Understanding Issue Correlations:
A Case Study of the Hadoop System

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Washington State University
Why Issue Study Matters?

Scalable distributed systems are complex [Yuan et al., OSDI’14]

Complicated System
Why Issue Study Matters?

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Complicated System + Error-prone
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Scalable distributed systems are complex [Yuan et al., OSDI’14]

Complicated System + Error-prone + Hard to Debug
Why Issue Study Matters?

Scalable distributed systems are complex [Yuan et al., OSDI’14]

Complicated System + Error-prone + Hard to Debug = Issue Study

Issue Pattern
Why Issue Study Matters?

Scalable distributed systems are complex [Yuan et al., OSDI’14]

Complicated System + Error-prone + Hard to Debug

Issue Study

Issue Pattern → Better Software & Debugging Tools
Hadoop: A Representative Distributed System
Hadoop: A Representative Distributed System

The Evolution of Apache Hadoop

- HDFS (Storage)
- MapReduce (Computation)

Number of Reported Issues (x1000)

The Evolution of Apache Hadoop

Hadoop: A Representative Distributed System

The Evolution of Apache Hadoop

Number of Reported Issues (x1000)

The Evolution of Apache Hadoop

HDFS (Storage)  MapReduce (Computation)
Hadoop: A Representative Distributed System

Learn from issues – more than 6 years of experience.
What Can We Learn From Issues?

Related Work

[Gunawi et al., SoCC’14]
What Bugs Live in the Cloud?

[Lu et al., FAST’13]
A Study of Linux File System Evolution
What Can We Learn From Issues?

Related Work

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A Study of Linux File System Evolution

Our Focus: Issue Correlations

Programming
Systems
Tools
Our Findings

- Half of the issues are independent
- MapReduce issues tend to relate to YARN
- One third of the issues have similar causes
- .......

[Diagram with ladybugs connected by lines]
Our Findings

- Half of the issues are independent
- MapReduce issues tend to relate to YARN
- One third of the issues have similar causes
- ......

- Memory: GC is still the No. 1 concern
- Storage: “99.99% of data reliability” is challenged
- Programming: one third of them relate to interfaces
- Tools: the logging in Hadoop is error-prone
- ......
Methodology Used in Our Study

Hadoop Ecosystem

- Hive
- HCatalog
- MapReduce
- HDFS

- Pig
- Mahout
- HBase
- Flume
- Cascading
Methodology Used in Our Study

**Computation**
- Hive
- HCatalog
- MapReduce

**Storage**
- HDFS

**Toolkits**
- Pig
- Flume
- Mahout
- Cascading

Hadoop Ecosystem
Methodology Used in Our Study

Computation
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Storage
- HDFS

Hadoop Ecosystem

Closed Issues
- 2359

Examined Issues
- 2180
Methodology Used in Our Study

**Computation**
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- HDFS
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Closed Issues: 2359
Examined Issues: 2180

Sampling Rate: 89.8%
Methodology Used in Our Study

Computation
- Hive
- HCatalog
- MapReduce

Storage
- HDFS

Hadoop Ecosystem

Closed Issues: 2359
Examined Issues: 2180
Sampling Period: ~6 years

Examined Issues: 2038
Sampling Period: 5 years

Sampling Rate: 89.8%
Methodology Used in Our Study

Issues

Description → Patches → Follow-up Discussions → Source Code Analysis
Methodology Used in Our Study

Issues

- Description
- Patches
- Follow-up Discussions
- Source Code Analysis

Labeling

- IssueID
- Subcomponent
- Type
- Causes
- CorrelatedIssueID
- Create/Commit Time

HPatchDB
Where Are the Correlated Issues From?

Do you know where I’m from?
Where Are the Correlated Issues From?

**External Correlation**
correlated issues appear in other systems

**Internal Correlation**
correlated issues appear in the same system

Where Are the Correlated Issues From?

<table>
<thead>
<tr>
<th></th>
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<td>External</td>
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A significant number of issues are independent.

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Half of them are from YARN.
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How the Issues Are Correlated?

Do you know our relationship?
How the Issues Are Correlated?

- **Similar Causes**
  Issues have similar causes

- **Blocking Other Issues**
  Issues need to be fixed before fixing other issues

- **Fix on Fix**
  Issues are caused by fixing other issues
26-33% of the issues have similar causes.
How the Issues Are Correlated?

These issues that block others appear more frequently in HDFS.

- **Percentage (%)**
  - **Similar Causes**
  - **Blocking Other Issues**
  - **Fix on Fix**

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<td>25%</td>
<td>30%</td>
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<tr>
<td>Blocking Other Issues</td>
<td>15%</td>
<td>10%</td>
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<td>Fix on Fix</td>
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How the Issues Are Correlated?

Mostly due to functional dependency.

- Similar Causes
- Blocking Other Issues
- Fix on Fix

![Graph showing percentage distribution for HDFS and MapReduce](image-url)
On the Issue Correlations with System Characteristics
On the Issue Correlations with System Characteristics

- 47%: Systems
- 27%: Programming
- 26%: Tools
How Issues Relate to Systems?
How Issues Relate to Systems?

![Graph showing the percentage of issues related to different systems. The systems include HDFS and MapReduce. The bars are color-coded to represent different categories: security, networking, storage, file system, memory, and cache. The percentages are not explicitly stated, but the graph visually compares the contributions of each category to the issues in the respective systems.]
How Issues Relate to Systems?

GC is still the No.1 concern, memory-friendly objects are preferred.

- LightWeightGSet Vs. java.util structure
- Object cache for long lived object: ReplicasMap, ReplicasInfo

Percentage (%)

HDFS | MapReduce

security | networking | storage | file system | memory | cache
How Issues Relate to Systems?

Many issues happened in file system like EXT4 appear in Hadoop.

File system semantic:
namespace management, file permission, consistency (e.g., fsck), etc.
How Issues Relate to Systems?

The statement of the 99.99% of data reliability in cloud storage is challenged.

Issues in rack placement policy:
0.16% of blocks and their replicas are in the same rack upon system upgrade.
One quarter of networking issues cause resource wastage.

Read a block:
Peer peer = new TcpPeer(dnAddr),
- return newBlockReader(…)
+ try{
+ reader = newBlockReader(…)
+ return reader
+ } catch (IOException ex) {
+ throw ex;
+ } finally {
+ if(reader == null) closeQuietly(peer);
+ }
How Issues Relate to Programming?

Percentage (%)

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<td>lock</td>
<td>20%</td>
<td>10%</td>
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<tr>
<td>interface</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>maintenance</td>
<td>10%</td>
<td>60%</td>
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How Issues Relate to Programming?

Half of them relate to code maintenance.
How Issues Relate to Programming?

Mainly caused by interface changes.
How Issues Relate to Programming?

5.6% of programming issues are caused by typos!

A fsimage cannot be accessed due to:
- `elif [ "COMMAND" = "oiv_legacy" ] then`
+ `elif [ "$COMMAND" = "oiv_legacy" ] then`
How Issues Relate to Tools?

The chart illustrates the percentage distribution of issues related to tools. The x-axis represents HDFS and MapReduce, while the y-axis shows the percentage (%) of issues. The issues are categorized into four types: configuration, debugging, documents, and testing.

- **HDFS**:
  - Configuration: 20%
  - Debugging: 40%
  - Documents: 30%
  - Testing: 10%

- **MapReduce**:
  - Configuration: 20%
  - Debugging: 50%
  - Documents: 30%
  - Testing: 10%
Logs are misleading: incorrect, incomplete, indistinct output.
How Issues Relate to Tools?

Logs are misleading: incorrect, incomplete, indistinct output.

Accessing a non-exist file via WebHDFS, FileNotFoundException is expected, but we get this:

```java
org.apache.hadoop.ipc.RemoteException: user = biadmin, proxyUser = null, path = /testWebhdfs
at org.apache.hadoop.hdfs.web.JsonUtil.toRemoteException(JsonUtil.java:114)
  at org.apache.hadoop.fs.FileSystem.exists(FileSystem.java:758)
```
A majority of configuration issues are related to system performance.

59% of the 219 configuration parameters in MapReduce are performance related.
Conclusion

1. Correlations Between Issues
   Issues are independent; 33% of issues have similar causes, etc.

2. Correlations With System Characteristics
   More efforts are required to achieve highly reliable distributed system
Thanks!

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Q&A