SpringFS: Bridging Agility and Performance in Elastic Distributed Storage

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Elasticity in Distributed Storage

- "Elasticity" in distributed storage:
  - ability to resize dynamically as workload varies
  - More difficult than elastic computing
- Benefits
  - Re-use for other purposes or reduce energy usage
  - Save machine hours (operating cost)
- Most distributed storage is not elastic
  - Designed for load balancing, not elasticity
  - E.g., GFS and HDFS
  - Deactivating servers may make data unavailable

SpringFS Contributions

1. Fill the gap

Some elasticity
Max peak write performance

Max elasticity
Sub-max peak write performance

2. Propose and address agility

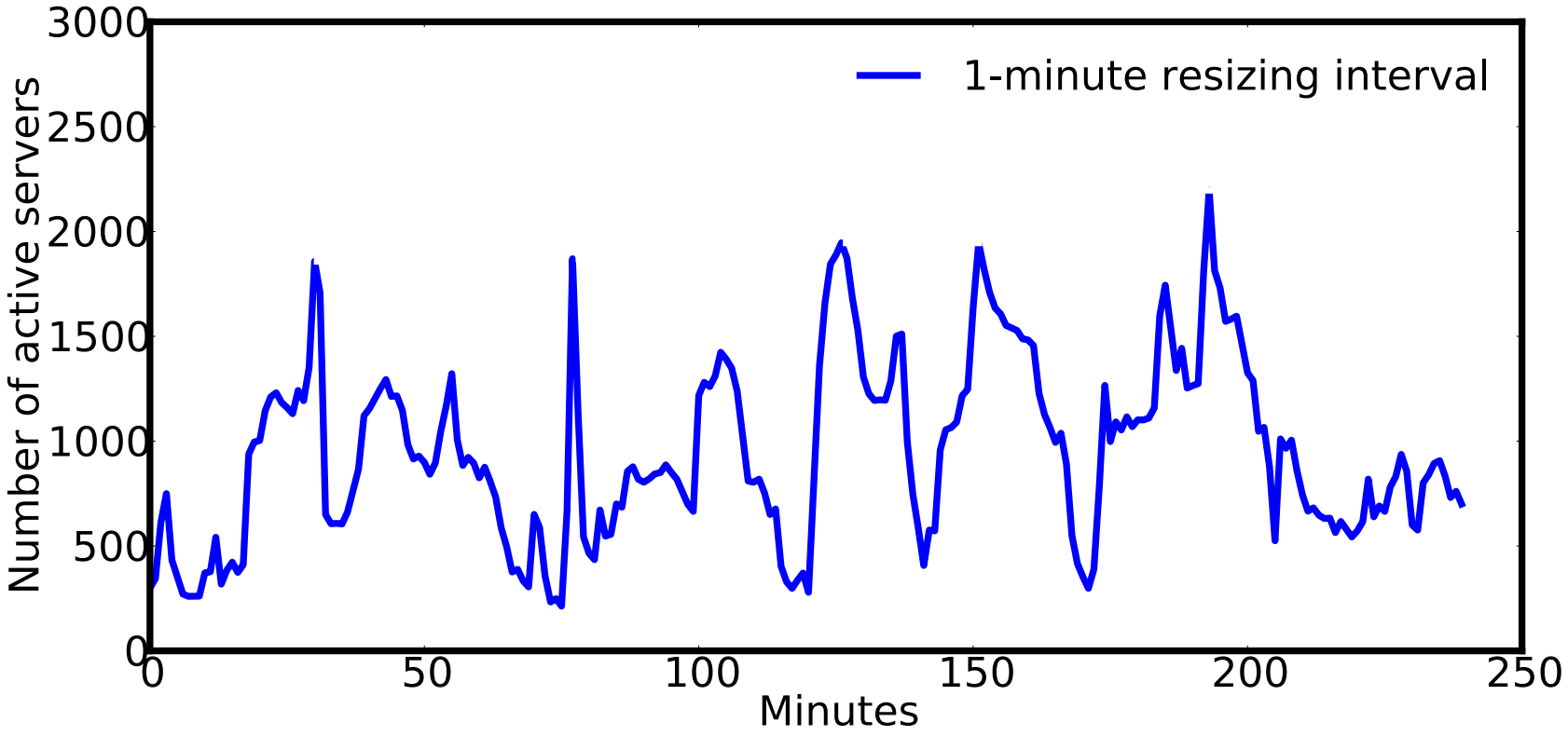
"**Agility**": speed of elastic resizing

minimize data migration ⇒ minimize machine hours

Key metrics

Agility is Important

"Burstiness" in the Facebook HDFS trace



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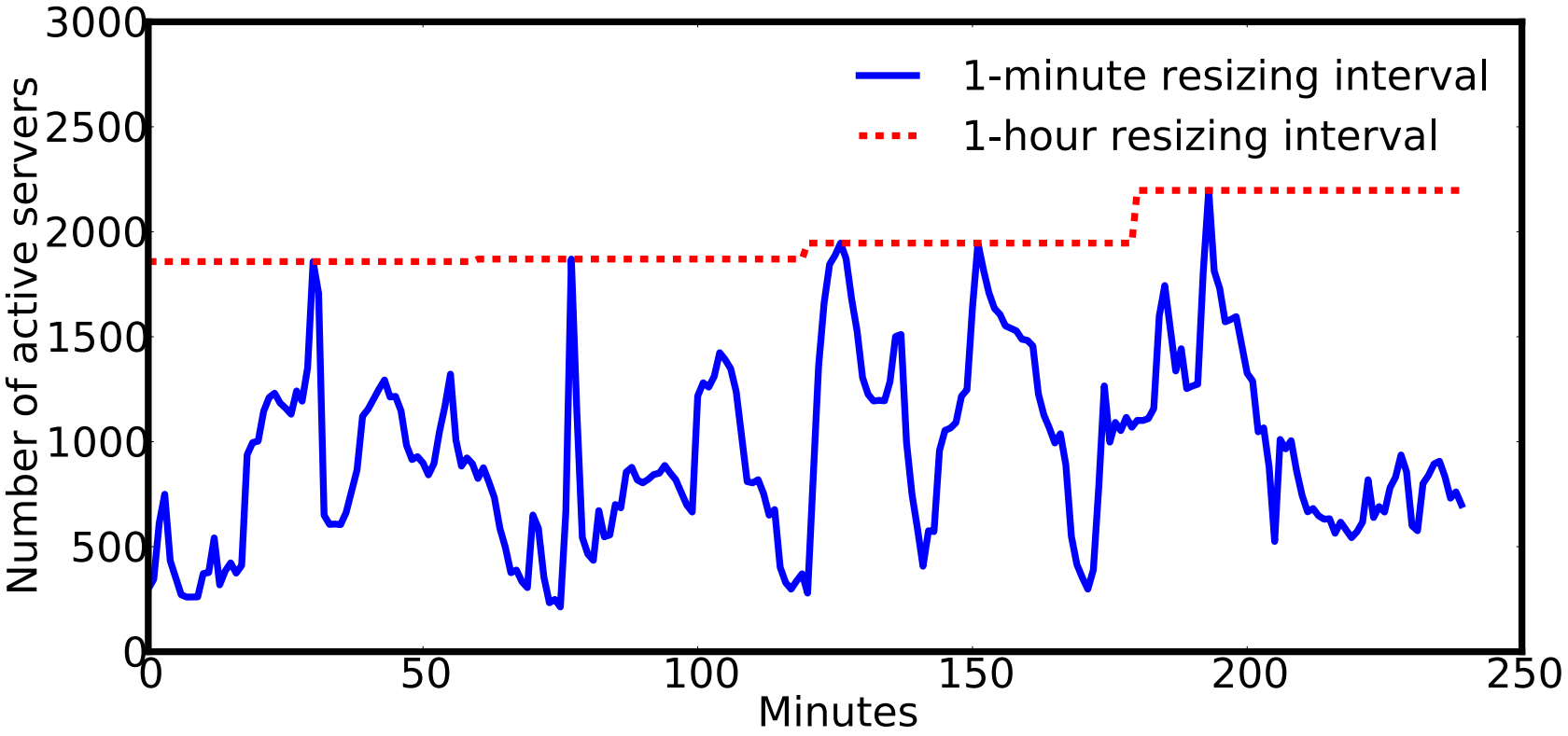

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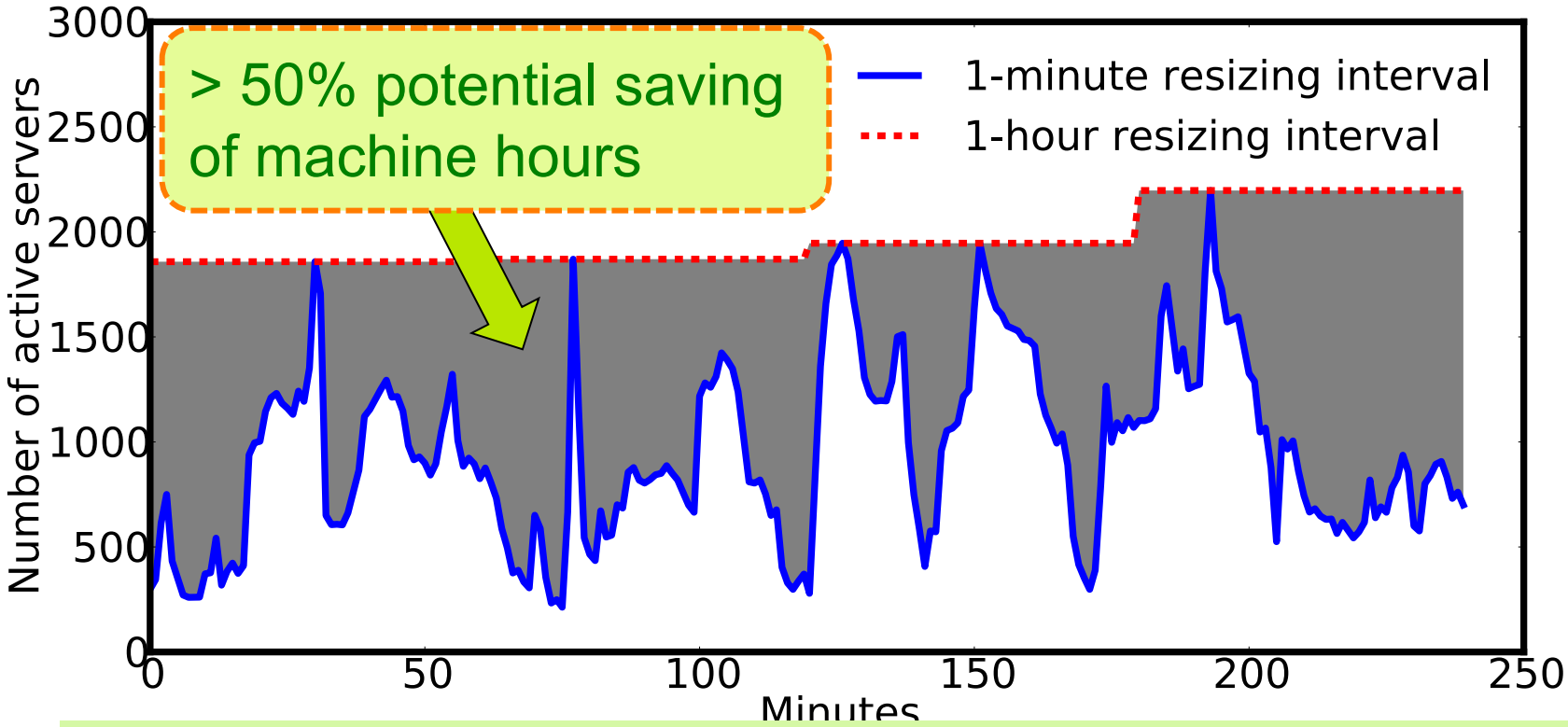
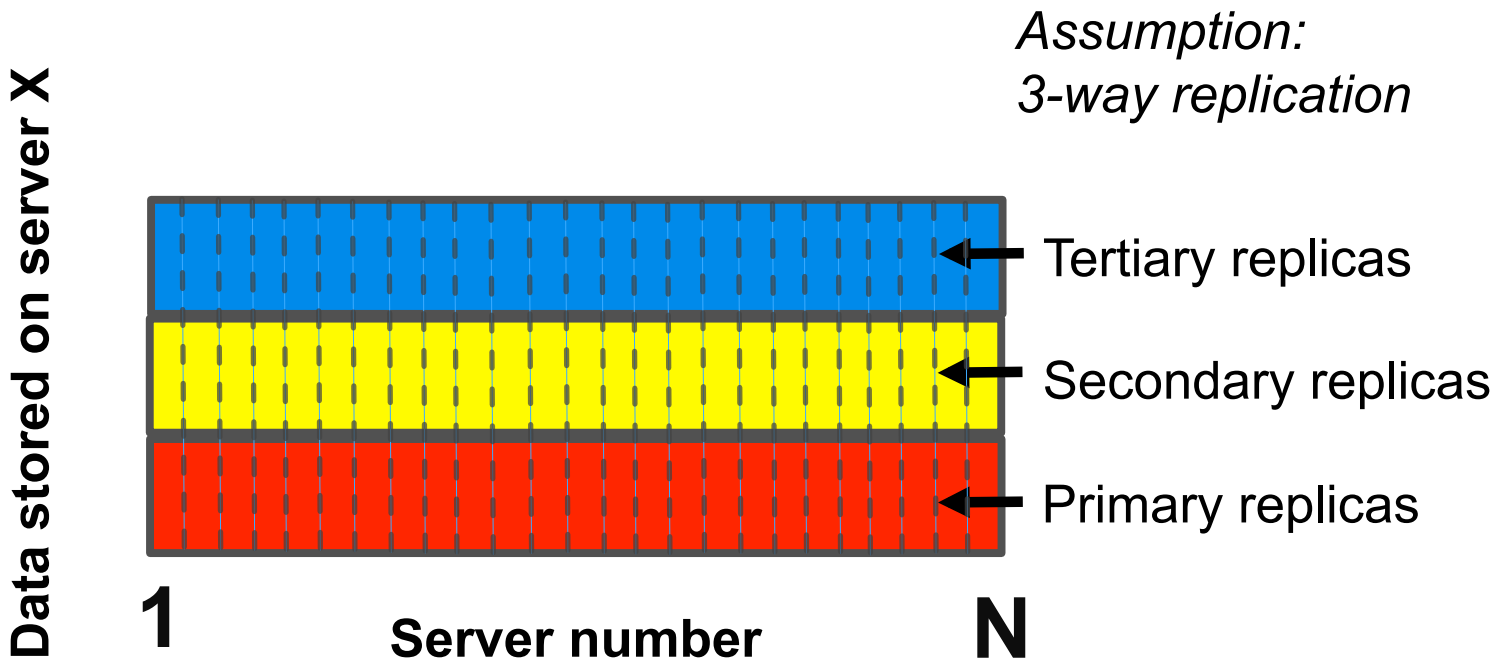


Agility allows close tracking of workload variation

Outline

- Introduction
- **Background and motivation**
- SpringFS design
- Evaluation
- Conclusion

Non-elastic Example: HDFS



Pseudo-random placement, even data layout

Almost all servers must be “on” to ensure 100% availability

- Little potential for elastic resizing

Data Layout in Elastic Storage

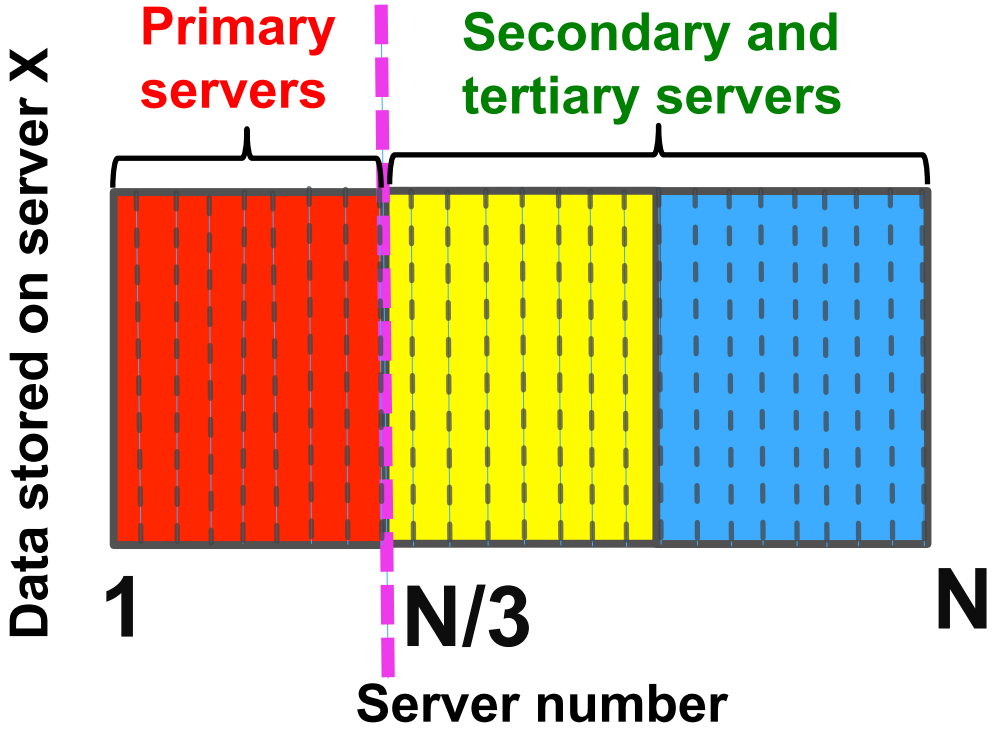
- General rule:
  - Take advantage of replication
  - Always keep the first (primary) replicas “on”
  - The other replicas can be activated on demand

- Notable examples: Sierra [1] and Rabbit [2]

[1] E. Thereska et al. Sierra: Practical Power-proportionality for Data Center Storage. Eurosys 2011.

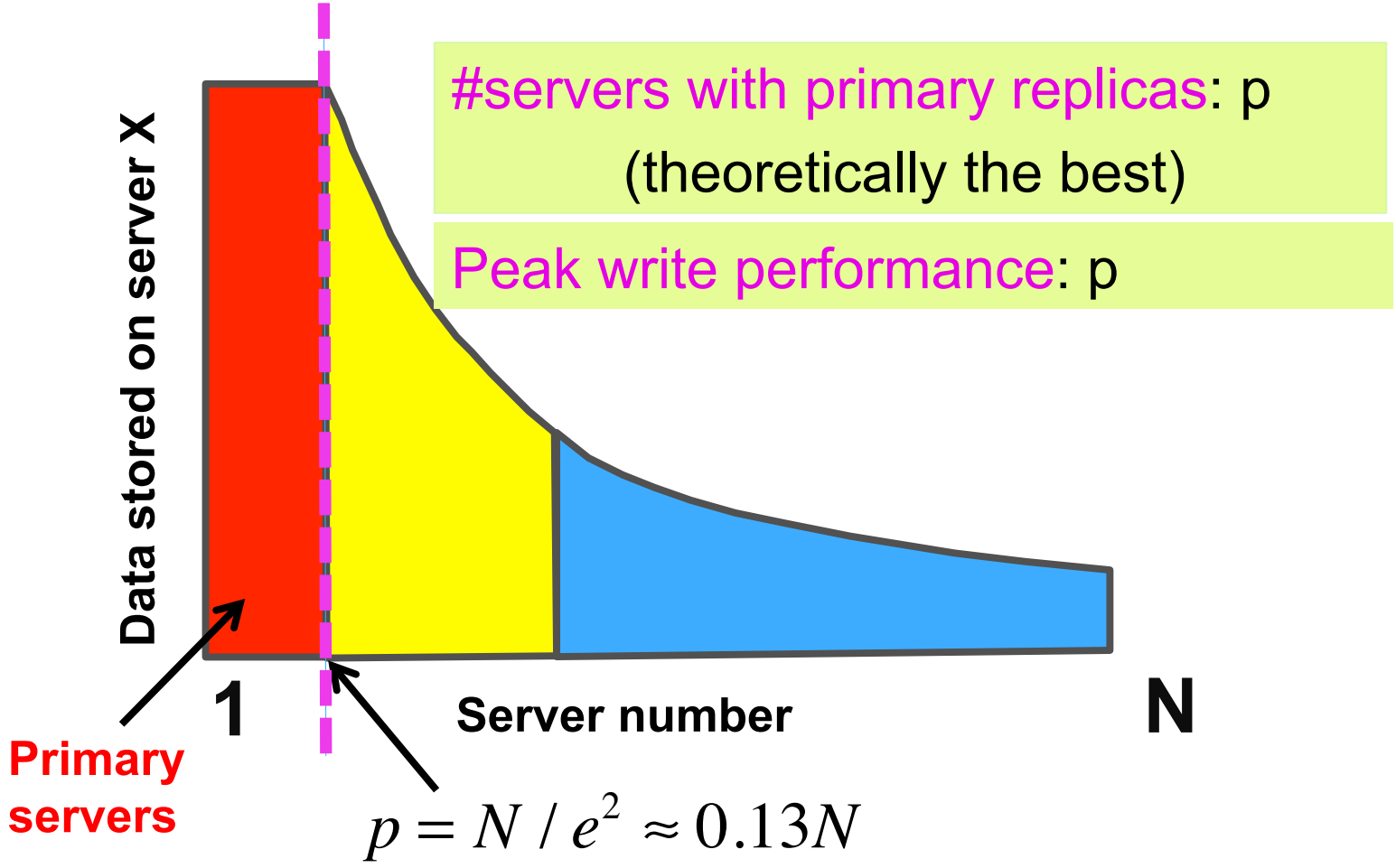
[2] J. Cipar et al. Robust and flexible power-proportional storage. SoCC 2010.

Sierra Data Layout

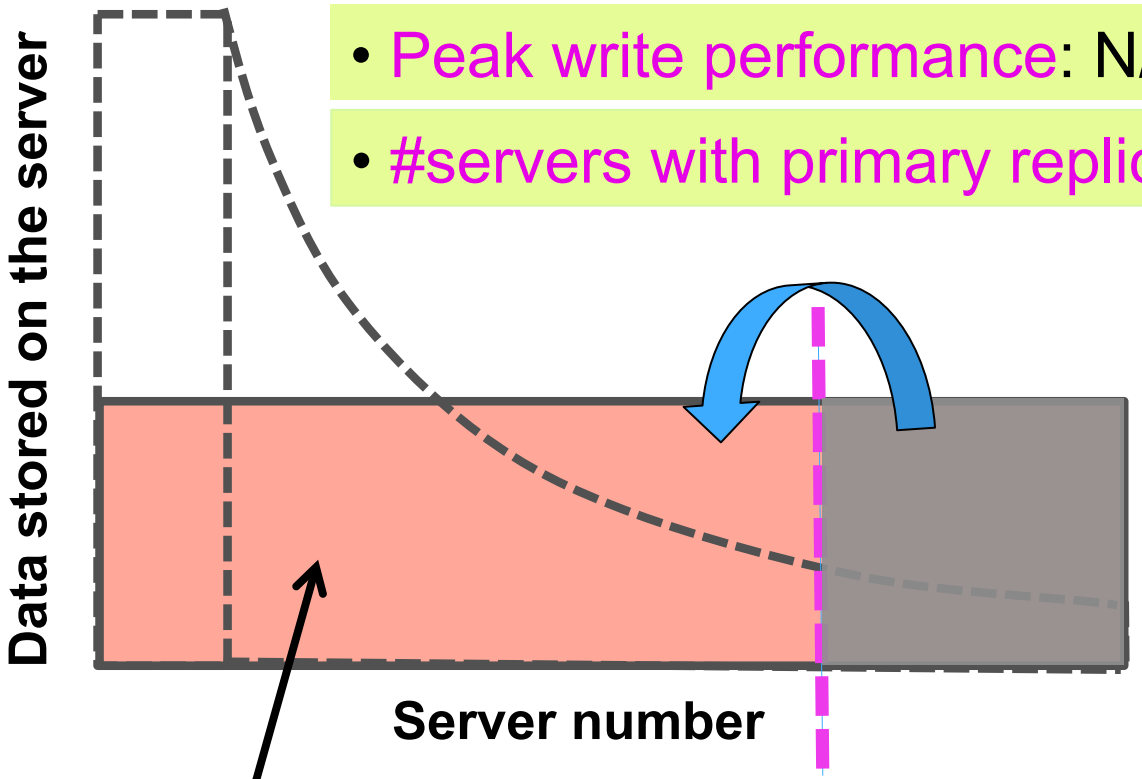


- Peak write performance: N/3 (as good as HDFS)
- #servers with primary replicas: N/3

Rabbit Equal-work Data Layout

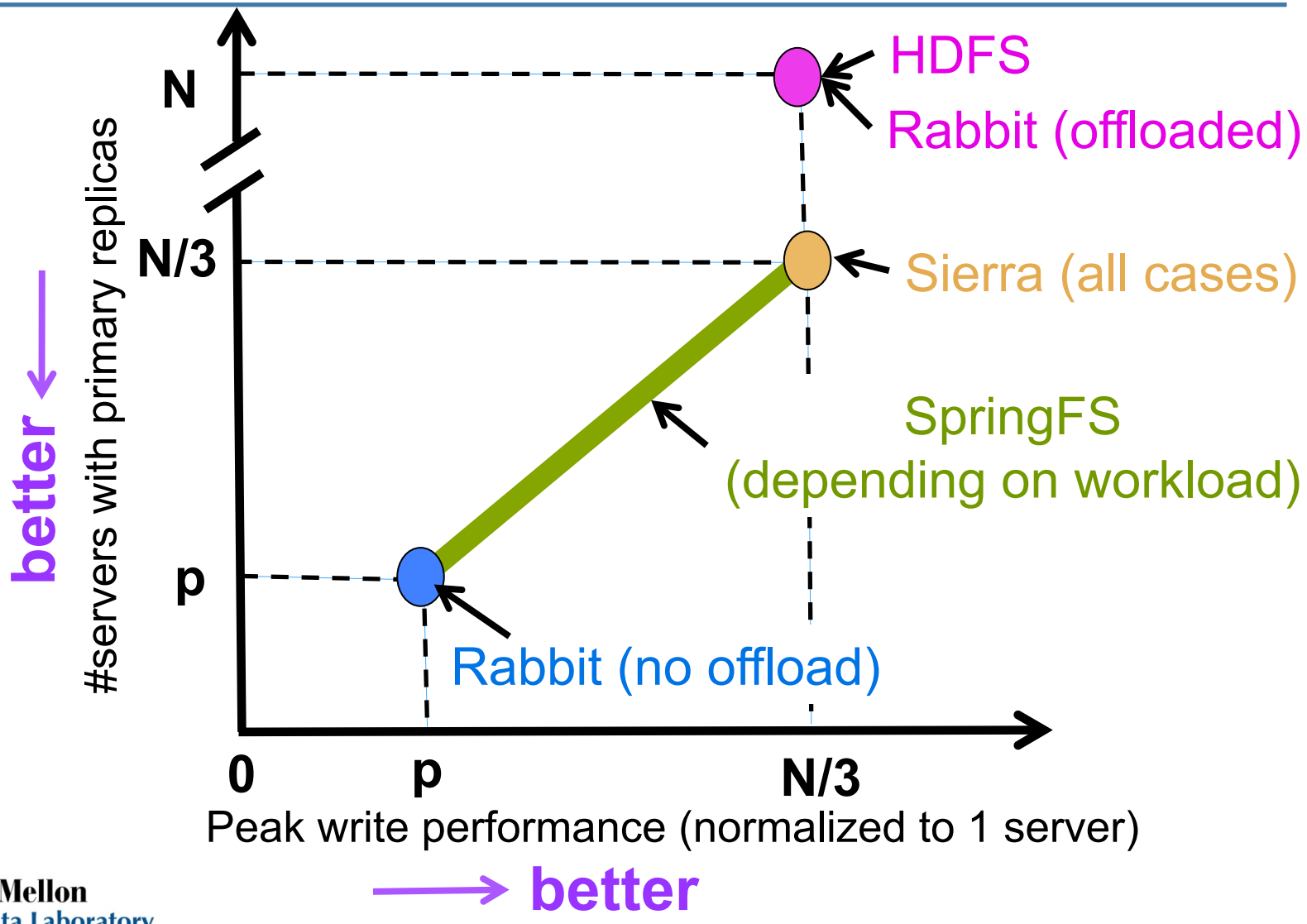


Rabbit When Using Offloading



Primary replicas spread across all active servers

Tradeoff Space



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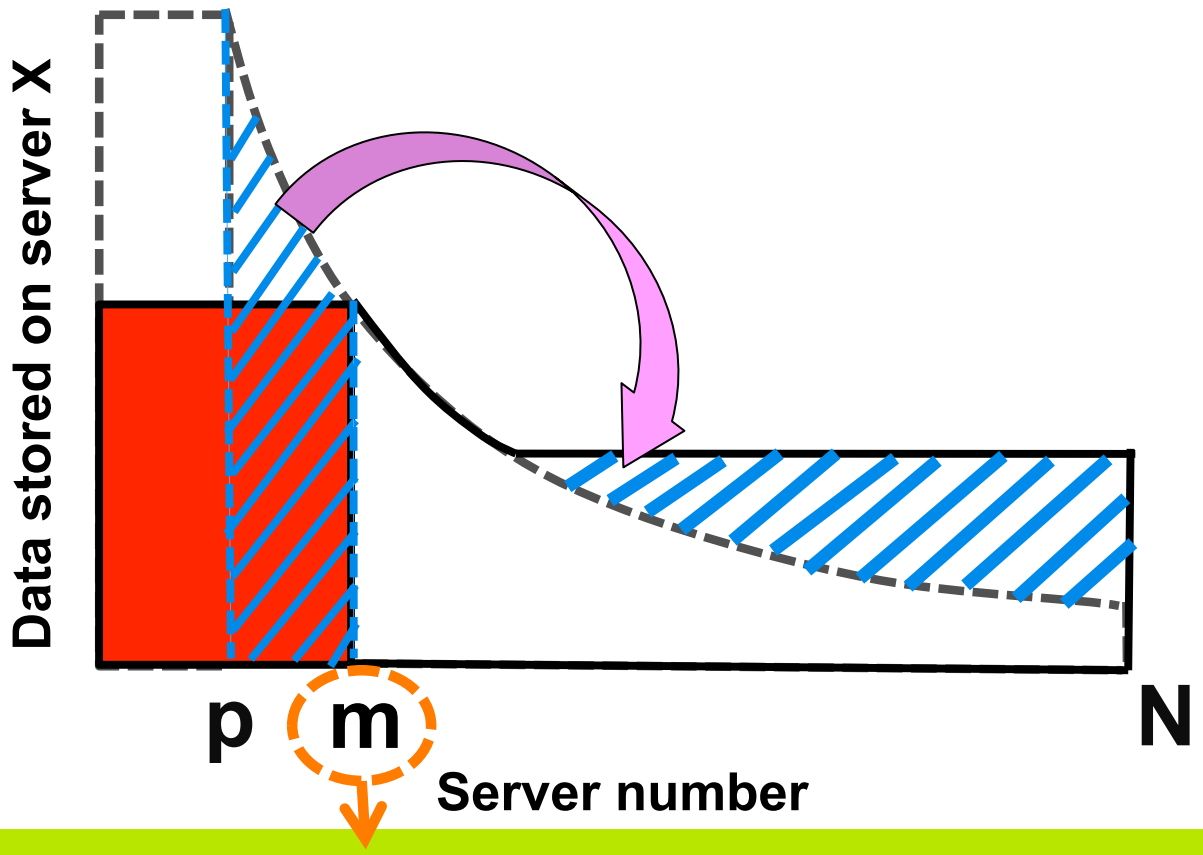
SpringFS Design

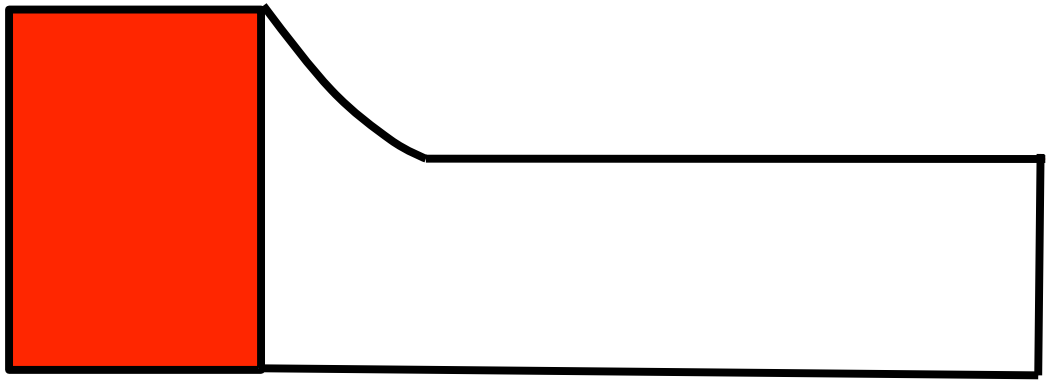
- ***Bounded write offloading***
  - Dynamically constrain distribution of primary replicas
- ***Read offloading***
  - Preferentially offload reads from write-heavy servers
- ***Passive migration***
  - Delay migration on server re-integration

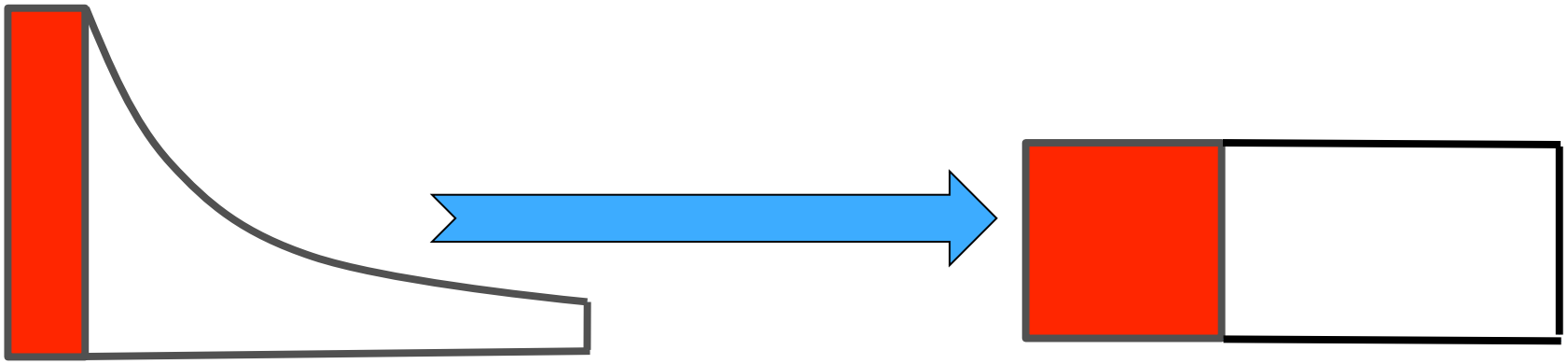
Bounded Write Offloading



Offload set: automatically adapts to workload

Bounded Write Offloading





SpringFS Implementation

- Modified instance of HDFS
  - Written in Java and Python
- Built and used a Scriptable HDFS interface
  - Data placement
  - Load balancing
  - Data Migration
  - Implement SpringFS and Rabbit in the same system
- Resizing agent
  - Activate/deactivate servers according to workload

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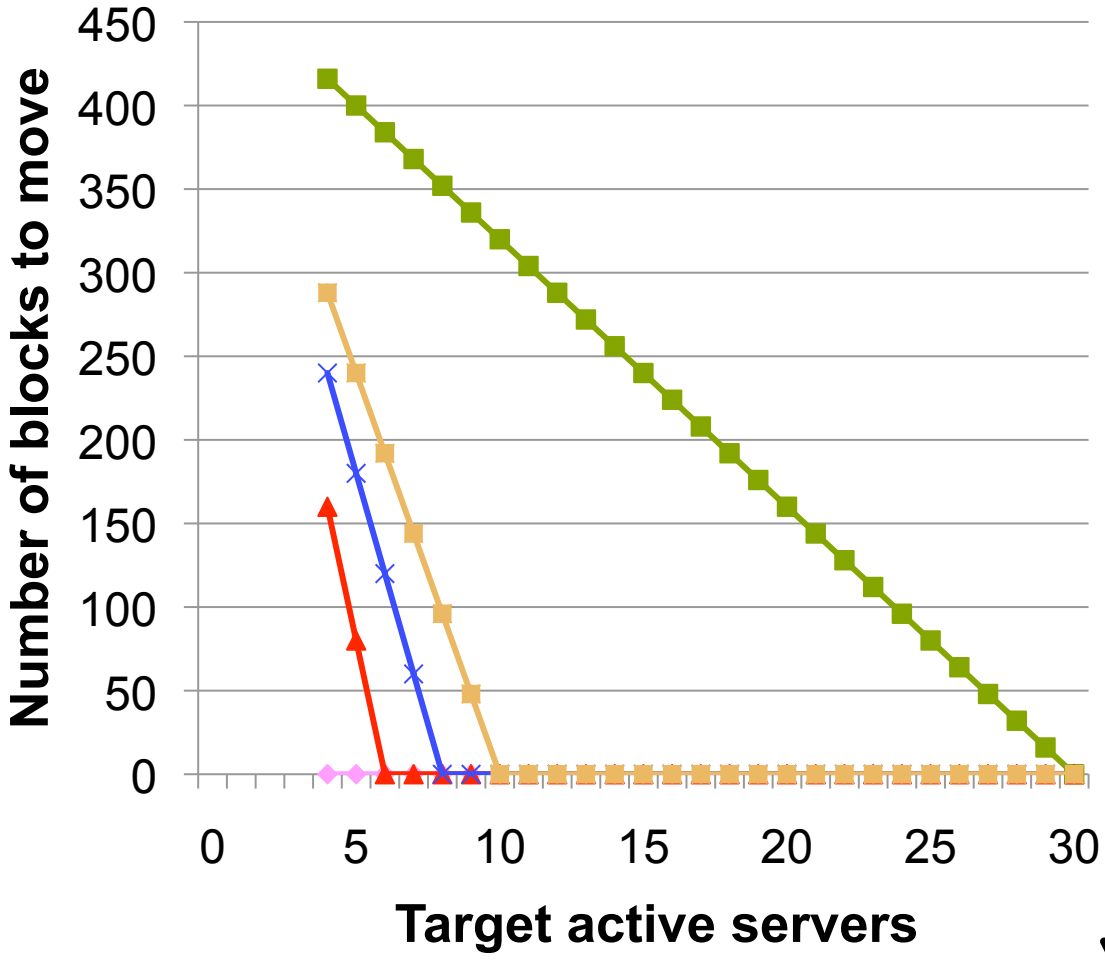
Evaluation Overview

- Experiments with SpringFS prototype
- Analysis with real-world traces
  - Hadoop/HDFS deployments at Facebook (FB) and Cloudera Customers (CC)
- Summary of results
  - SpringFS improves over state-of-the-art designs
    - Reduces data migration
    - Reduces machine hour usage (often near-ideal)
    - Provides range of options between Rabbit and Sierra

Data Migration in SpringFS Prototype



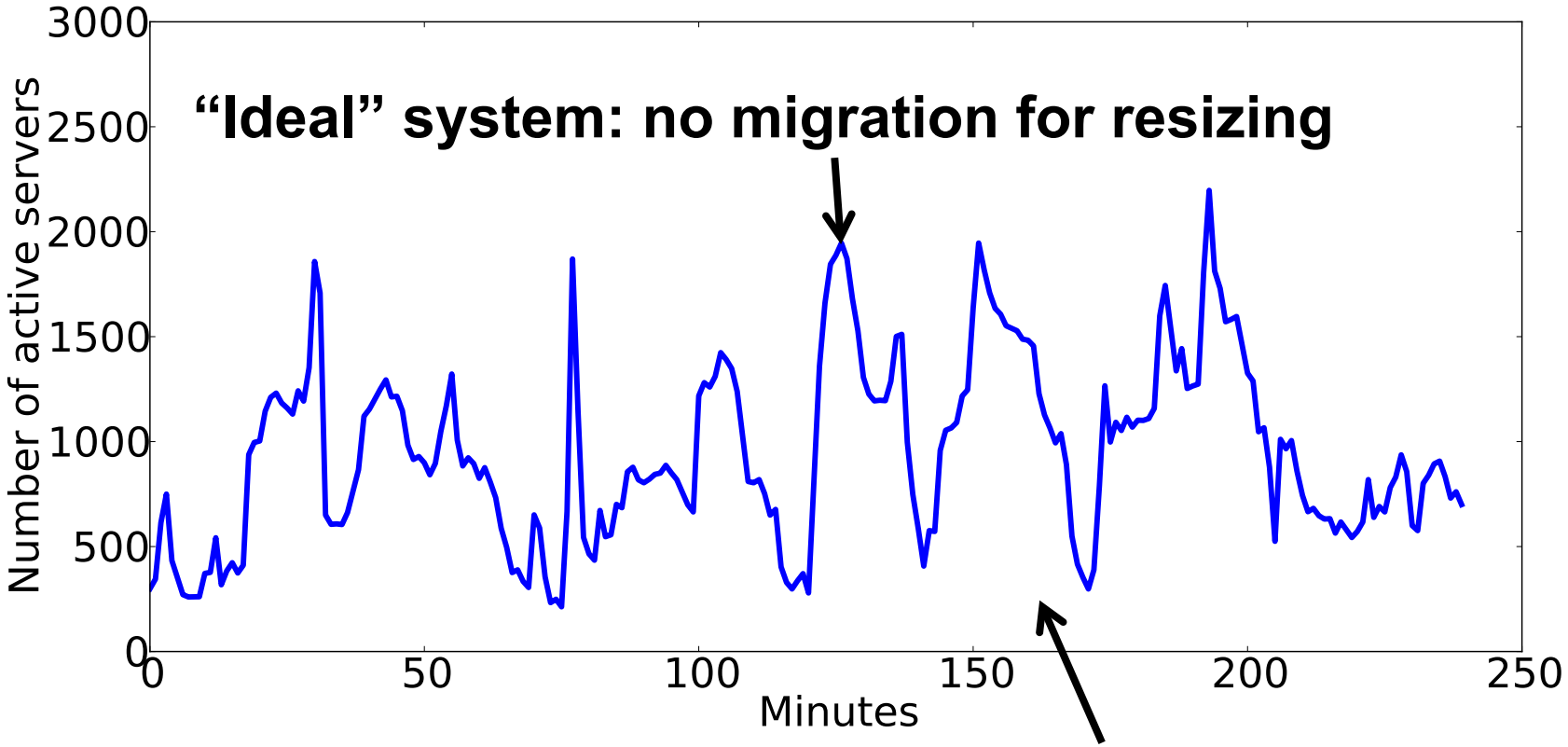
Experimental setup:

- 30 DataNodes
- 4 primary servers
- 2GB file per server
- 128MB block size

Rabbit (no offload)
Rabbit (offload=30)
SpringFS(offload=6)
SpringFS(offload=8)
SpringFS(offload=10)

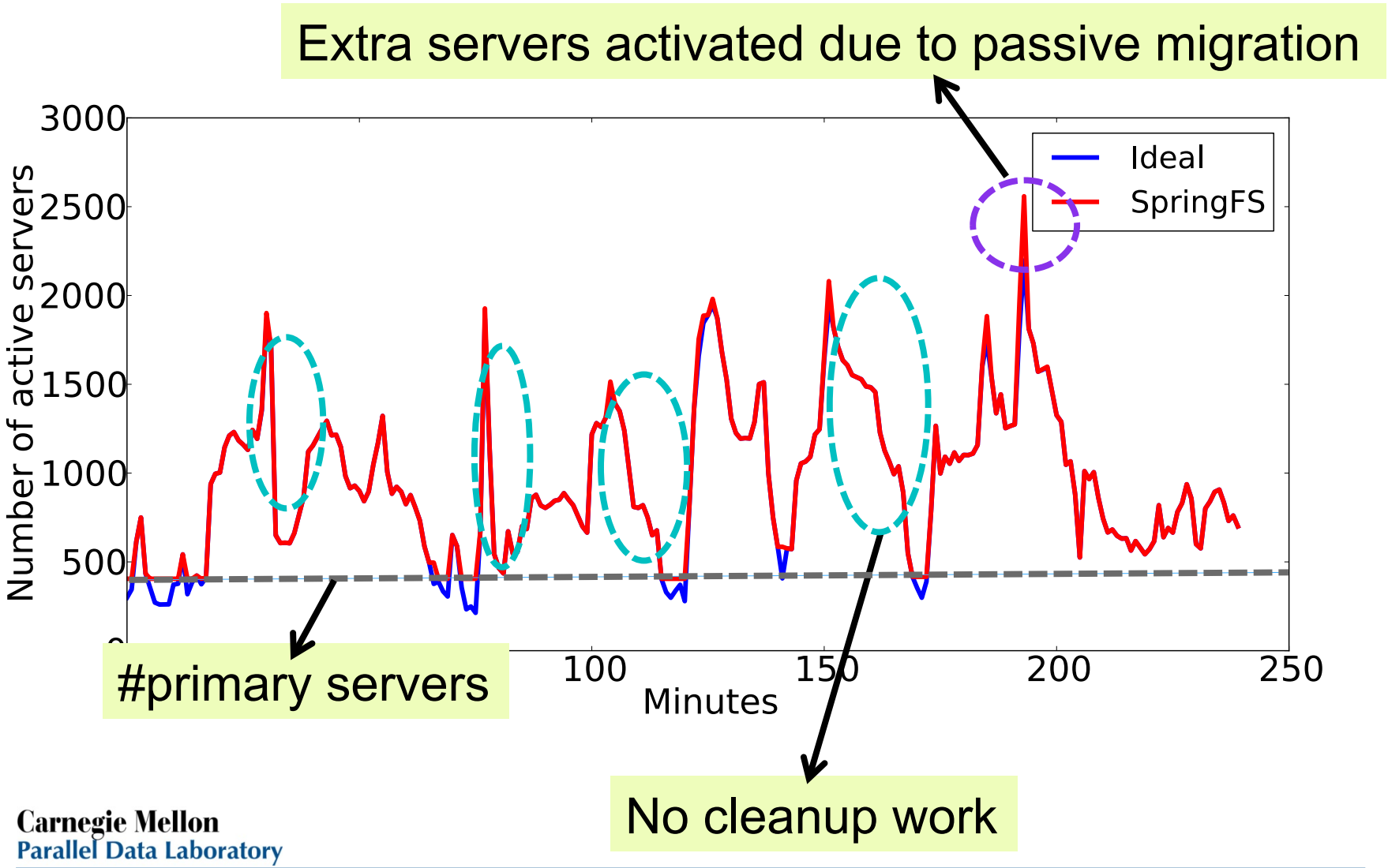
Same performance

Policy Analysis with the Facebook Trace

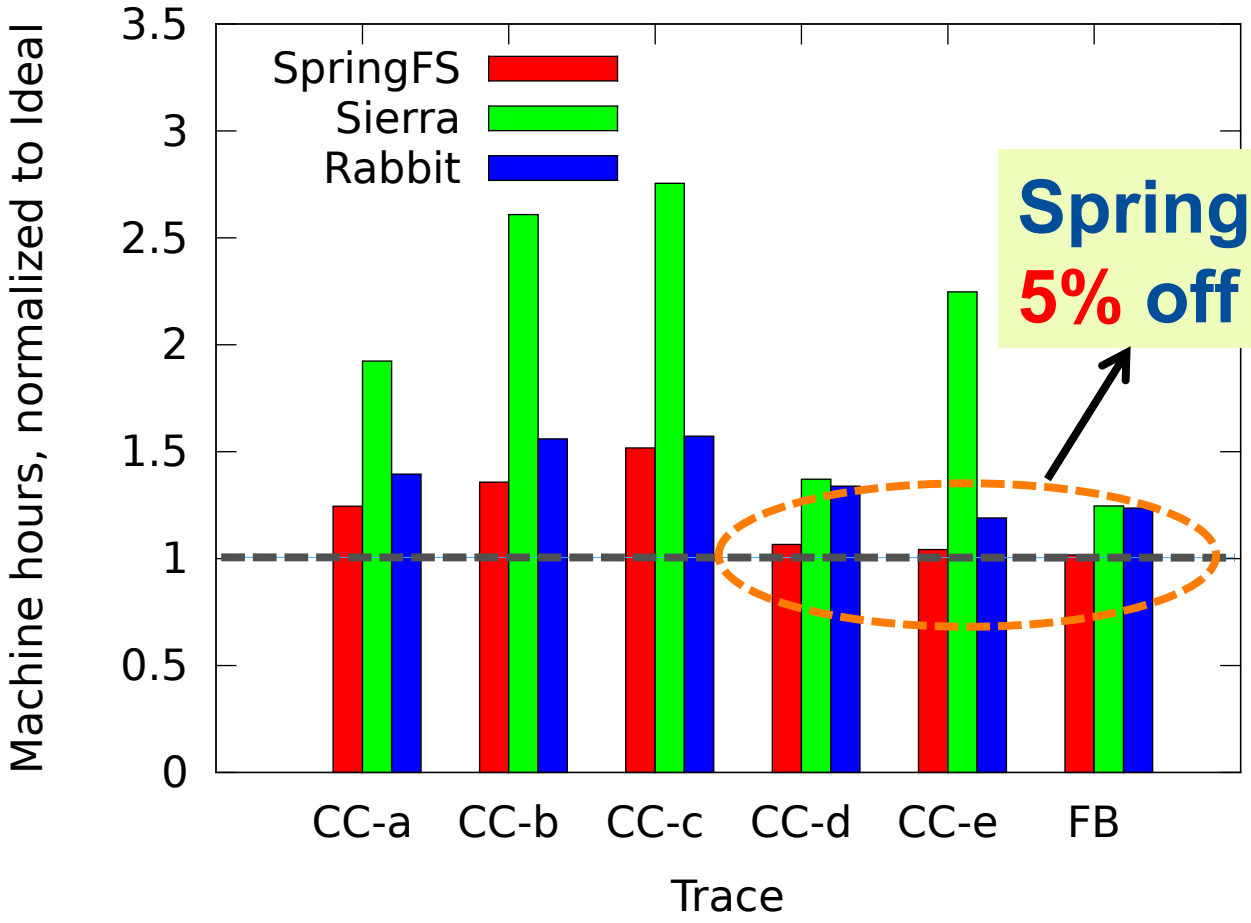


Area under curve: aggregate machine hour usage

Machine Hours (SpringFS vs. Ideal)



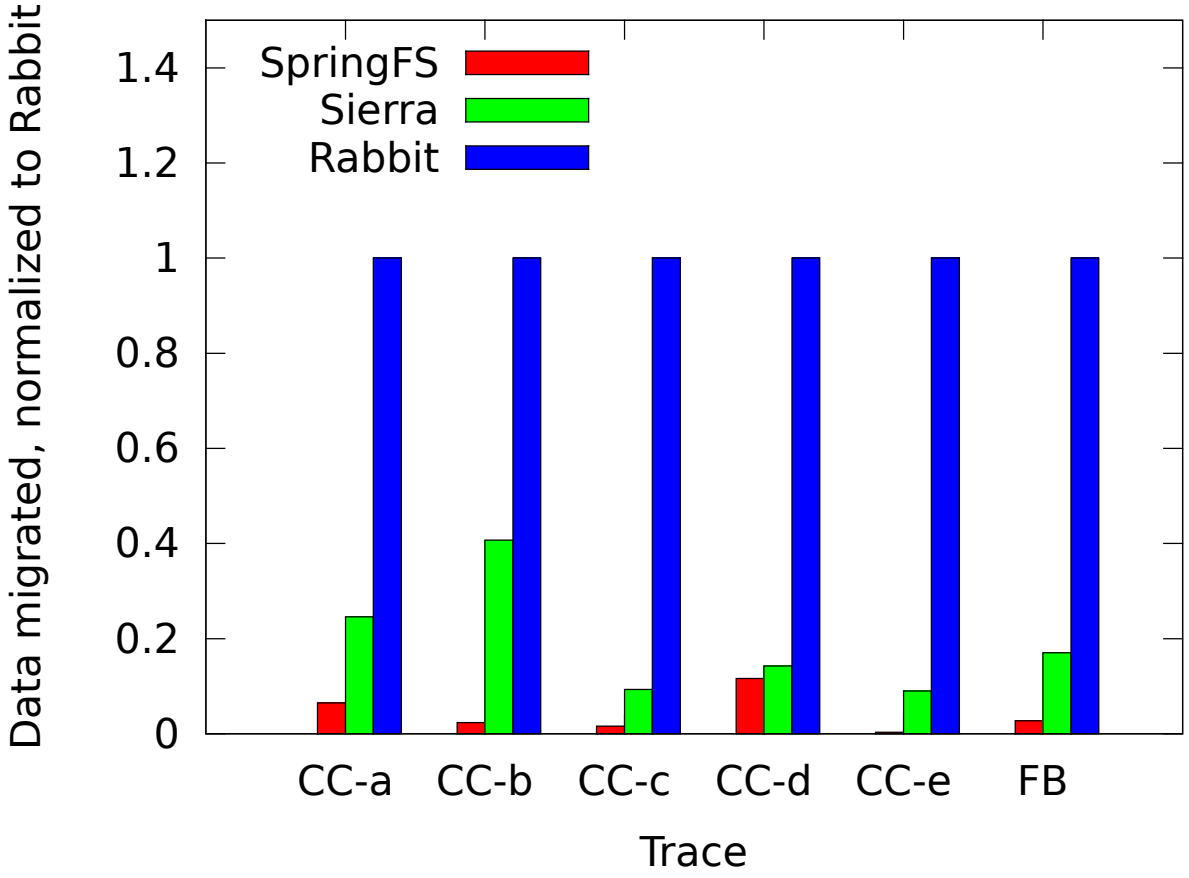
Machine Hour Usage



SpringFS within 5% off "Ideal"

SpringFS: 6-120% improvement

Data Migration



SpringFS: 9-208X improvement

Conclusion

- SpringFS: a new elastic distributed storage
  - Fills the gap in state-of-the-art designs
- Agility is important
  - Ability to track workload burstiness
- Address agility by minimizing data migration
  - Bounded write offloading
  - Read offloading + passive migration
- Much lower machine hour usage