An Empirical Study of File Systems on NVM

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Motivation

- Need a thin software stack to access data from fast NVM
  - Persistent memory abstractions
  - NVM optimized file systems

- What characteristics of traditional block based file systems are good for NVM?
  - Can traditional file systems be fine tuned using mount and format options?
  - Can it be optimized with minor changes?
  - How does the performance of traditional file systems compare with NVM-optimized one?
  - What file system features help improve performance on NVM?

Overview

- Related Work
- Experimental Methodology
- Experimental Results
- Recommendation and Conclusion

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POSIX interface, re-designing the file system for NVM	POSIX library interposers or bypass file system	New Programming Models and Data-Structures	Adjust operating system, storage stack or file system configurations

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• PMFS	• Moneta-D	• Mnemosyne	• Lee et al
• SCMFS	• Bankshot	• PMem-Lib	• Our work.
• BPFS	• Aerie	• NV-Heaps	
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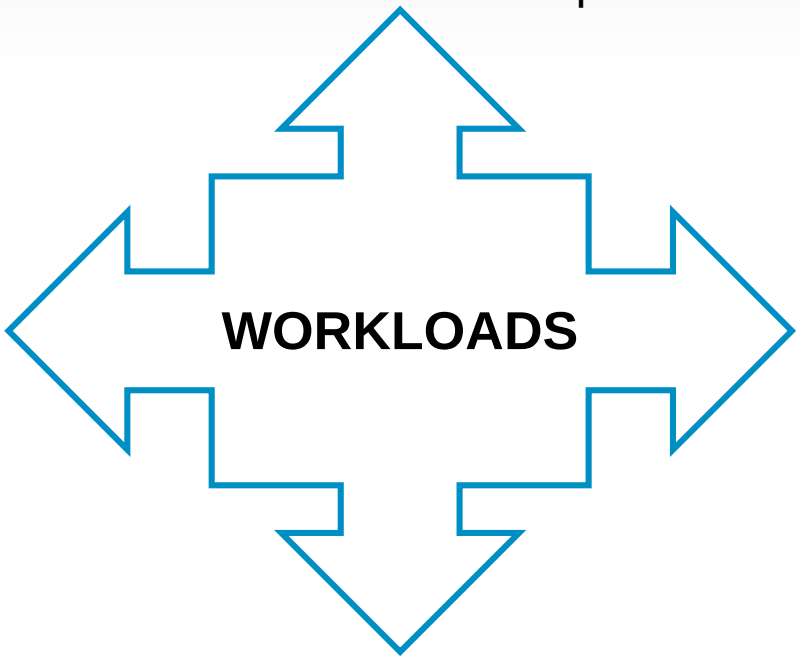
Experimental Methodology

Workloads

FileServer :Moderate directory depth, moderate no. of large files, data and metadata operations



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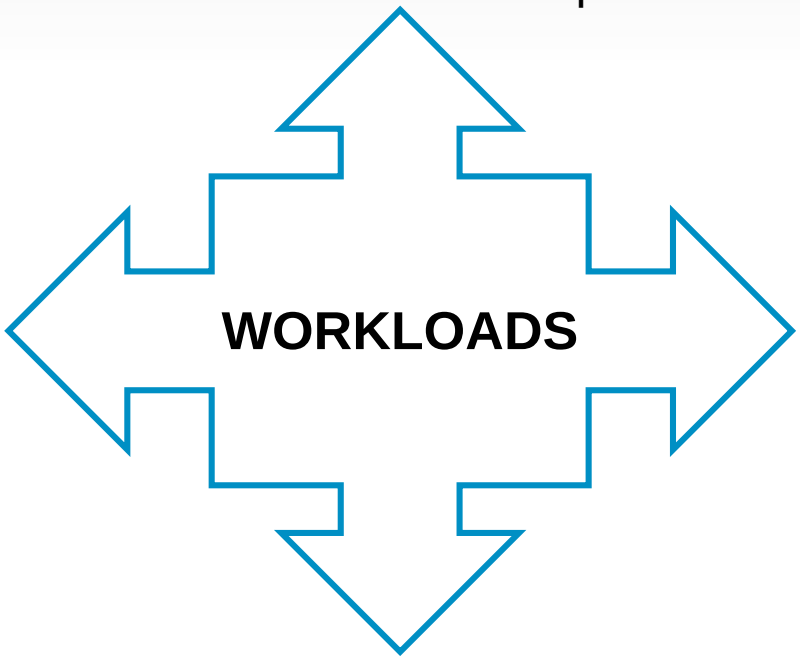

WebProxy:Flat namespace, large no. of small files, data and metadata operations

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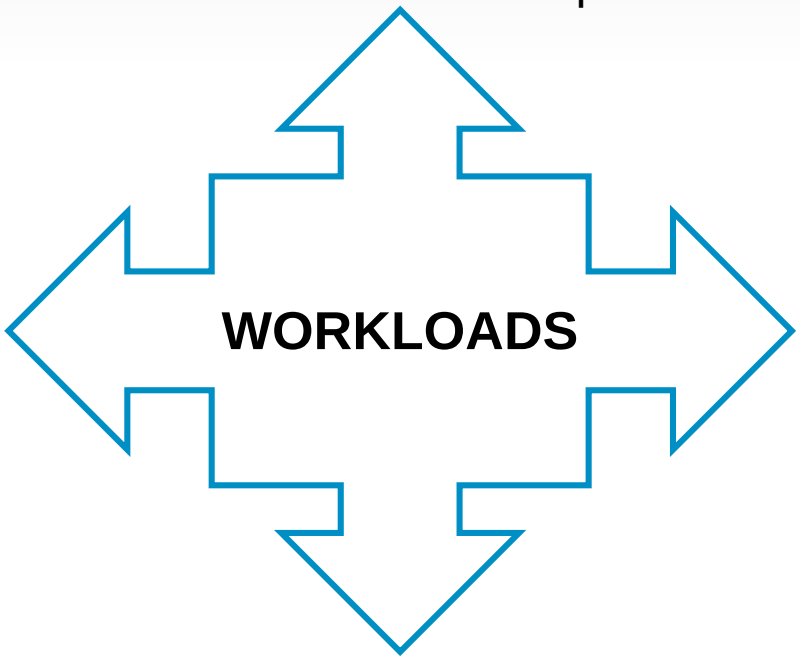

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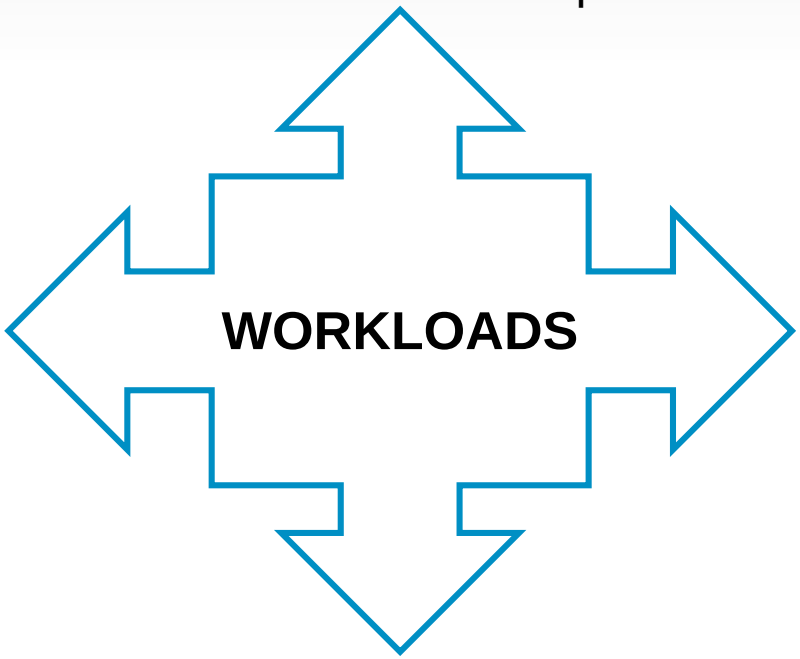

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Key-Value Store: Uses Memory-Mapped Semantics (load/stores)

Experimental Methodology

File System Characteristics (varied using mount and format options)

- **Inode Structure**: Linear vs B+ Tree
- **Block Size**: Fixed vs Variable sized extent
- **Layout/Update**: In-place vs Log-structured vs Hybrid
- **Allocation Strategy**: Immediate vs Delayed
- **Parallel Allocation** (Concepts like Allocation/Block group)
- **Journal**: Ordered vs Write-Back vs Data
- **Execute-in-place(XIP)**

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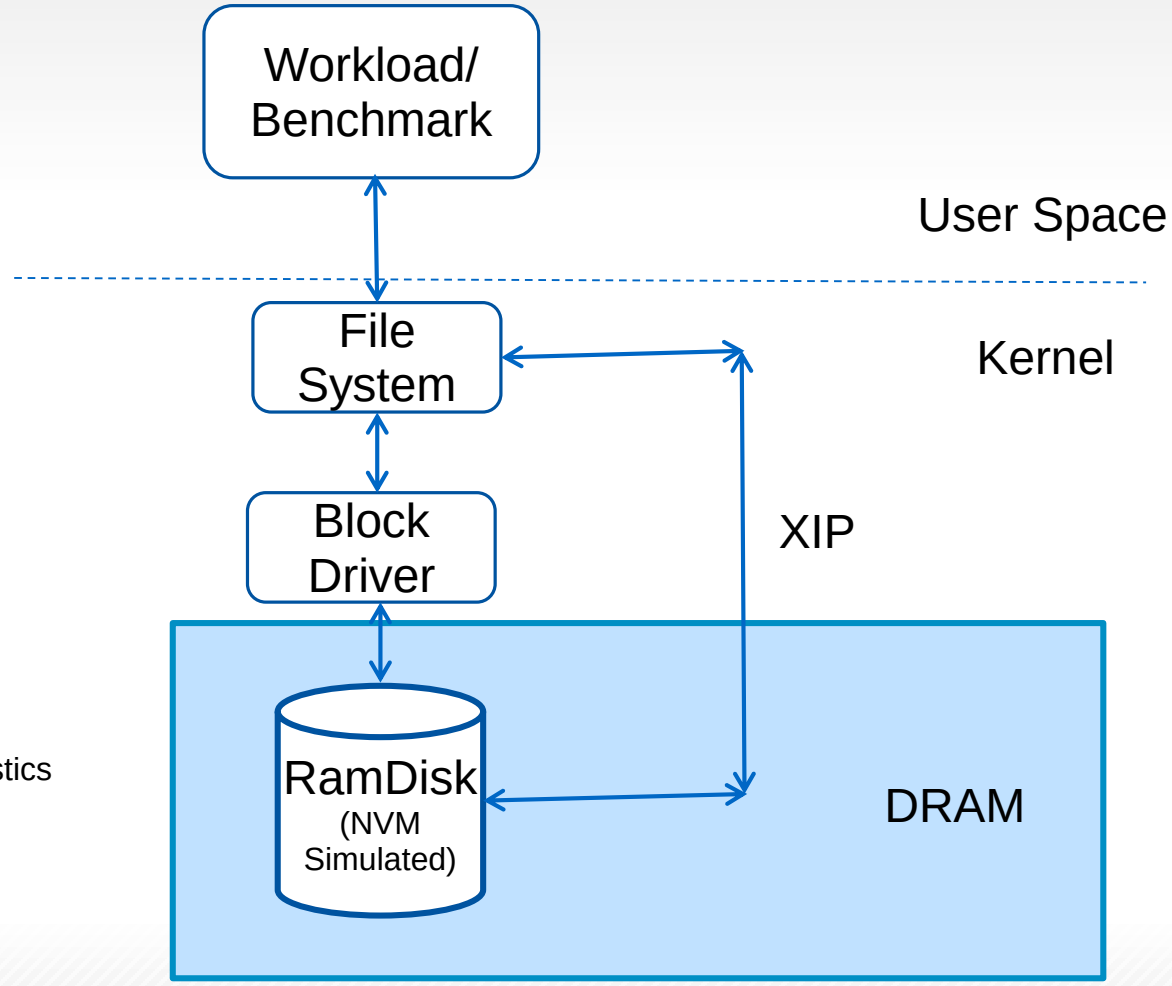
File Systems Evaluated

Ext2, Ext3, Ext4, XFS, F2FS, NILFS2, PMFS

Experimental Methodology

Experimental Setup



Limitations:

- NVM characteristics not simulated
- Not considered recoverabiliy

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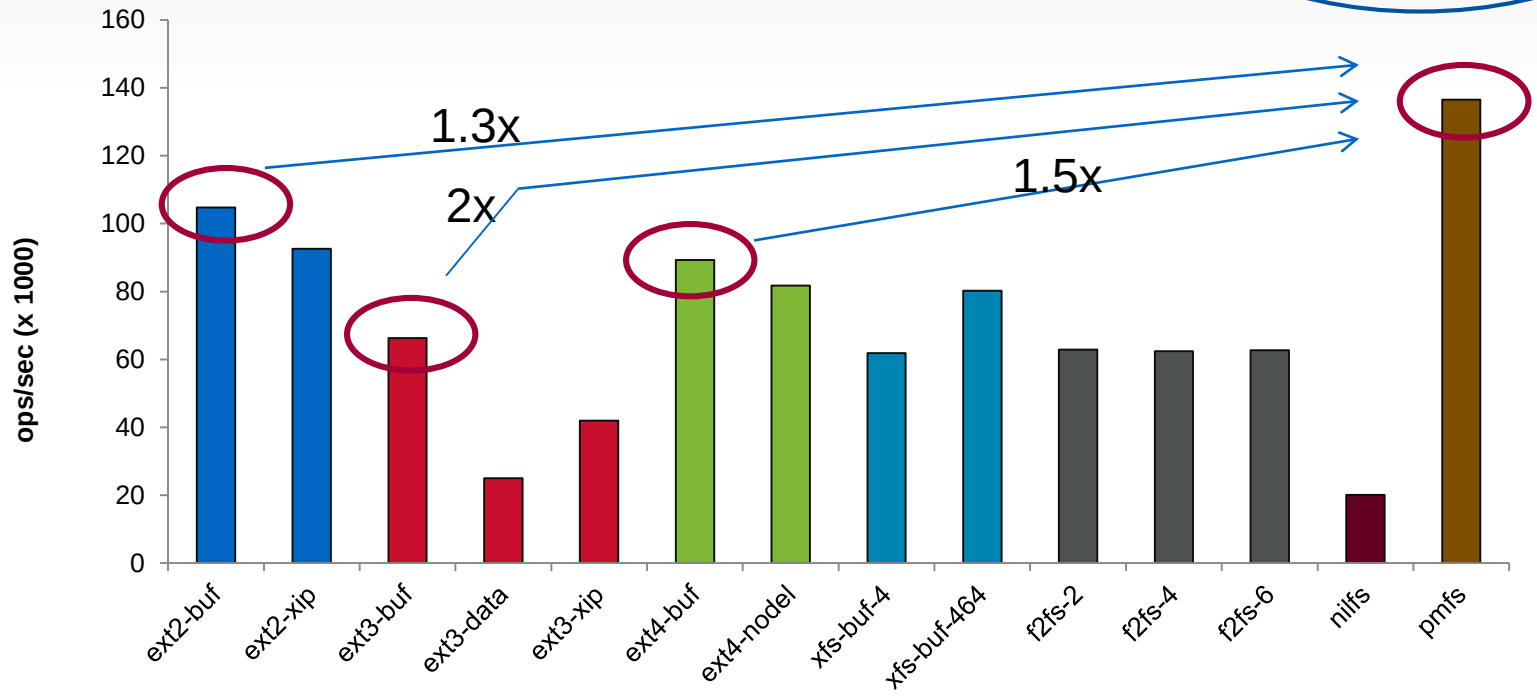
FileServer (Throughput)

XIP support, atomic updates and fine grained logging

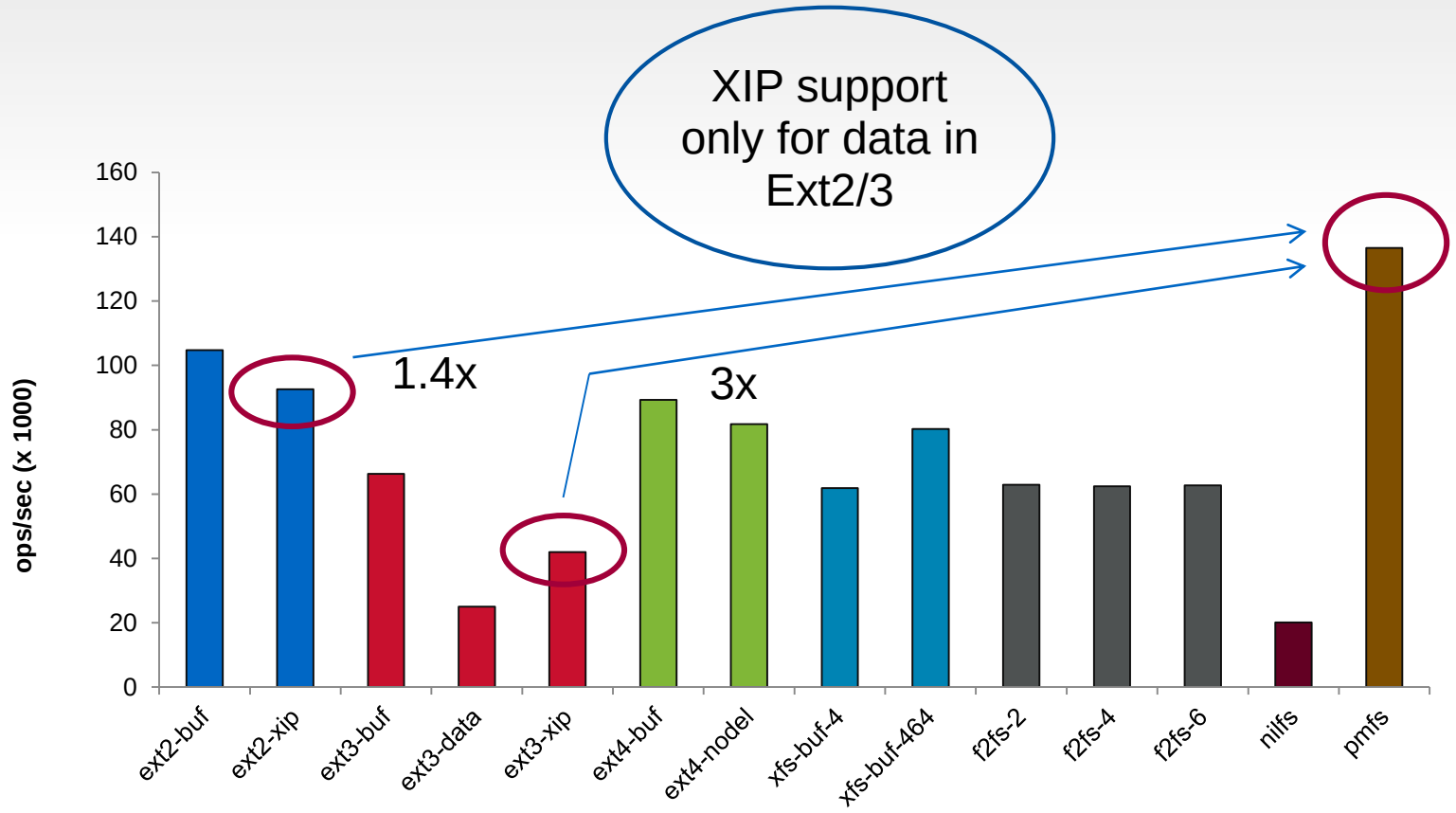


100K files of size 128KB

Higher is better

NetApp

FileServer (Throughput)



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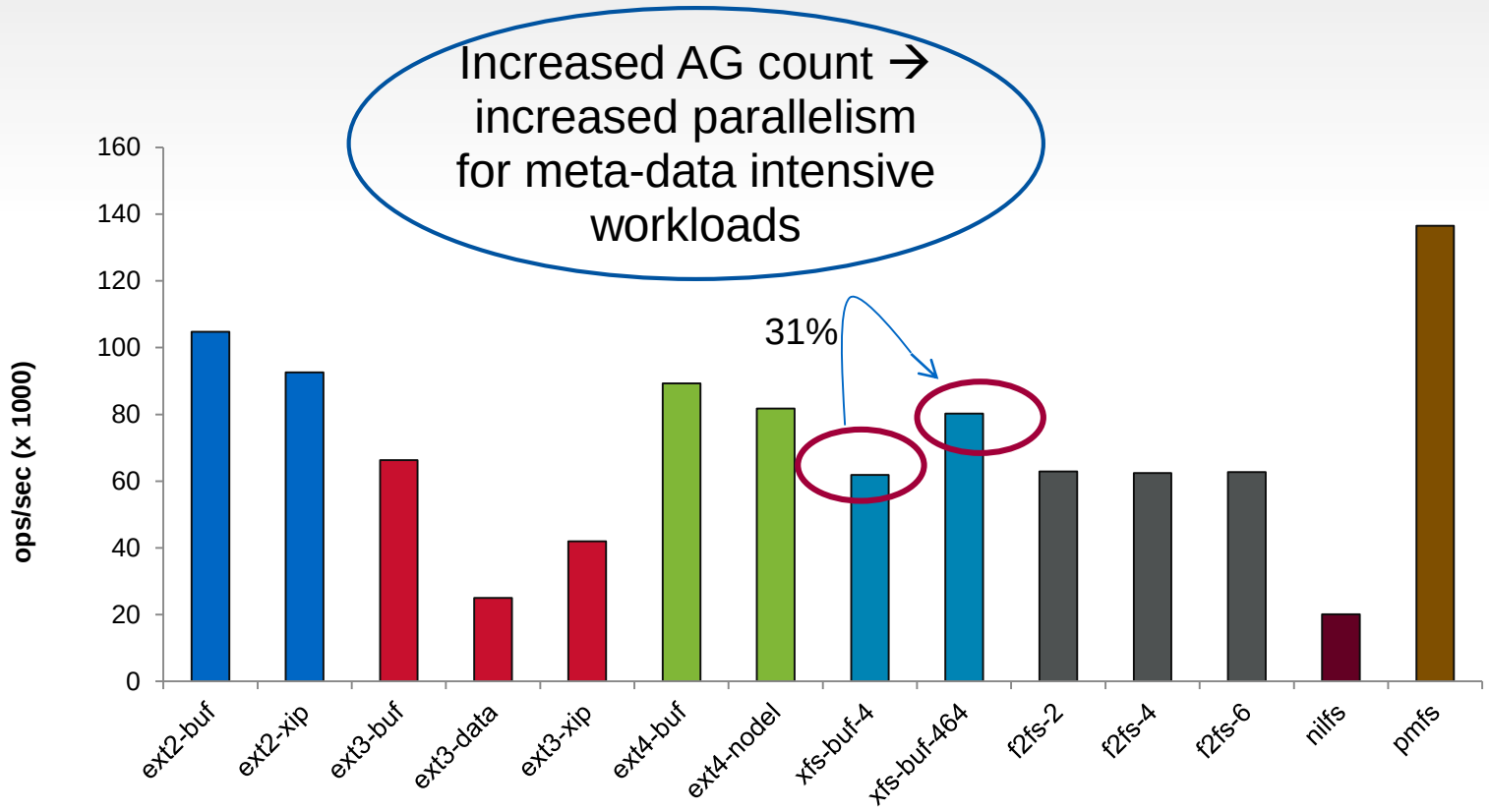

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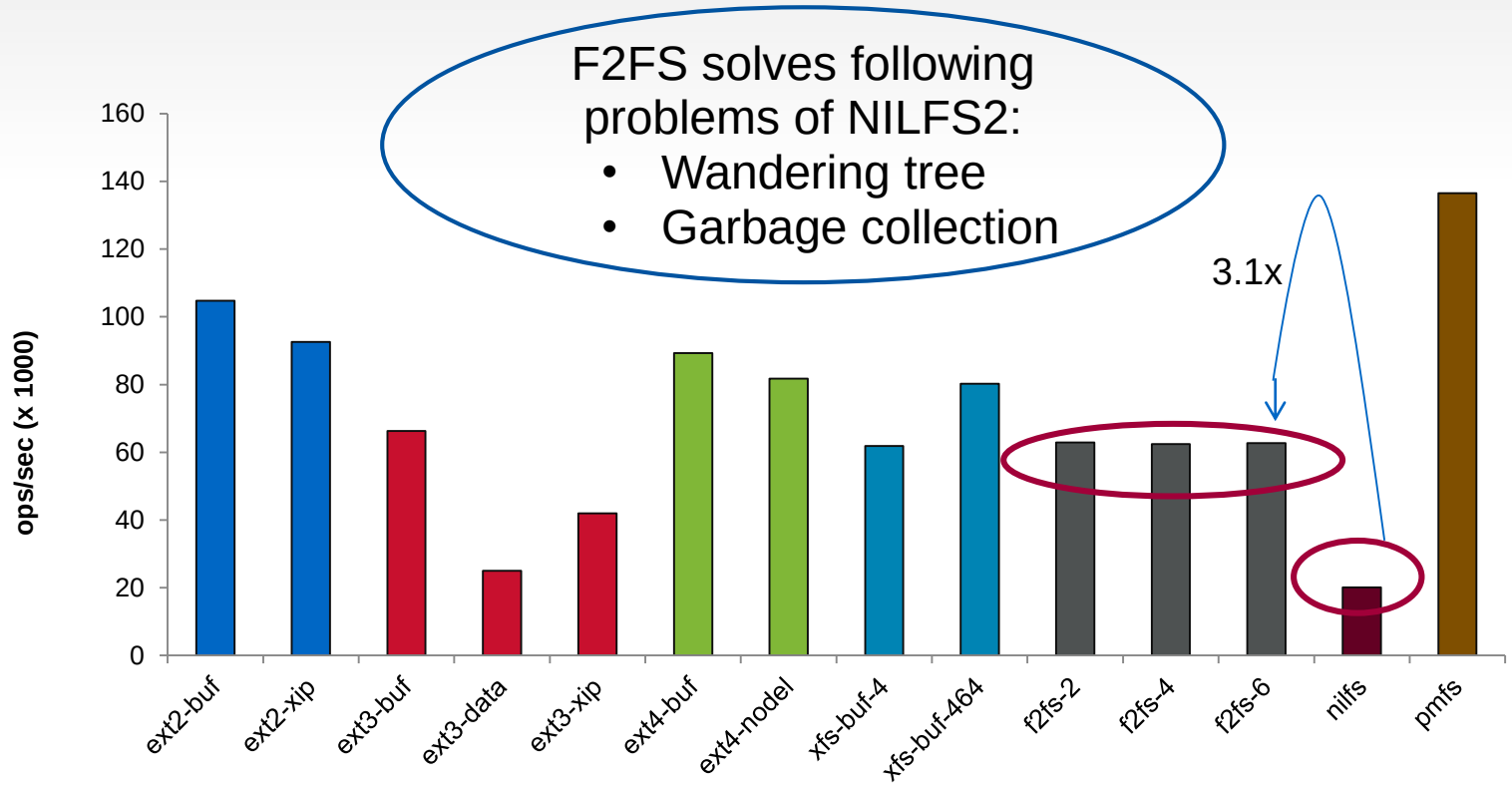

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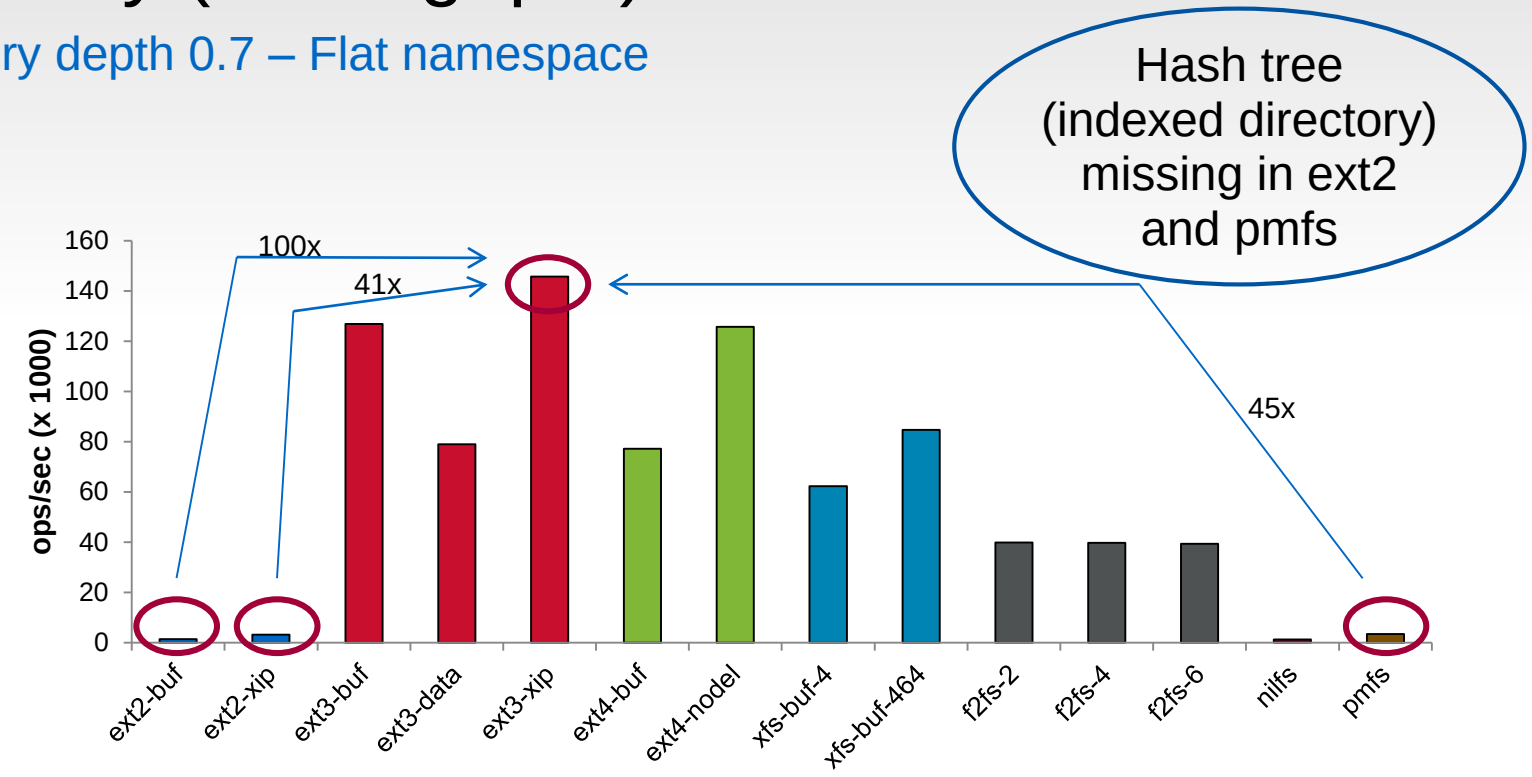
WebProxy (Throughput)

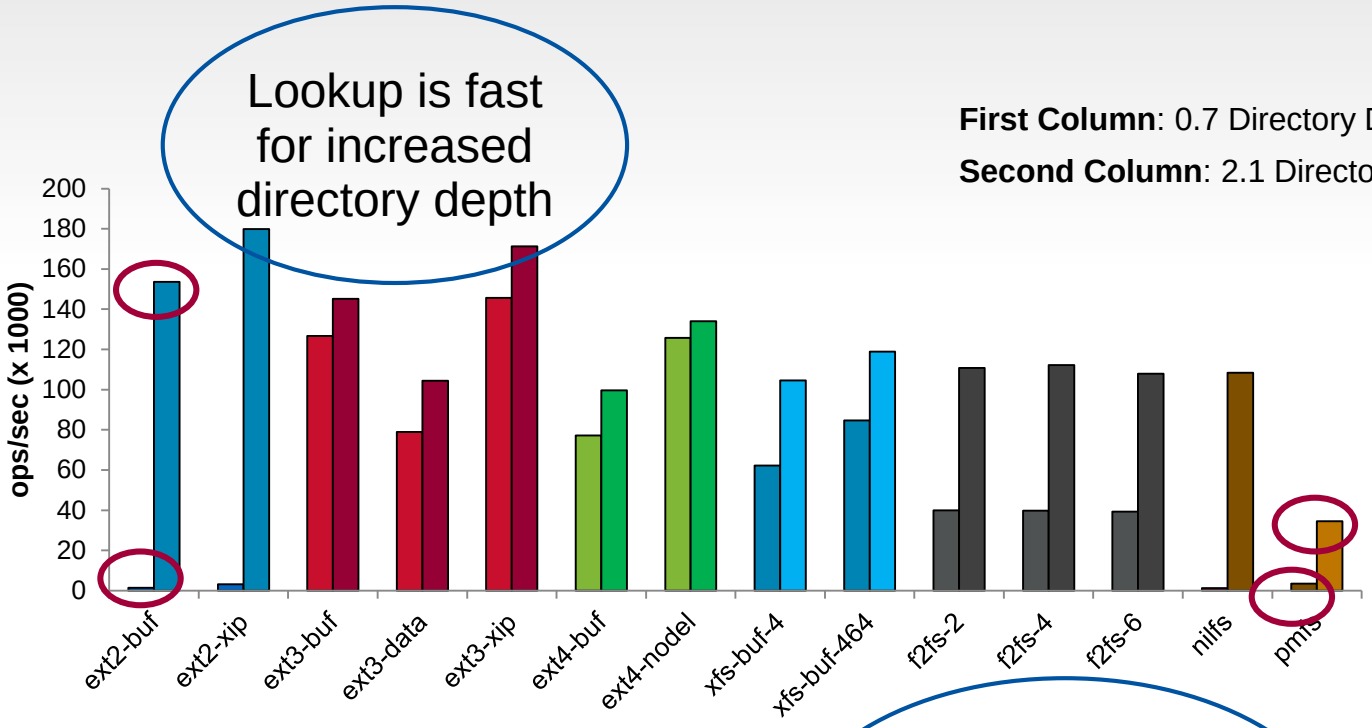
At directory depth 0.7 – Flat namespace



500K files of size 32KB

Higher is better

WebProxy (Throughput)



First Column: 0.7 Directory Depth

Second Column: 2.1 Directory Depth

Higher is better

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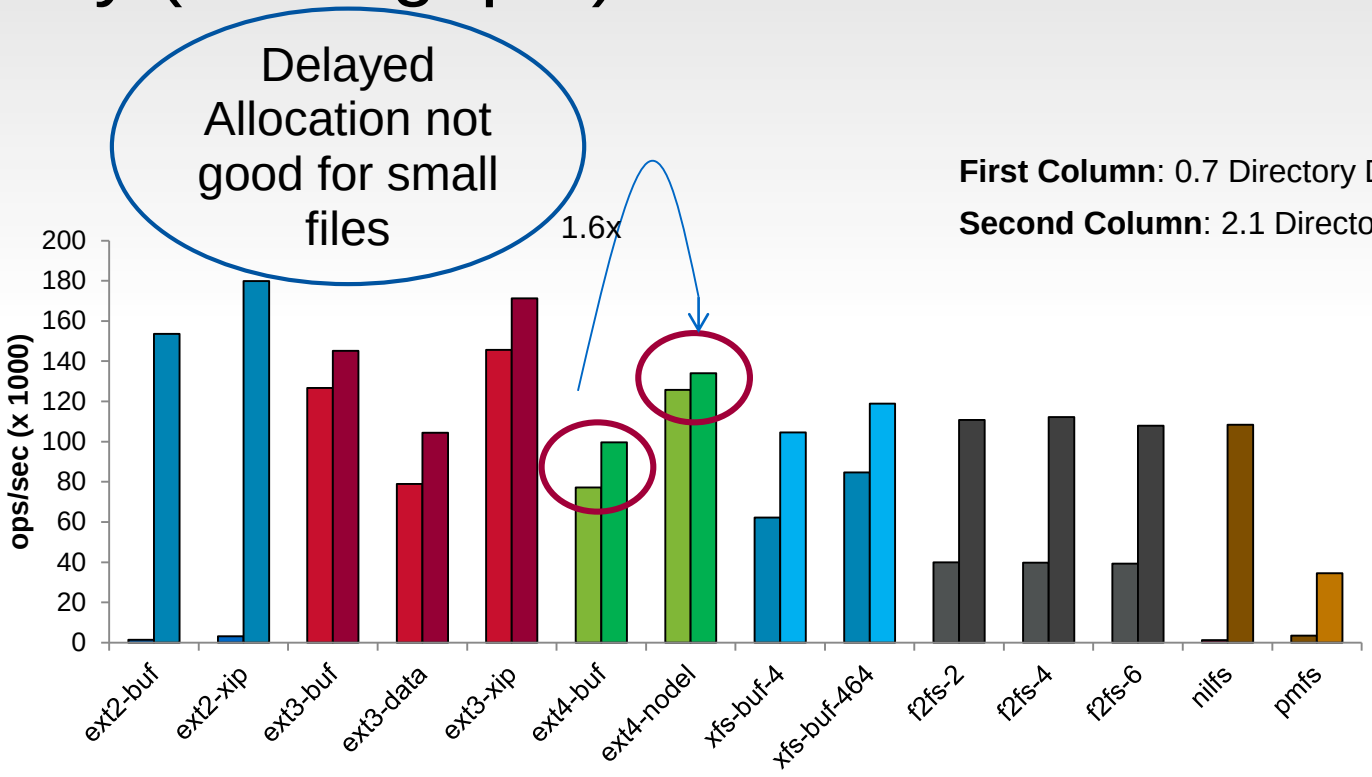

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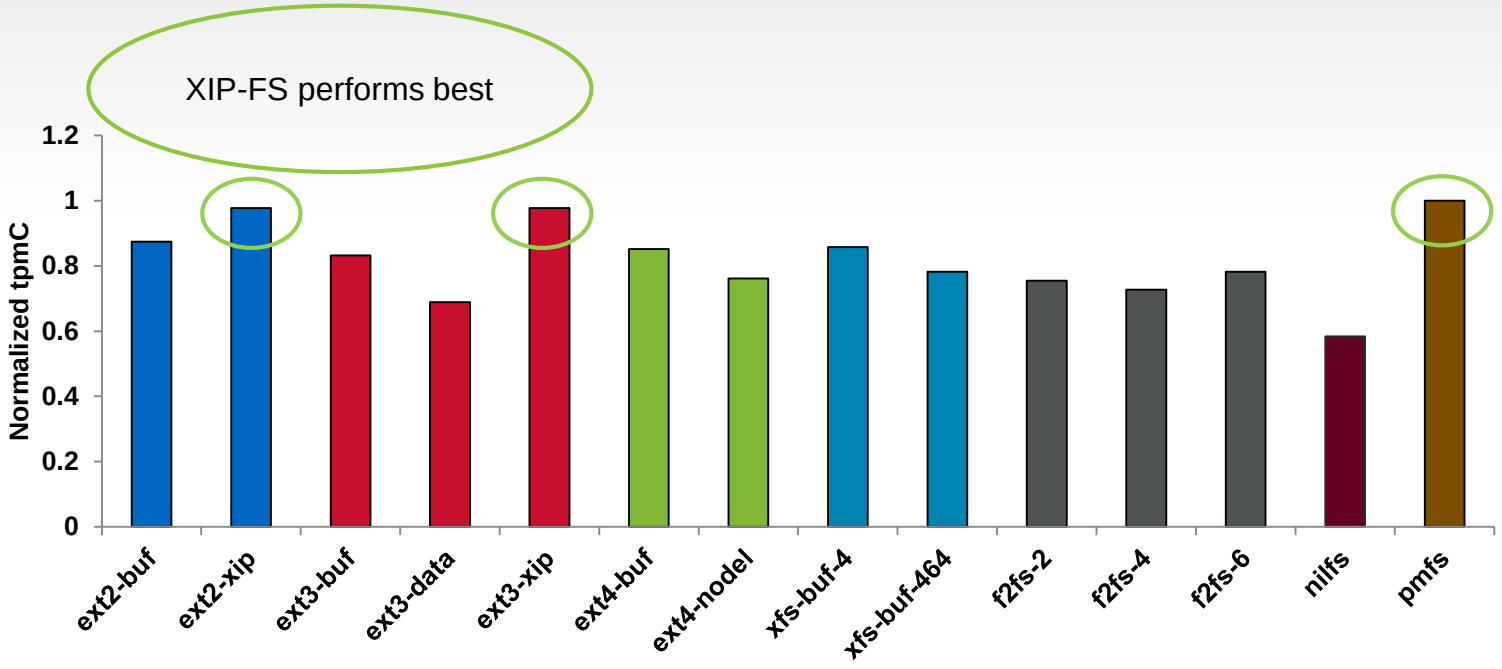
OLTP Database(TPC-C on MySQL)



400 warehouse, total size 38GB

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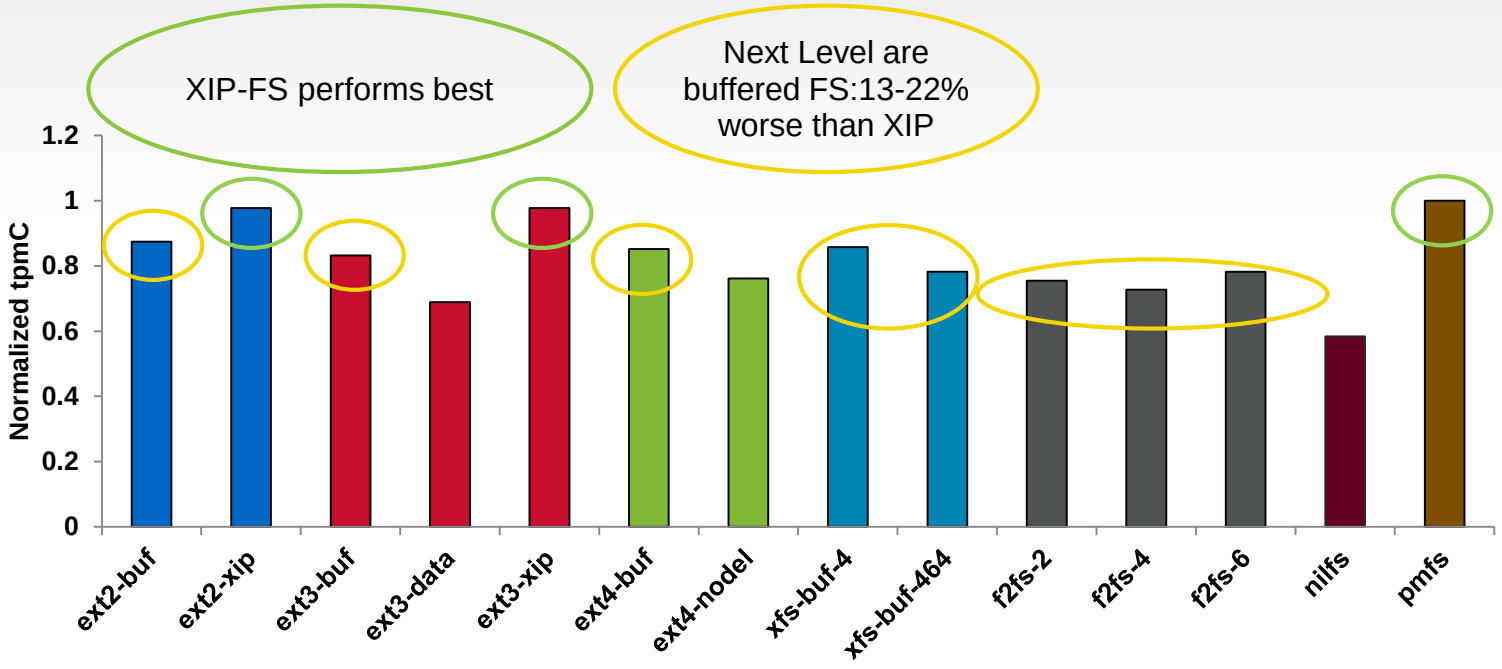

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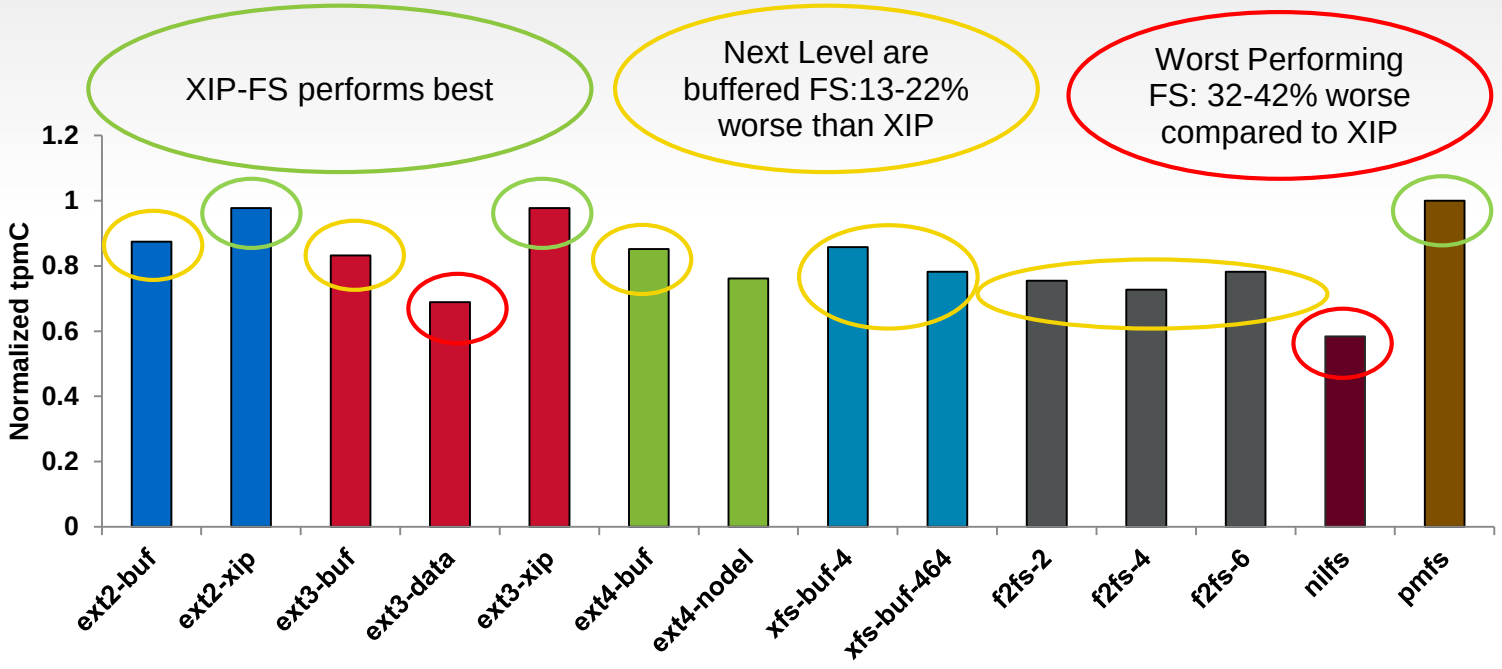

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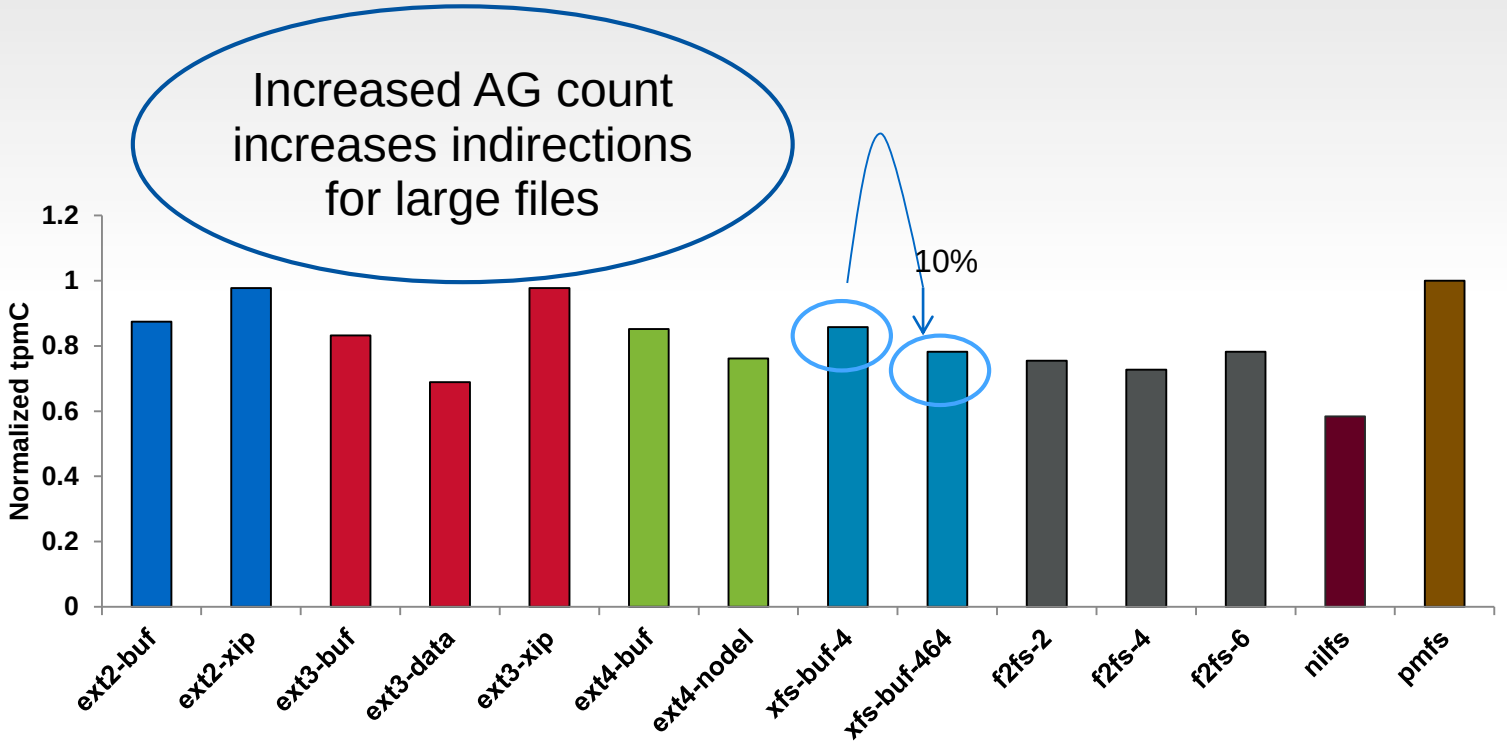
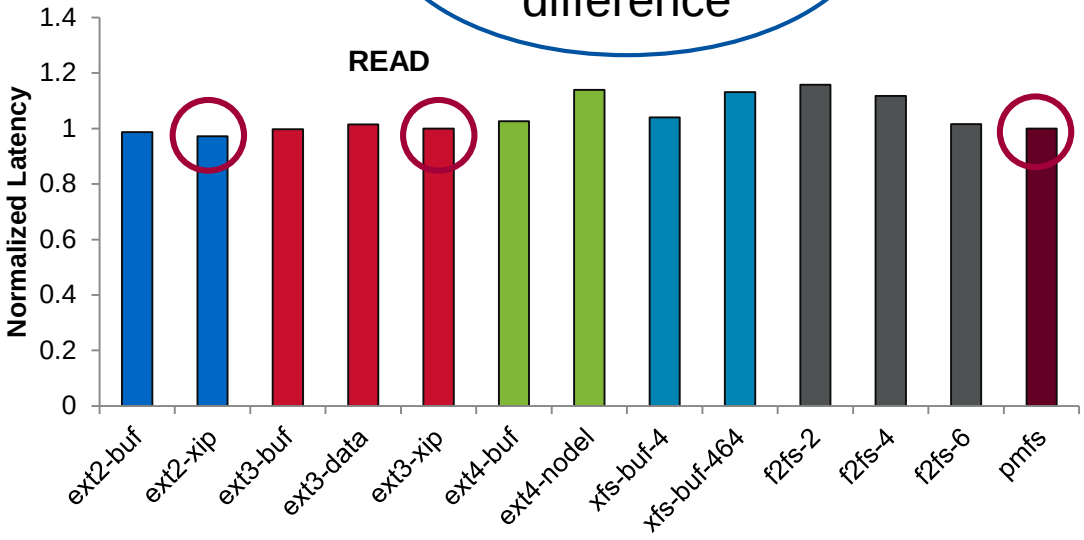


Higher is better

Key-Value Stores (YCSB on MongoDB) - Latency

WORKLOAD C

Reduced page faults blurs performance difference



READ=100%

10 million records, total size 36GB

Lower is better

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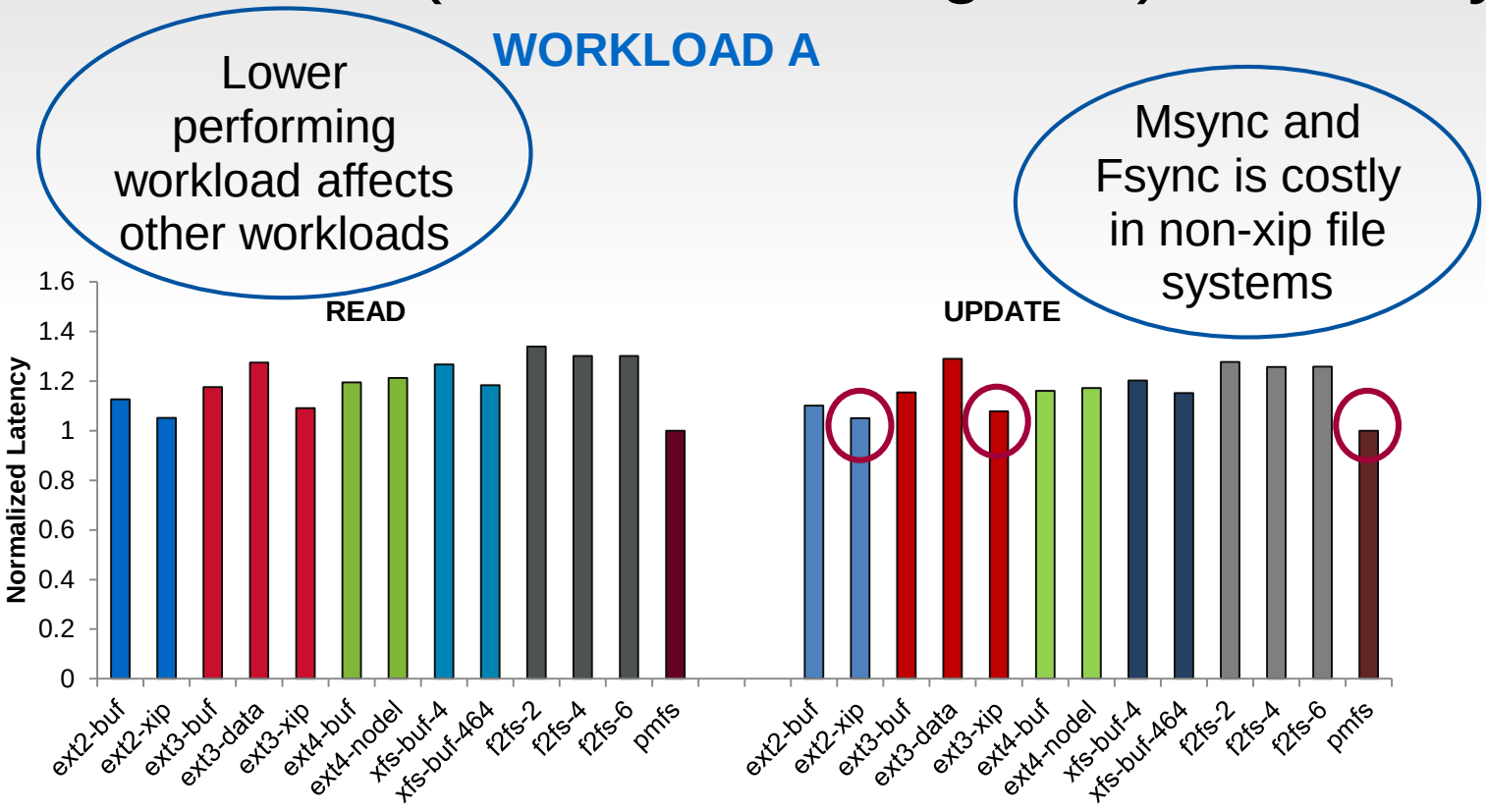
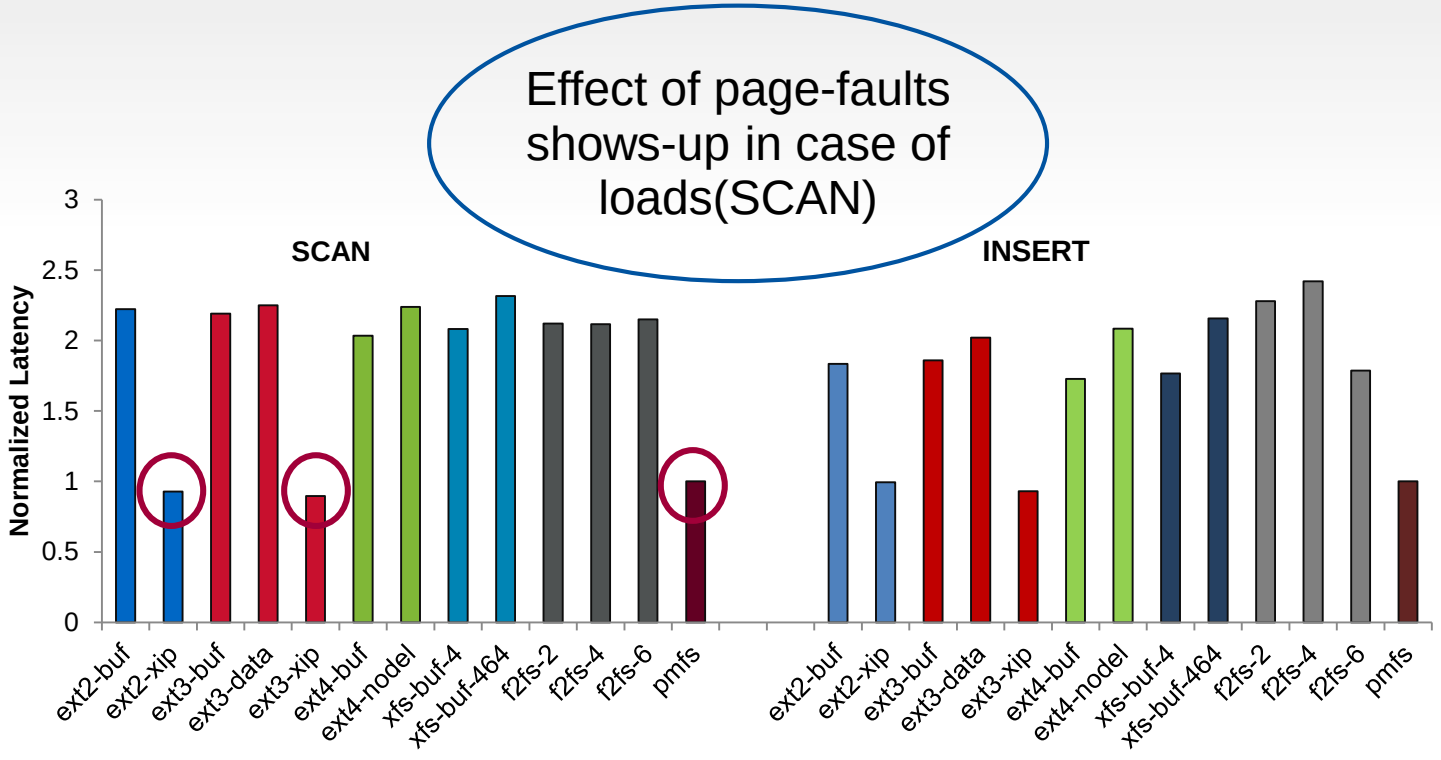


READ=50% UPDATE=50%

Lower is better

Key-Value Stores (YCSB on MongoDB) - Latency

WORKLOAD E



SCAN=95% INSERT=5%

Lower is better

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Recommendation and Conclusion

- Recommendation for traditional and new file systems
  - In-place update layout
  - Execute In Place
  - Simple and parallel allocation strategy
  - Fixed sized data blocks

Thank you