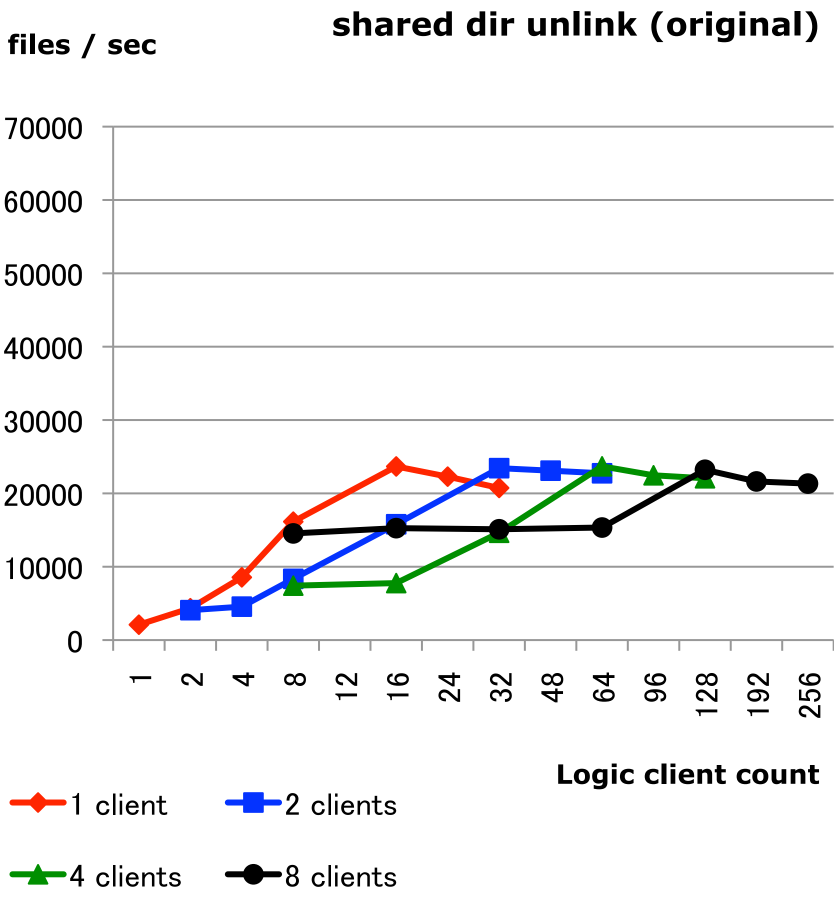
Opencreate under shared dir





Unlink under shared dir





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Thank You

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