Light-weighted HDFS Disaster Recovery

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Intel SSG/OTC

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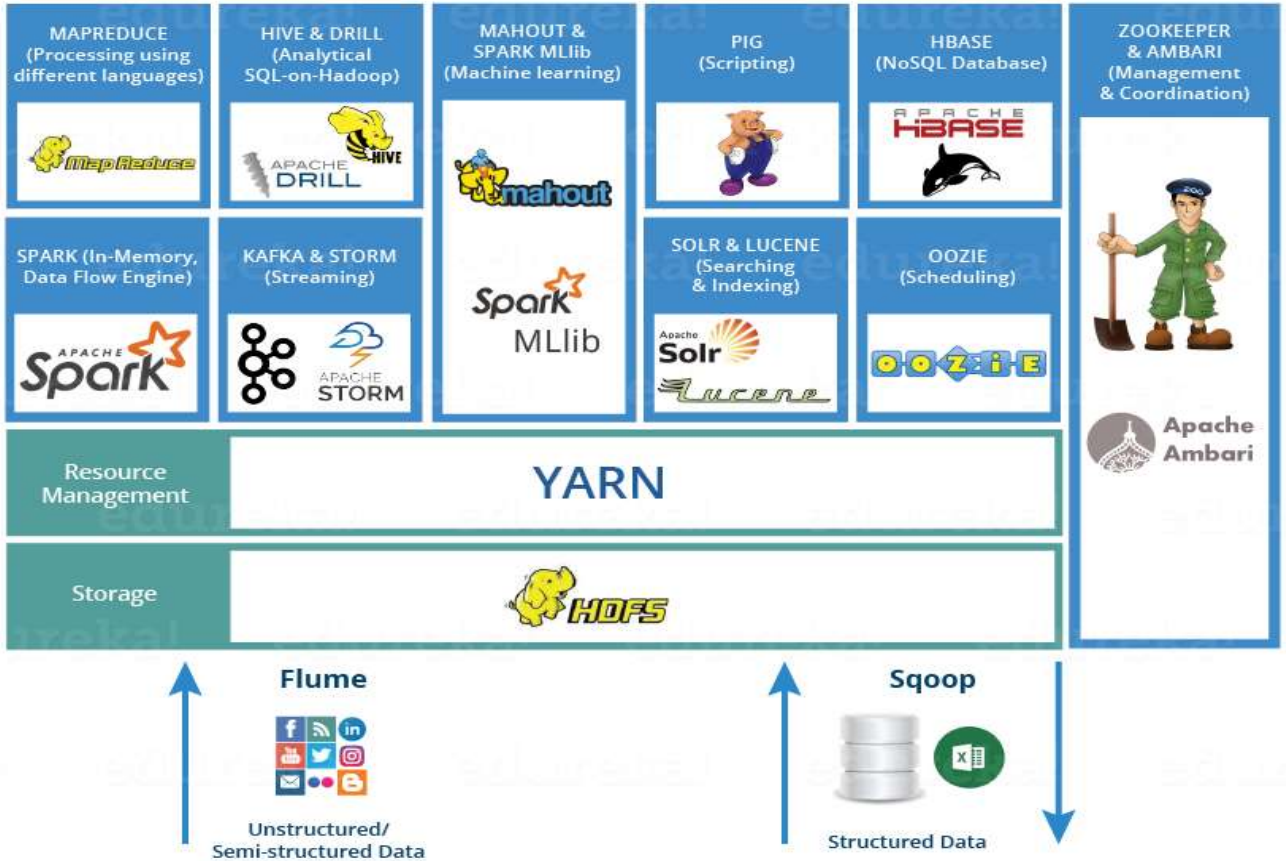
Outlines

- Background & Motivation
- Basic Design & Experience
- Evaluation
- Example & Demo

Background & Motivation

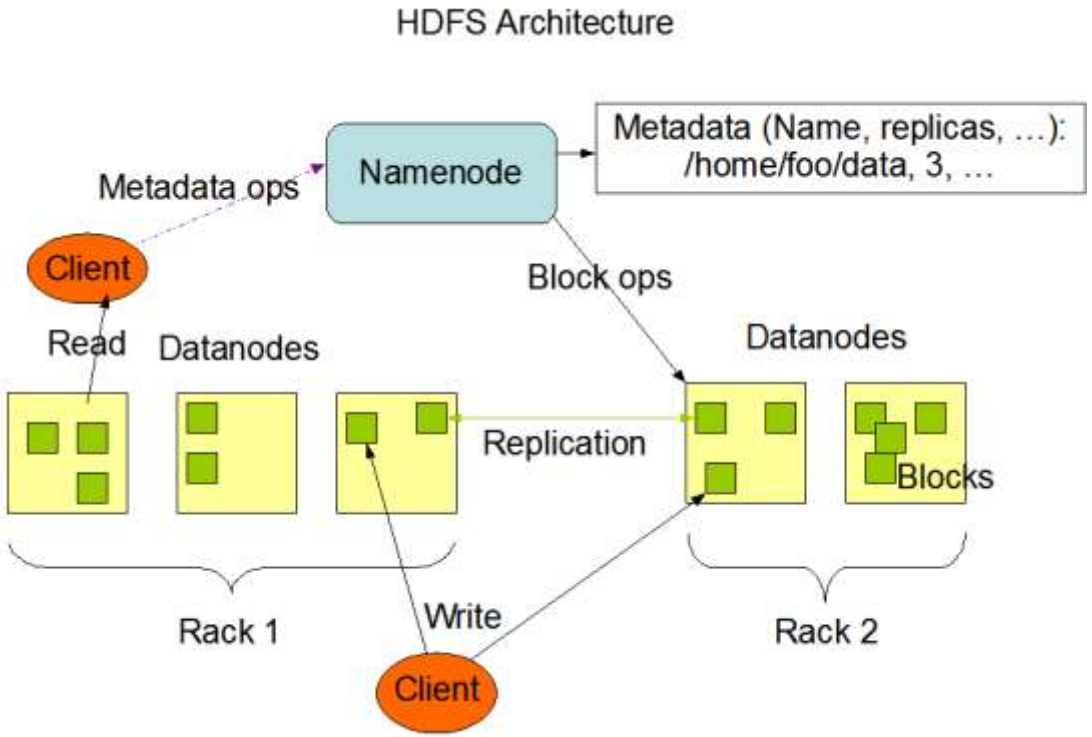
- HDFS (Hadoop Disturbed File System) is widely used in production



Source: https://www.edureka.co/blog/hadoop-ecosystem?utm_campaign=social-media-edureka-sep-ss&utm_medium=crosspost&utm_source=quora

Background & Motivation

- HDFS is architected to operate efficiently at scale for **normal hardware failures within a datacenter**
  - Disk, node or rack fails will not affect HDFS
- But HDFS is **not designed to handle datacenter failures**
  - If data center is down, we lost everything (meta and data)



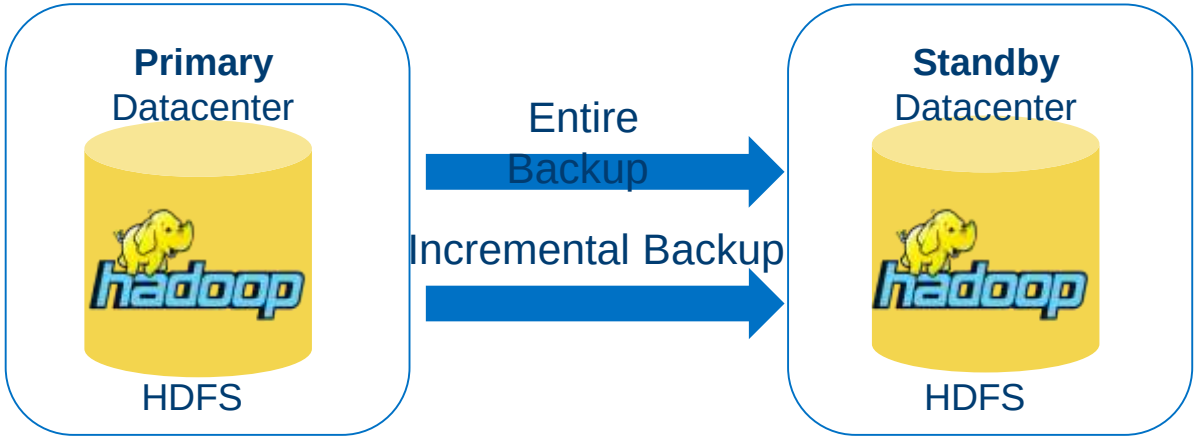
Source: https://hadoop.apache.org/docs/stable/hadoop-project-dist/hadoop-hdfs/HdfsDesign.html

Background & Motivation

- Disaster Recovery is not equal to backup
  - **Essential**
    - **Location Separated –** High latency & limited bandwidth
    - **No Data loss -** Backup & recovery
    - **High Availability –** Switch to standby data center
  - **Additional**
    - Performance - Higher is better
    - Resource Usage - Don’t use up all resource/ bandwidth
    - …
- **But let’s focus on backup**

Basic Design & Experience

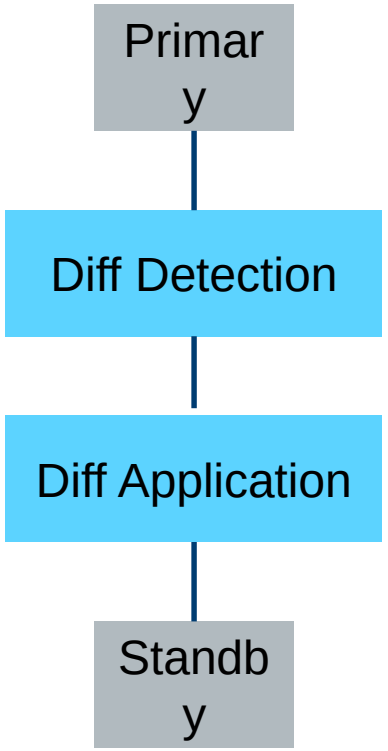
- Backup HDFS from Primary (local) to standby (remote)
  - Entire/Base backup – first backup, focus on performance, no tricks (compression and encryption)
  - **Incremental backup** – lots of **fun** & **pain**



Quit similar to version control system, such as Git

Basic Design & Experience

- **Incremental Backup**
  - **Diff detection - What is changed?**
    - Find out (**incremental)** difference
    - Building diff application tasks/list
  - **Diff application - How to apply changes to remote?**
    - Apply diff content to Standby Cluster
- **Key points**
  - Precise diff (algorithm)
  - Performance (concurrency) & Resource usage (CPU, memory and bandwidth)
  - Corner cases – merge failed with N conflicts



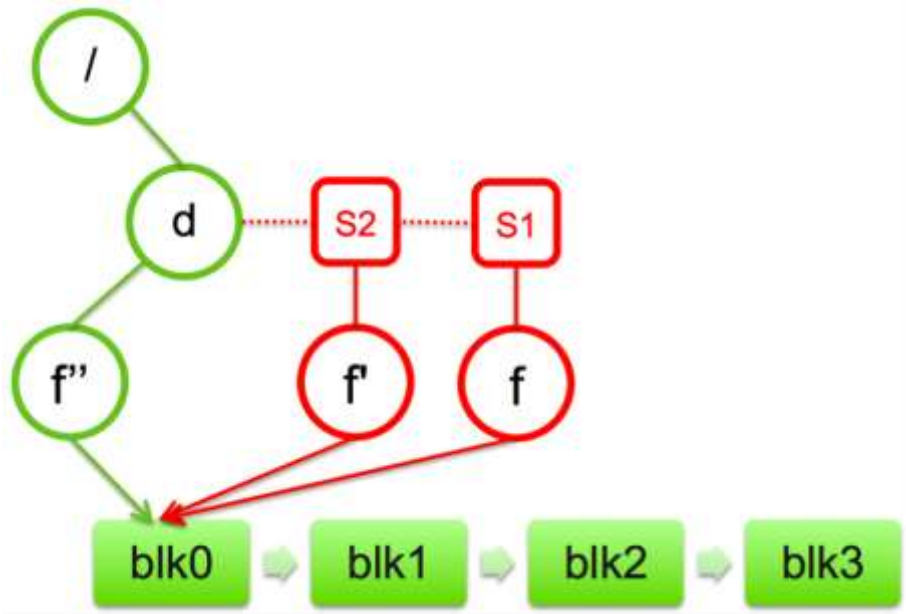
git fetch (patch) from remote

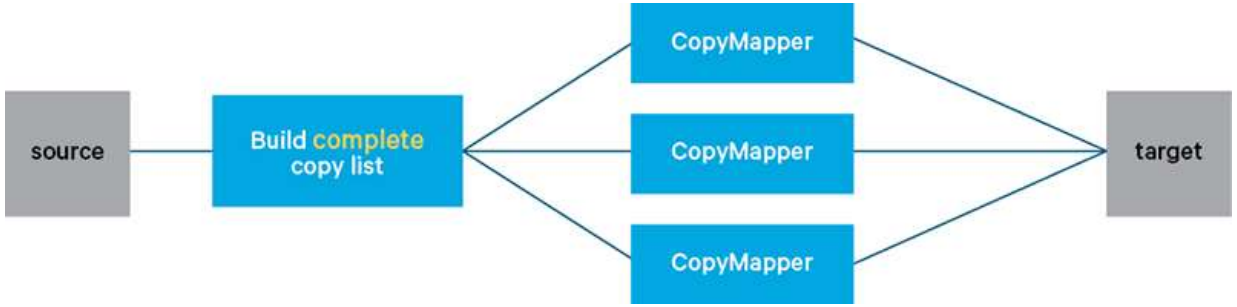
git rebase/merge

```
Auto-merging pom.xml
CONFLICT (content): Merge conflict in pom.xml
Automatic merge failed; fix conflicts and then commit the result.
```

Basic Design & Experience

- **DistCp's Advantages**
  - **Build-in** tool/command in Hadoop
  - Track changes with **Snapshot**
    - Snapshot report for diff detection (Create, Delete, Rename, Modify)
    - Copy from Snapshot (Snapshot is a reference which helps keeping deleted blocks)
  - Apply changes with **MapReduce**
    - Copy contents concurrently in block level
    - Old version in file level



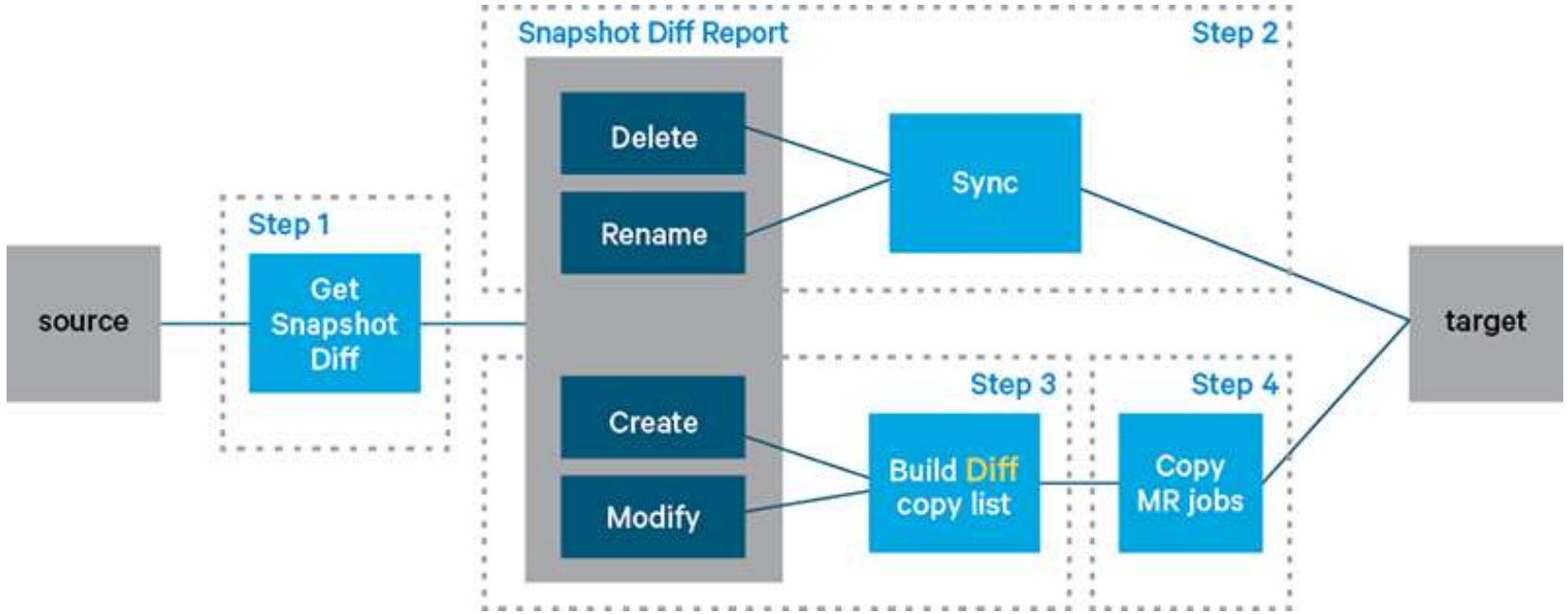


Source: https://community.hortonworks.com/articles/60546/hdfs-snapshots-1-overview.html
Source: http://blog.cloudera.com/blog/2015/12/distcp-performance-improvements-in-apache-hadoop/

Basic Design & Experience

- **DistCp does great jobs in most cases**

distcp -update -diff s0 s1 <sourceDir> <targetDir>



Source: http://blog.cloudera.com/blog/2015/12/distcp-performance-improvements-in-apache-hadoop/

Basic Design & Experience

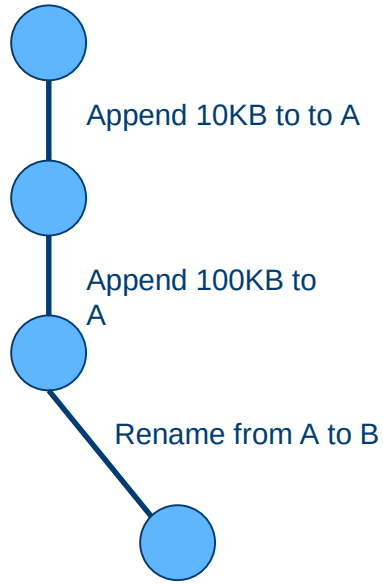
- **Pain points of DistCp:**
  - **Snapshot is not perfect**
    - Cannot take snapshot on root directory
    - **No details** about **Modify** (need to compare files)
    - **Corner cases**
  - **MapReduce is too heavy to incremental backup**
    - **1 container (2 GB memory & 1 core) for 10KB appe**
    - **Long launch time**
  - **Requires administrator** (failed tasks, snapshot manageme
  - No resource usage & bandwidth control

#	First op	Second op	Items in snapshot diff report	Extra Actions
1	create A	rename A -> B	create B	
2		rename A's parents C -> D	create C/A	Change path of create op from C/A -> D/A
3		rename A's child A/C -> A/D	create A	
4		rename a pre-existing C into A	create A	Exclude C while traversing A
5		rename A's child C out of A	create A, create C	
6		modify A	create A	
7		modify A's parents	create A, modify A's parents	
8		modify A's children	create A	
9		delete A	NULL	
10		delete A's parents	NULL	
11		delete A's children	create A	
12	modify A	rename A -> B	modify A, rename A -> B	Change path of modify op: A -> B
13		rename A's parents C -> D	modify A, rename A's parent C -> D	Change path of modify op: C/A -> D/A
14		rename A's children	modify A, rename A's children	
15		delete A	delete A	
16		delete A's parents	delete A's parent	
17		delete A's children	modify A	
18		create A	N/A	
19		create A's parents	N/A	
20		create A's children	modify A, create A's children	
21	delete A	create A	delete A, create A	
22		modify A	N/A	
23		rename A -> B	N/A	
24	rename A -> B	delete A	N/A	
25		delete A's parents-before-rename	delete A's parents-before-rename, rename A -> B[1]	
26		delete B's parents	delete B's parents, delete A	
27		delete A's children	N/A	
28		delete B's children	delete A's children, modify A, rename A -> B	Change path of modify op: A -> B
29		modify B	modify A, rename A -> B	Change path of modify op: A -> B
30		create A	create A, rename A -> B	No need to change path A of create op, since the newly created A is not the same as the old "A" which is renamed to B

Source: http://blog.cloudera.com/blog/2015/12/distcp-performance-improvements-in-apache-hadoop/

Basic Design & Experience

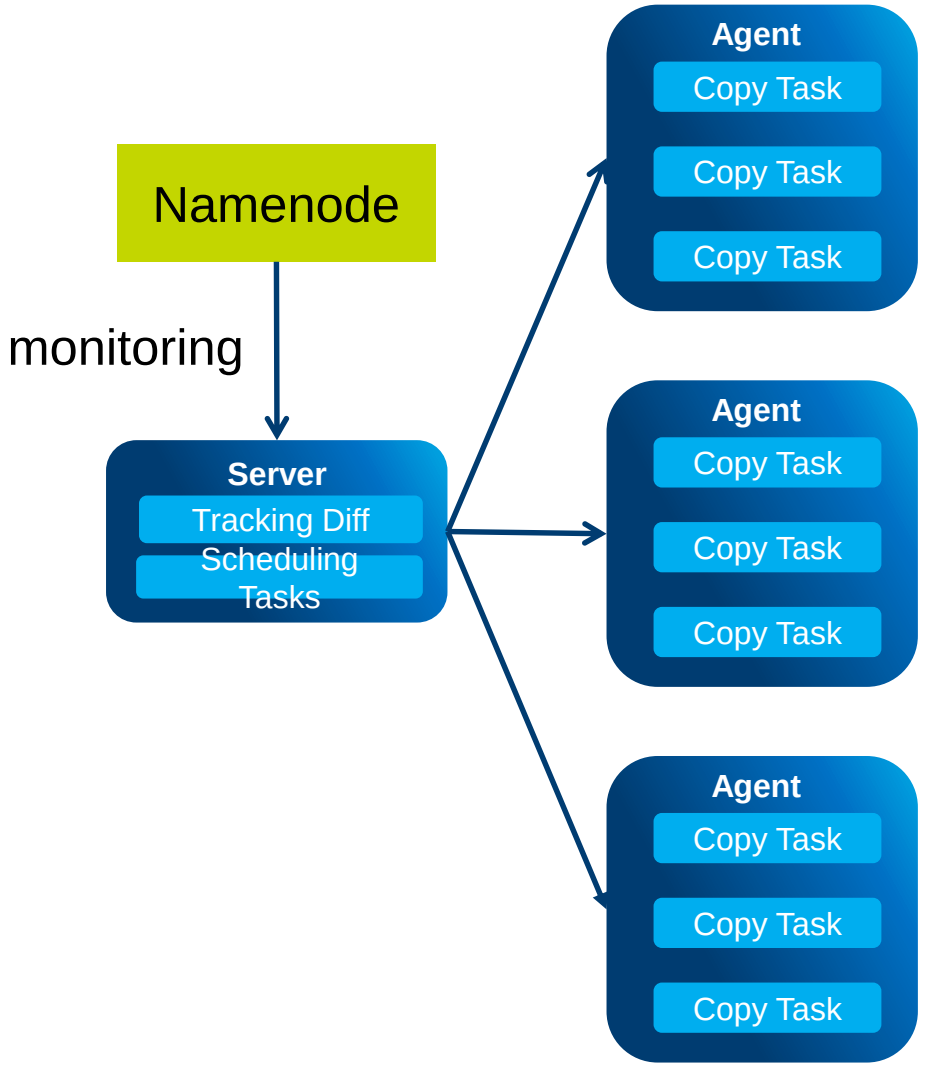
- **We want to address above problems in this way:**
  - **No Snapshot** – Track changes with **log (Inotify/editlog) post-processing**
    - Track changes in details (Create, Delete, Rename, **Meta**, **Close**, **Append**, **Truncate**) v.s. Snapshot (Create, Delete, Rename and Modify)
    - Build **lineage** from **Inotify** (subset of editlog)
    - Translate Events into tasks, e.g.,
      - Append means copy content from primary to remote
      - Delete means delete file in remote
      - …



Basic Design & Experience

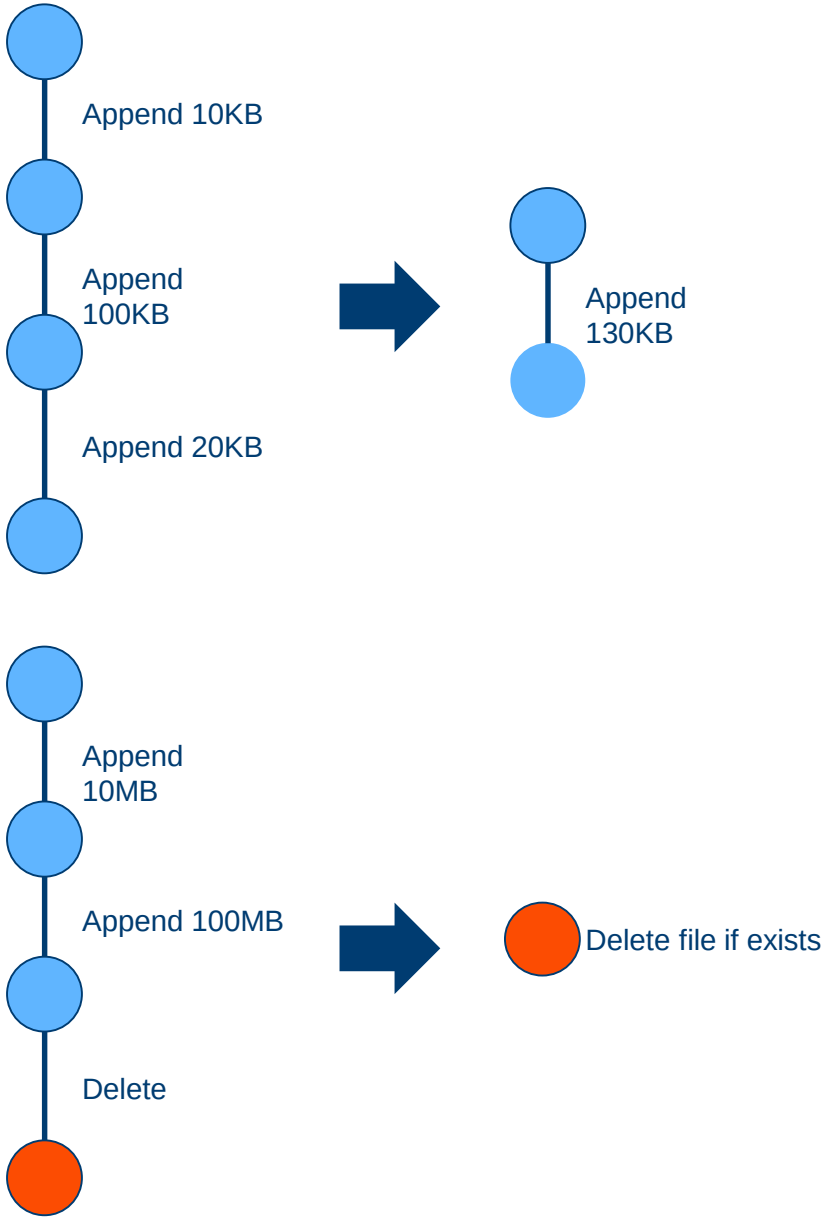
- **No MapReduce – Long running services**
  - Server
    - Tracking changes
    - Scheduling tasks
    - Resource and bandwidth management
  - Agents
    - Applying changes to remote

Sometimes, they don't even have MapReduce



Basic Design & Experience

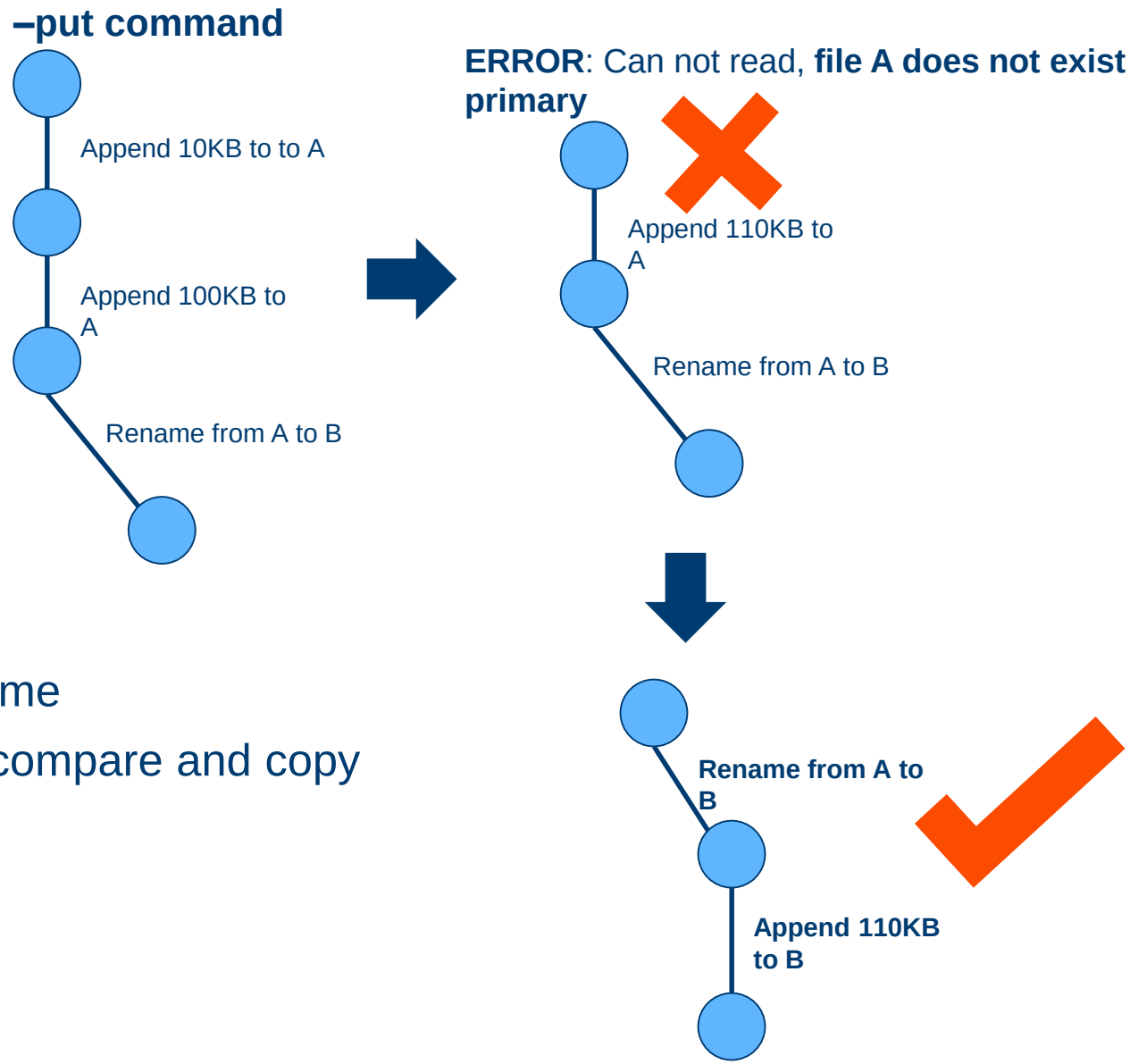
- **Advantages of SSM DR (Disaster Recovery)**
  - **Diff Detection: Log post-processing**
    - **Near real-time** diff detection
    - **More details than Snapshot, e.g., Modify**
    - Diff & Lineage is **mergeable**
    - Limited Impact to Namenode
      - Getting Inotify has **impact** to Namenode
      - Getting EditLog has **no impact**
  - **Diff Application: Long running Services**
    - Light-weighted for Cluster/Data center
    - Auto scale & bandwidth control
    - Can be Containerized



Background & Motivation

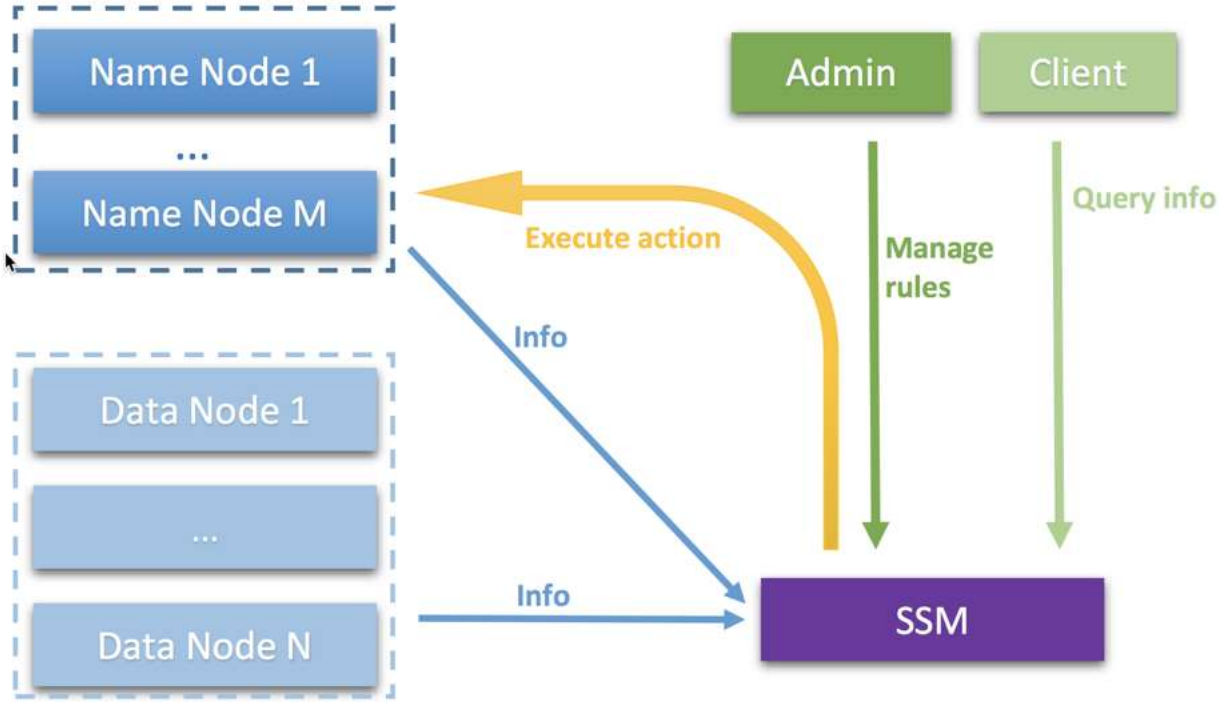
- **Pain points (painful experience)**
  - Corner cases
  - No more Locality

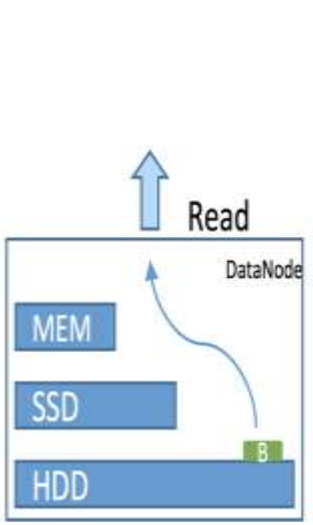
- How to handle it?
  - Corner cases
    - Handle general cases, such as rename
    - Let tasks fail, then trigger a directly compare and copy
  - No Locality
    - High speed network
    - Place agent near datanodes

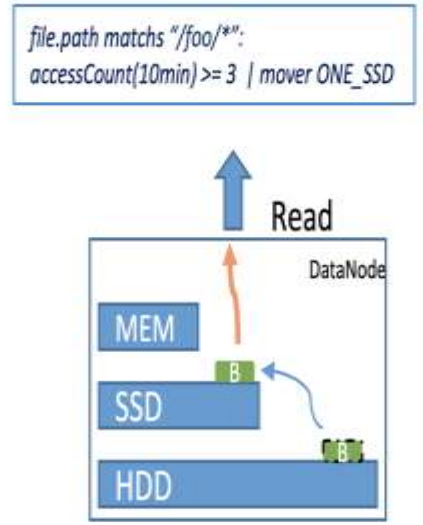


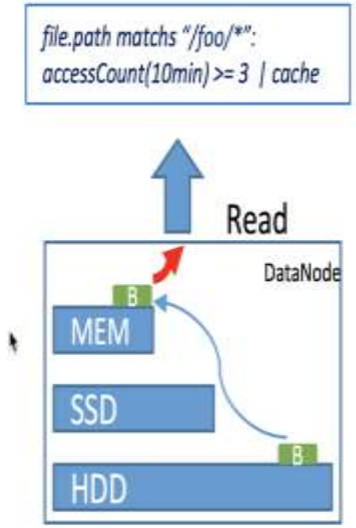
Basic Design & Experience

- Build Disaster Recovery Based on SSM (Smart Storage Management, Open source on Github)



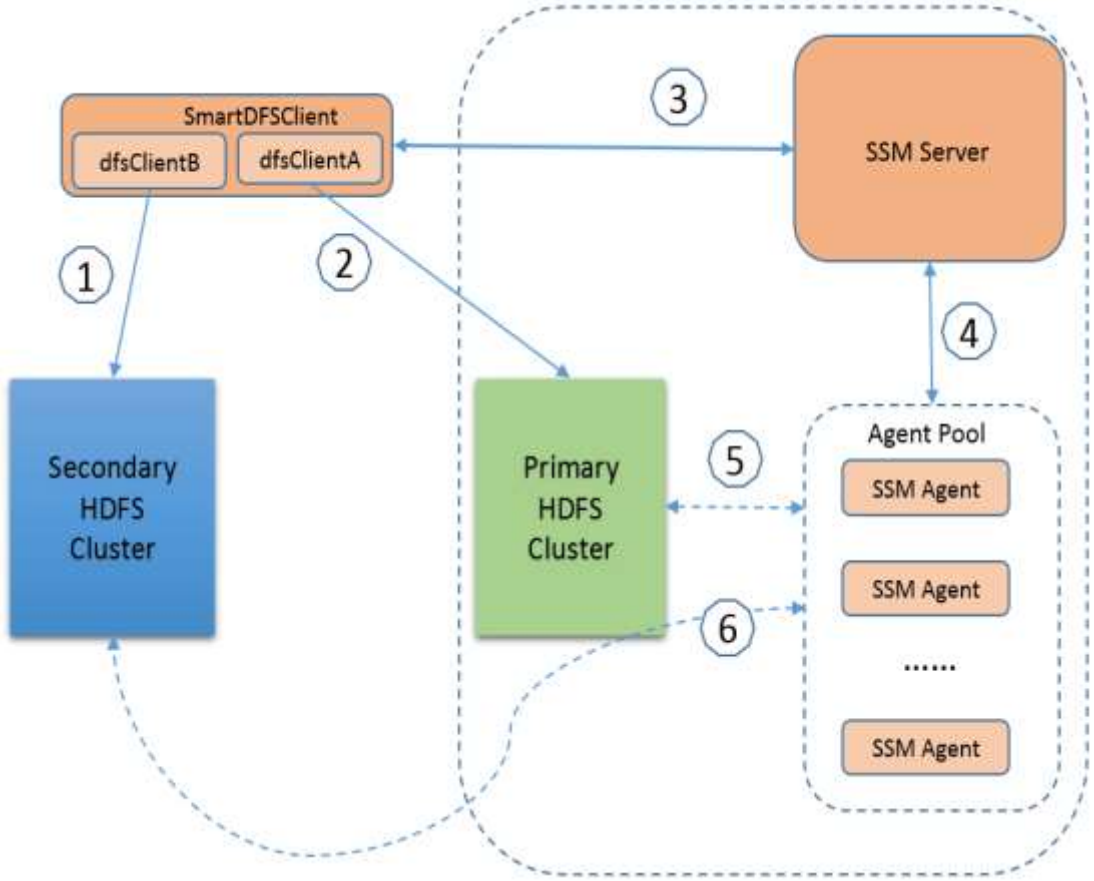






Basic Design & Experience

- Reuse SSM modules and metadata
  - SSM's Metadata for diff detection
  - SSM's modules (Agents and actions) for diff applicati
- Features
  - Smart management based on Rules
  - Near real time incremental backup
  - Less resource requirement
  - High Availability & Transparent read/backup (TODO)



Evaluation - Test Environment

HDFS Clusters

- Primary HDFS 4 Nodes
- Secondary HDFS 4 Nodes

SSM

- SSM Server
- 3 SSM Agents installed on Primary datanodes

Testing Methodology

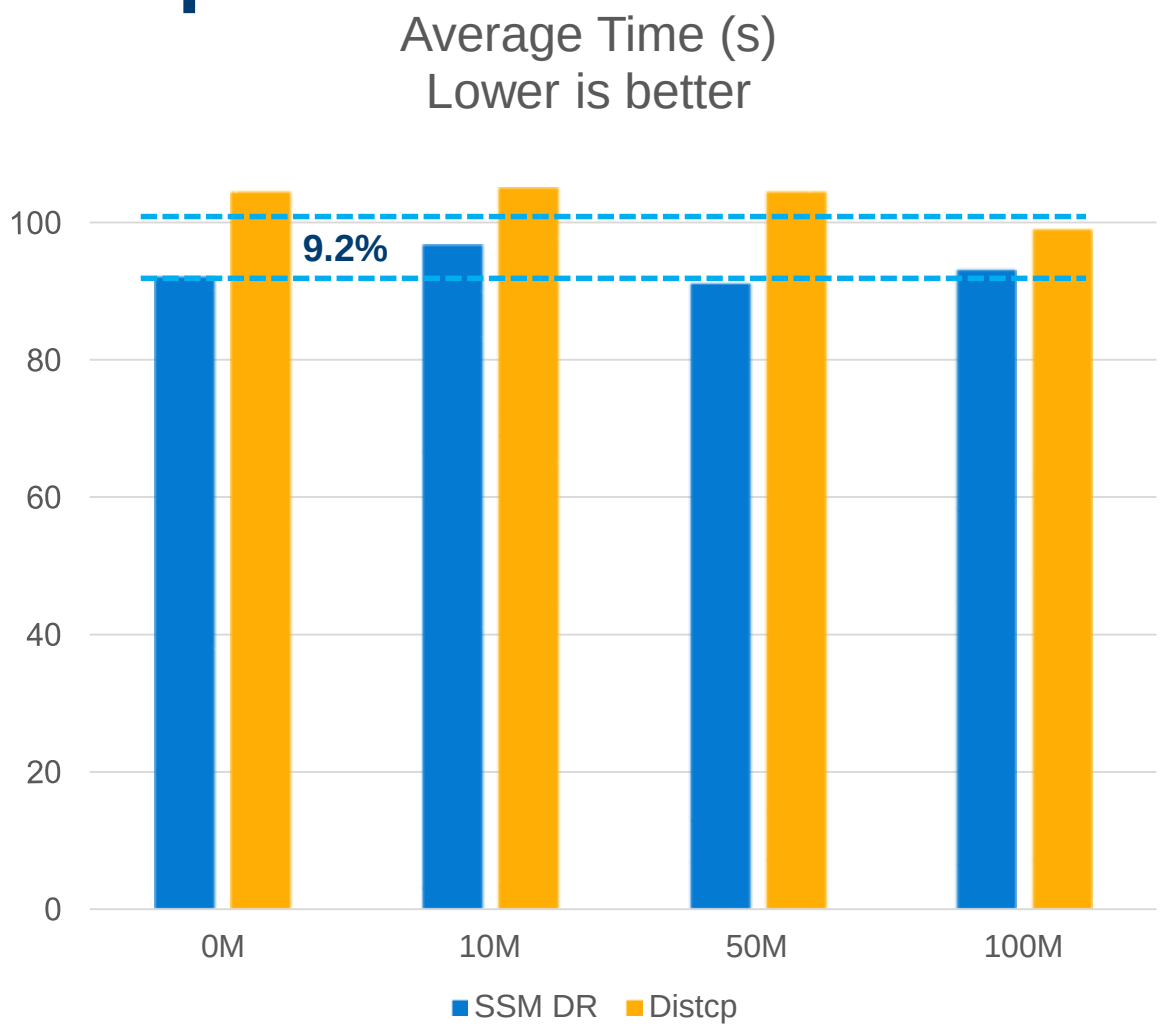
- Compare SSM DR with distcp
  - 10K small files – 1MB
  - 1K large files – 100MB

Hardware configuration	
Processor	Intel(R) Xeon(R) CPU E5-2699 v3 @ 2.30GHz
DRAM	256GB DDR4 16x16GB @ 2133MHz
Network	10GbE
Disks	5 x SATA(2TB) ST2000NM0011

Software configuration	
OS	CentOS 7.3.1611 x86_64
Hadoop	2.7.3
Metastore	Mysql 5.7.19
Java	JDK1.7.0_141

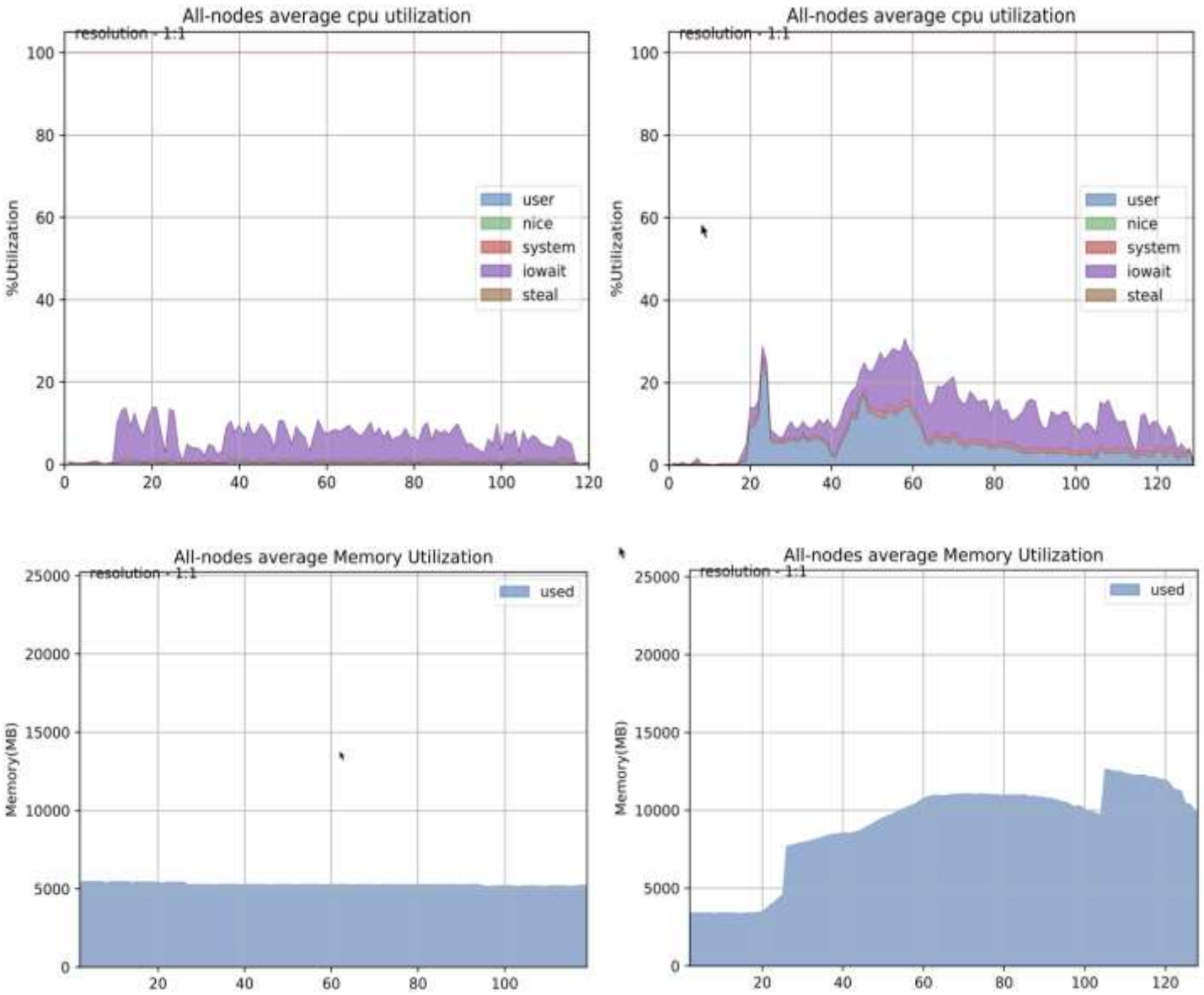
Workload-2 1MB Files Batch Backup

- Workload:
  - **10000 files * (1MB**) and 60-concurrency
- Result:
  - SSM DR will performer 9.2% **better** than DistCp



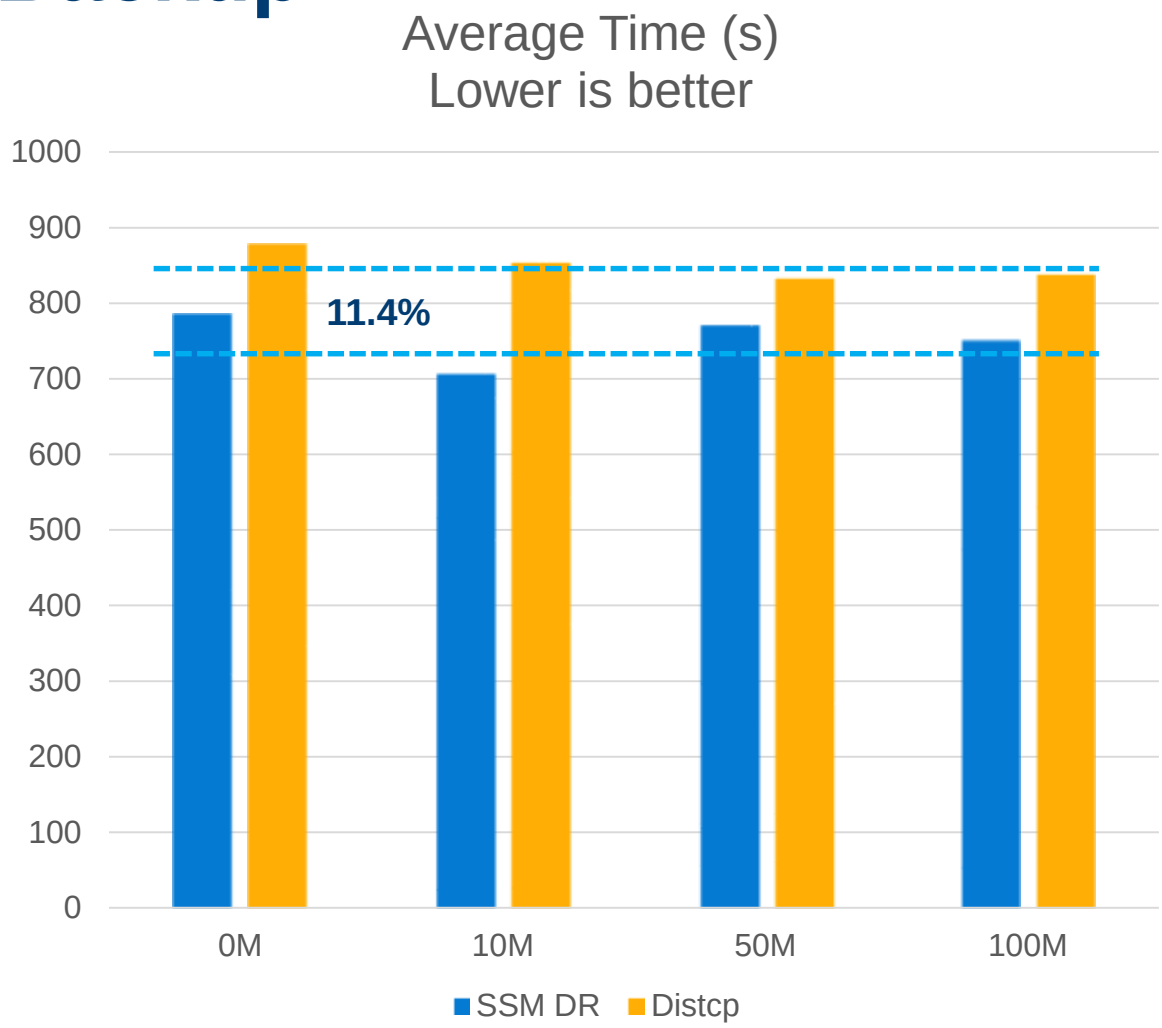
Resource Usage

- Workload:
  - Batch backup files (**10000 *1MB**)
- Result:
  - SSM DR requires **less** resource than DistCp on working nodes
    - **46%** less CPU
    - **41%** less memory



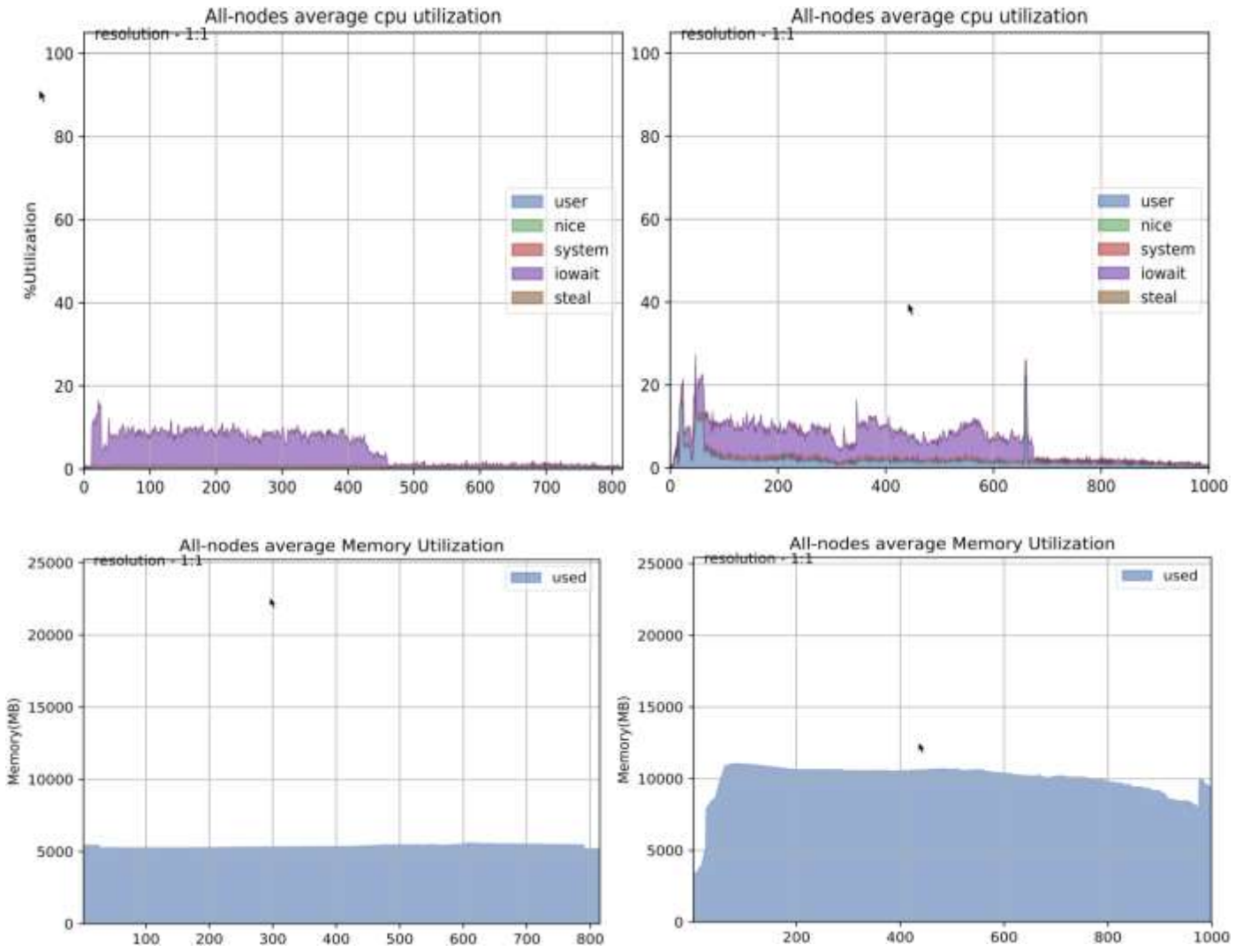
Workload-2 100MB Files Batch Backup

- Workload:
  - 1000 files * (100MB) and 60 concurrency
- Result:
  - SSM DR performs 11.4% **better** than DistCp



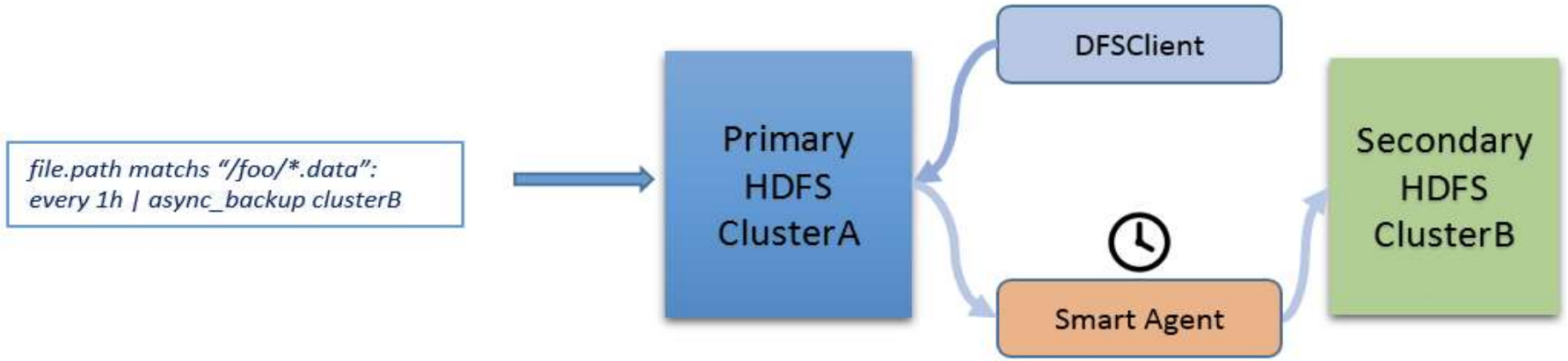
Resource Usage

- Workload:
  - Batch backup files (**1000 *100MB**)
- Result:
  - SSM DR requires **less** resource than DistCp on working nodes
    - **26%** less CPU
    - **46%** less memory



SSM Disaster Recovery: Example and Demo

- Rule
  - file: every 500ms | path matches "/src1/*" | sync –dest hdfs://namenode:9000/dest1/
  - file: every 2s | path matches "/src/*.txt" | sync –dest hdfs://namenode3:9000/dest/



Thanks

- Q&A
- More details
  - https://issues.apache.org/jira/browse/HDFS-7343
  - https://events.static.linuxfound.org/sites/events/files/slides/ApacheBigDataEurope2016-SSM.pdf
  - https://github.com/Intel-bigdata/SSM

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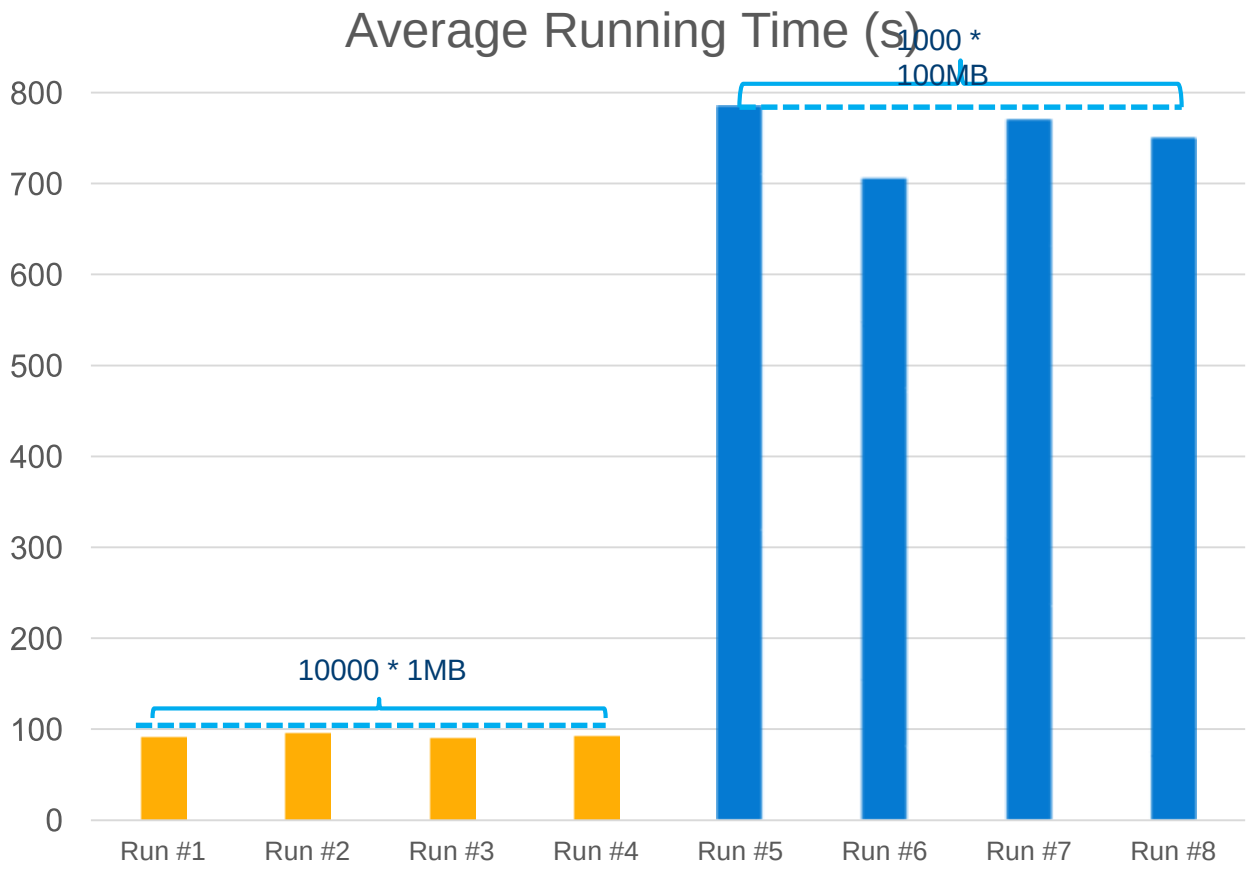
Namespace Impact on SSM's Performance

- Workload:
  - Batch backup files
  - (0M, 10M, 50M, 100M) files in namespace
- Result:
  - Namespace has **very limited** impact on SSM Disaster Recovery's performance



Basic Design & Experience

- **Diff Detection**

Methods	View	Advantage	Dis-advantage
Directly Scan	Result view	Easy to develop	1. Long laterncy 2. Network overhead 3. Impact to Namenode 4. Not real-time
HDFS Snapshot	Result view	Easy to develop	1. A few constrains caused by snapshot 2. Impact to namenode 3. Not real-time
Log based	Continually View	**1. Real time async is possible** **2. Less impact to namenode**	Hard to develop and maintain

- V
  - Nearly real-time Async based on incremental diffs
  - Limited or no impact to namenode

Basic Design & Experience

- **Diff Detection**

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- V
  - Nearly real-time Async based on incremental diffs
  - Limited or no impact to namenode

Basic Design & Experience

- Diff Application

Methods	Advantage	Dis-advantage
Container based (e.g., map-reduce)	Easy to develop	1. More resource 2. Less parallelism in the same cluster
Task based	**1. Less resource usage** **2. More parallelism (multiple tasks in single container)**	1. In some cases, agents needed 2. Hard to develop

- We found: **Task based** is works better
  - **Light-weighted: multiple tasks in one container**
  - Hard to develop is not a question any more: lots of distributed frameworks, e.g., Akka

Basic Design & Experience

- Our **light-weighted** DR basic design
  - Diff Detection without Snapshot
    - Long running service monitoring **Editlog or Inotify**
    - **Directly Scan** to handle corner cases and namespace mis-match
  - Diff Application without Map-reduce
    - **Agents based on Akka** (can be replaced by other frameworks)
      - **Master** dispatch diff application tasks
      - **Slaves** apply diff to remote (multiple tasks in one container)

Light-weighted for Cluster/Data center:

1. Limited Impact to HDFS (HDFS event don't know DR
2. Less resource requirement
3. Can be Containerized (in future)