Pfimbi : Accelerating Big Data Jobs Through Flow-Controlled Data Replication

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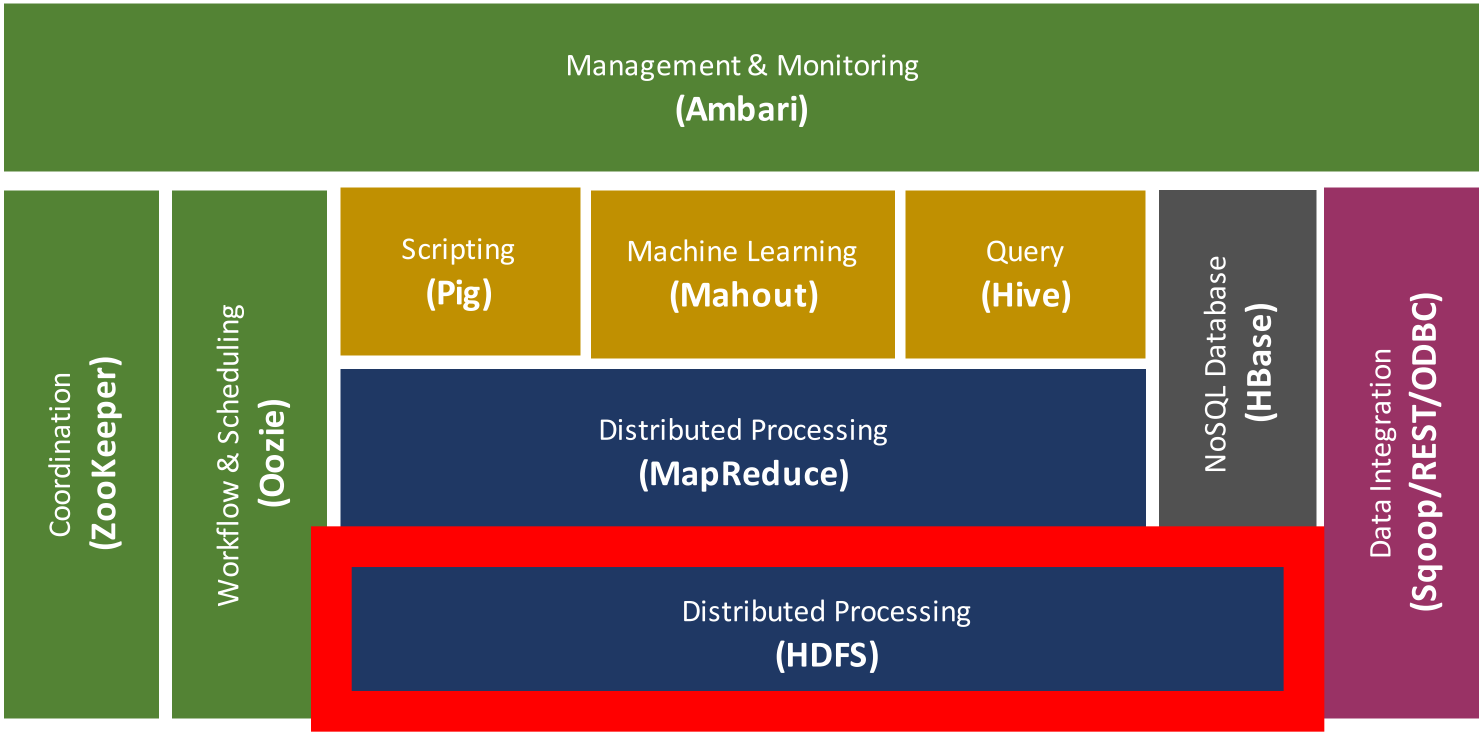
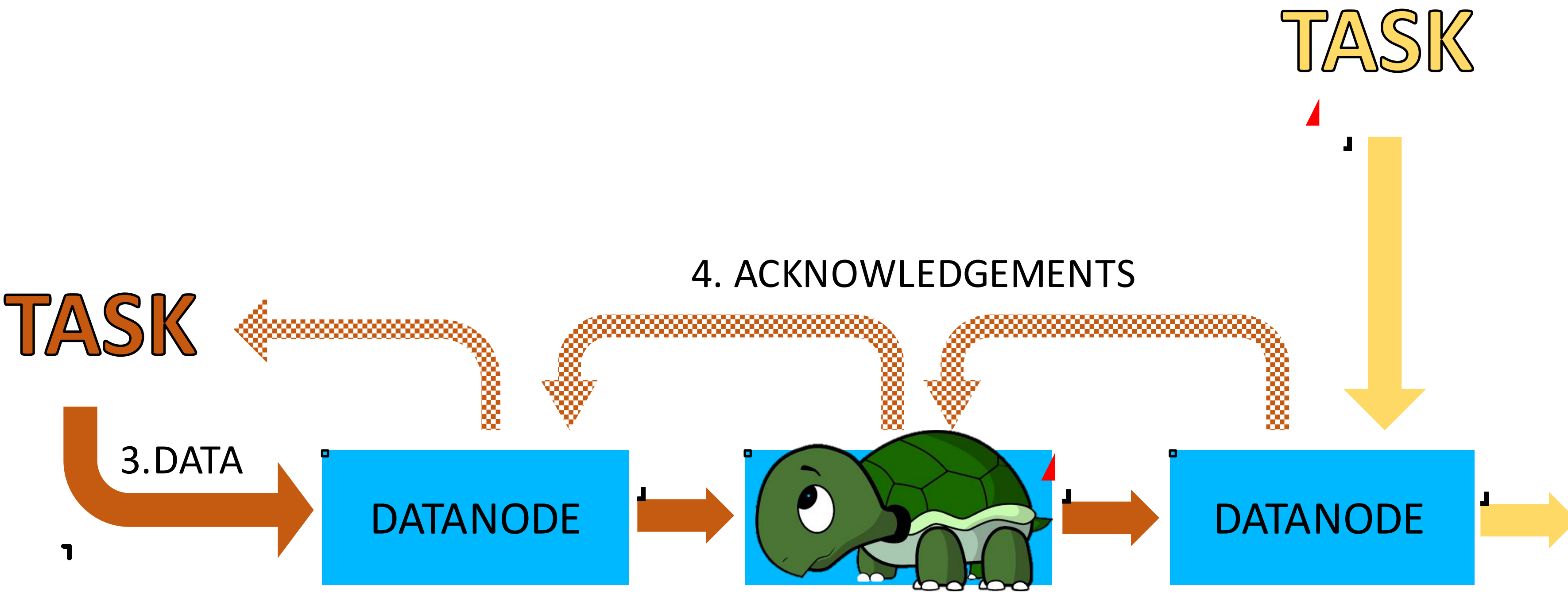
DFSs have a critical role on the Big-Data landscape



- Rich ecosystem of distributed systems around Hadoop and Spark
- Predominantly use HDFS for persistent storage
- A performant HDFS benefits all these system

Image reproduced from https://www.mssqltips.com/sqlservertip/3262/big-data-basics--part-6--related-apache-projects-in-hadoop-ecosystem/

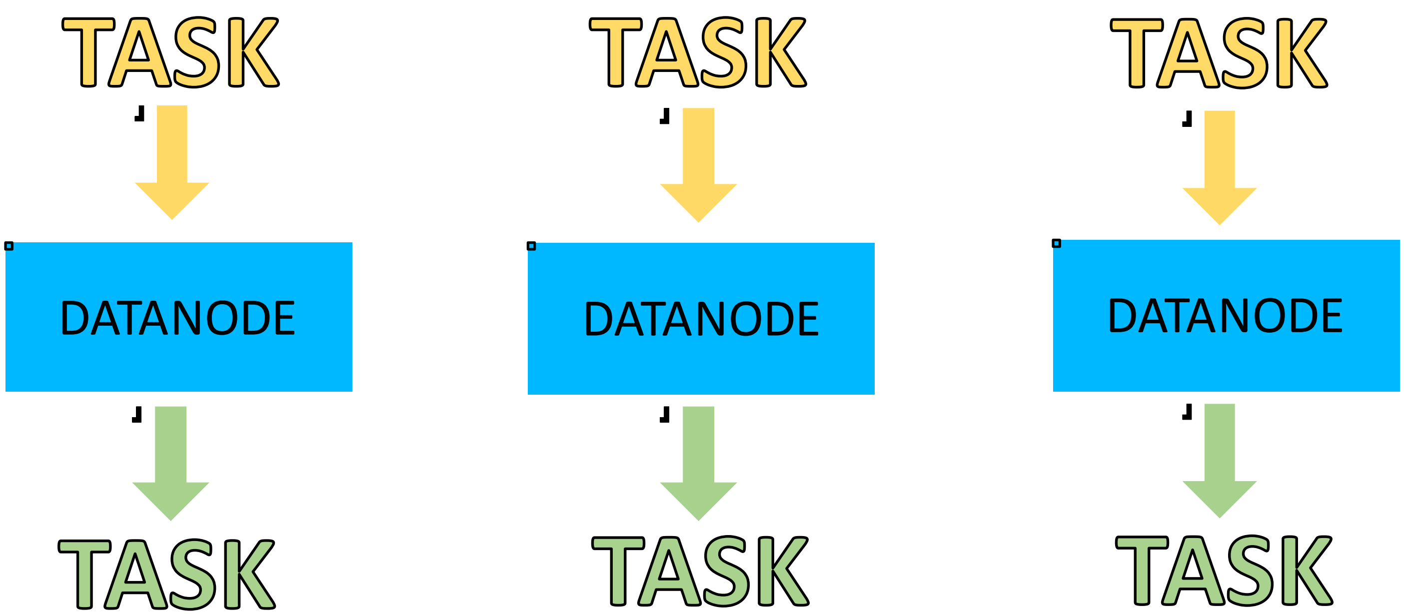
Synchronous data replication in HDFS and its shortcomings



- Bottlenecks affect the whole pipeline
- Contention between primary writes and replication

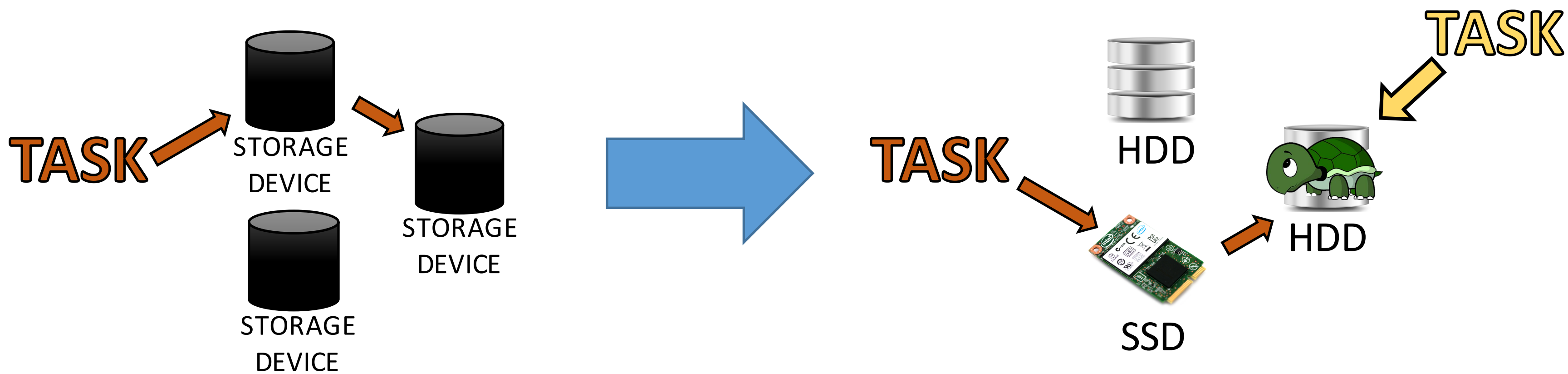
Synchronous replication seldom helps boost application performance

- In a study by Fetterly et al. only about 2% of data was read within 5 minutes of being written [TidyFS: USENIX ATC 2011]
- Fast networks reduce the cost of non-local reads
- There can be data locality without replication

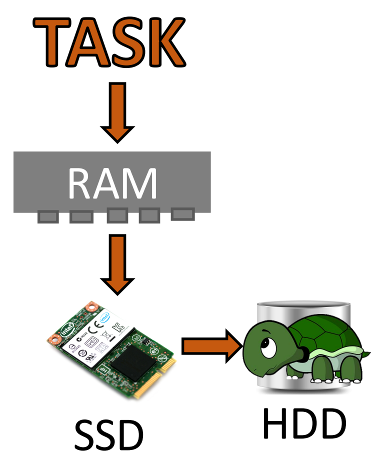


Synchronous replication impedes industry efforts to improve HDFS

- Heterogeneous storage

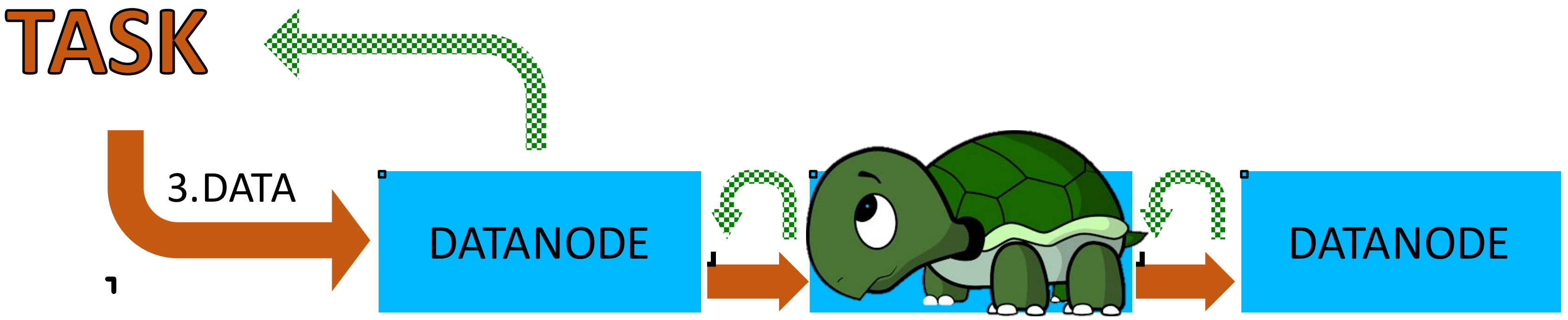


- Memory as a storage medium

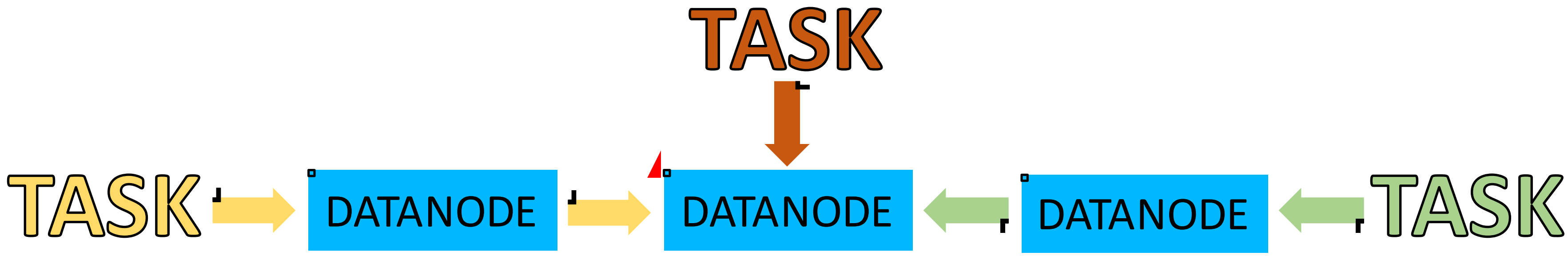


SSD image from : http://www.storagereview.com/intel_ssd_525_msata_review

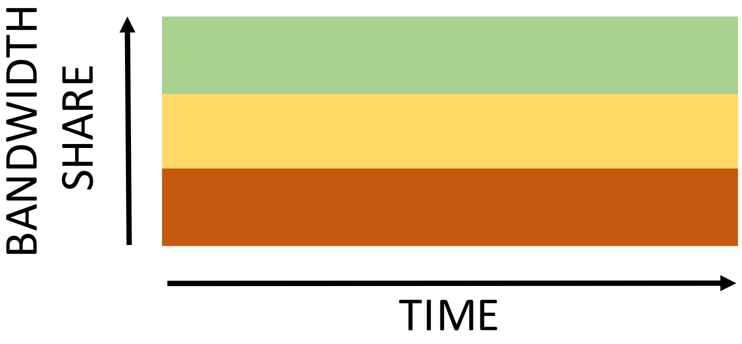
Asynchronous replication relieves the effects of pipeline bottlenecks



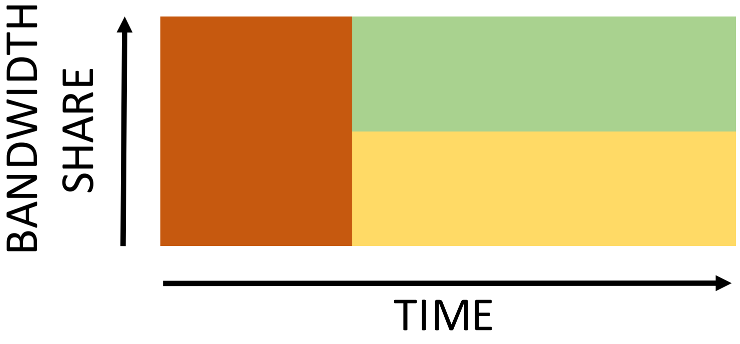
Beside asynchronous replication, we need flow control to manage contention



WITHOUT
FLOW CONTROL



WITH
FLOW CONTROL

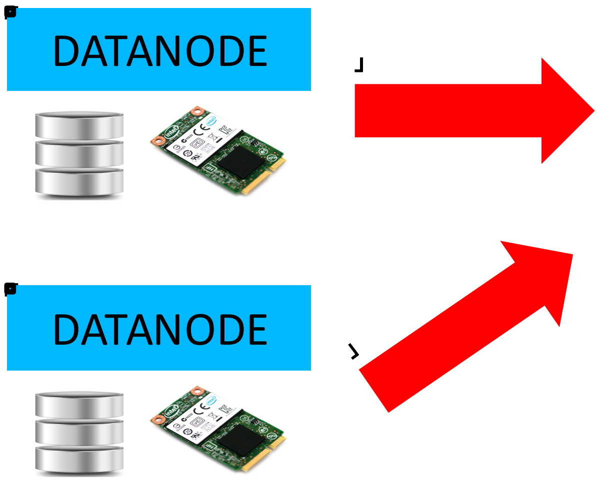


Pfimbi effectively supports flow controlled asynchronous replication

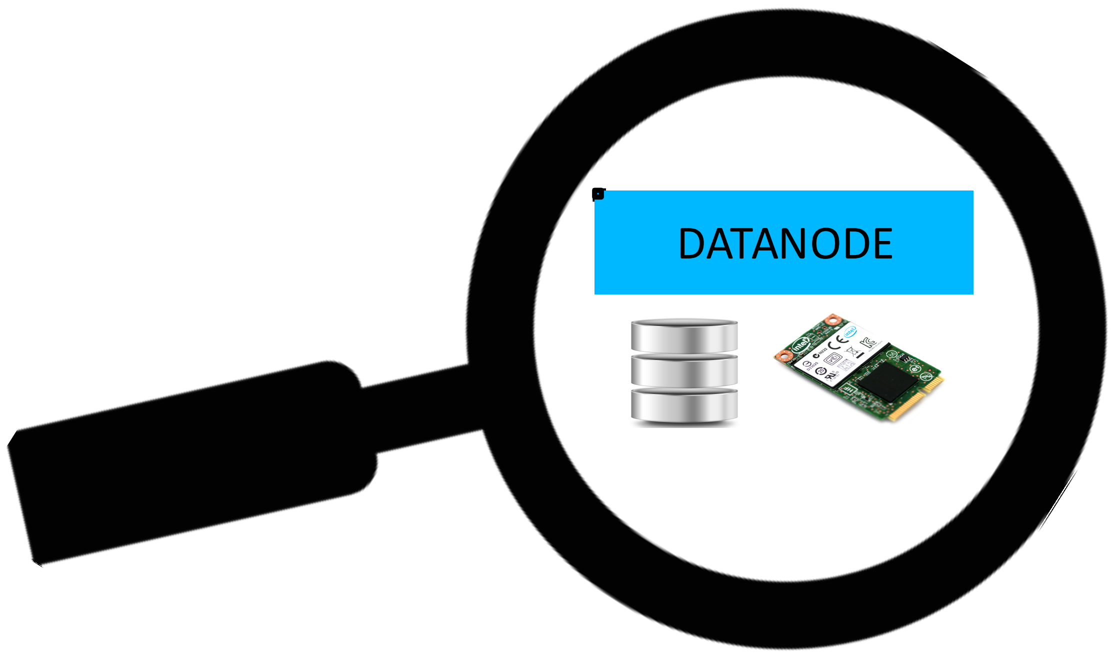
- Allows diverse flow control policies
- Cleanly separates mechanisms from policies
- Isolates primary writes from replication
- Avoids IO underutilization

Pfimbi Overview

- Inter-node flow control



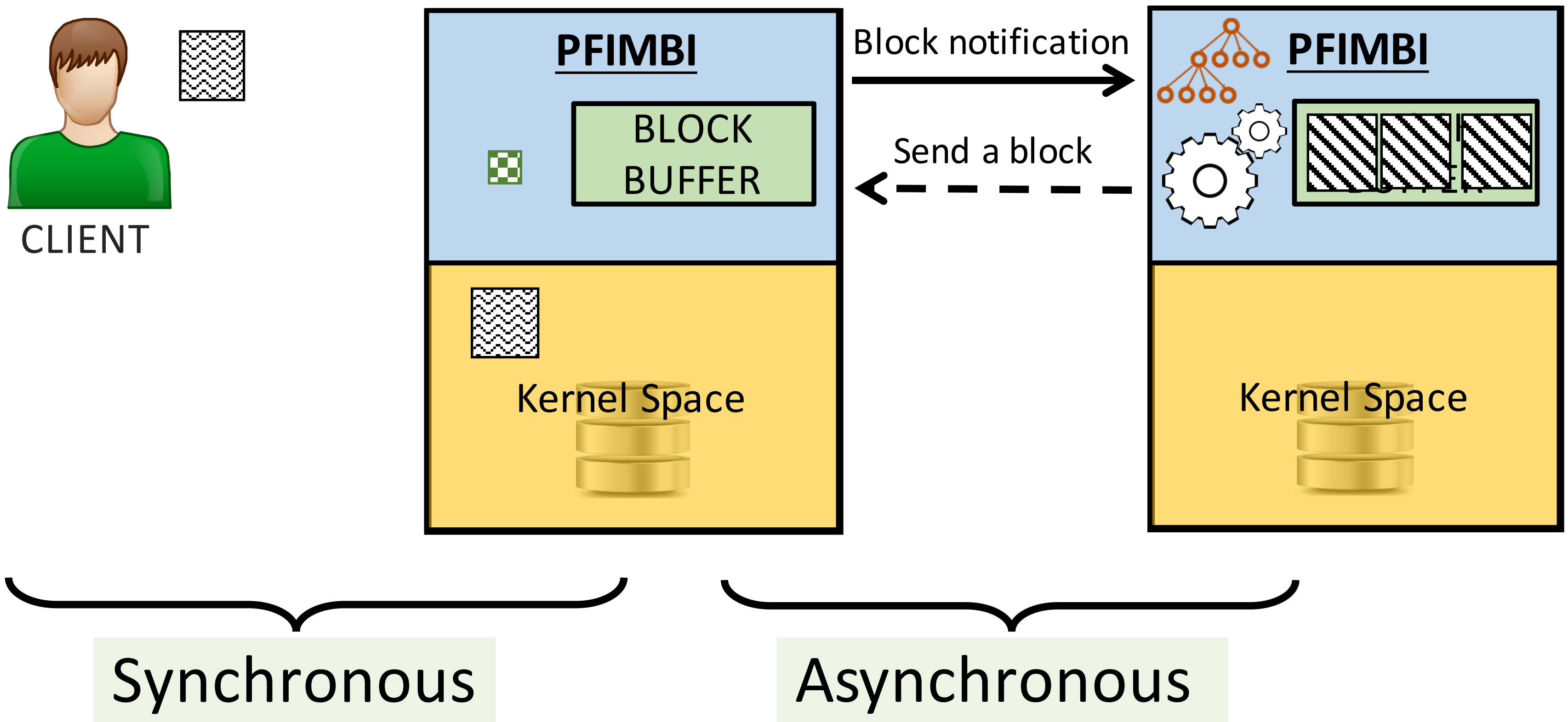
- Intra-node flow control



SSD image from http://www.storagereview.com/intel_ssd_525_msata_review; Magnifier image from https://commons.wikimedia.org/wiki/File:Magnifying_glass_icon.svg

Inter-node flow control

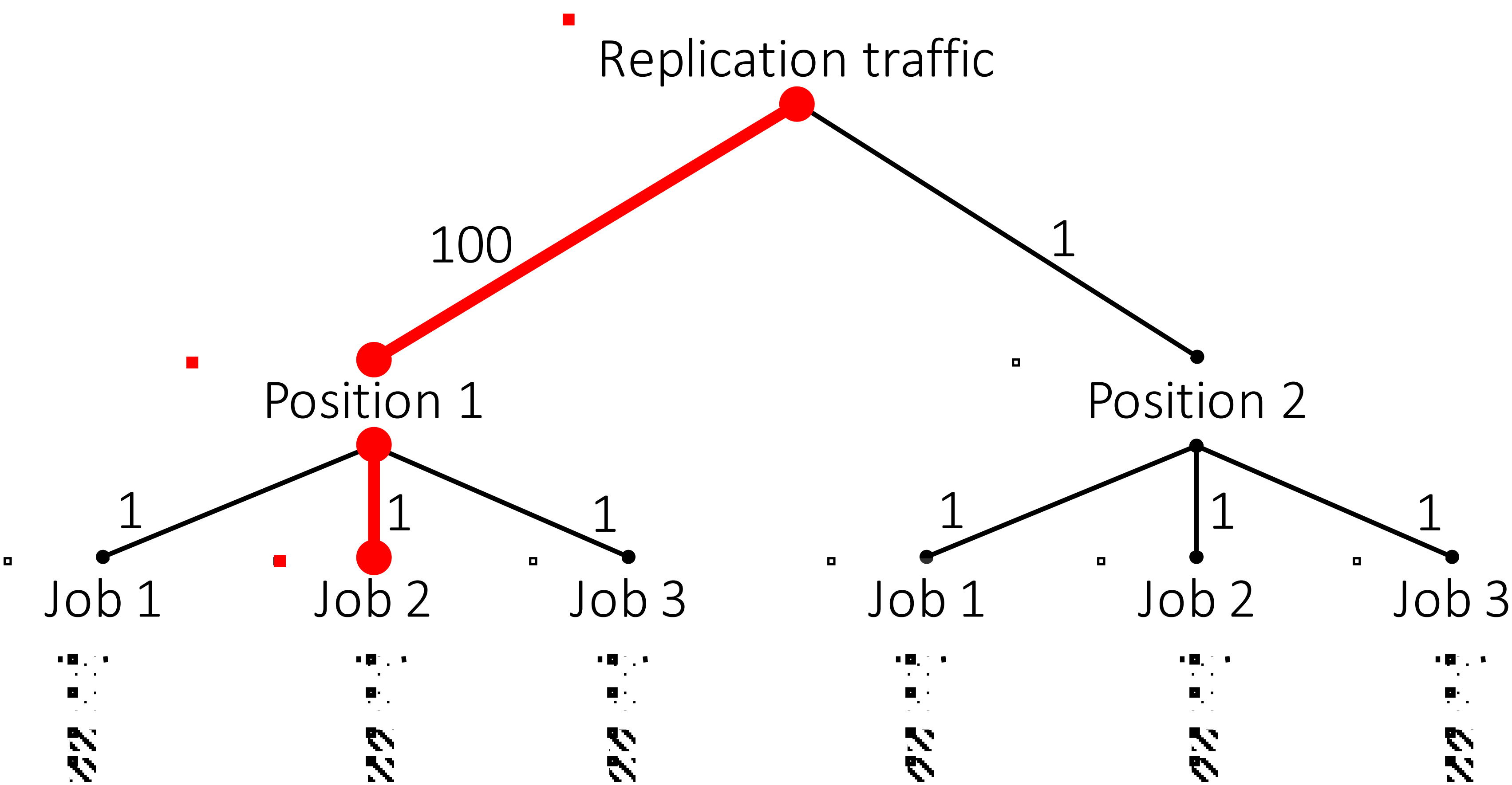
- Client API : (# of replicas , **# of synchronous replicas**)
- Timely transfer of replicas to ensure high utilization
- Flexible policies for sharing bandwidth



Hierarchical flow control allows Pfimbi to implement many IO policies

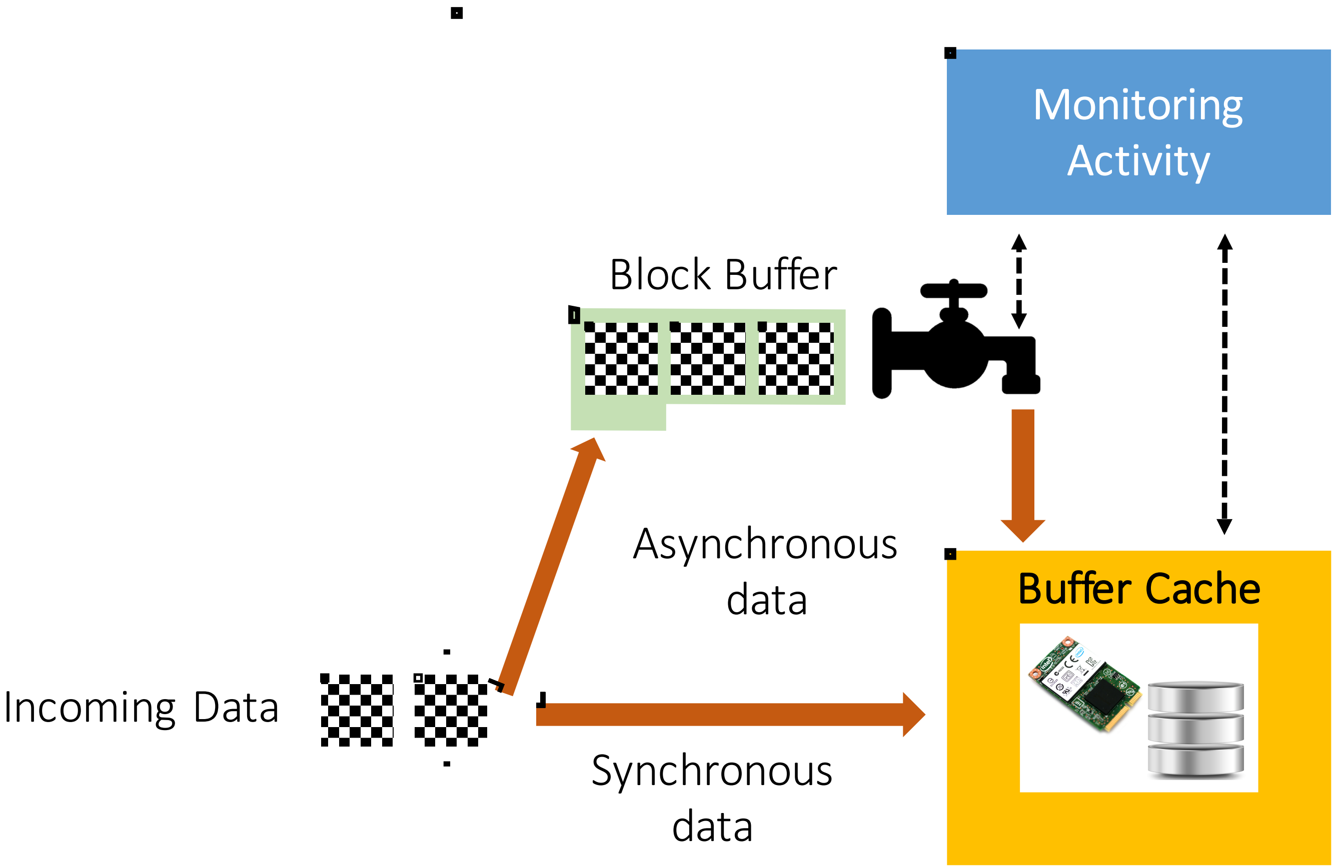
- Example 1 : prioritize replicas earlier in the pipeline

- Example 2 : fair sharing of bandwidth between jobs



Intra-node flow control

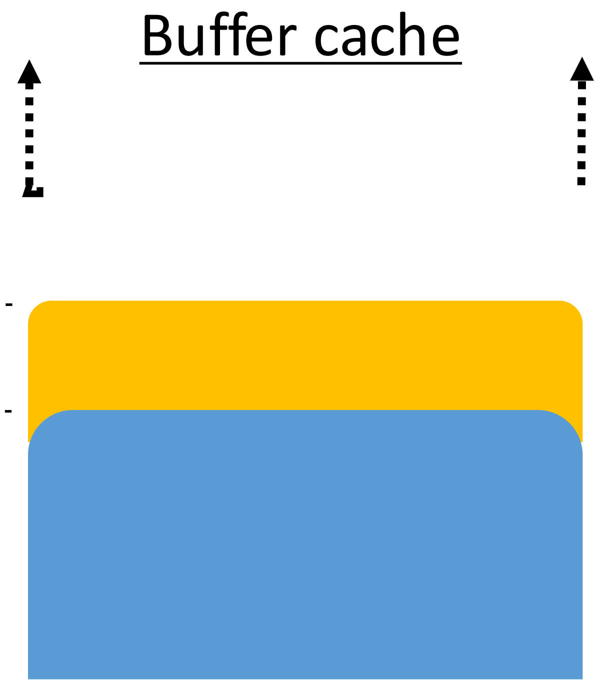
- Isolate synchronous data from asynchronous data
- Avoid IO underutilization



Tap image from https://image.freepik.com/free-icon/bathroom-tap-silhouette_318-63404.png

Intra-node flow control
Pfimbi's strategy

- Keep the disk fully utilized
- Limit the amount of replication data in the buffer cache



Threshold for asynchronous replication : **T + δ**

OS threshold for flushing buffered data : **T**

	Typical Values
T	10% of RAM (~13GB)
δ	500MB
Buffer Cache	20% of RAM (~26GB)

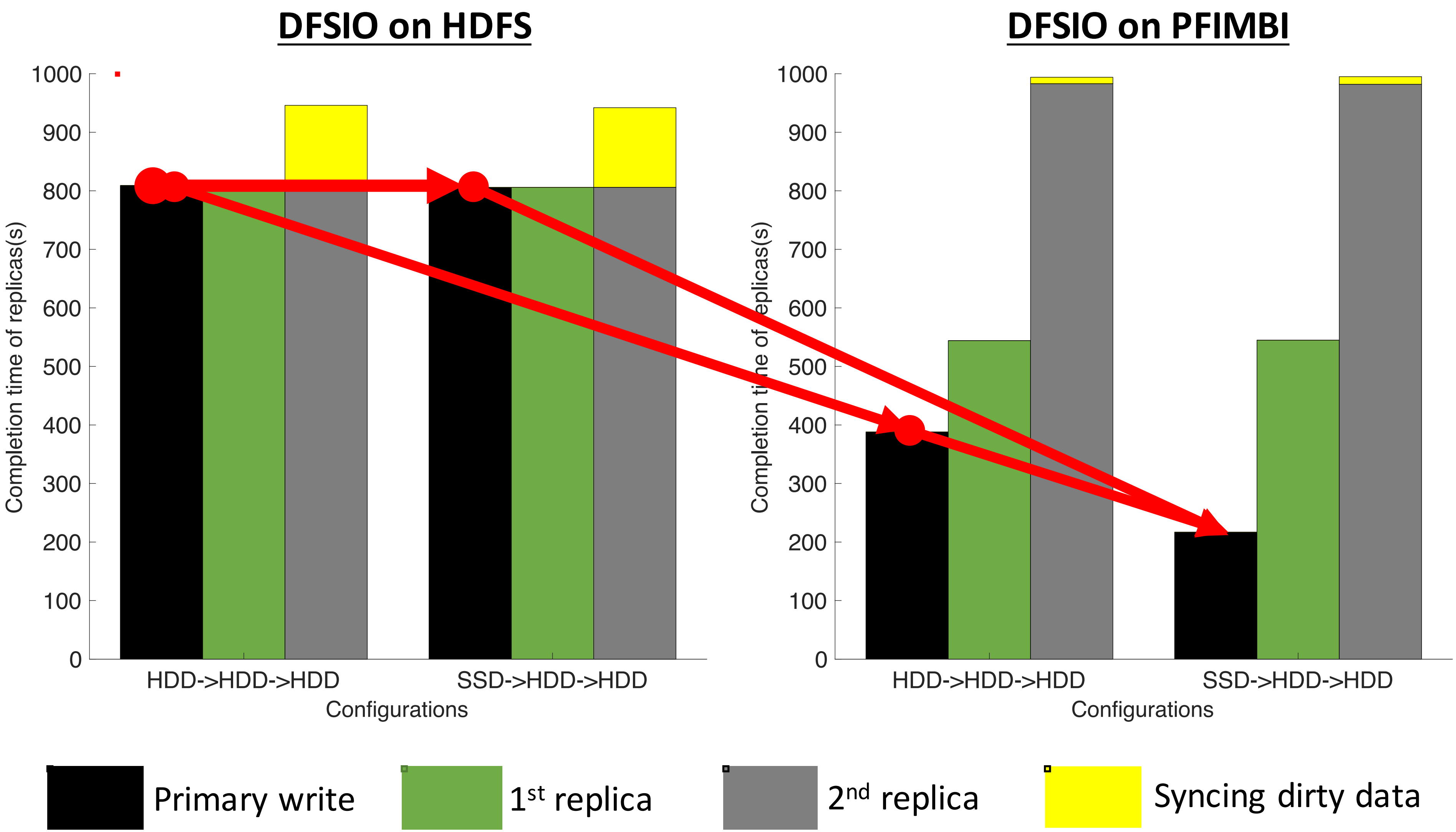
Additional topics that are discussed in detail in the paper

- Other activity metrics and their shortcomings
- Consistency
  - We maintain read and write consistency
- Failure handling
  - Same mechanism as in HDFS to recover from failures
- Scalability
  - Pfimbi's flow control is distributed

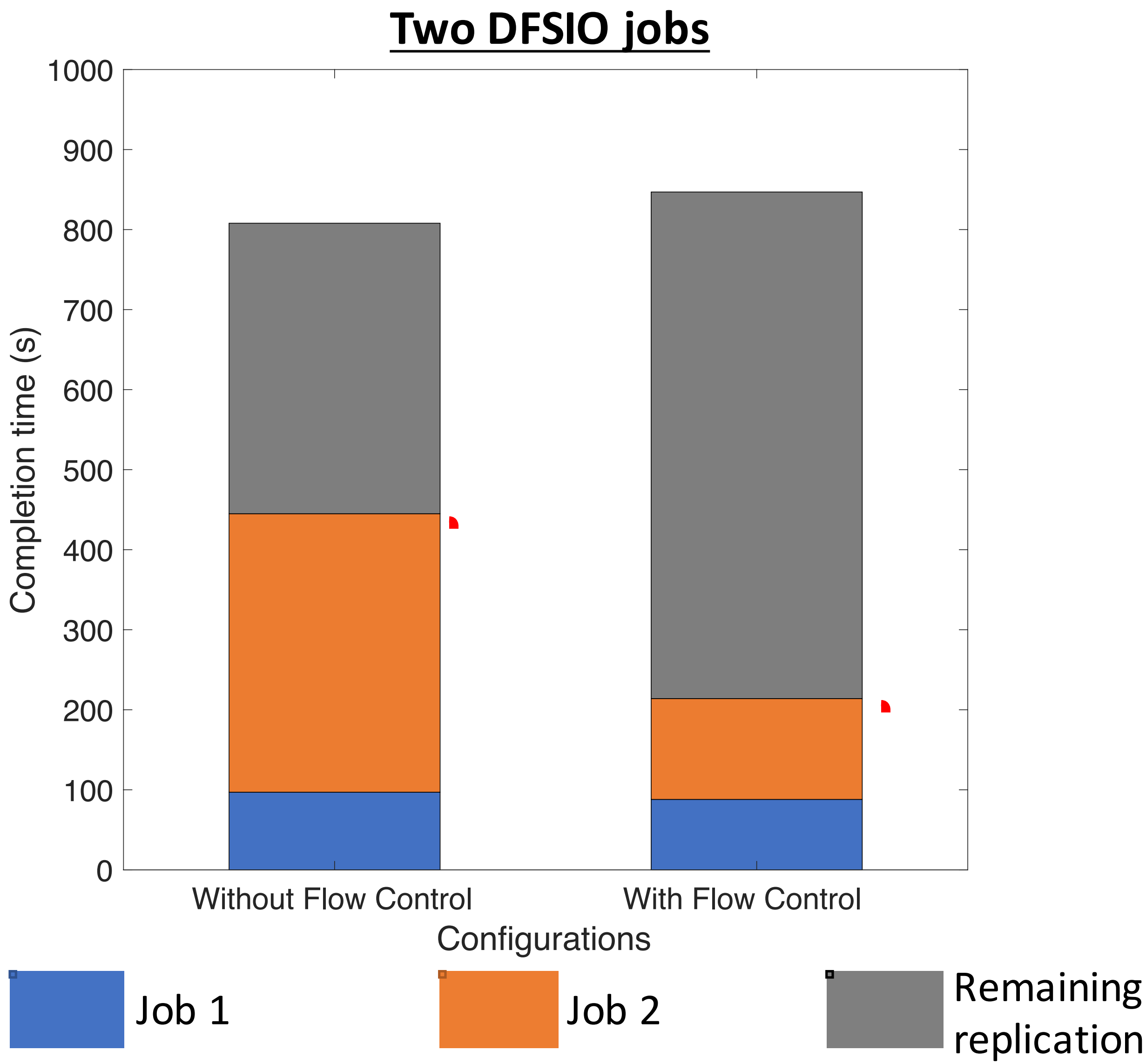
Evaluation

- 30 worker nodes
  - NodeManagers collocated with DataNodes
- 1 Master node
  - ResourceManager collocated with NameNode
- Storage
  - 2TB HDD
  - 200GB SSD
  - 128GB DRAM

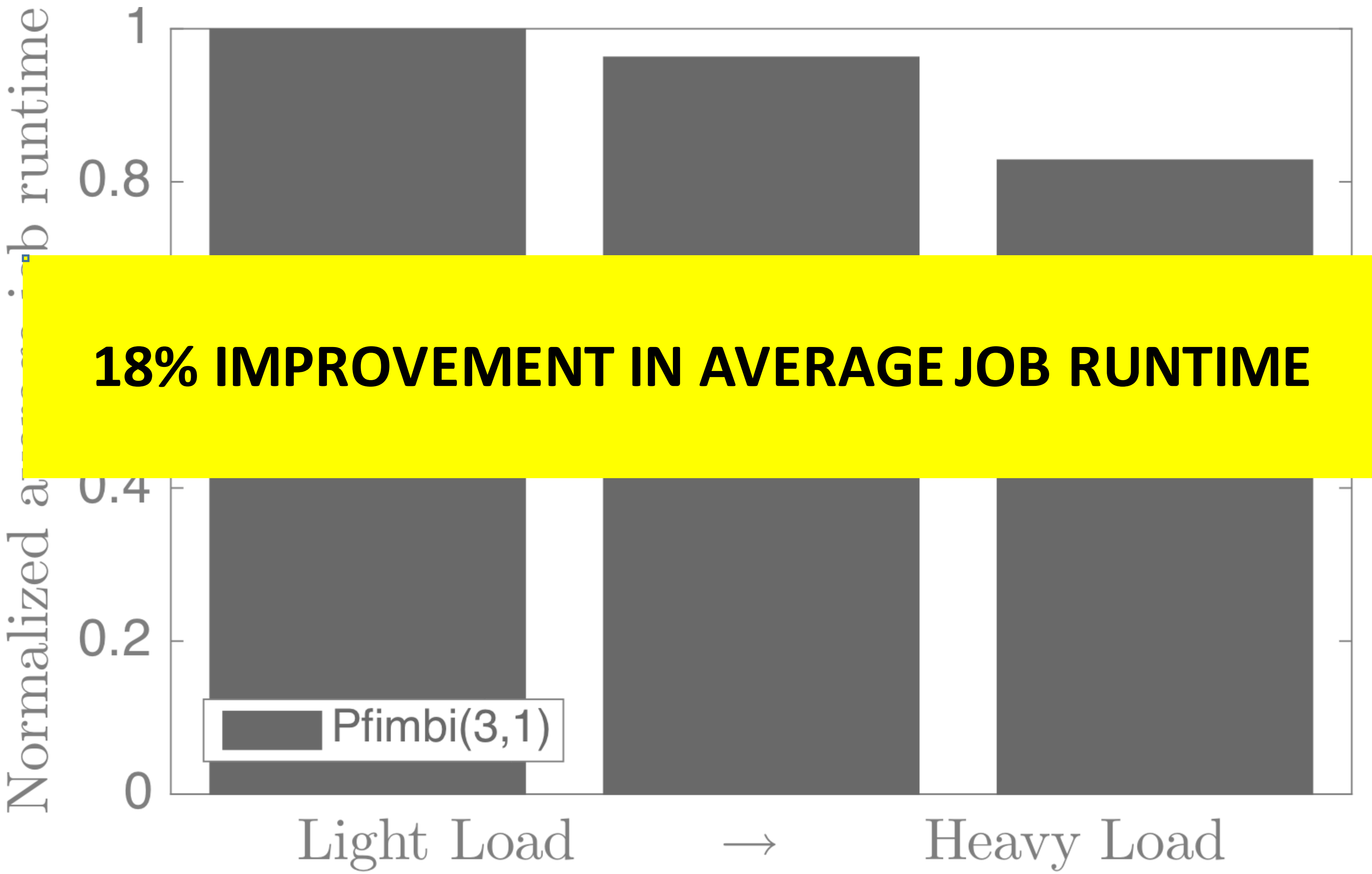
Pfimbi improves job runtime and exploits SSDs well



Necessity of flow control when doing asynchronous replication



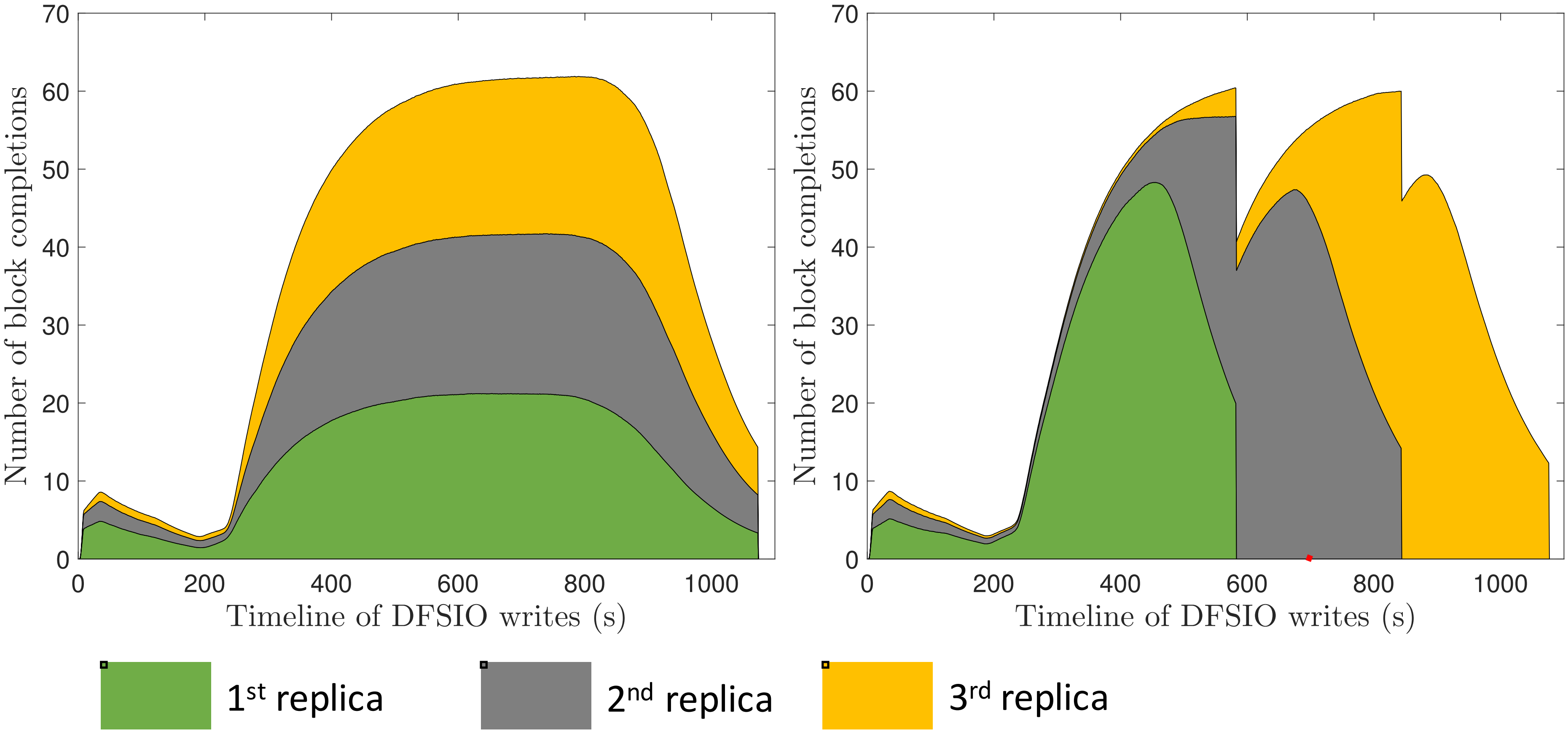
Pfimbi performs well for a mix of different jobs: SWIM workload



18% IMPROVEMENT IN AVERAGE JOB RUNTIME

Policy Example: Pfimbi can flexibly divide bandwidth between replica positions

Equal weights | **Weights in ratio 100:10:1**



Related Work

- Sinbad [SIGCOMM 2013]
  - Flexible endpoint to reduce network congestion
  - Does not eliminate contention within nodes
- TidyFS [USENIX ATC 2011]
  - Asynchronous replication
  - No flow control leads to arbitrary contention
- Retro [NSDI 2015]
  - Fairness and prioritization using rate control
  - Synchronous replication

Conclusion

- Pfimbi effectively supports flow controlled asynchronous replication
  - Successfully balances managing contention and maintaining high utilization
  - Expressive and backward compatible with HDFS