Striping without Sacrifices: Maintaining POSIX Semantics in a Parallel File System

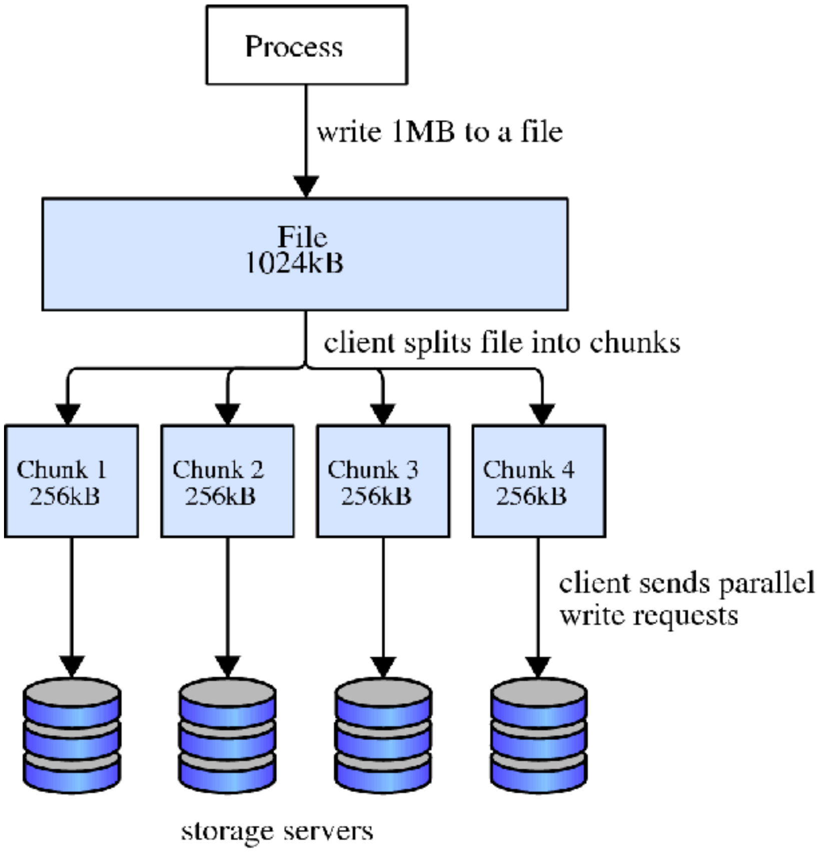
Jan Stender
Björn Kolbeck

Zuse Institute Berlin

Outline

- Introduction
- Problem Description
- Striping Protocol
- Summary

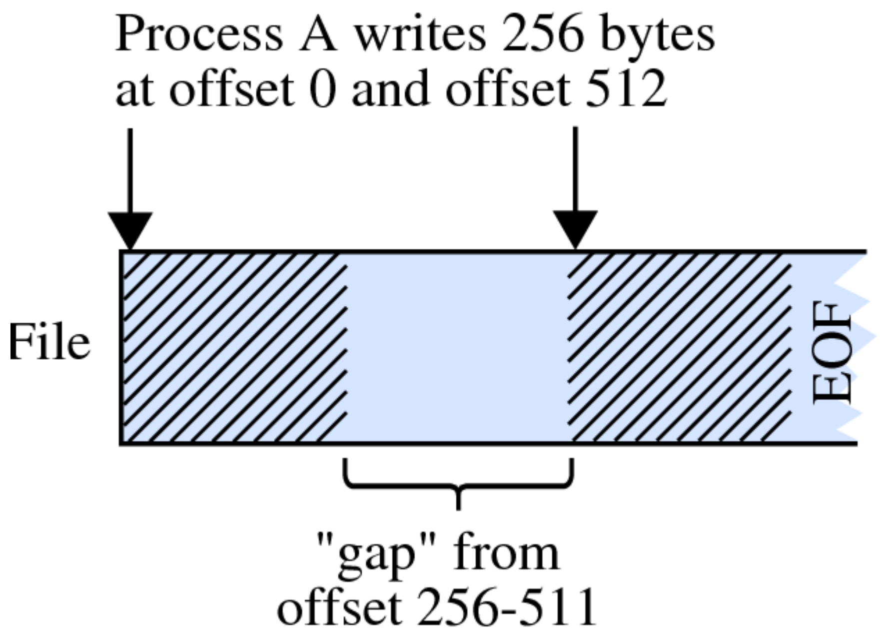
- Striping increases the performance of file systems
  - a single file is split up in chunks scattered across multiple storage resources
  - chunks can be accessed in parallel
  - a single file can be accessed with the accumulated performance of multiple storage resources
- Parallel file systems have distributed storage resources
  - chunks reside on different storage servers



Introduction

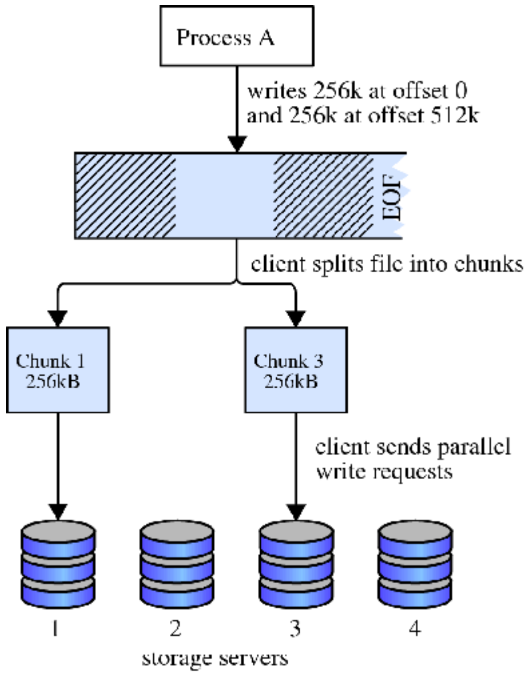
- General-purpose file systems are expected to be POSIX-compliant
  - well-defined interfaces and behavior
  - no specific API, applications run w/o being modified or re-linked
  - POSIX-compliant file systems can be used by any application
- POSIX defines how read and write operations behave in certain corner cases:
  - "gaps"
  - reading beyond EOF

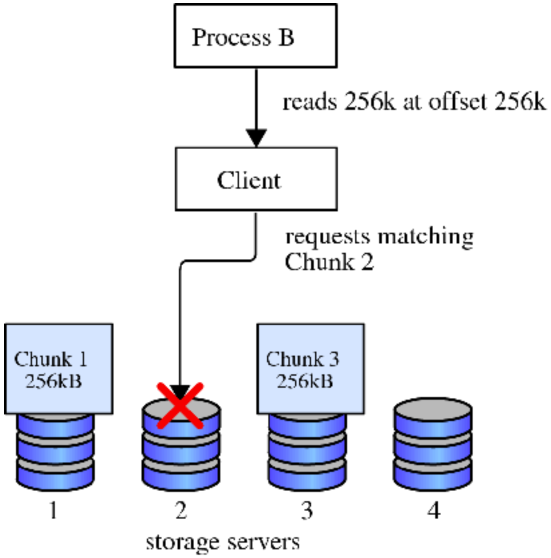
- Gaps
  - writes at an offset beyond EOF implicitly creates a gap, i.e. a region of missing data
  - reading bytes in a gap must return binary zeros
- EOF
  - reading a range of bytes to an offset beyond EOF must prune the resulting buffer (less bytes than requested)



Problem Description

- Problem: How to distinguish between a gap and the EOF in a parallel file system?
  - process *A* creates new file by writing chunk *1* and *3*
  - chunk *2* is not explicitly filled with data



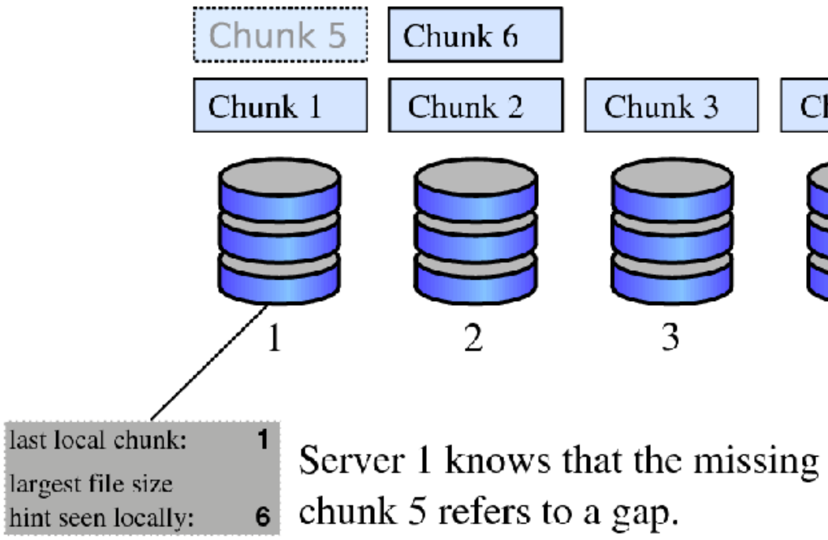


  - process *B* requests missing chunk *2*
  - storage server *2* must decide whether to respond with an empty buffer (EOF) or a zero-padded buffer (gap)

Problem Description

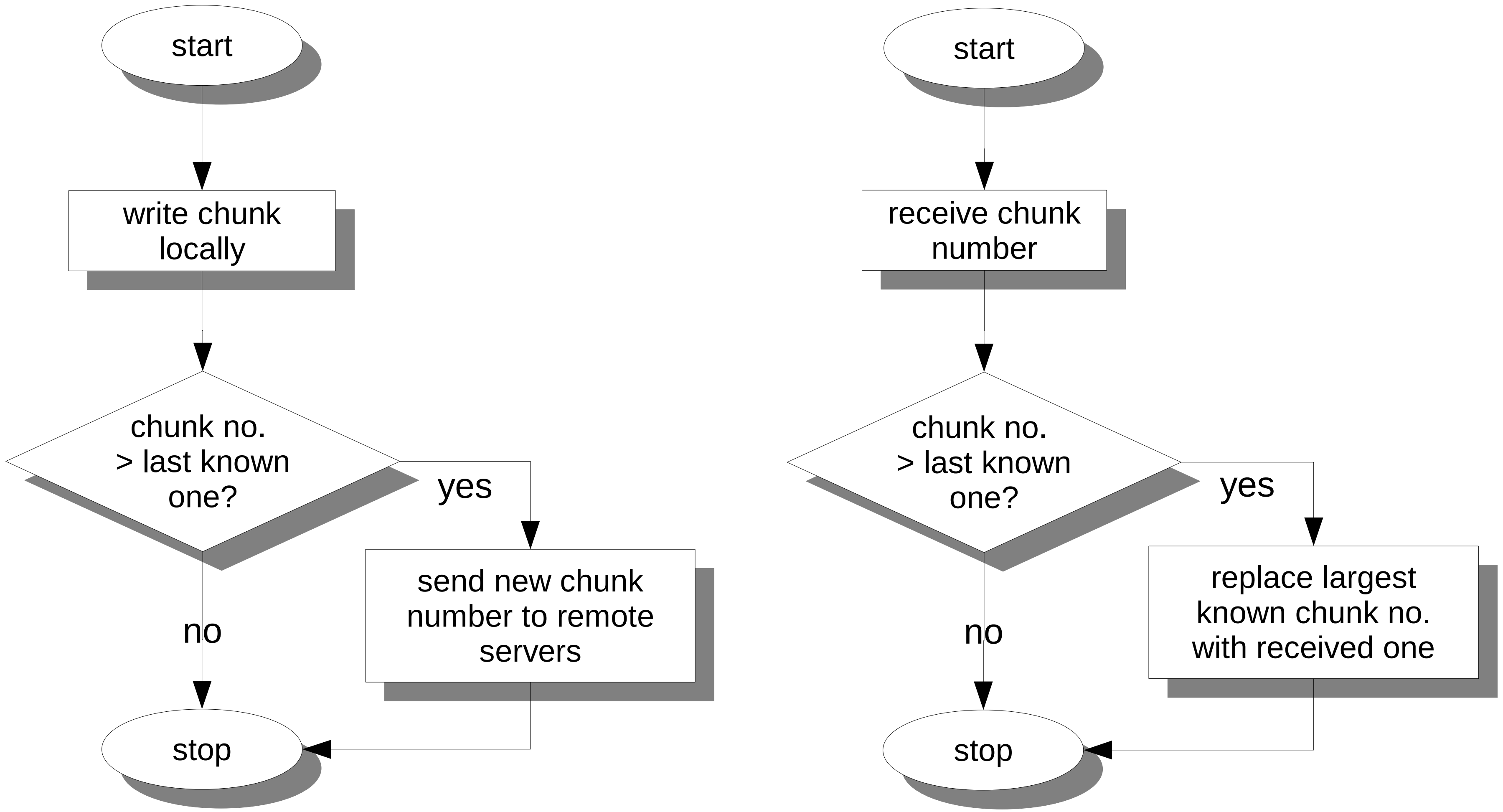
- Basic idea: provide for a consistent view on the file size among all storage servers
- However, ...
  - synchronizing each append-write operation across all storage servers is too expensive
  - a central server that stores the file size would be a bottleneck

- Solution: decentralized, loosely-synchronized approach
  - storage servers disseminate and keep track of hints about the current file size (i.e. the globally last chunk number)
  - if a requested chunk is missing, these hints are used to decide between a gap and an EOF
  - if no decision is possible, the file size is explicitly synchronized by fetching the last chunk number from all storage servers
  - implicit assumption: files grow monotonously



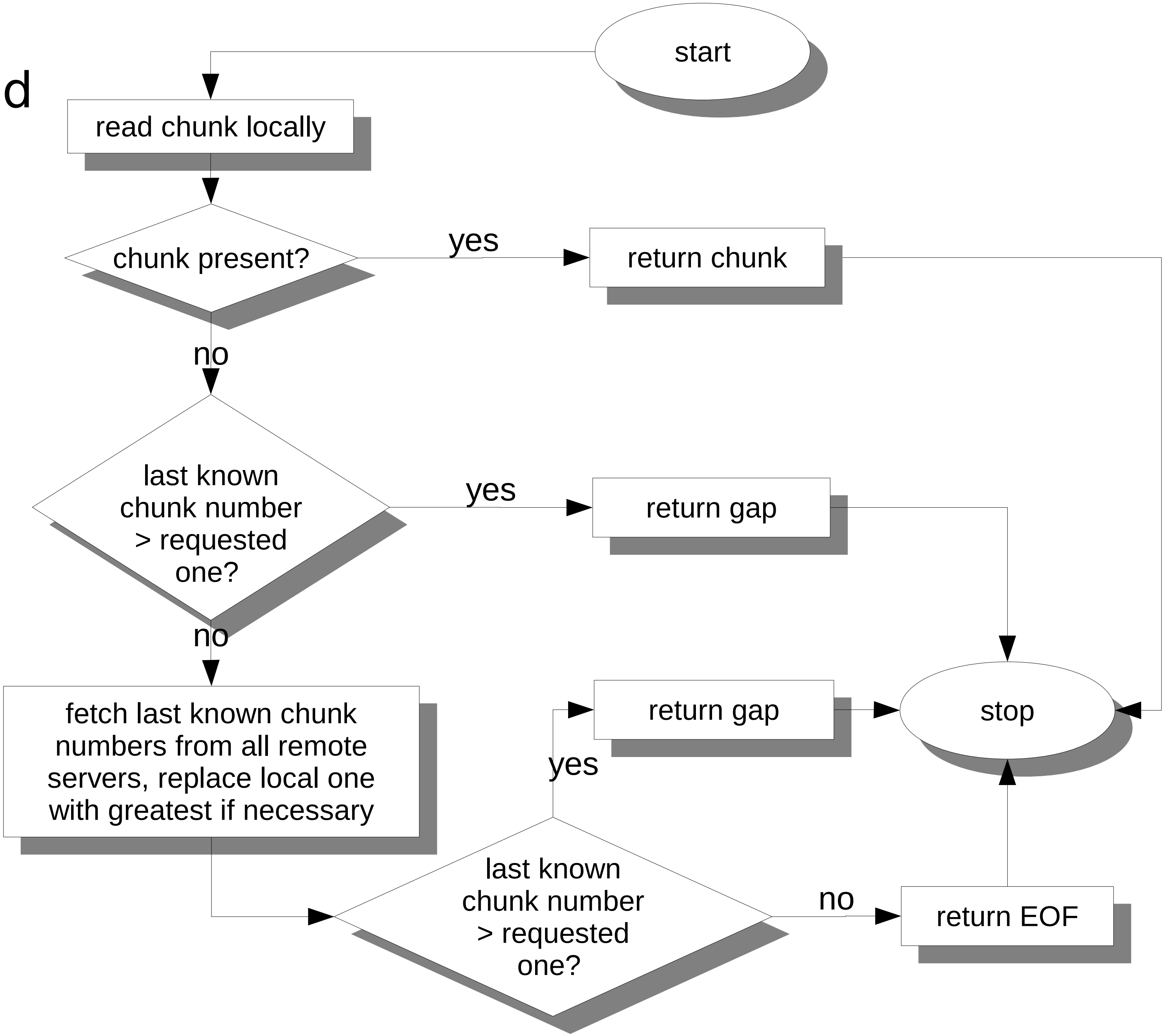
Striping Protocol

- Write

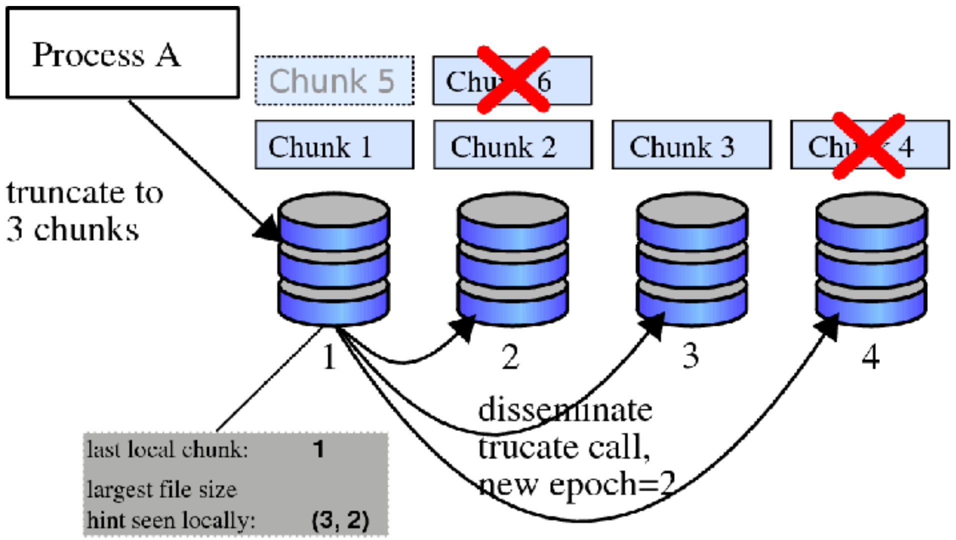


Striping Protocol

- Read

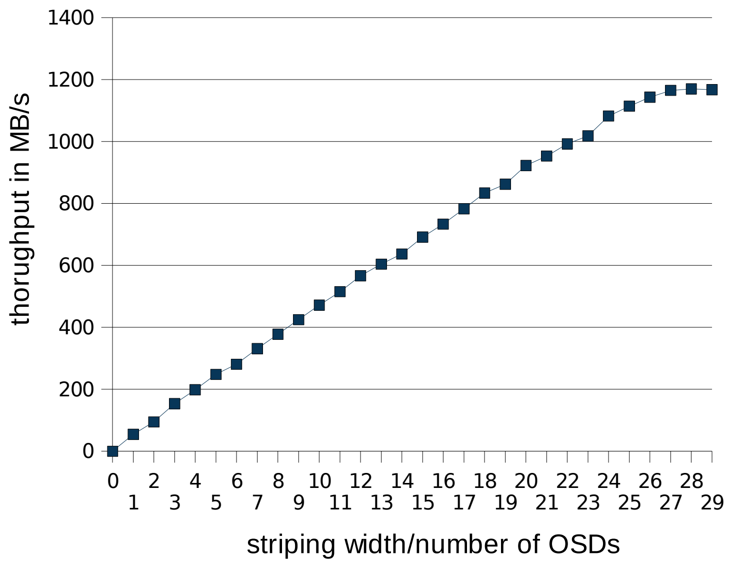


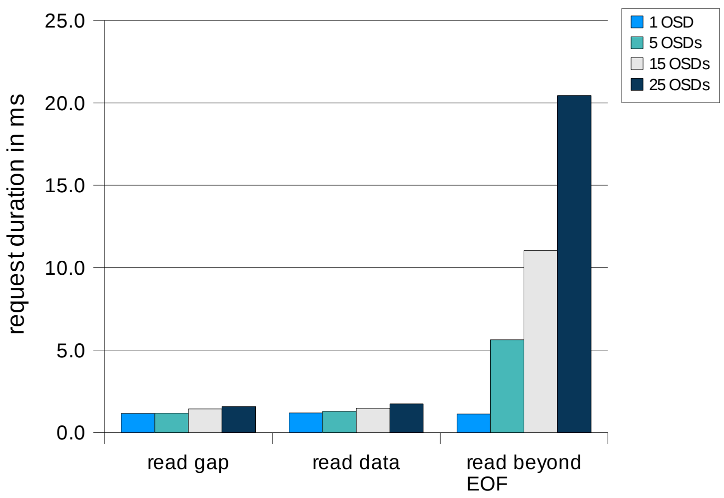
- Truncate
  - problem: violates our monotony assumption on the file size
  - solution: "truncate epochs"
  - file size hints consist of chunk number + epoch number
  - a designated server is responsible for truncate operations
    - it increments the epoch number
    - it synchronously updates the file size + epoch on all remote servers
  - a server receiving a file size hint updates its local chunk and epoch number if
    - the received epoch number is greater than the local one
    - both epoch numbers are equal and the received chunk number is greater than the local chunk number

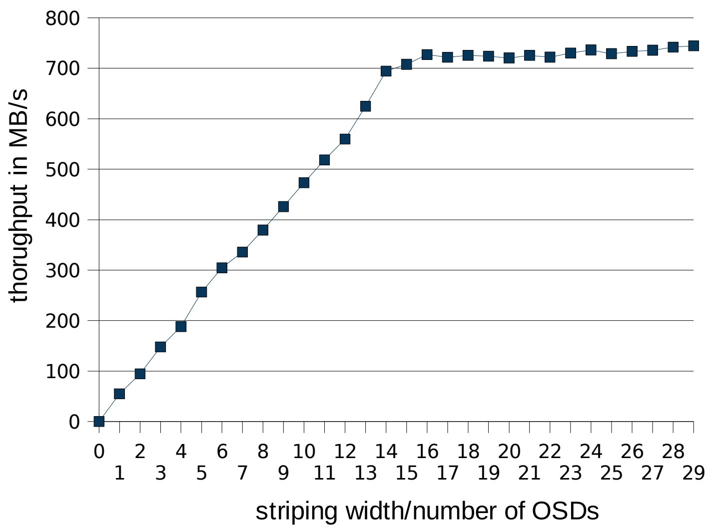


Experimental Results

- reads and append writes scale linearly
- low latency for reading gaps and data, as no file size synchronization is necessary
- higher latency for reading beyond the EOF, due to file size synchronization







Summary

- The suggested protocol exhibits a POSIX-compliant behavior while ensuring scalability
- Frequent operations are fast
  - append and random writes
  - reads in file bounds
- The protocol does not enforce locking
  - parallel access is possible by multiple clients
- The protocol inherently supports sparse files

Thank you!

Questions?

Funded by the European Commision's FP6 programme
under contract #FP6-033576