Horus: Fine-Grained Encryption-Based Security for High Performance Petascale Storage

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The Problem

- Large files contain potentially sensitive data
- File data can be leaked by many HPC elements (disk, client, metadata server)
- Ensure data confidentiality in the face of physical and software attacks

Design Principles

Prevent compromise by metadata server and storage nodes

- Encrypt / decrypt all data at the client

Restrict client leaks to only parts of the file to which the client has access - Most clients don't need access to the whole file

Provide a small, stateless trusted computing base

Hierarchical Keyed Hash Tree (KHT)

Single file root key can encrypt / decrypt the entire file

Successively lower keys in the tree are based on a keyed hash depending on

- Parent key
- Level in the tree
- Position in the level

Deriving keys lower in the tree is fast and simple

Deriving keys higher in the key or at the same level is "difficult"

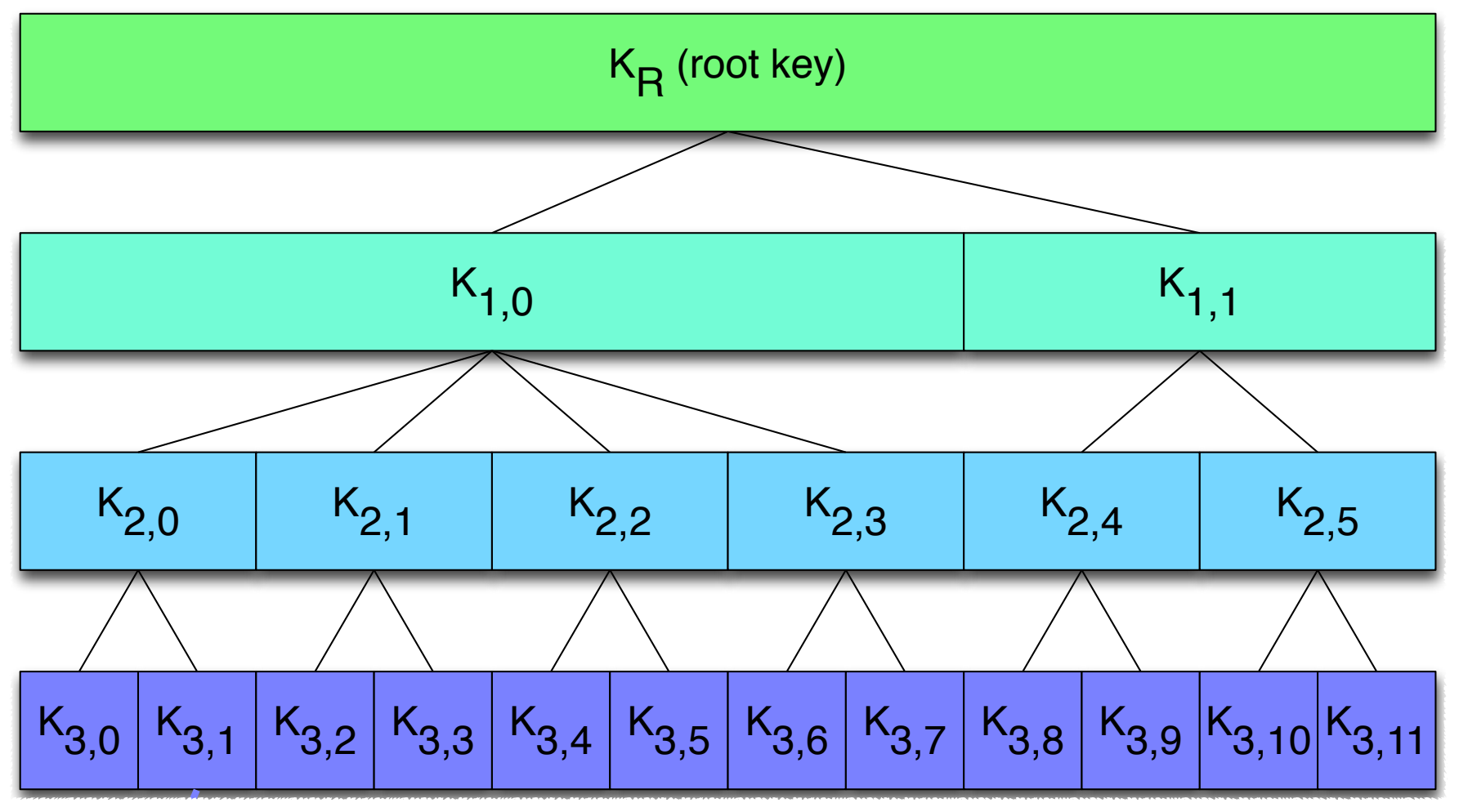


Figure 1: KHT

Evaluation

Machine setup: Intel(R) Xeon(R) CPU E5620 2.40GHz, Mem 24GB, Seagate® Constellation.2™ SATA. Running Fedora 16 Linux in x86-64 mode. Implemented as user-space library. Using Intel AESNI acceleration instructions.

Requesting Keys from KDS via RPC

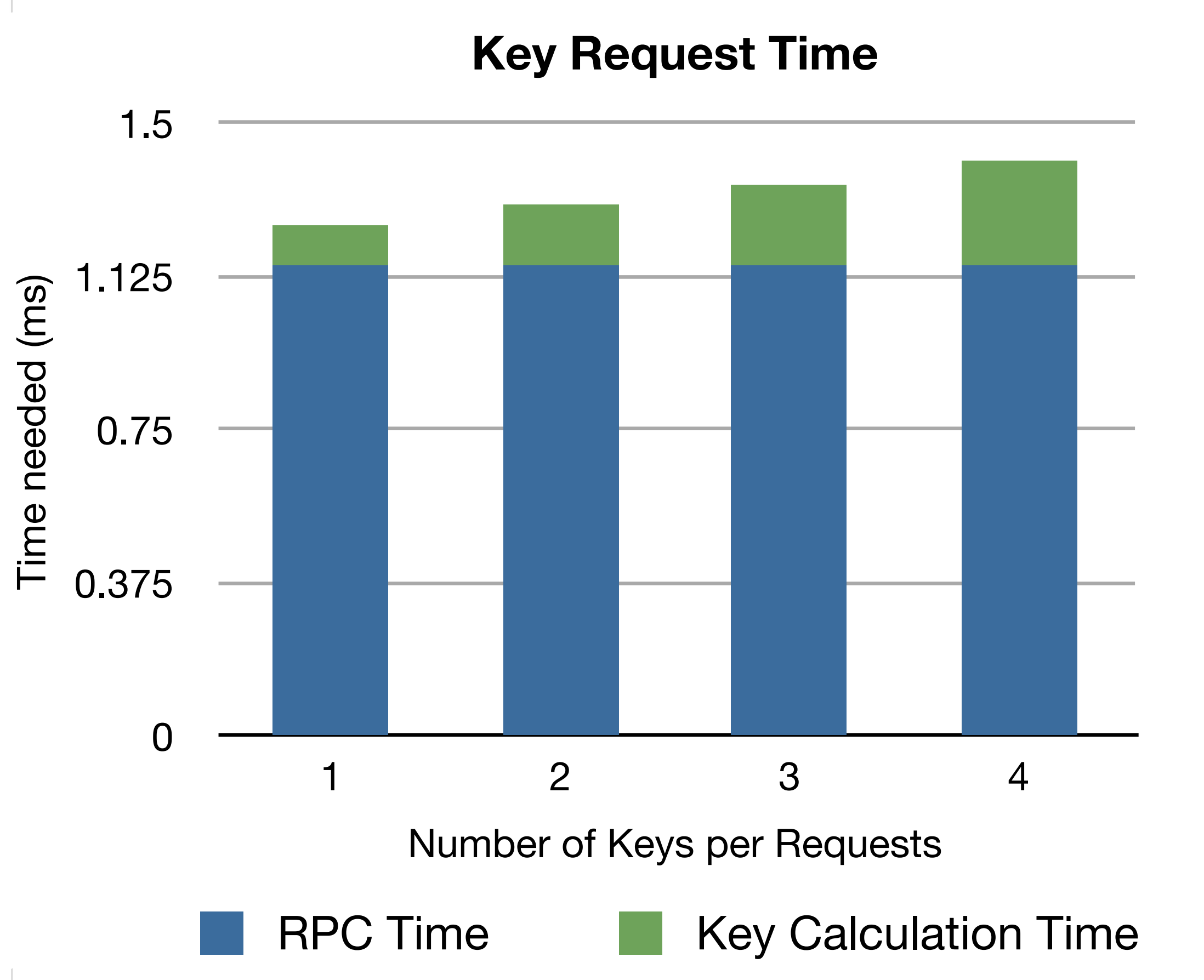


Figure 2

KHT Hashes need per MB

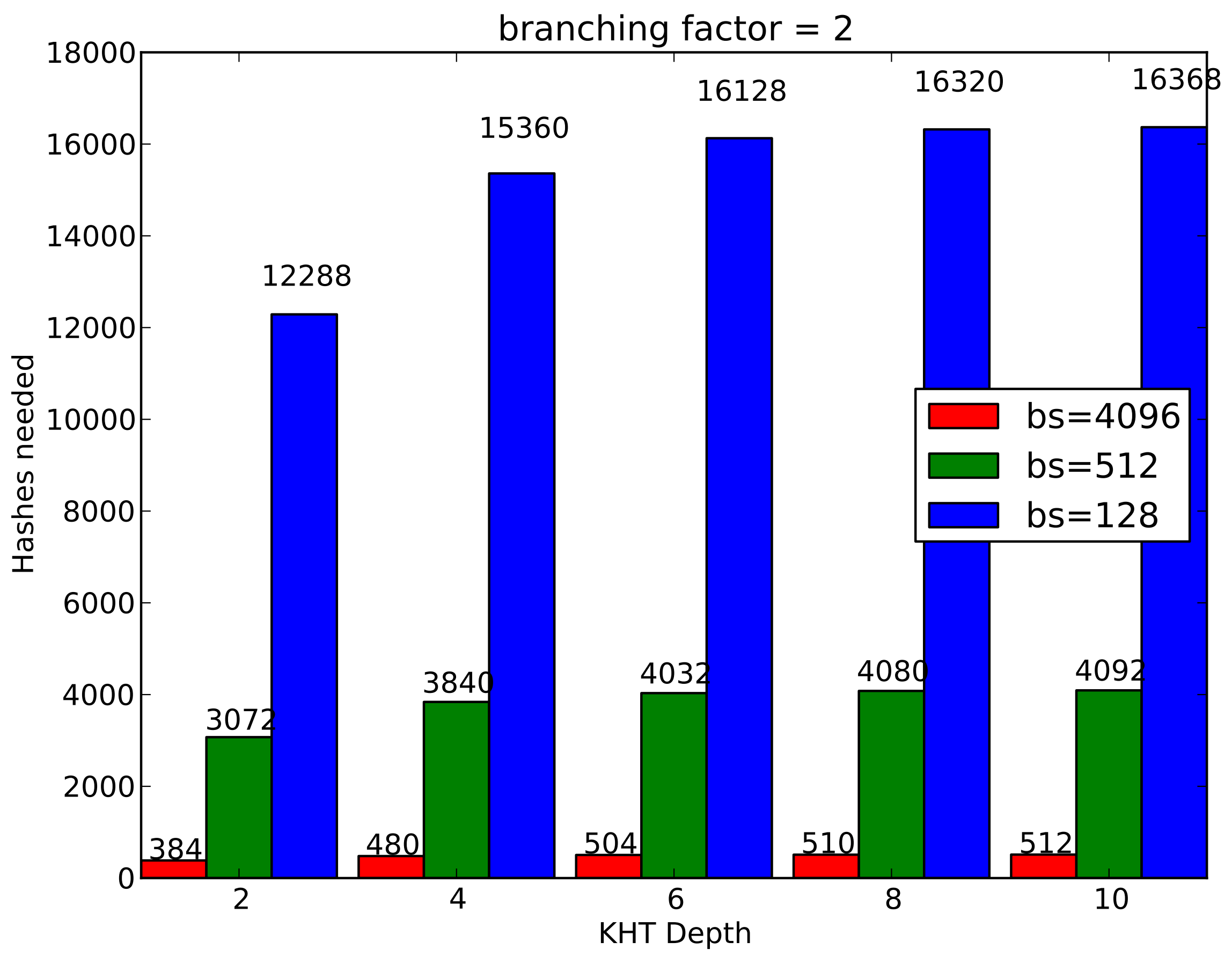


Figure 3

Key Calculation Overhead (for 2GB data, block size = 4096)

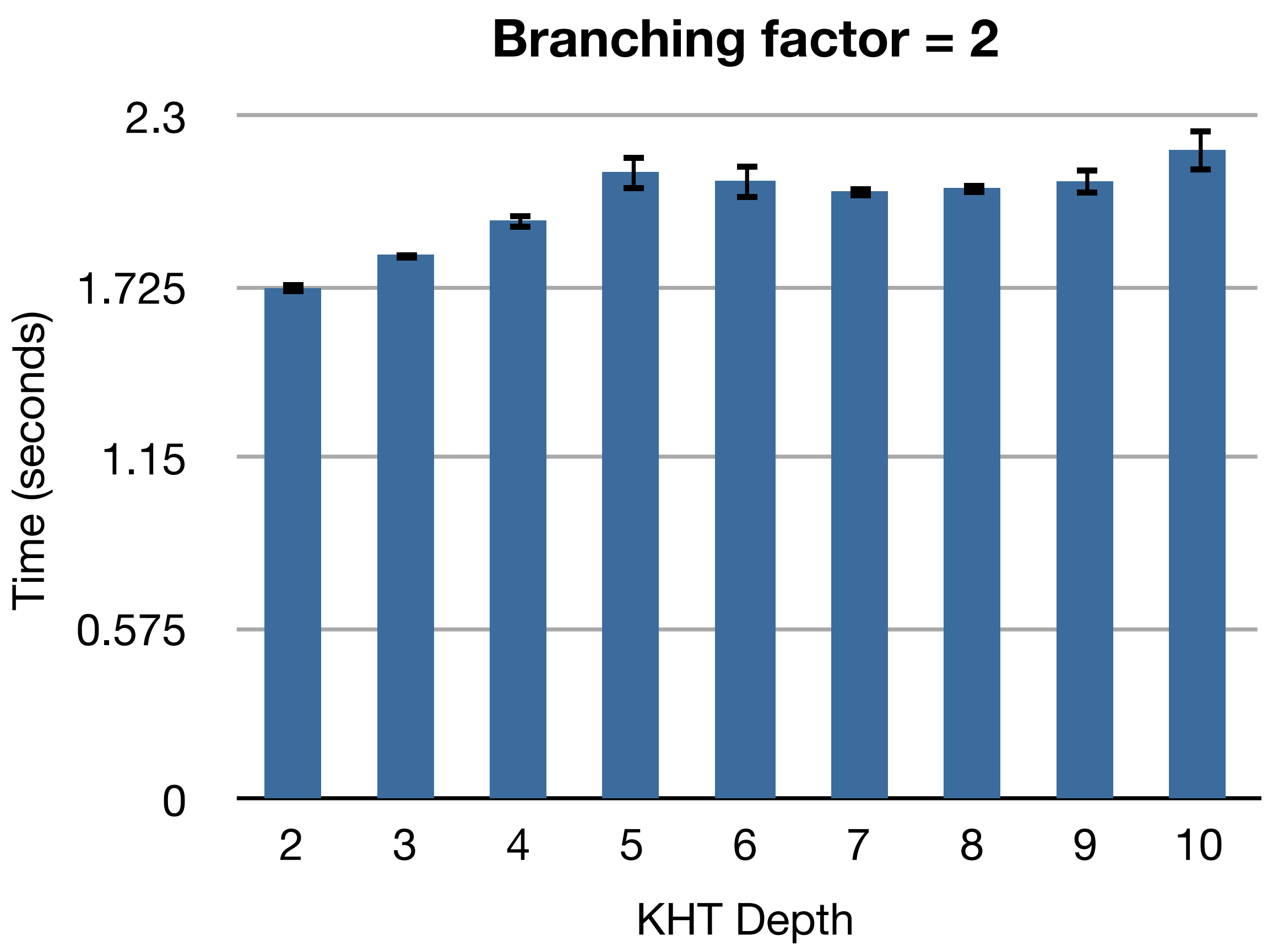


Figure 4

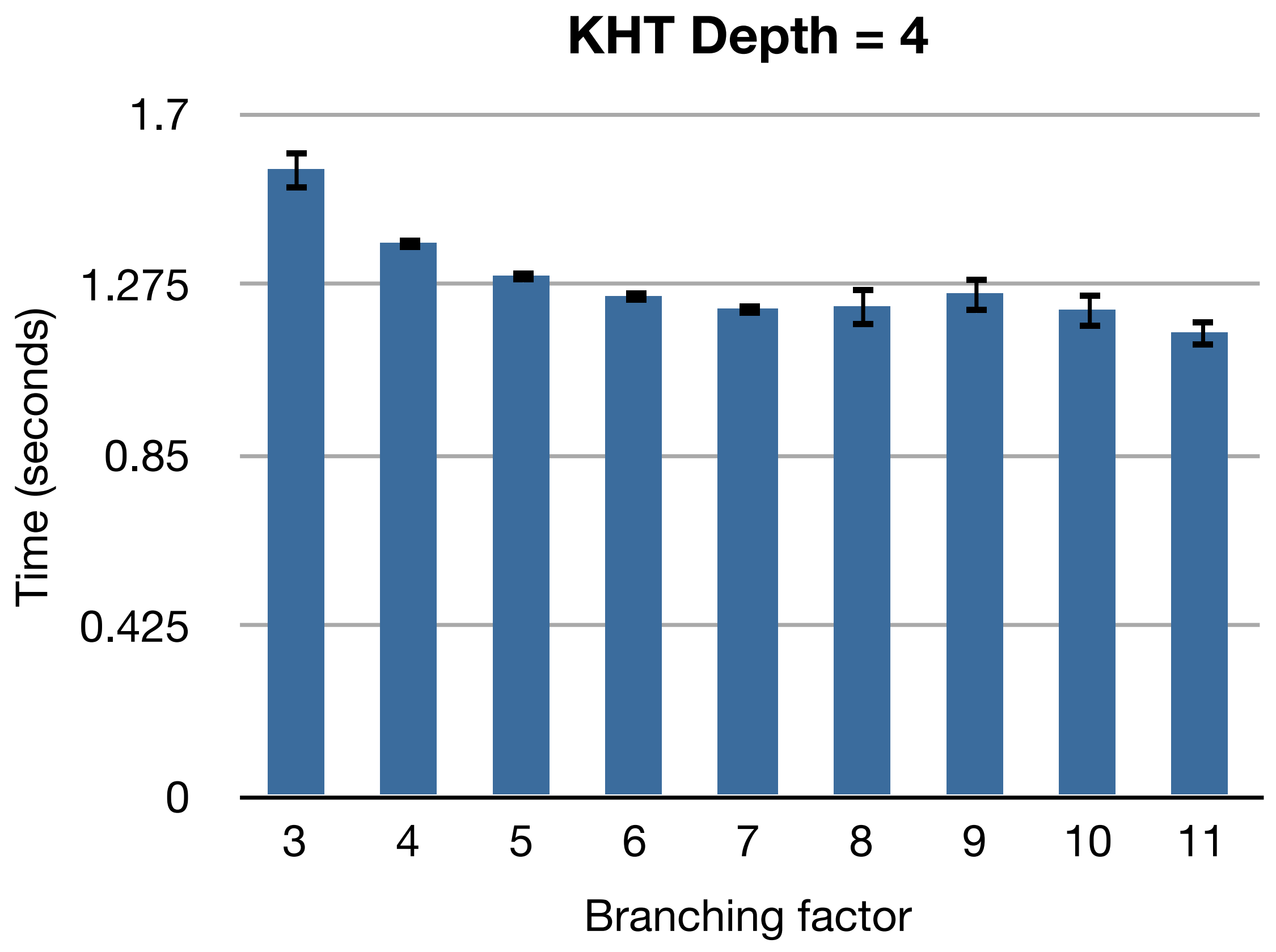


Figure 5

Read / Write Throughput (block size = 4096)

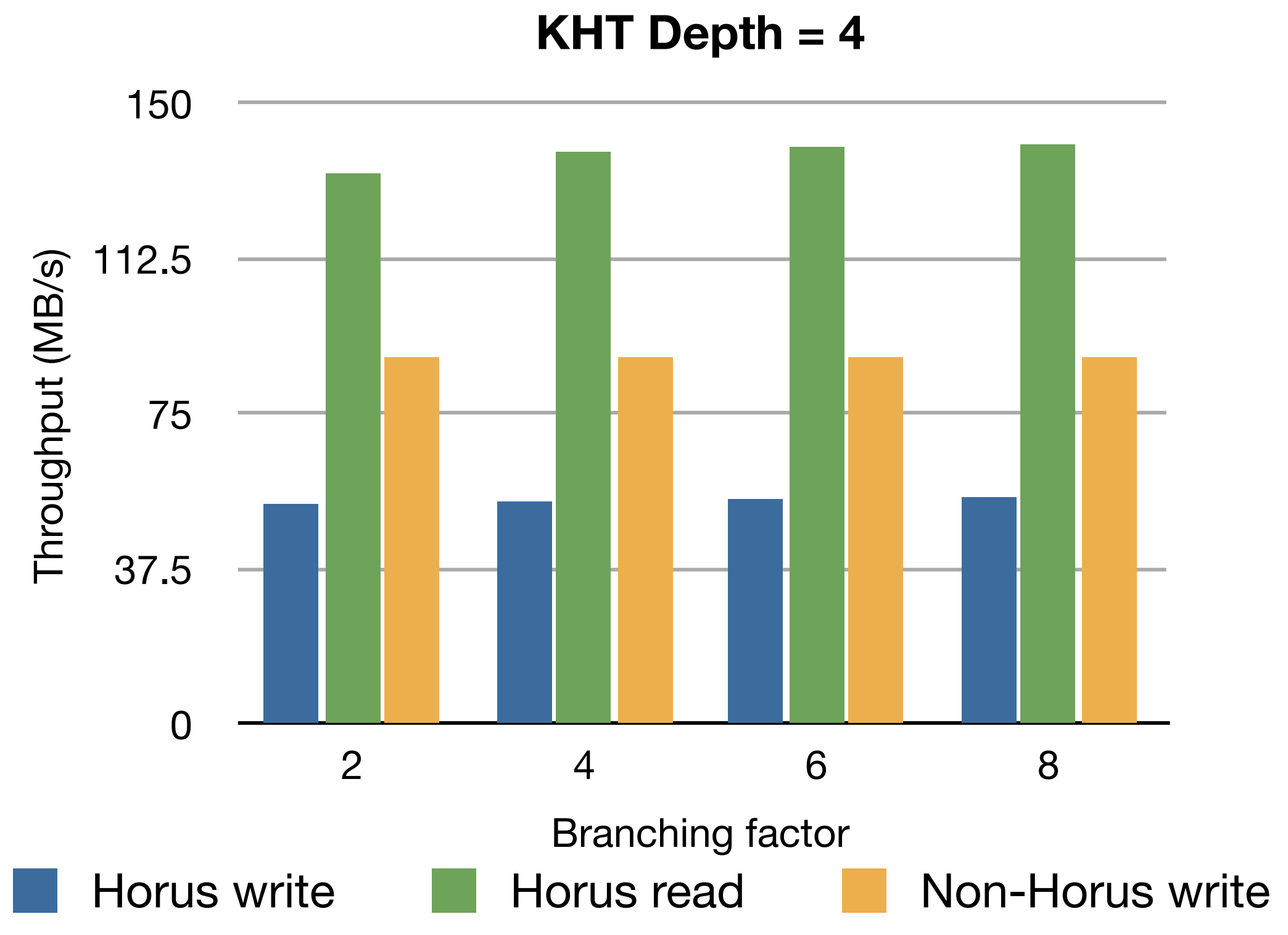


Figure 6

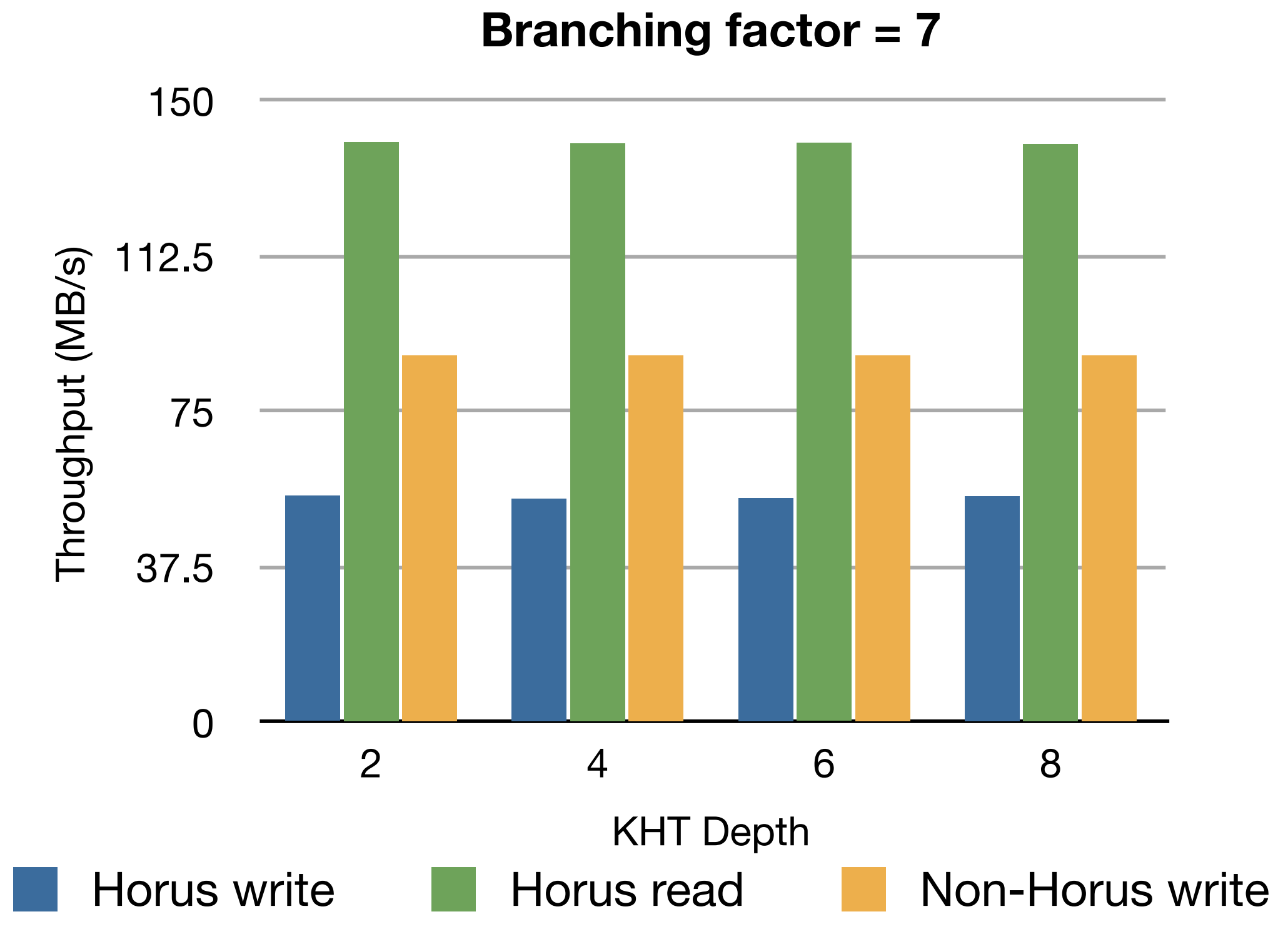


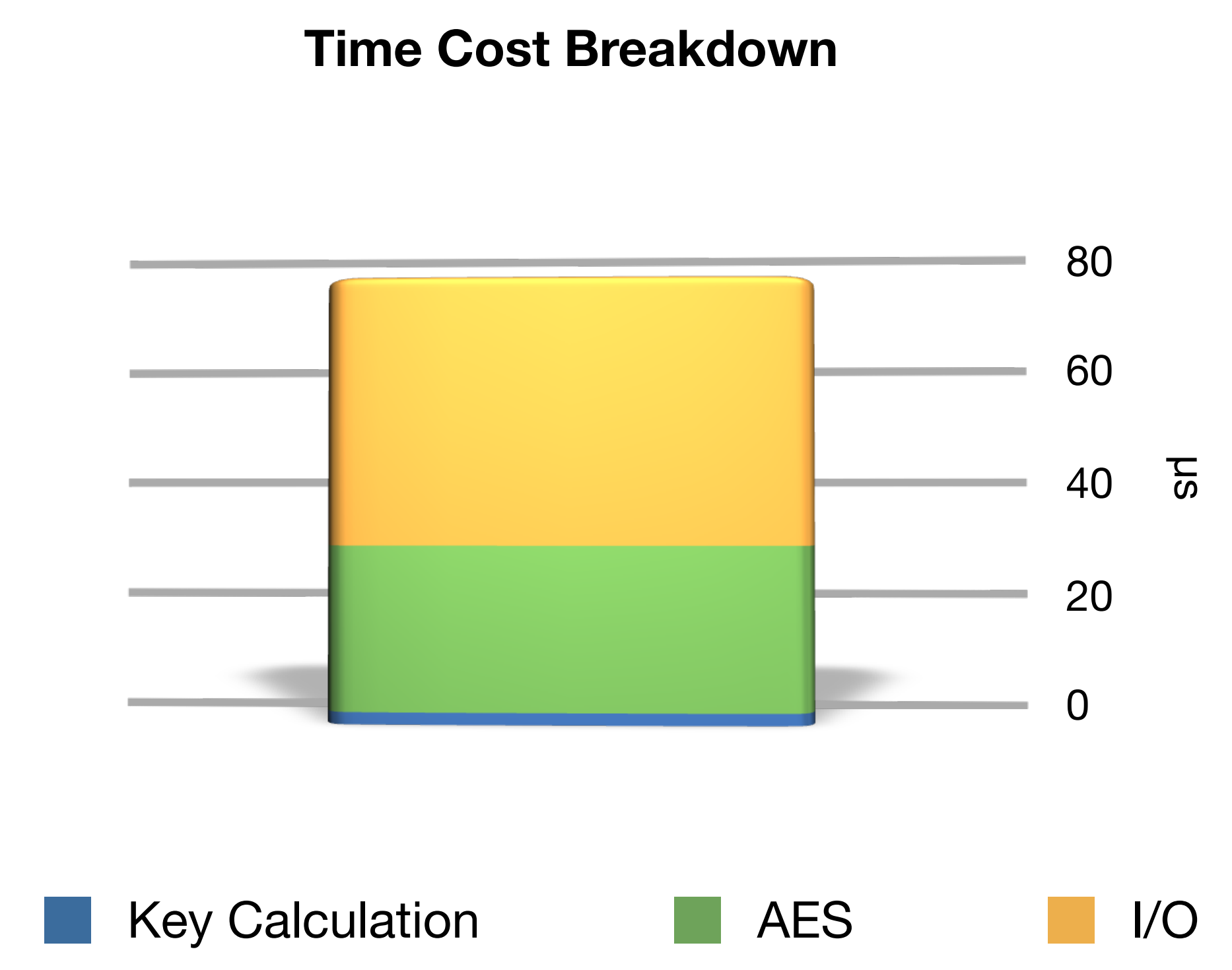
Figure 7

Time Cost Breakdown

Time for one keyed hash: 1.986 µs.

Time for one 4096-byte block AES (using Intel AESNI instructions): 27.265 µs.

Disk I/O: 44.047 µs



Ongoing Work

- Implementation in Linux file systems (using FUSE)
- Integration with Ceph
- Open source the prototype

Reference

Ranjana Rajendran, Ethan L. Miller, Darrell D. E. Long, Horus: Fine-Grained Encryption-Based Security for High Performance Petascale, PDSW'11

Conclusion

- With Horus, each client can only access the parts of large files that they are allowed to access
- Using KHT for key management is well understood and the performance penalty is reasonable

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