Using XRootD to Minimize Hadoop Replication

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Introduction

- The UCSD T2 uses the Hadoop Distributed File System (HDFS) for our Storage Element
- Hadoop cuts a file into small chunks known as blocks
- These blocks are distributed throughout the cluster
- Blocks are replicated N times to provide redundancy
- The UCSD T2 is also a part of the AAA CMS XRootD Federation
- The Federation provides global redundancy for files that are available at multiple CMS sites

HDFS XRootD Fallback

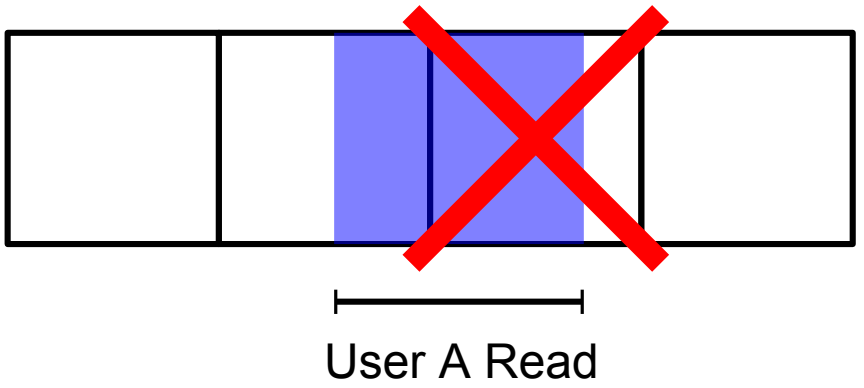
- Local Hadoop replication is expensive!
  - If N=2 we only get to utilize half our physical disk for storage
- Why not take advantage of the global replication the XRootD Federation already provides us?
- At UCSD we have developed a system that does exactly this, the **HDFS XRootD Fallback system**
- HDFS Fallback allows a site to reduce Hadoop replication to 1, freeing up considerable local physical space

HDFS XRootD Fallback

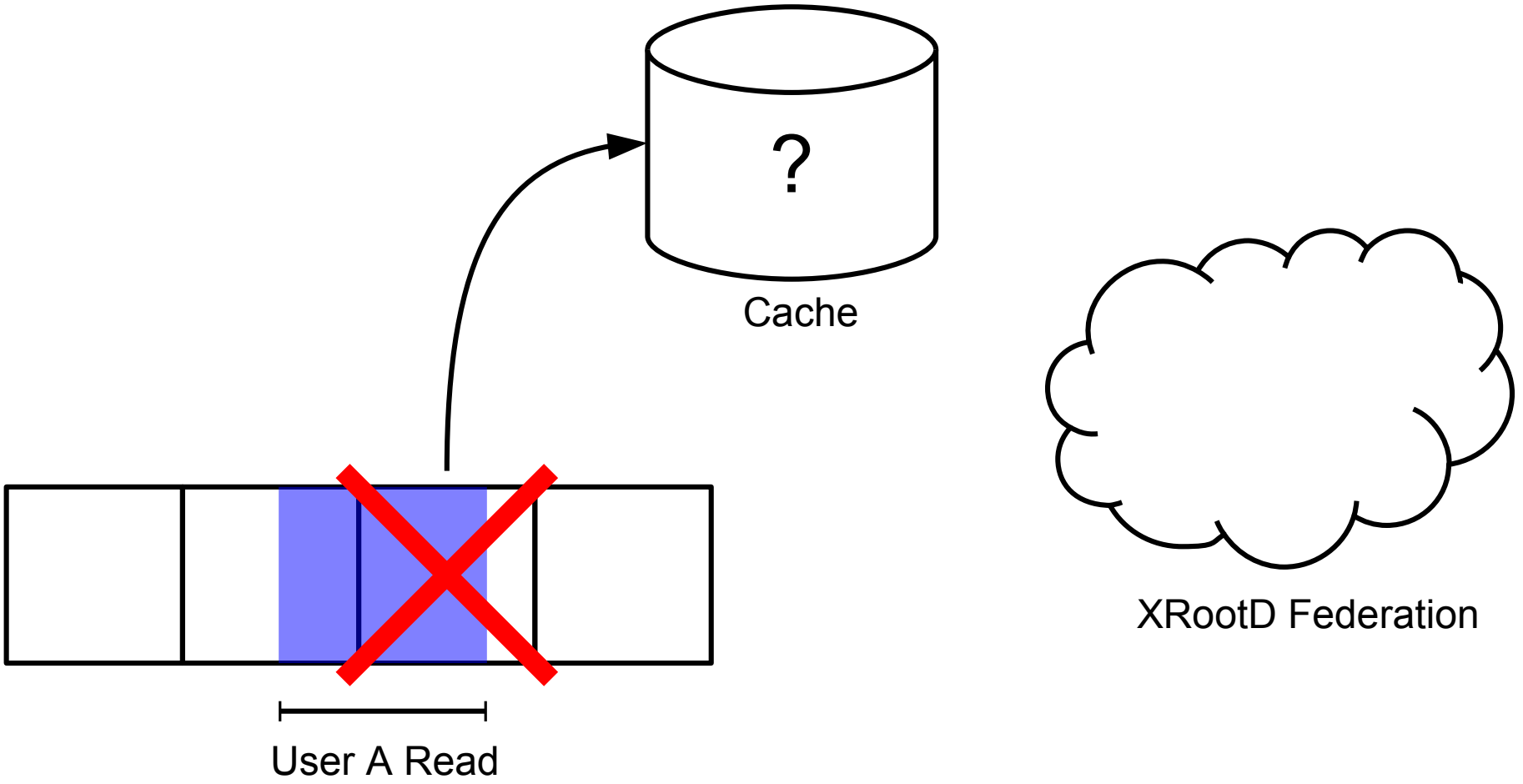
- The architecture is composed of two major components:
- **hdfs-xrootd-fallback** – accesses broken blocks on demand via XRootD, and caches them locally for future requests
- **hdfs-xrootd-healer** – injects fallback-fetched blocks back into hadoop to repair broken files in local storage

Fallback Architecture

- In Hadoop, if a file block cannot be located anywhere, the read will throw an IOException when a user program tries to access that portion of the file



Fallback Architecture



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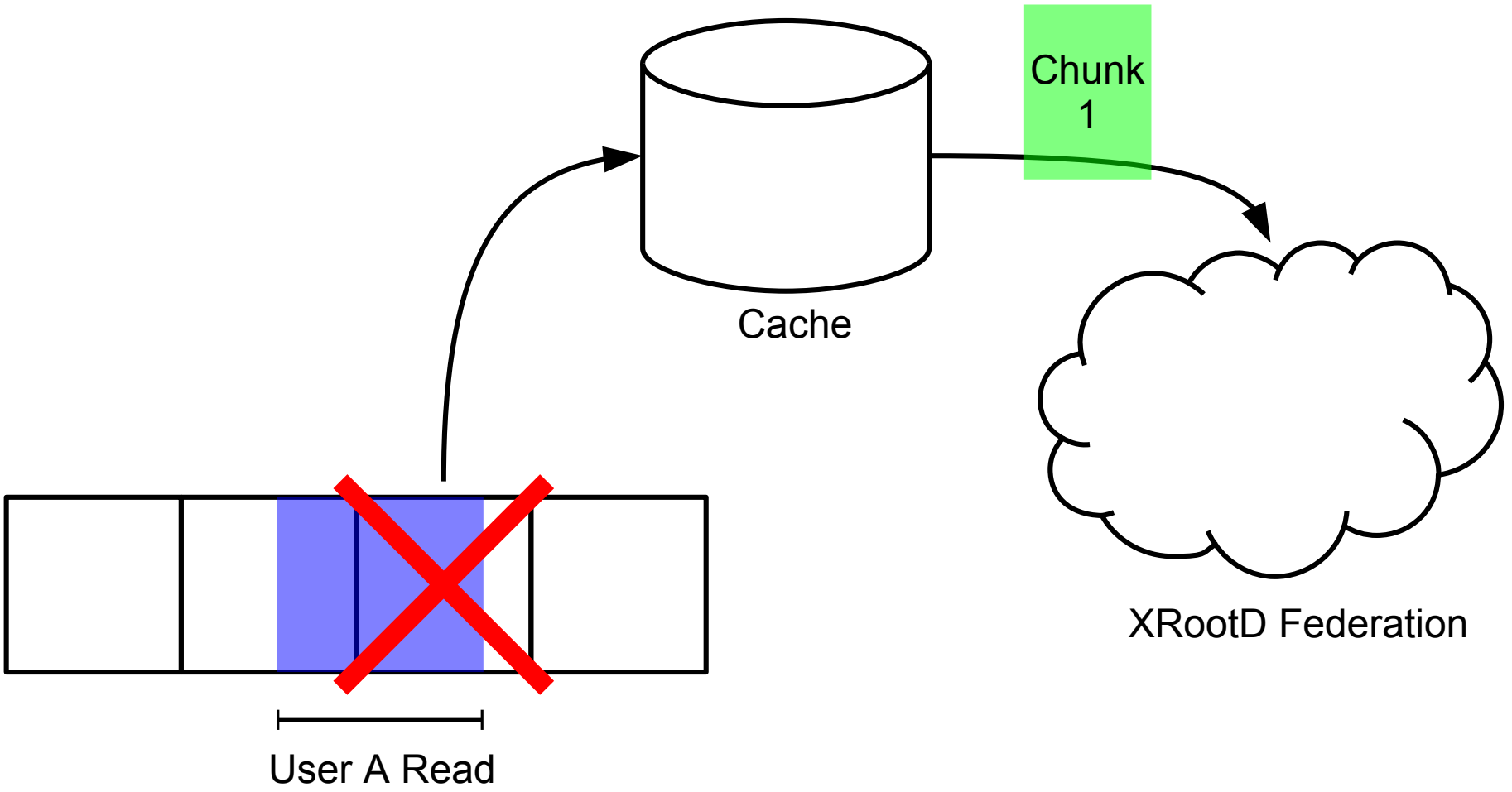

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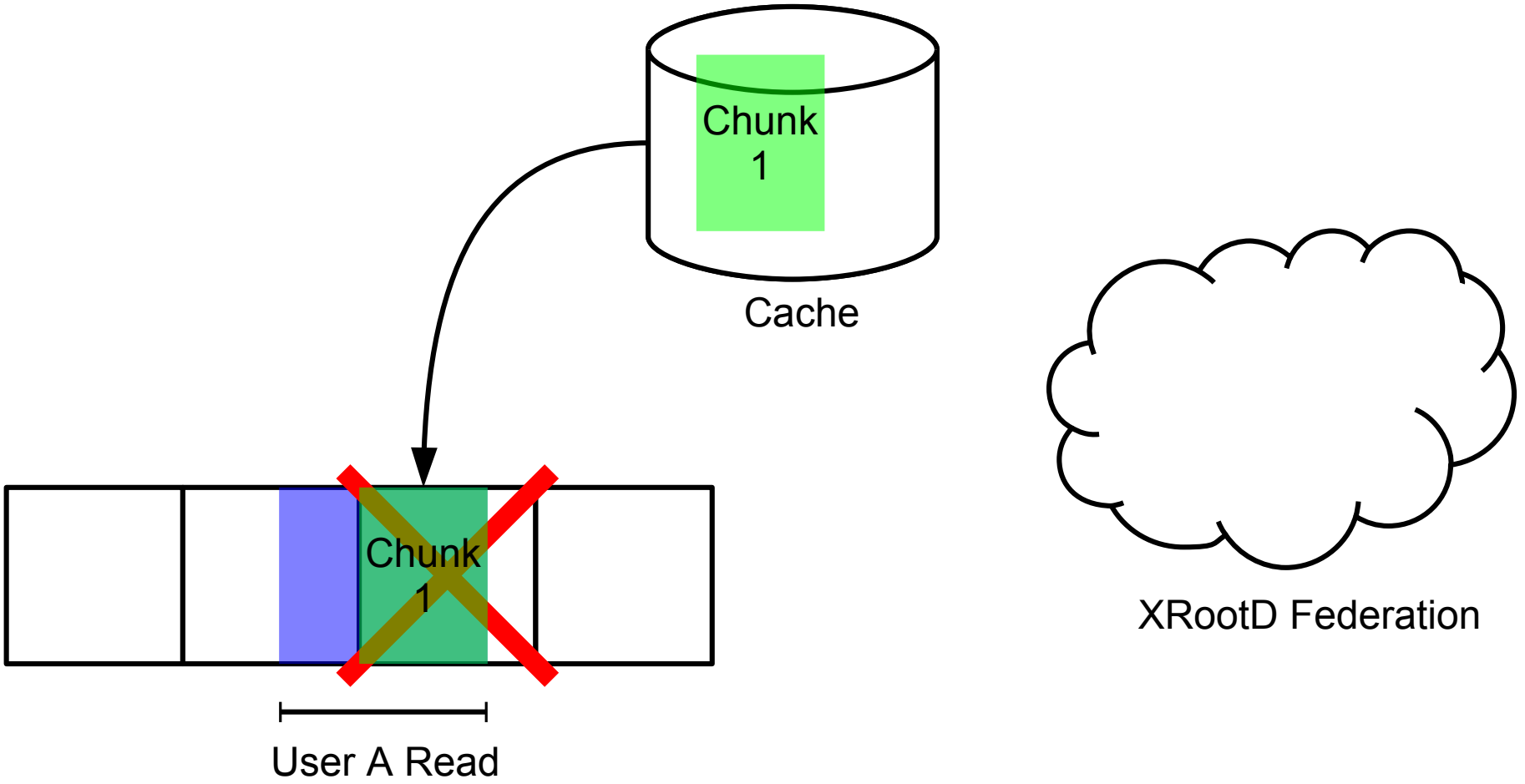

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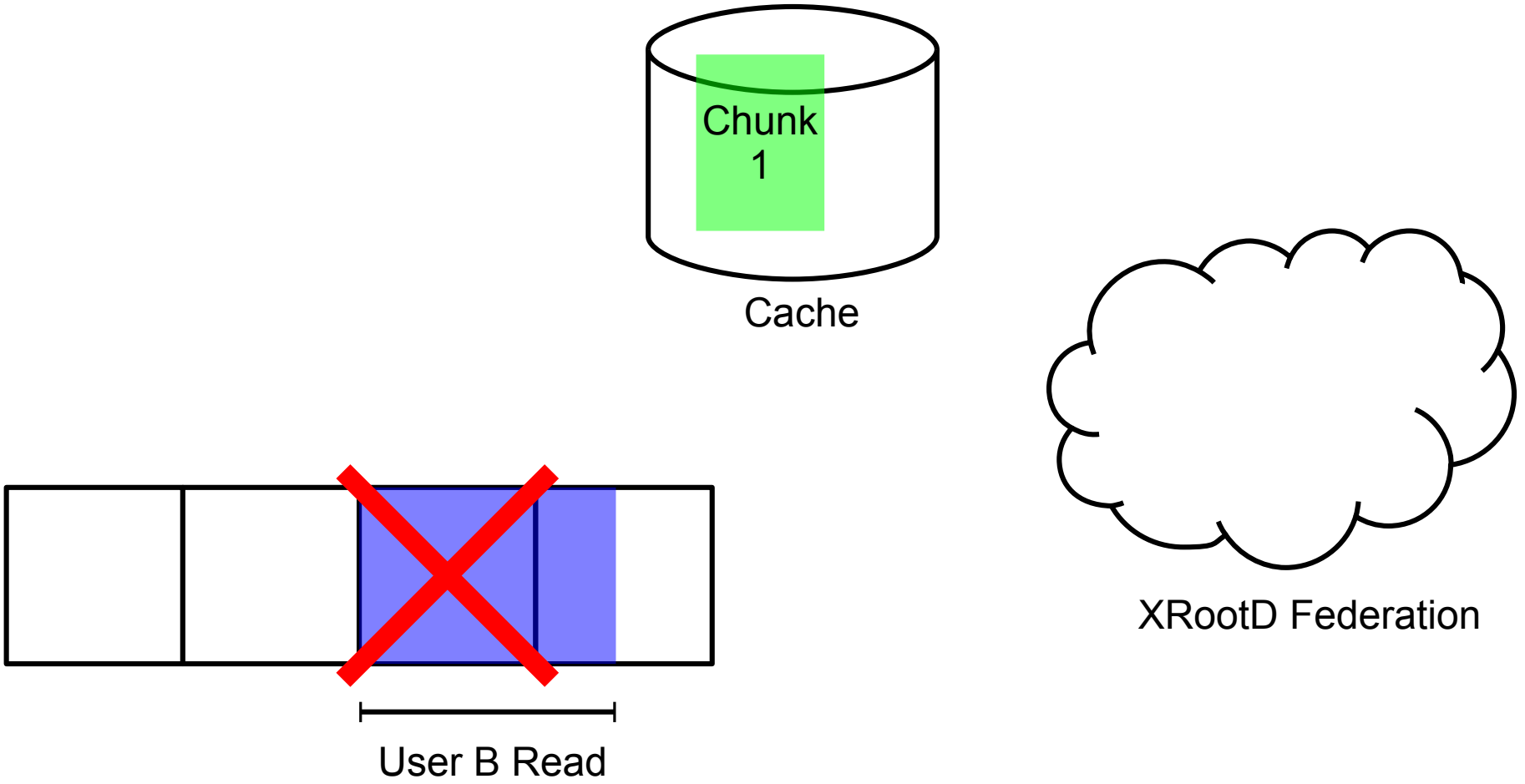

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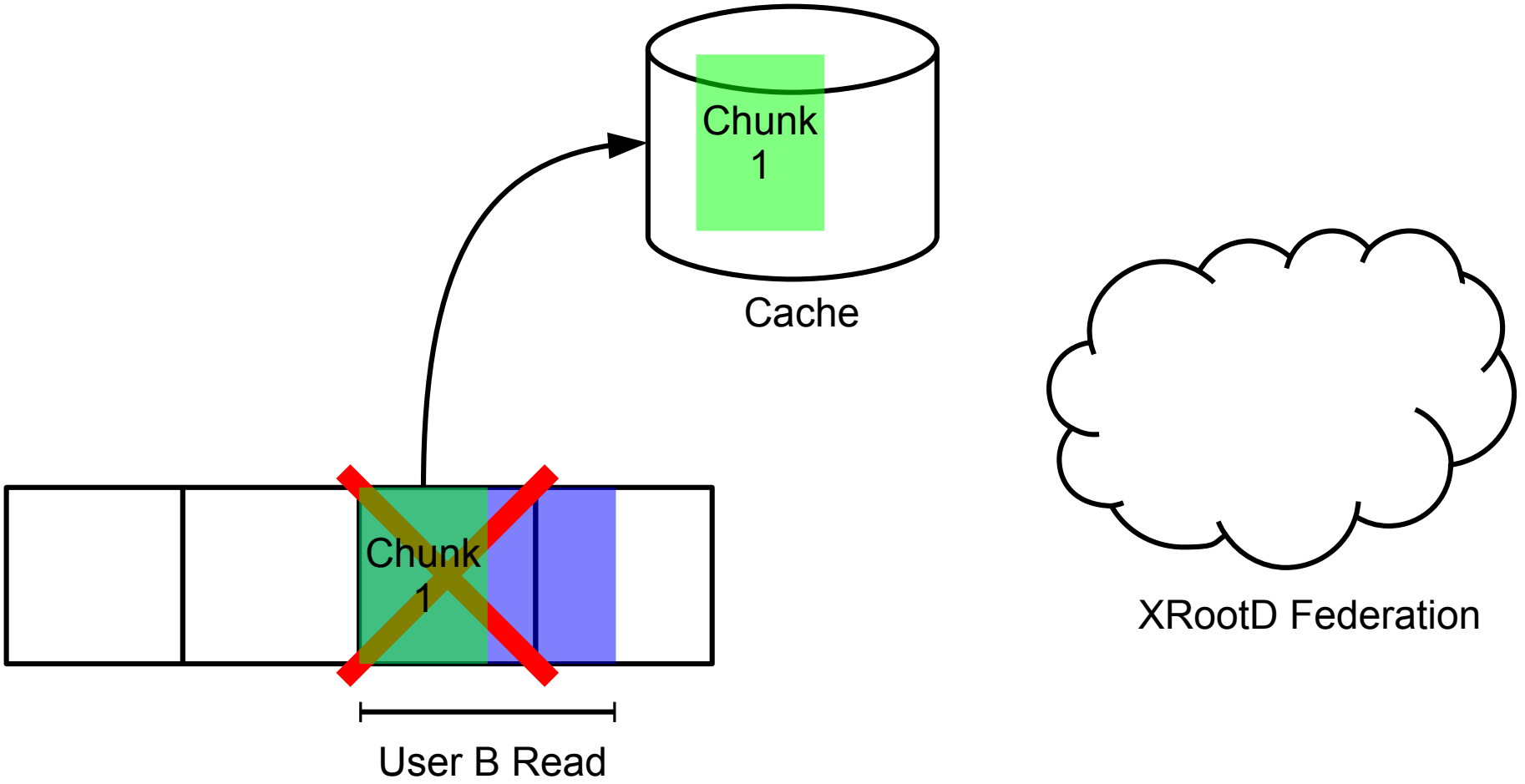

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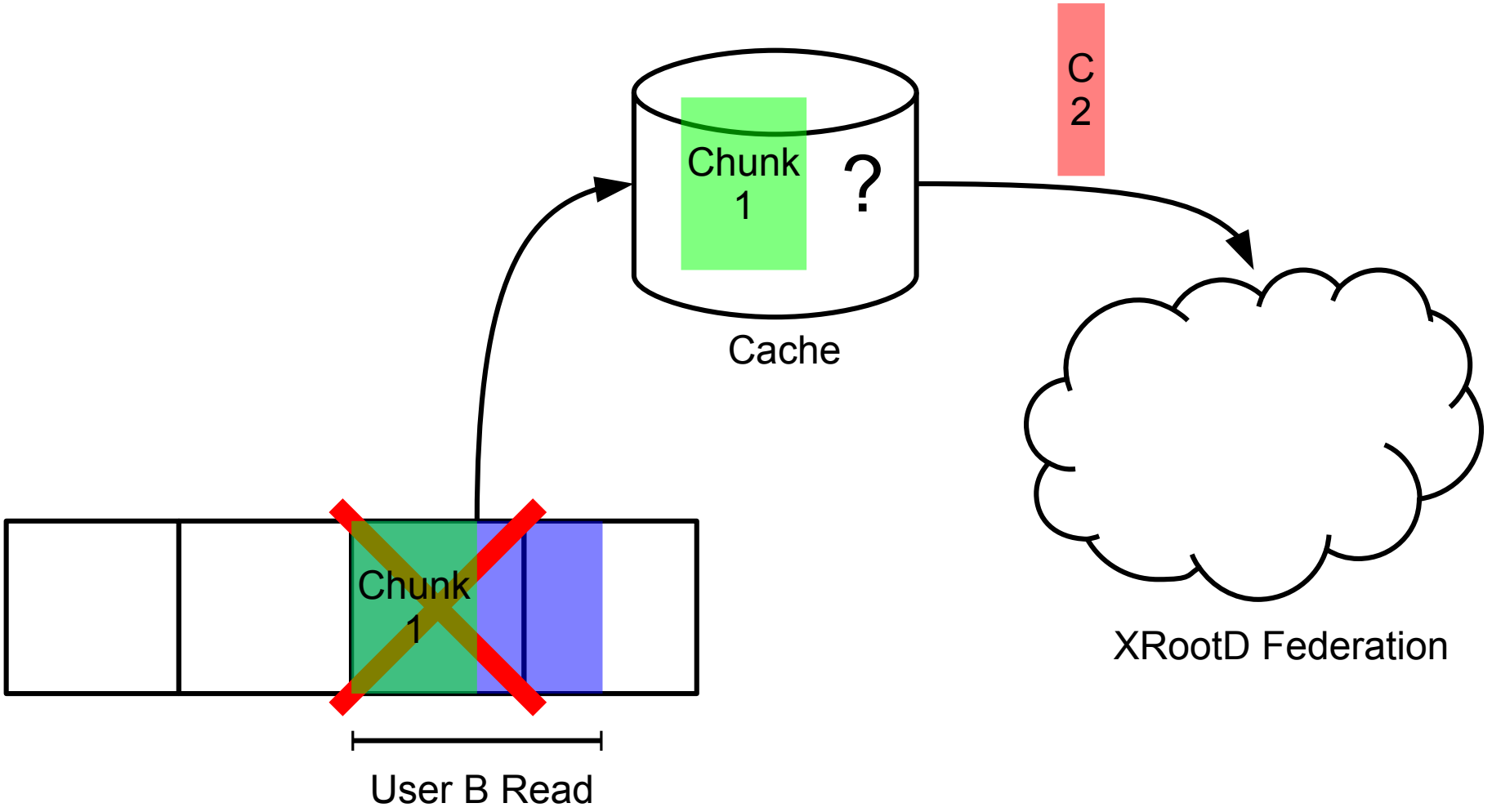

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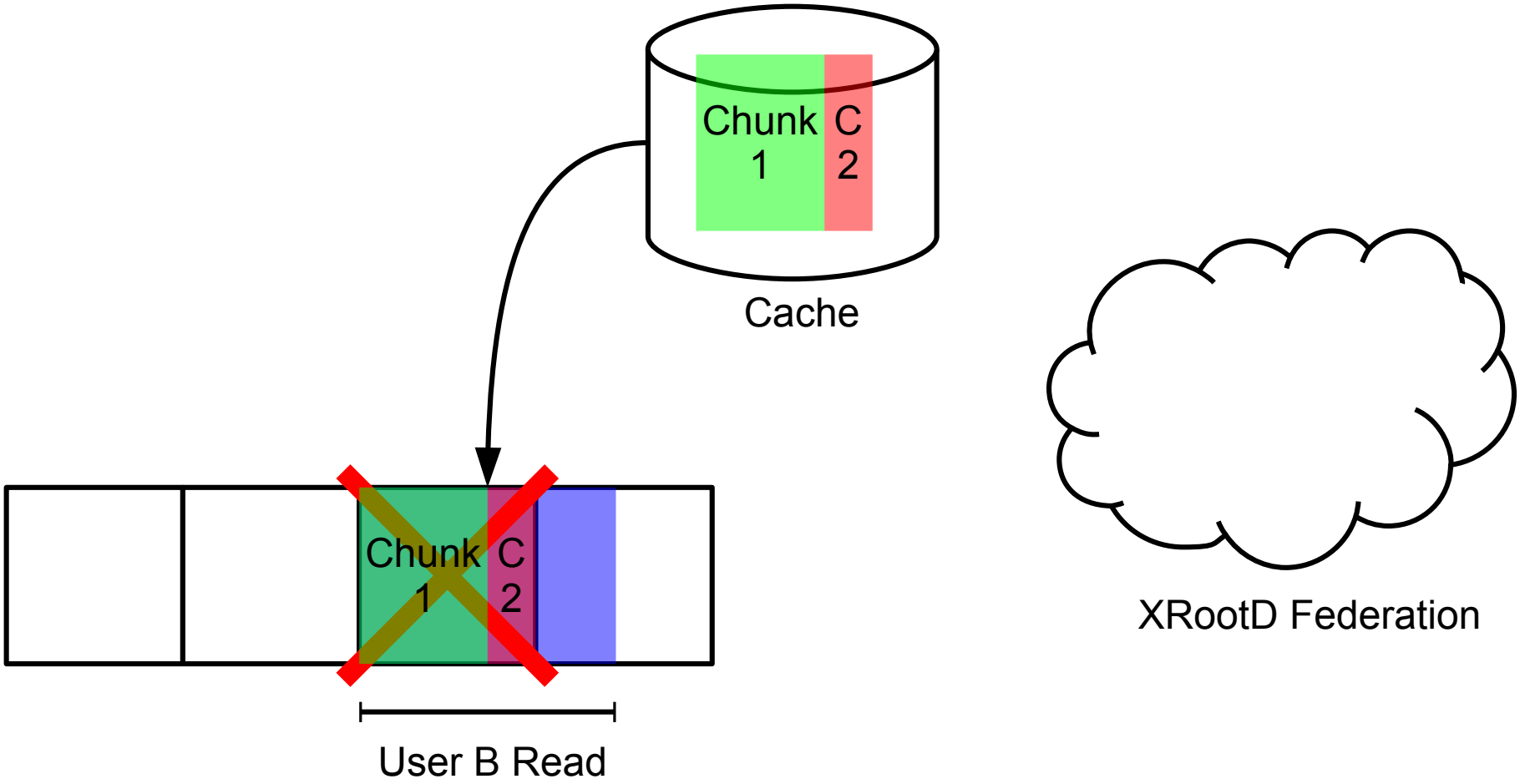
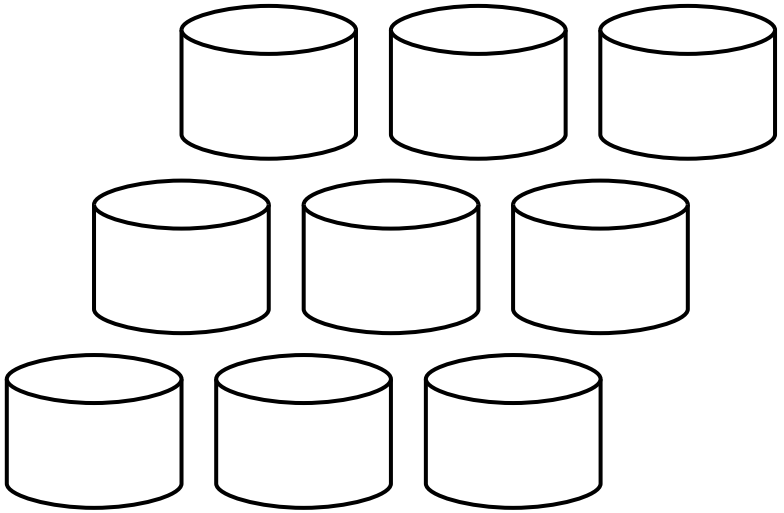
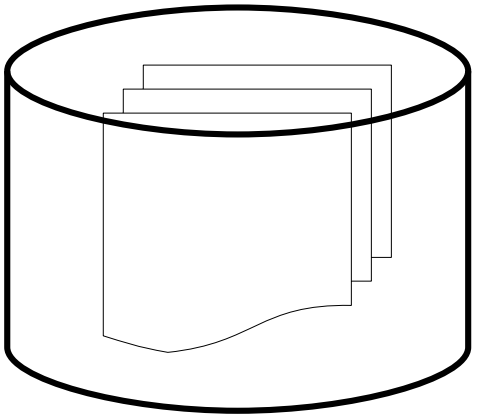


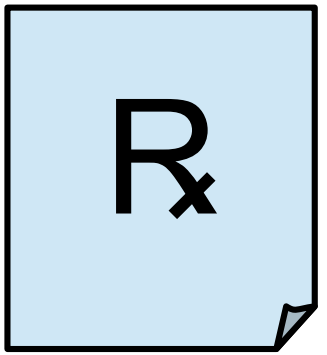
Healer Architecture





Cache

Namenode



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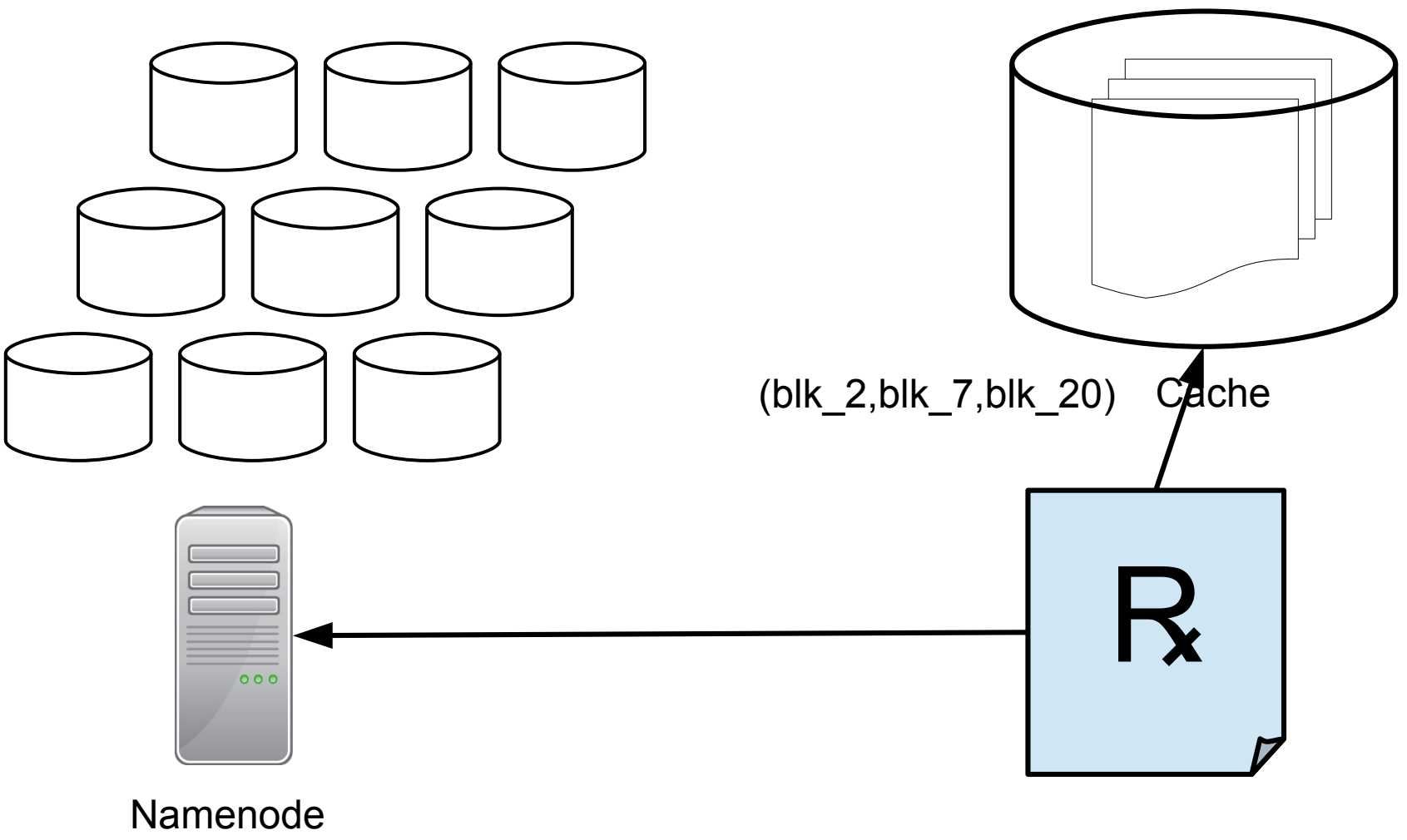

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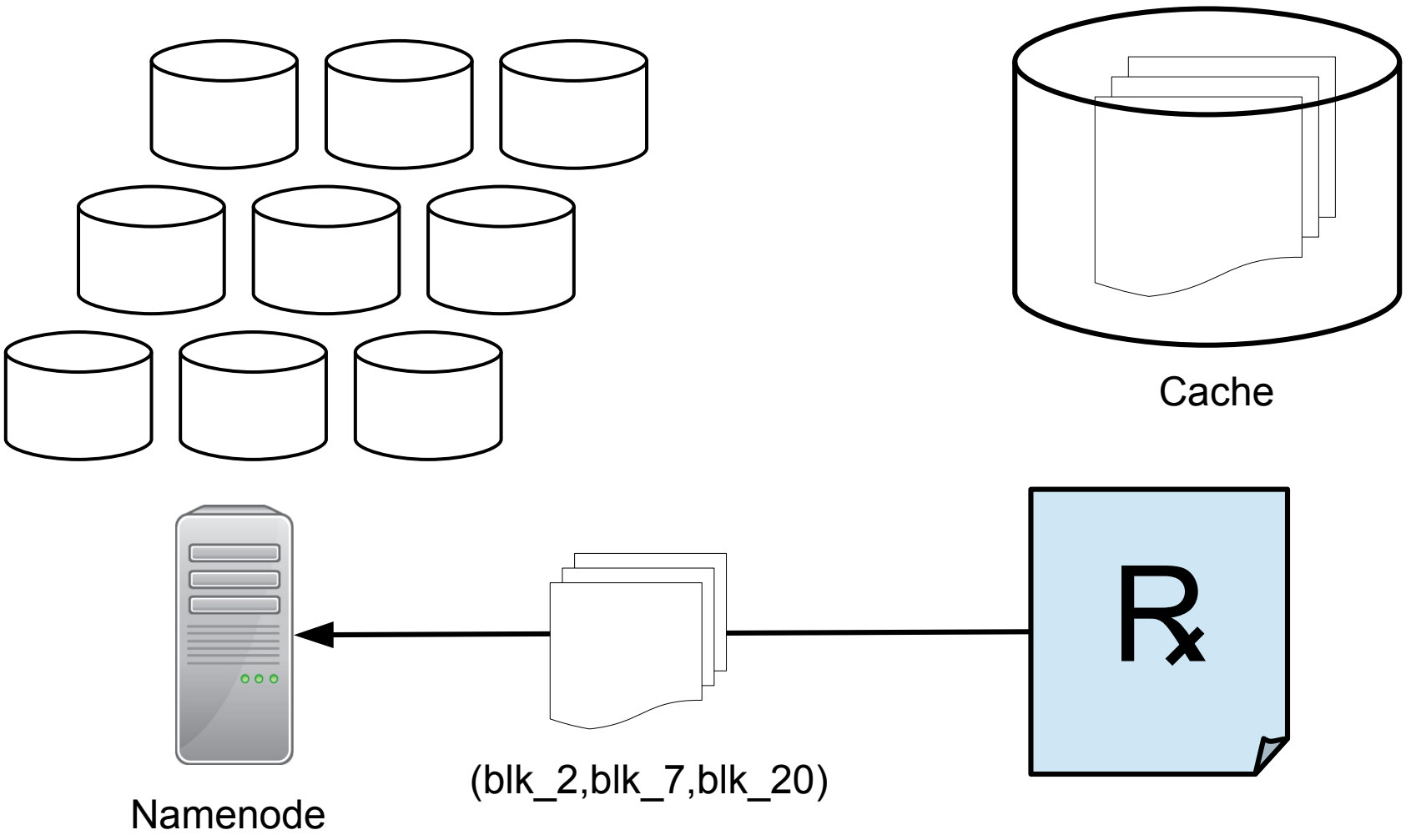

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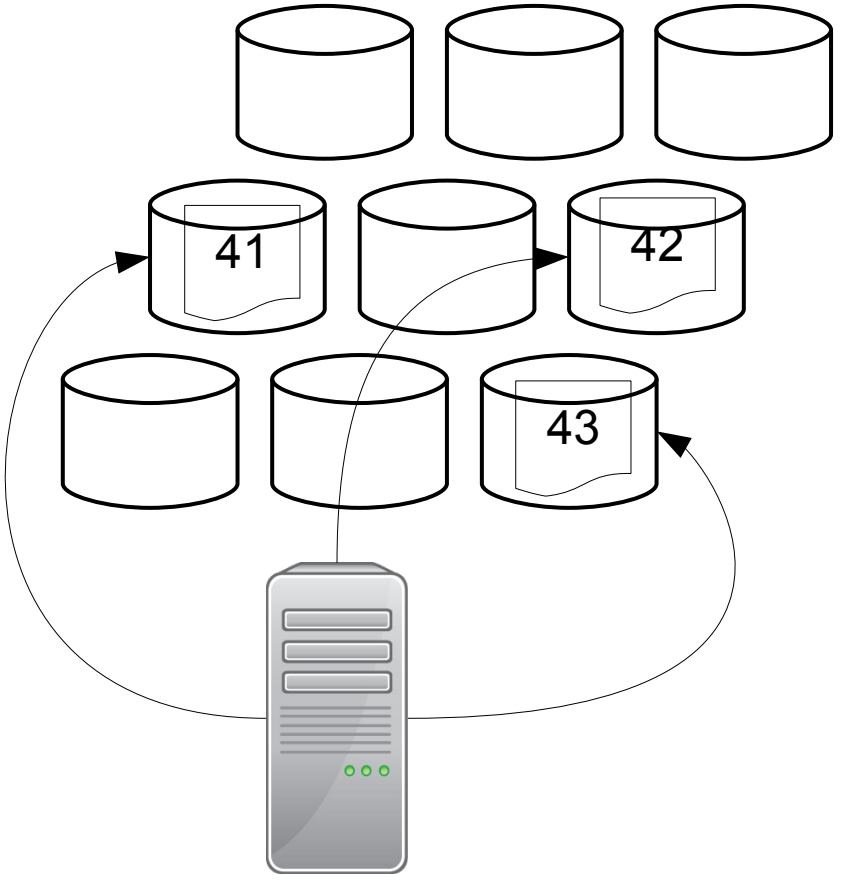

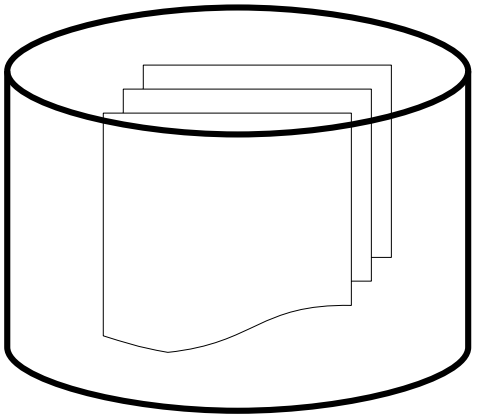

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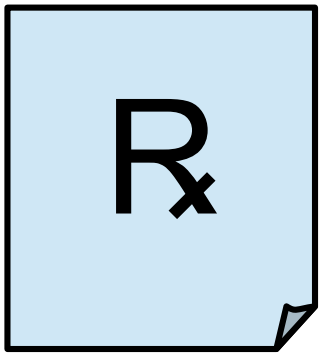
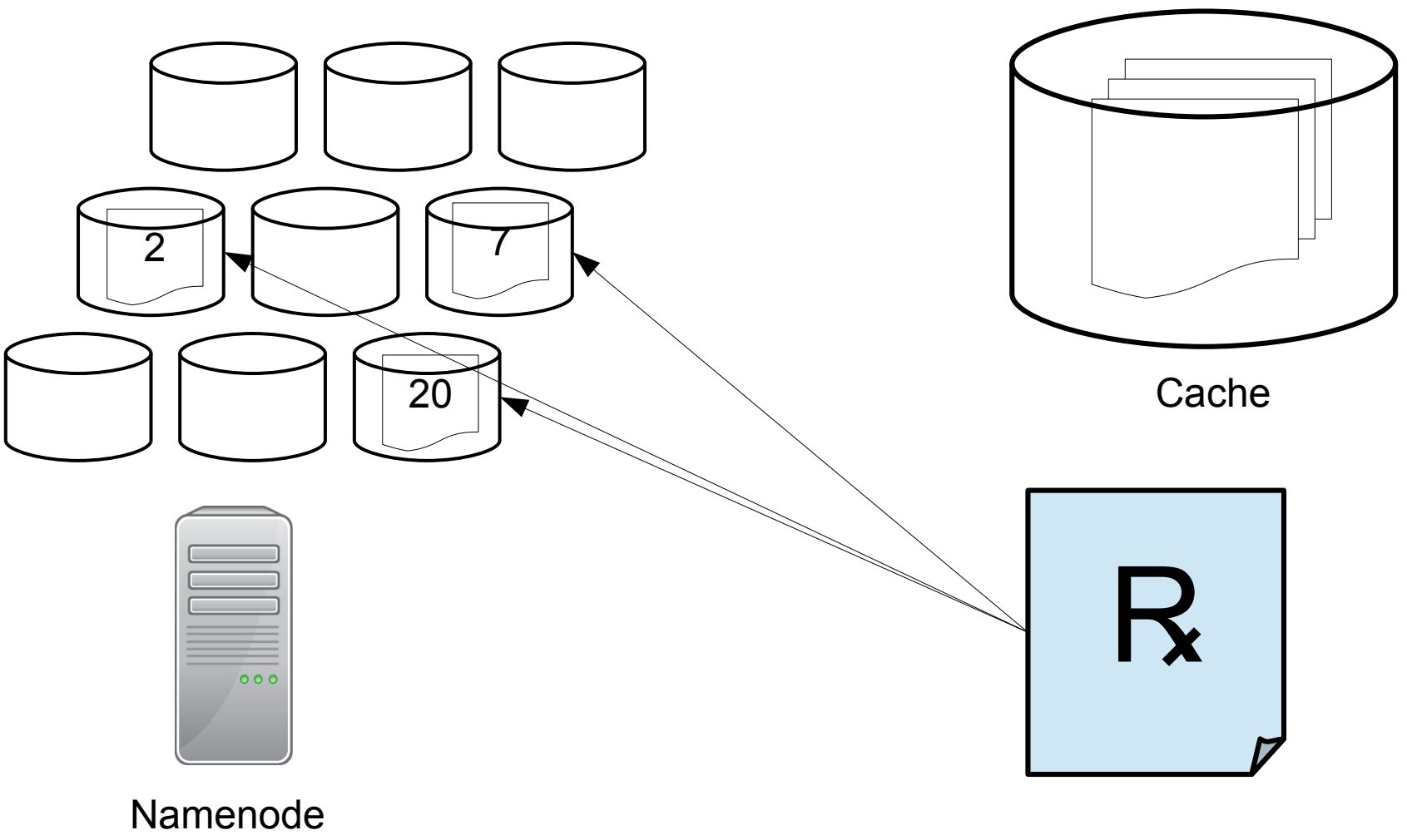


Healer Architecture



Running Fallback at UCSD

- In April 2014 we turned on hdfs-xrootd-fallback
- Since then we've reduced replication factor to 1 on a set of directories:

```
/cms/store/data/Run2012A
/cms/store/data/Run2012B
/cms/store/data/Run2012C
/cms/store/data/Run2012D
/cms/store/data/Fall13
/cms/store/data/Summer13
/cms/store/mc/Summer12_DR53X
/cms/store/himc
/cms/store/relval
```

- This has effectively freed 236 TB (11%) of physical storage space in our cluster

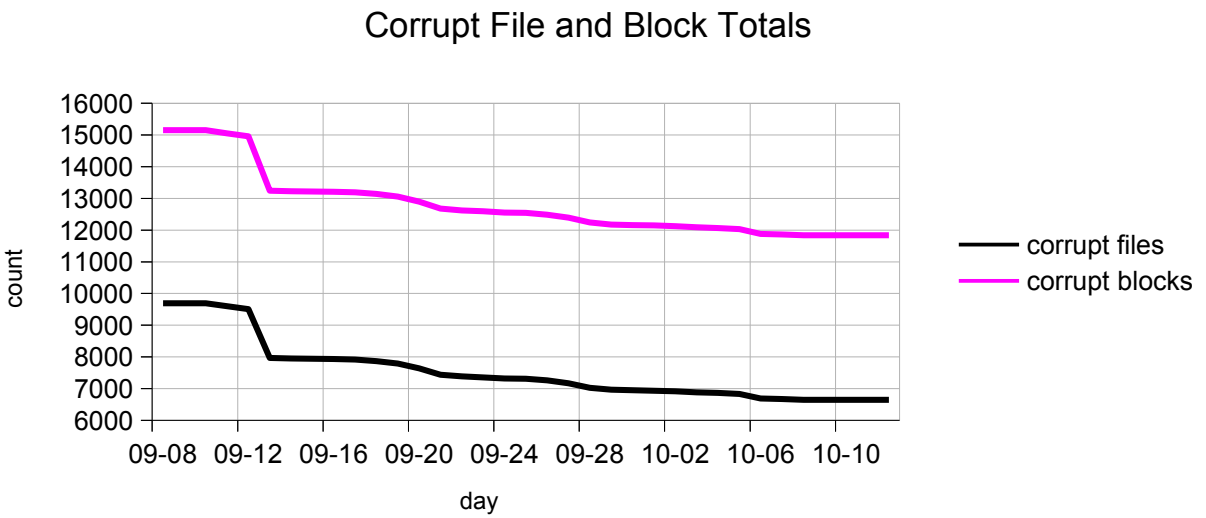
Running Fallback at UCSD

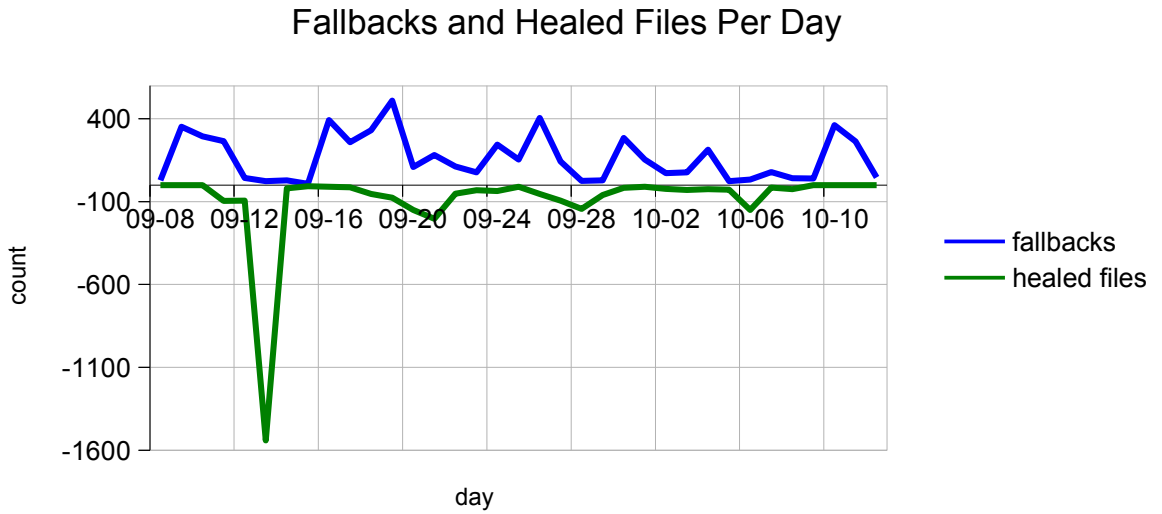
- Current storage summary:

Live Nodes	101
Configured Capacity	2.55 PB
DFS Used	1.96 PB
DFS Used%	76.82 %
Total Files	18173219
Total Blocks	43245486
Missing Blocks	15420

- On September 10, 2014, we finished implementing and turned on the hdfs-xrootd-healer

Fallback Statistics





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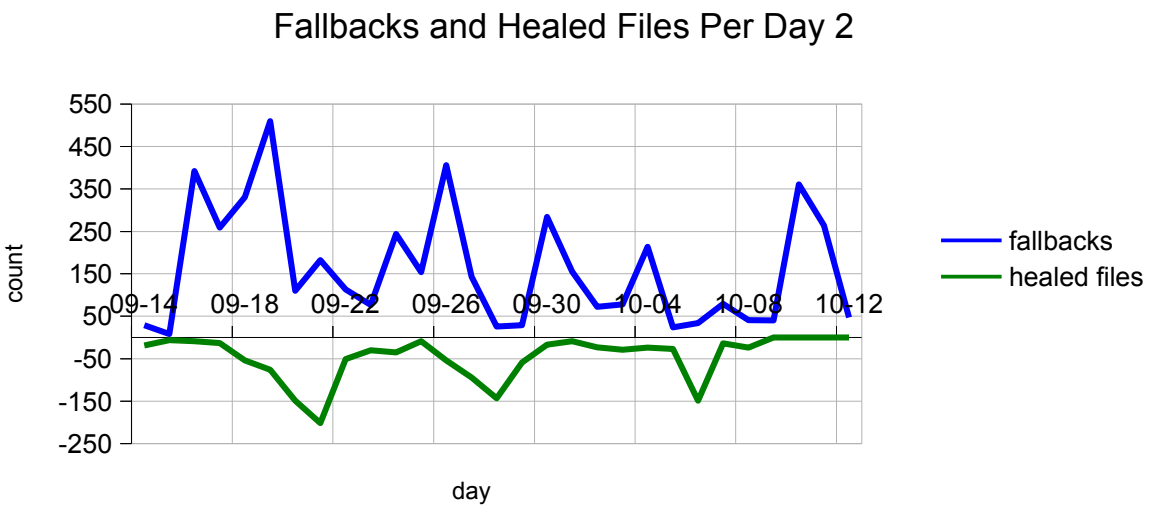

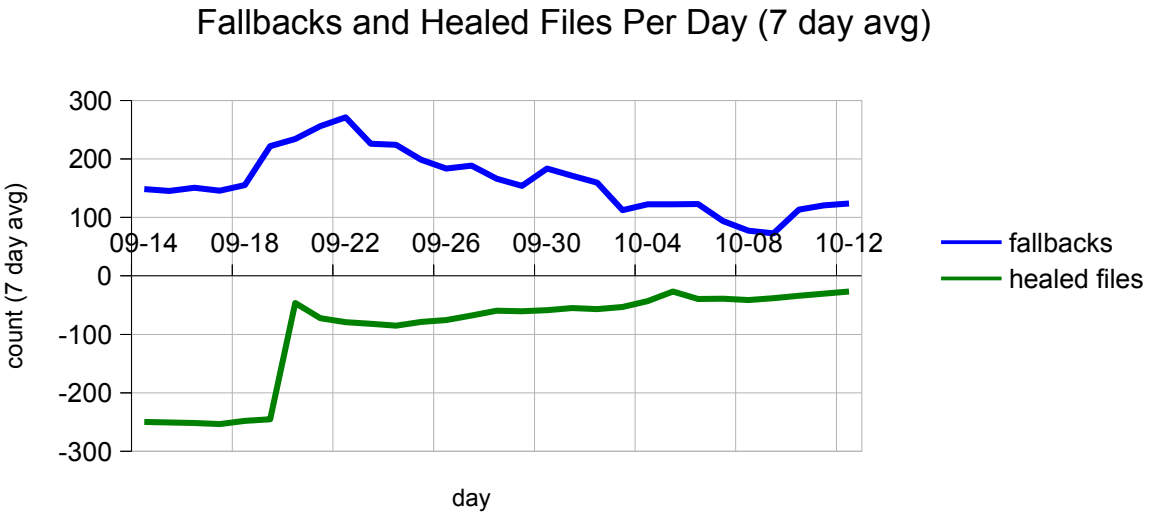

Data Corruption

- gridftp-hdfs plugin stores checksums in /cksum dir in hadoop (MD5,Adler32,CRC32,cksum)
- Performed bulk MD5 checksum verification over all healed files
- Of the 3048 files we healed, 41 were corrupt (1%), due to corrupt blocks received from XRootD
- We had to manually re-corrupt these blocks to ensure we don't serve corrupt data to users
- Turned off healing until we implement corruption protection
- Plan to contact sites that served corrupt blocks and work with admins to understand the source of corruption

Data Corruption

- Important finding – A subset of corrupt files went undetected when comparing Adler32 checksums!
- Errors were only detected using MD5
- These corrupt blocks have a strange but consistent pattern:

```
        offset          bits
orig 16974170 ...01100011
new  16974170 ...01100111
-------------------------
orig 16974186 ...01110101
new  16974186 ...01110001
```

- A single bit is flipped on, 3 positions from the right
- And then another is flipped off in the same position, 16 bytes later

Data Corruption

- Our best guess is this is due to some hardware malfunction, e.g. a bad network switch
- We have not yet determined if it is local (UCSD) or from a remote site serving us through XRootD

Summary of Fallback

	Count	Percent
Total Files	66410	100%
Good Files	51483	77%
Corrupt Files	11838	18%
Healed Files	3048	5%
Bad Cksum	41	0.06%