Enabling Manycore Scalability in F2FS Metadata for *unlink()* Operation

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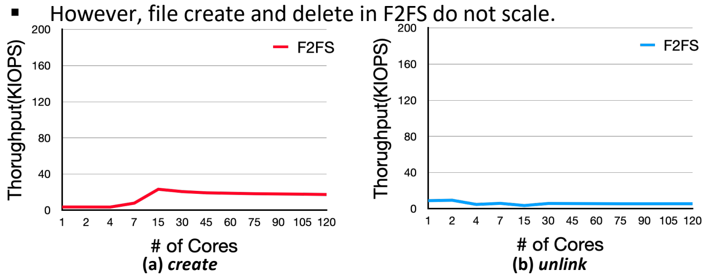
F2FS Metadata Scalability Limitations

- Manycore servers are expected to bring great scalability in file systems due to their large number of cores.
- However, file create and delete in F2FS do not scale.



(a) *create* (b) *unlink*

Figure 1. < Manycore scalability in file *create* & *unlink* in F2FS>

- We tested file create & unlink scalability with F2FS using FxMark.

Unlink Metadata Operation in F2FS

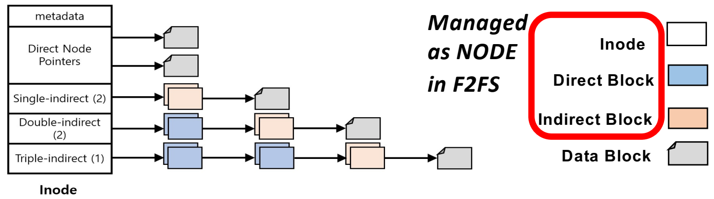


Figure 2. < F2FS File Structure>

- Figure 2 shows the F2FS File Structure with Node.
- Node is identified via *nid* and stored in an on-disk structure, Node Address Table (NAT).

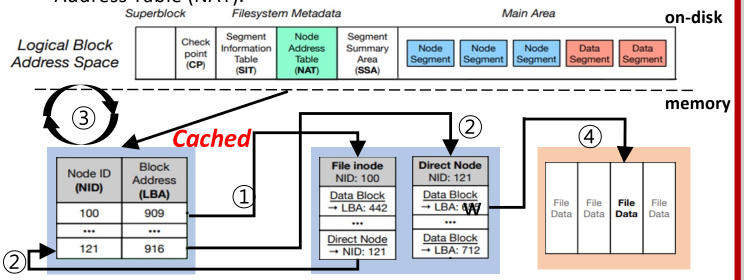


Figure 3. <*unlink()* process in F2FS>

- Figure 3 shows how F2FS processes *unlink()* with on-disk & in-memory data structures including NAT.

Step ①. Find inode by checking cached node in memory.
Step ②. Find the Direct Node's id in cached NAT.
Step ③. Check the number of *Free nids*. If it is not sufficient, refill *Free nid.*
Step ④. Delete Direct node's link to File data that will be deleted.

- F2FS should maintain enough *Free nid*s for future *create().*
- *Free nid* Bitmap to check *Free nid* is used to obtain *Free nid* fast in memory.
- If *Free nid* is below the threshold, F2FS will run *Free nid* Scan, which scans the *Free nid* Bitmap and checks the NAT directly.

Metadata Scalability Bottlenecks

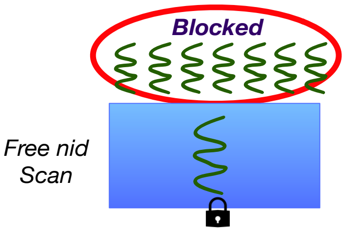


Figure 4. < Blocking in *Free nid Scan* >

- The main cause of the scalability bottleneck of F2FS for parallel *unlink* operations in the Manycore system is a large critical section (CS).
- Figure 4 shows that parallel processing efficiency of threads executing *unlink()* is highly limited by a large CS in *Free nid Scan.*

Proposed Design and Implementation

We propose two techniques(Optimistic *Free nid* Scan, *Heuristic Free nid* Bitmap Scan) to mitigate thread execution efficiency in parallel ***unlink()*** and unnecessary search in *Free nid Scan* **.**

1. Optimistic *Free nid Scan* divides the *Free nid Scan* into two parts to increase the thread execution efficiency.

Step ① . Scanning *Free nid* Bitmap.
Step ②. Only case for Step 1 fails, fill *Free nid* from NAT in the SSD.

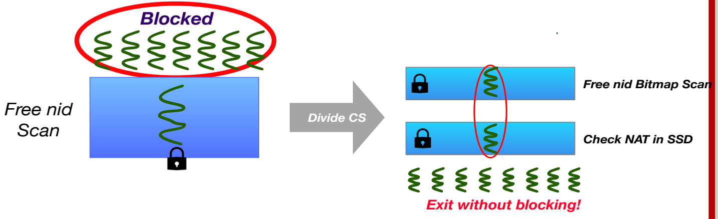
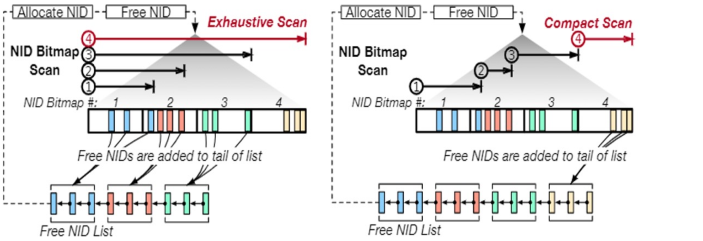


Figure 5. < Improved Parallel I/O by Optimistic *Free nid Scan* >

- In vanilla F2FS, most of the threads are blocked until the preceding one finishes *Free nid* Scan.
- By the *Optimistic Free nid Scan*, threads that were previously blocked will not be blocked any longer, increasing thread's parallel execution efficiency.

2. Heuristic *Free nid* Bitmap Scan starts scanning from point where previous Bitmap Scan ended.

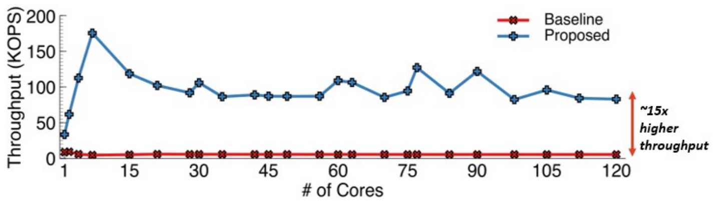


(a) Exhaustive Scan in vanilla F2FS **(b) Compact Scan by Heuristic *Free nid* Bitmap Scan**

Figure 6. < Scan length reduction by Heuristic *Free nid* Bitmap Scan>

- In vanilla F2FS, *Free nid* Bitmap Scan starts from the beginning of the bitmap, increasing the latency of *Free nid* Bitmap Scan.
- Figure 6 shows by Heuristic *Free nid* Bitmap Scan, the total bitmap scanning time is reduced, and the blocking time of threads is minimized.

Evaluation



- We evaluated our proposed design on 120-core manycore server equipped with 740GB memory and Samsung 970 EVO SSD.
- We compared the proposed approach with Baseline (Vanilla F2FS version).
- We tested using MWUL workload in FxMark, where multiple threads perform unlink in their private directory in MWUL workload.
- The proposed approach outperforms Baseline F2FS and improved manycore scalability to 15 cores.
- Throughput of proposed design sustains after 15 core due to the mutex lock in the call path. We identified this is the fundamental limiting factor.

Acknowledgement

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