系统设计第五课

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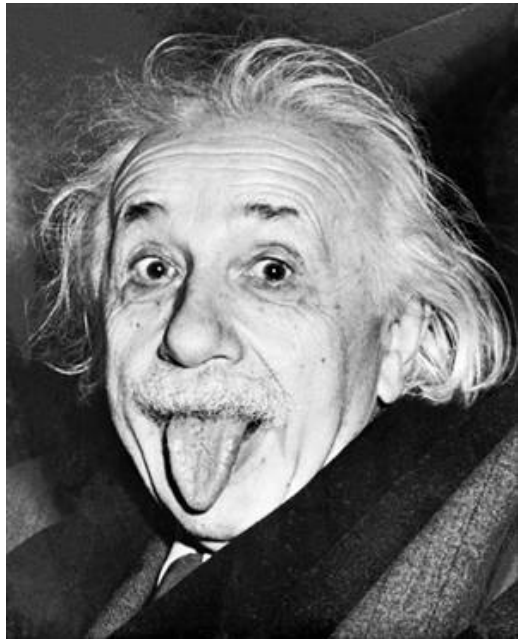

System_Design_5

Distributed system

张无忌

2016-02-06

V4.00

九章算法

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After class_5, you can answer

- Design distributed file system(GFS) and database(BigTable)?
  - Google, DrawBridge, Yelp
- Calculate word appearance/inverted index/anagrams with MapReduce
  - Google, Twitter, Drawbridge, Zenefits, Bloomberg, Genapsys, Liveramp, …

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Interviewer: design search engine

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Three Musketeers of Google

MapReduce
（名人）

BigTable
（？？）

GFS
（高富帅）

Read More

Novice, http://url.cn/SVDkio
Novice, http://url.cn/deN2uC
Novice, http://url.cn/Vf6ABZ
Expert/Master, http://url.cn/EZNxGe
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Do not recite the details of papers,

but find a suitable solution under your scenario.

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Interviewer: What is the layers of your search engine?

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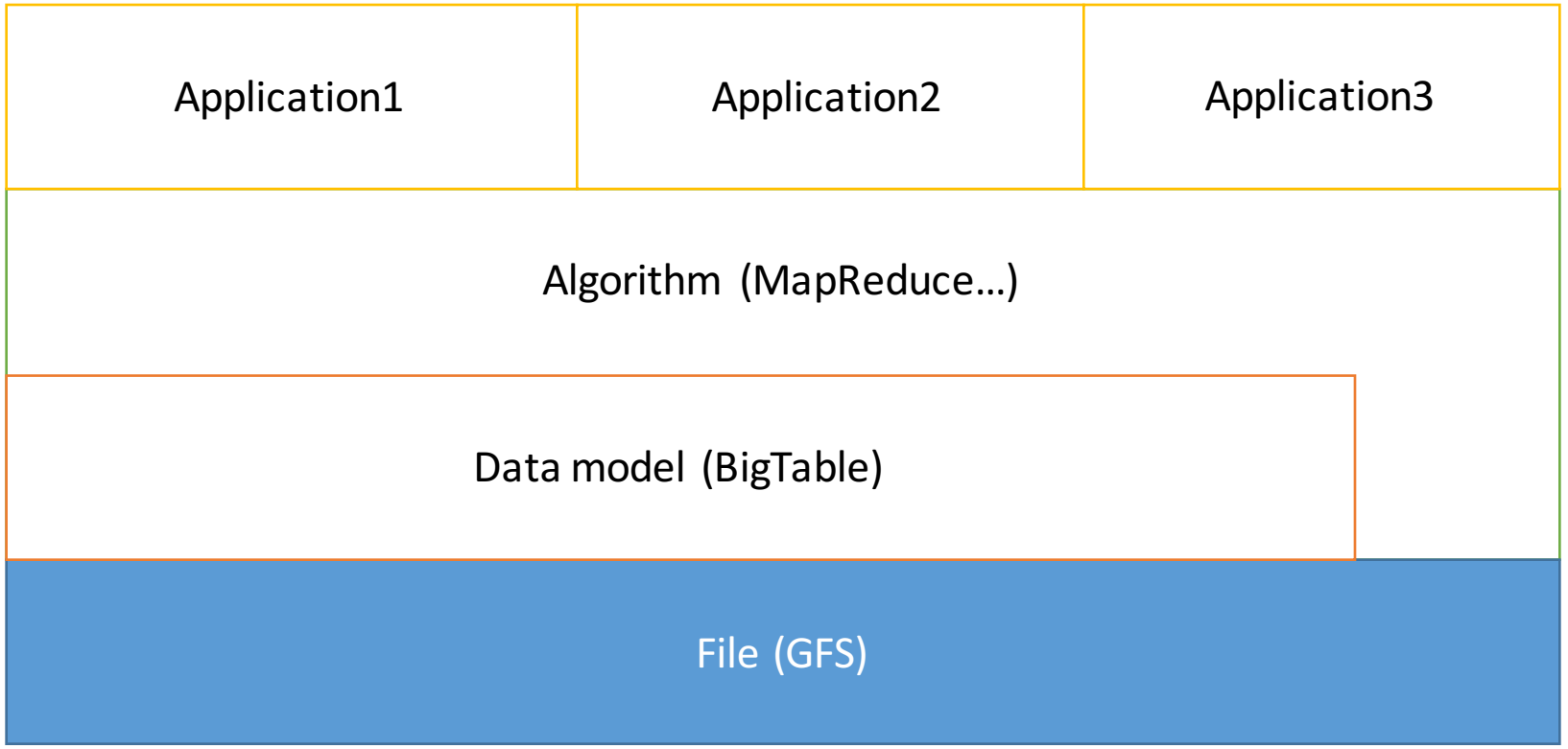
Layers of system



Let’s design with a bottom-up method

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Google File System

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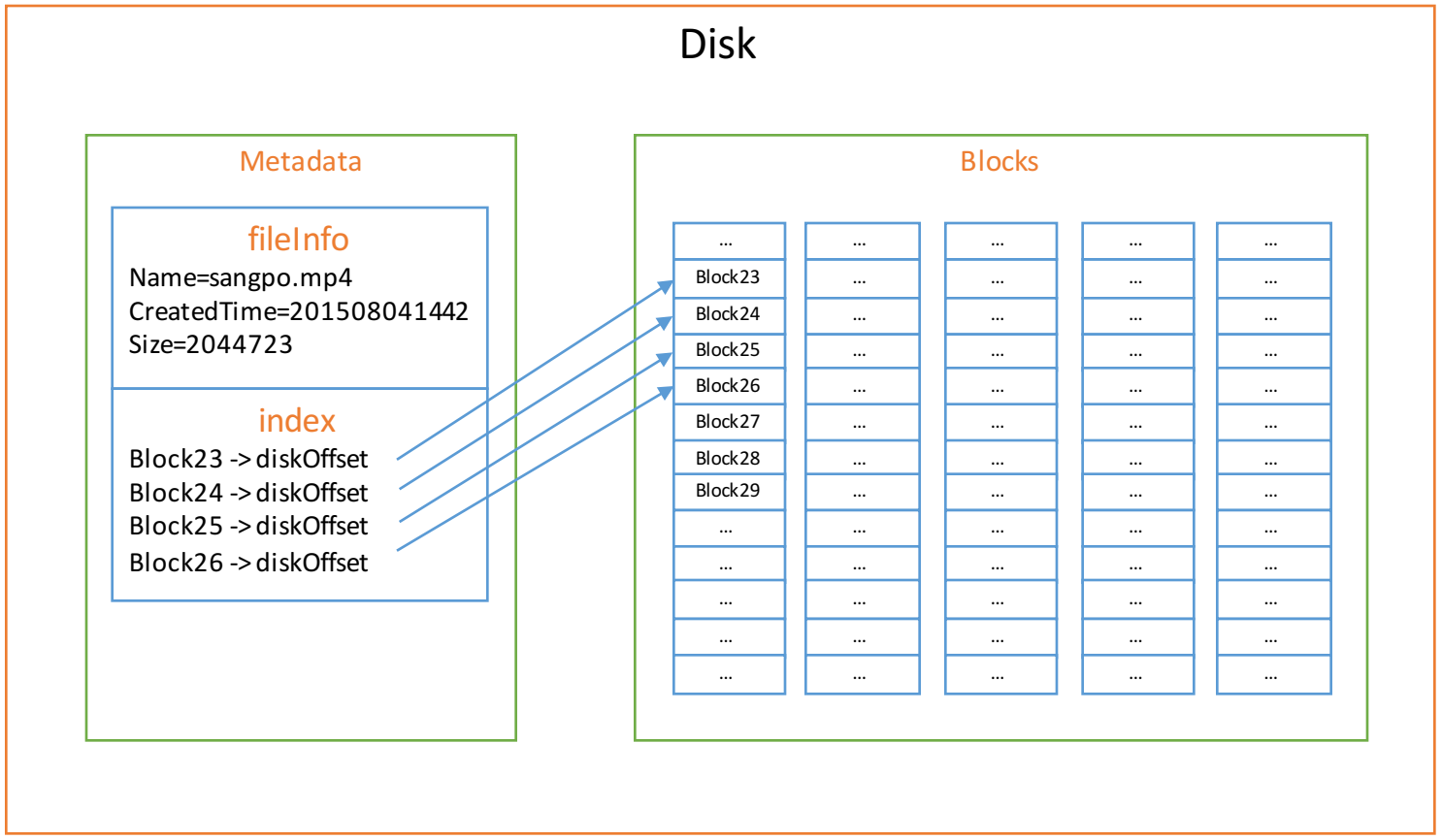
How to save a file?



Key point

- 1 block = 1024Byte

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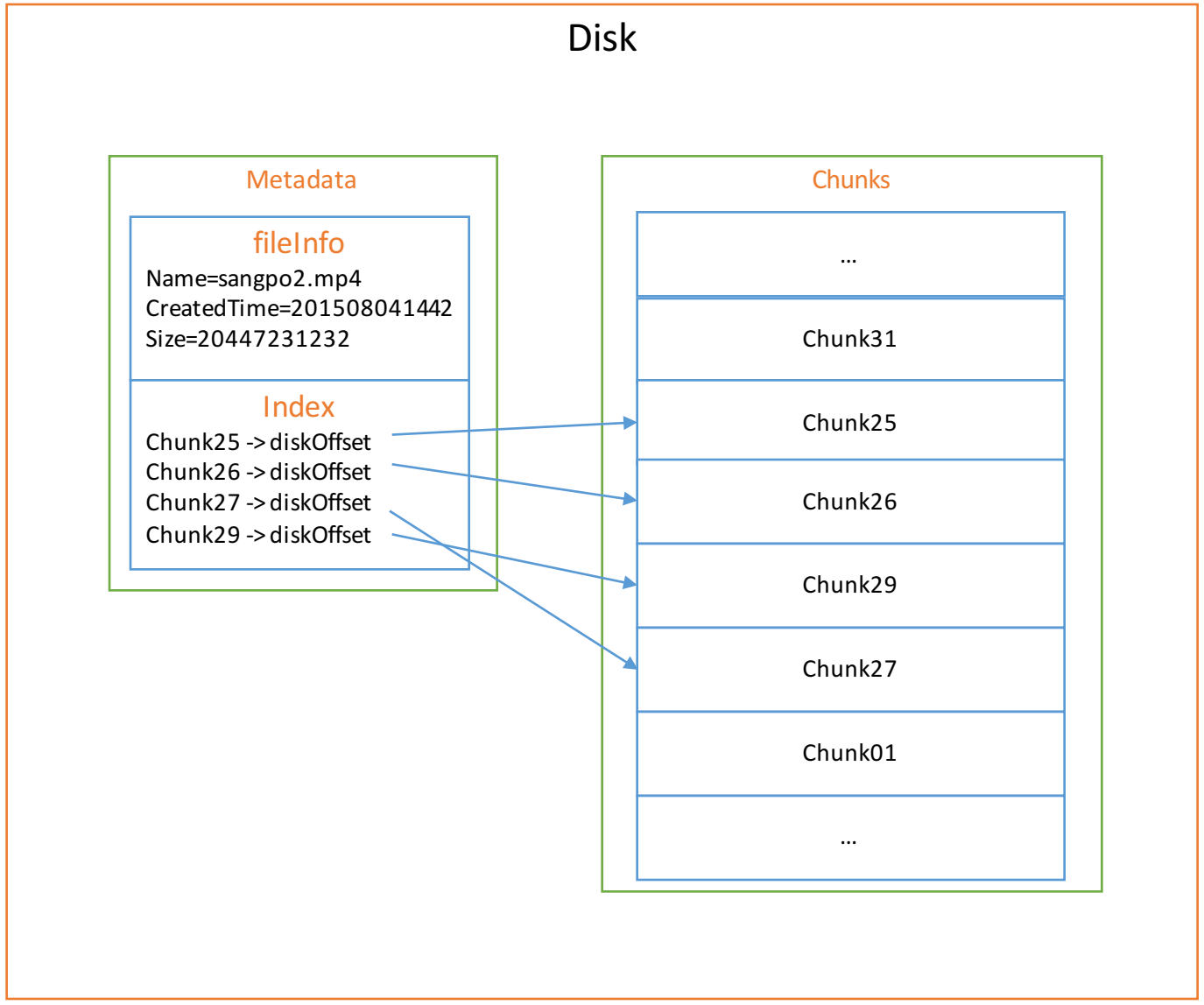
How to save a large file?



- Key point
  - 1 chunk = 64MB
    = 64*1024
    = 65,536 blocks
- Advantage
  - Reduce size of metadata
  - Reduce traffic
- Disadvantage
  - Waste space for small files

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Interviewer: How to save an extra-large file?

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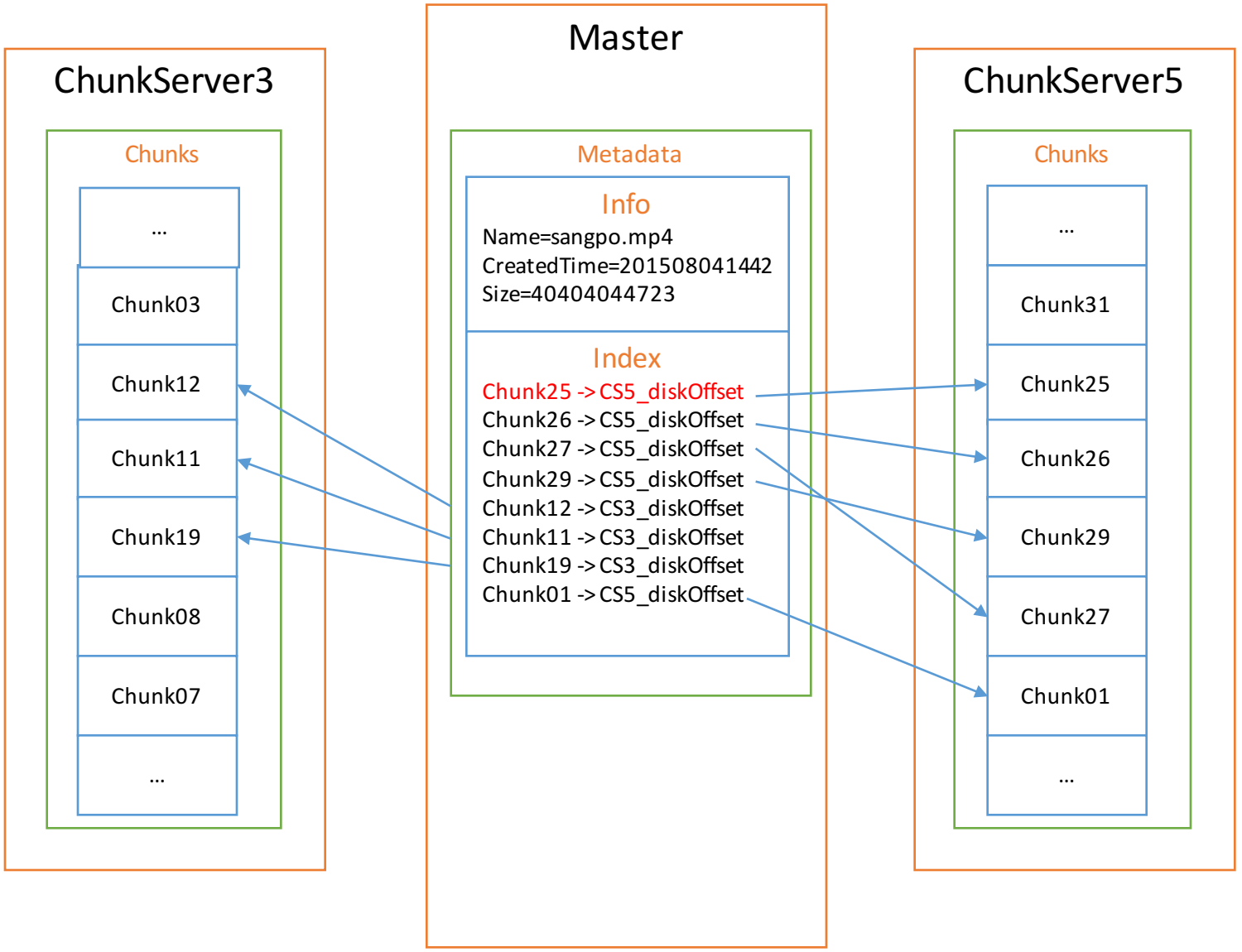
How to save an extra-large file?



- Key point
  - One master + many ChunkServers
- Disadvantage
  - Any change of the diskOffset of a chunk in a ChunkServer need to notify the Master

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Interviewer: How to reduce traffic and storage of master?

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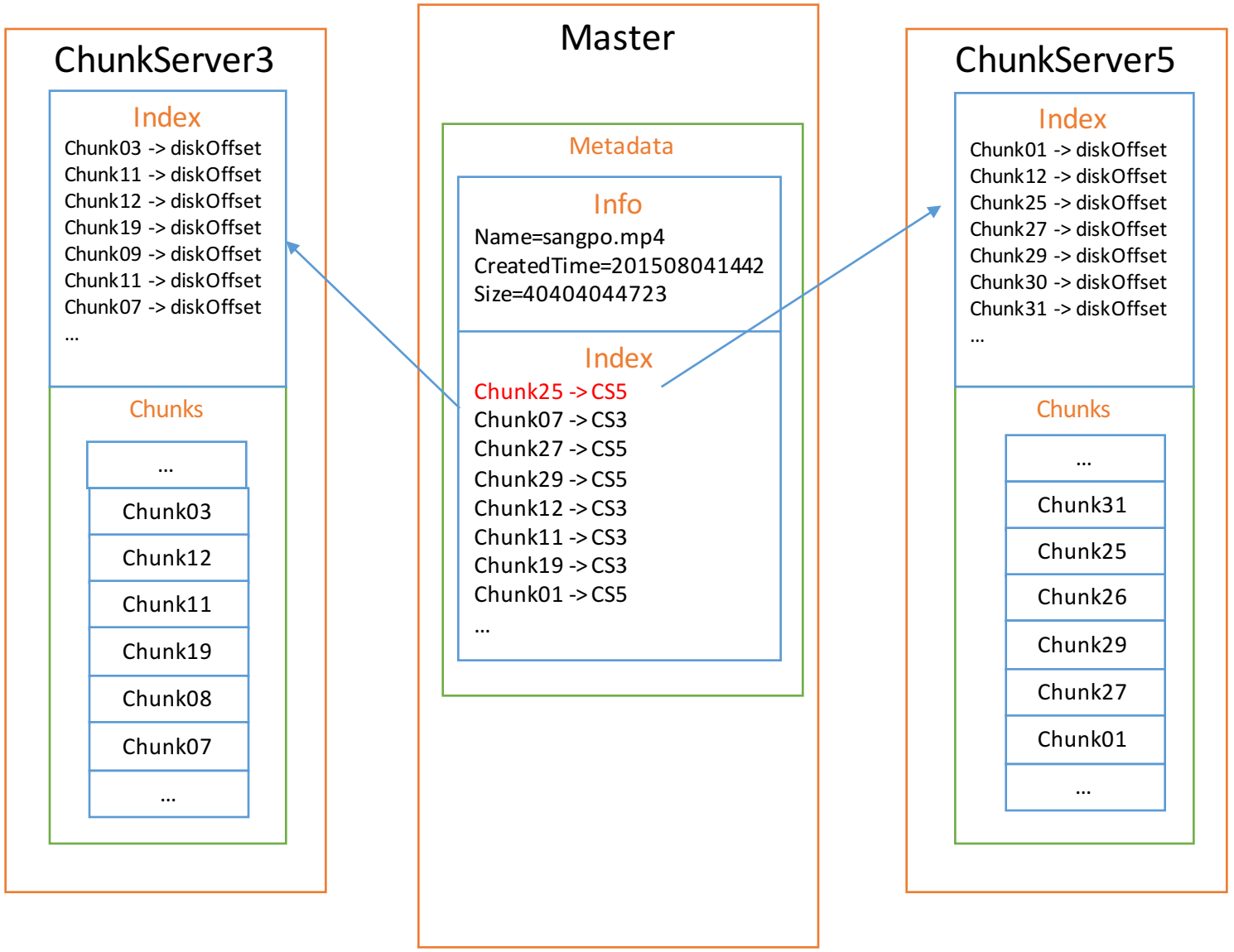
How to reduce traffic and storage of master?



- Key point
  - The master don't record the diskOffset of a chunk

- Advantage
  - Reduce the size of metadata in master
  - Reduce the traffic between master and ChunkServer

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Interviewer: How to identify whether a chunk on the disk is broken?

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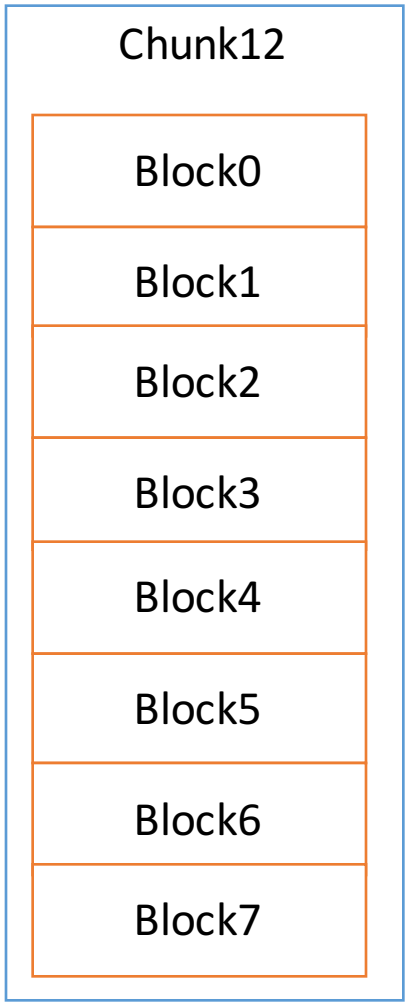
How to identify whether a chunk on the disk is broken?



metadata
Block0 -> checksum
Block1 -> checksum
Block2 -> checksum
...

- Key point
  - 1 chunk = a list of blocks
  - 1 block = 64KB
  - Each block has a checksum
  - 1 checksum = 32bit
  - The size of checksum of 1T file
    - 1T/64KB*32bit = 64MB

- It will compare its checksum when it reads a block

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Interviewer: How to avoid data loss when a ChunkServer is down/fail?

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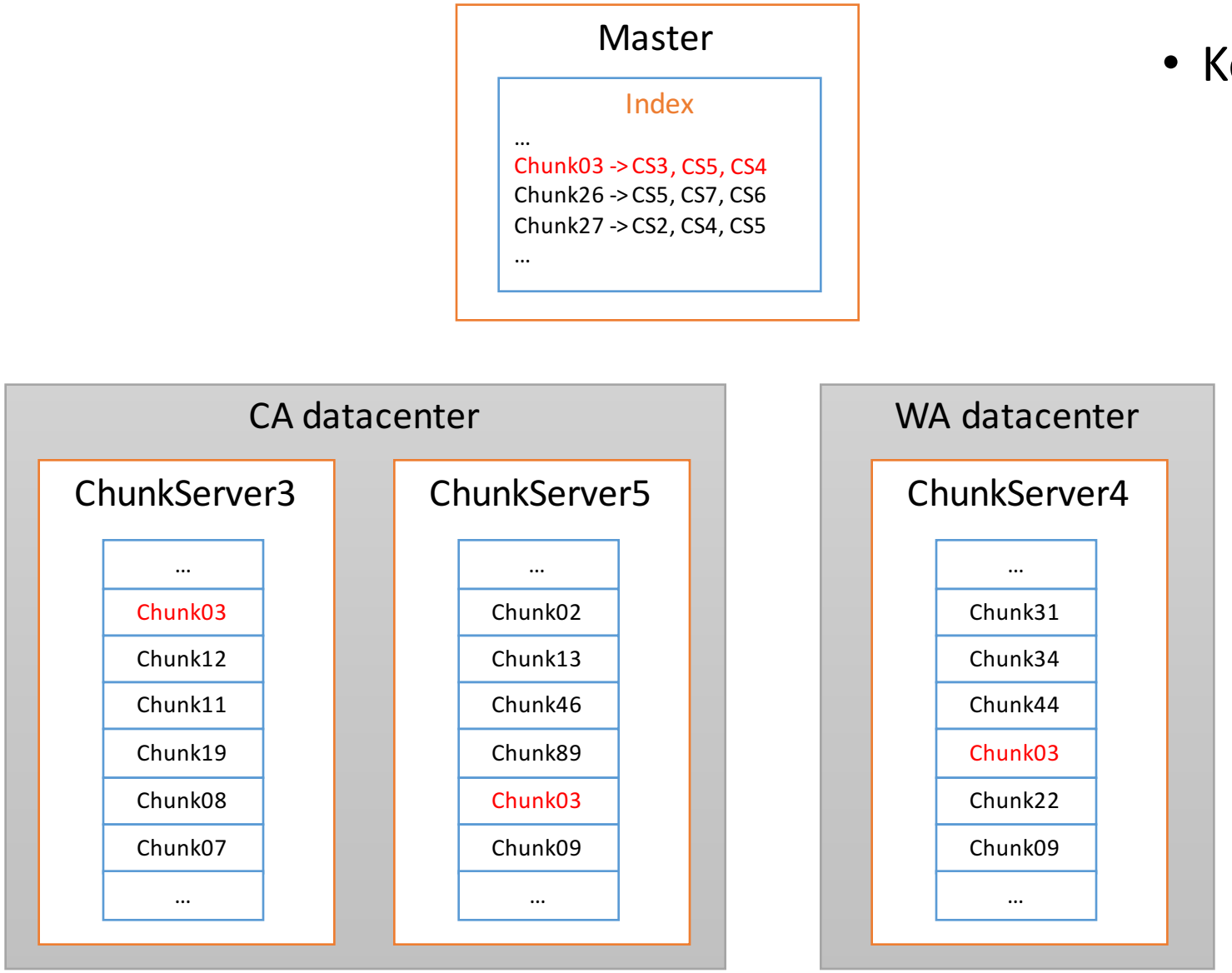
How to avoid the loss of data when a ChunkServer is down/fail?



- Key point
  - Replicate the Chunks
  - How many replications?
    - 3
  - How to select ChunkServers of a chunk?
    - Server with below-average disk space utilization
    - Limited number of “recent” creation
    - Across racks: 2+1

Read More

Expert/Master, http://url.cn/d1BrZU

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Interviewer: How to recover when a chunk is broken?

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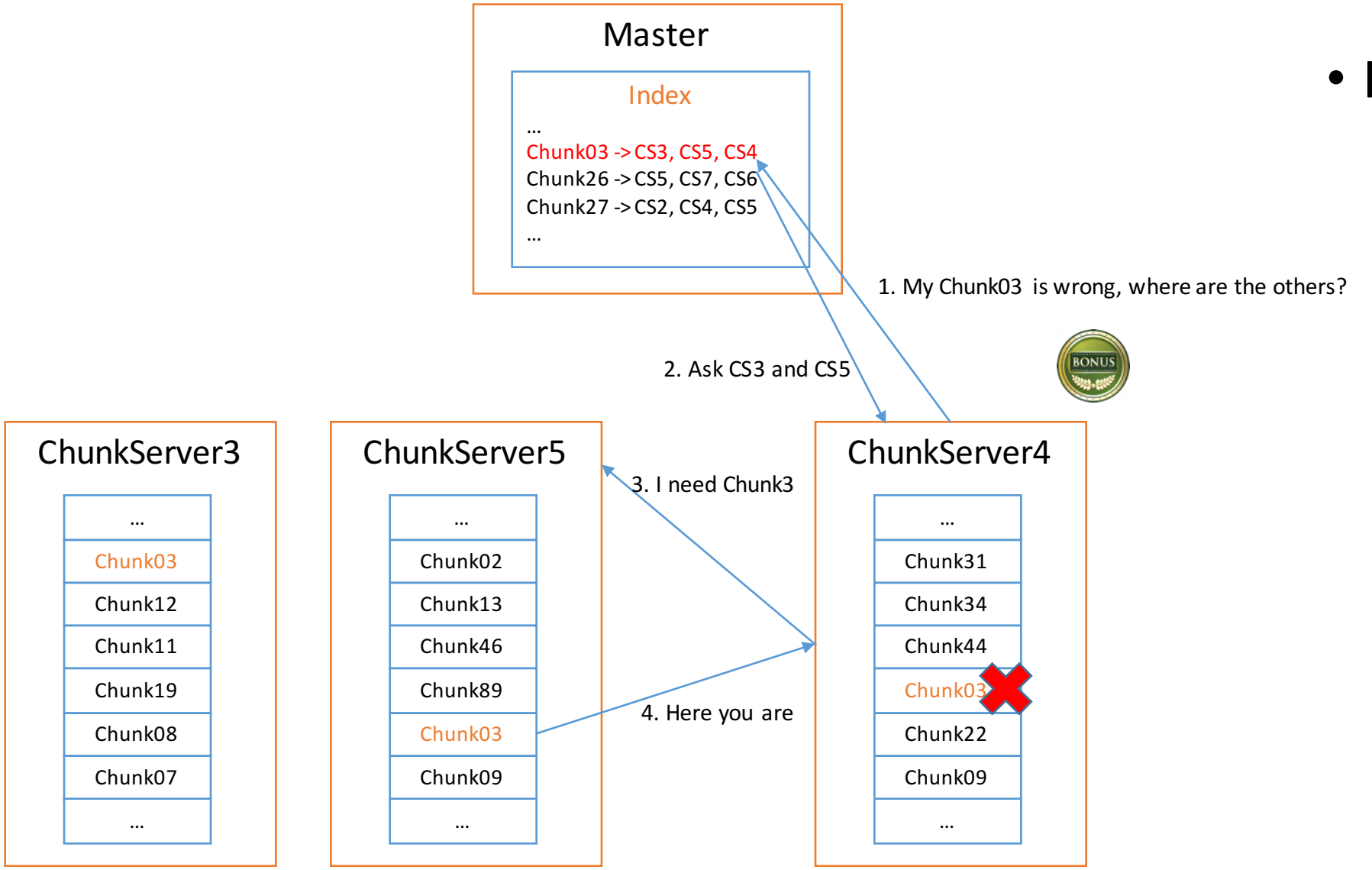
How to recover when a chunk is broken?



- Key point
  - Ask master for help

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Interviewer: How to find whether a ChunkServer is down?

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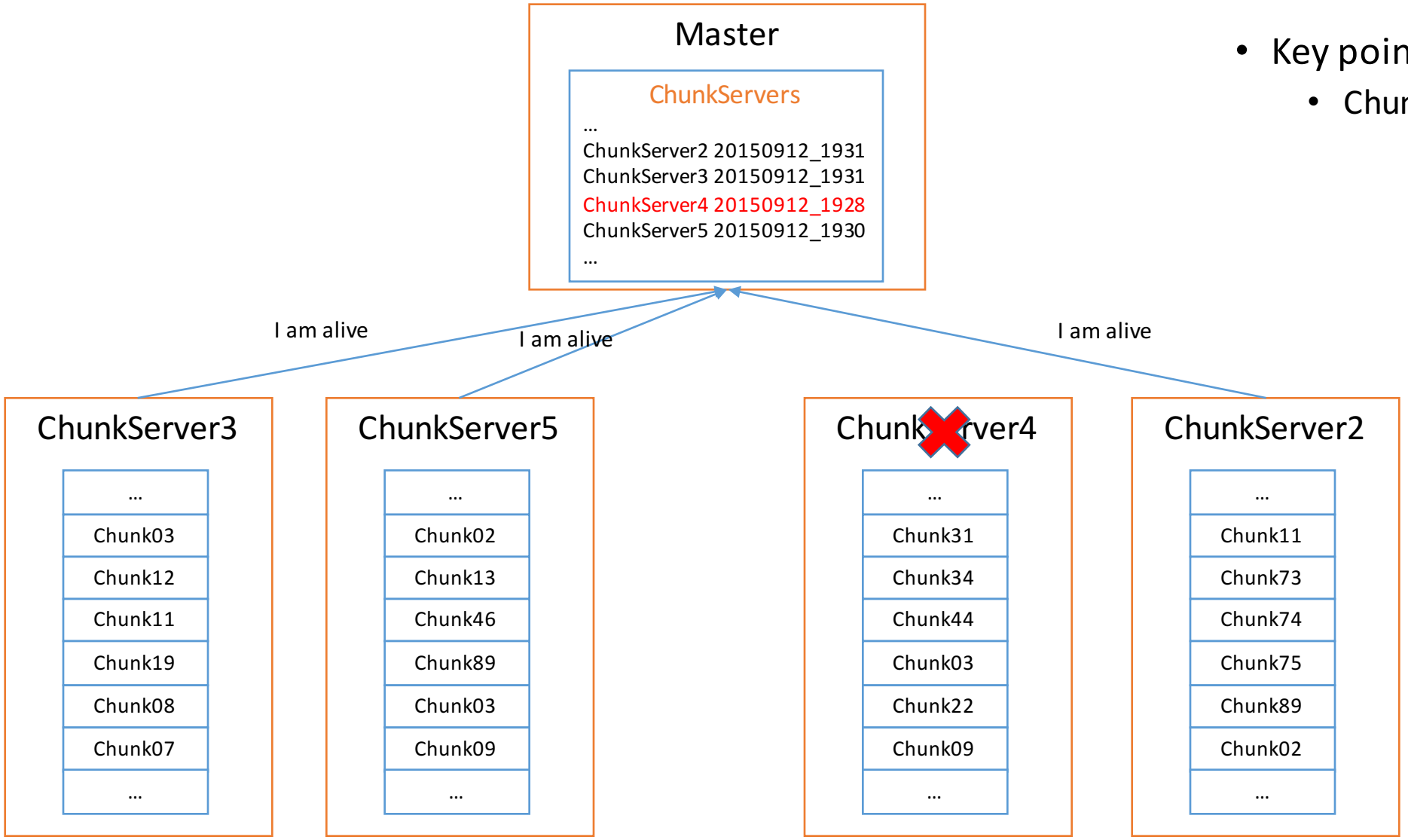
How to find whether a ChunkServer is down?



- Key point
  - ChunkServer sends heartbeat

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Interviewer: How to recover the data when a ChunkServer is down?

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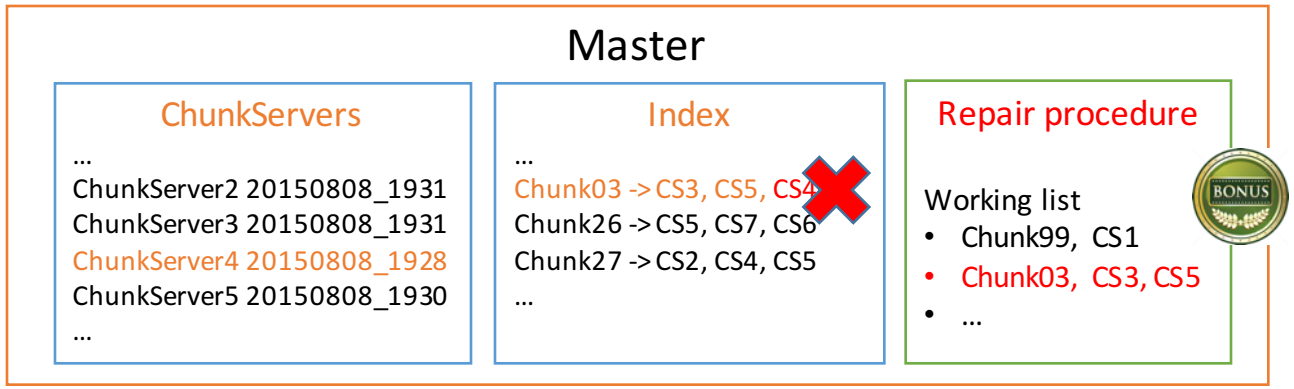
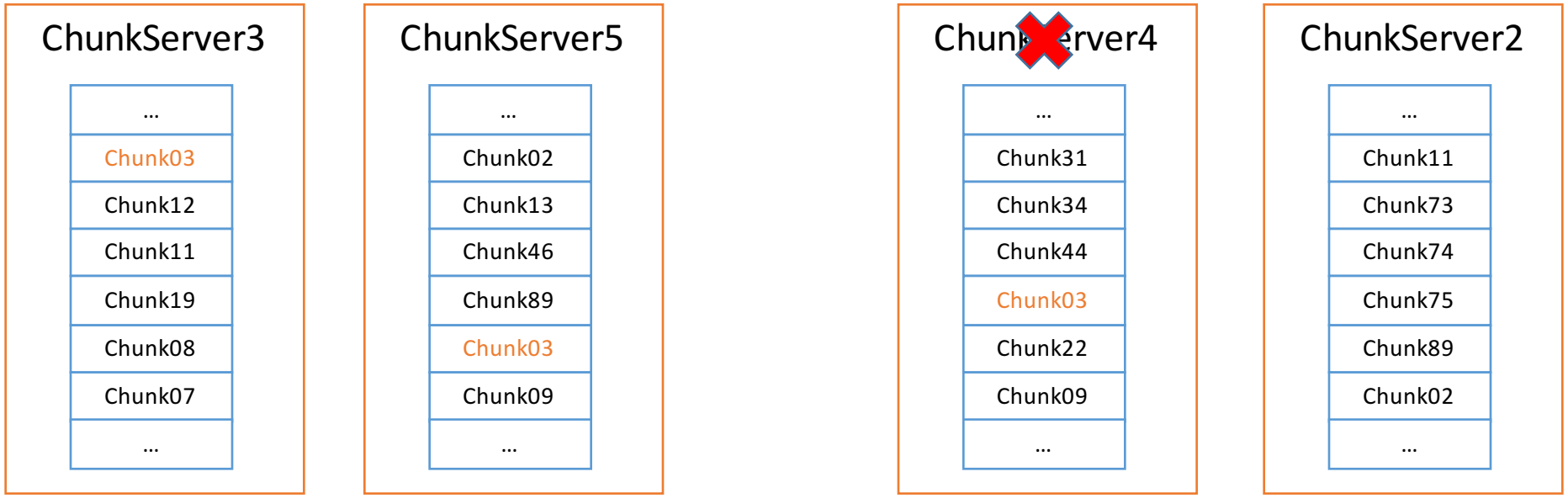
How to recover data when a ChunkServer is down?



- Key point
  - Repair priority is based on the number of replications



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Interviewer: How to avoid hot spot?

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How to avoid hot spot?

Master

Rebalance procedure

Chunk stats
- Chunk00, access frequency = 100
- Chunk01, access frequency = 50
- ...

Server stats
- ChunkServer01, free space = 21%, free bandwidth = 15%
- ChunkServer02, free space = 50%, free bandwidth = 21%
- ...

- Key point
  - Replicate a chunk into more replications when it is busy
  - Fill the ChunkServer with more space and more bandwidth

ChunkServer3	ChunkServer5	ChunkServer7	ChunkServer2
...	...	...	...
Chunk03	Chunk02	Chunk31	Chunk11
Chunk12	Chunk13	Chunk34	Chunk73
Chunk11	Chunk46	Chunk44	Chunk74
Chunk19	Chunk89	Chunk03	Chunk75
Chunk08	Chunk03	Chunk22	Chunk89
Chunk07	Chunk09	Chunk09	Chunk02
...	...	...	...

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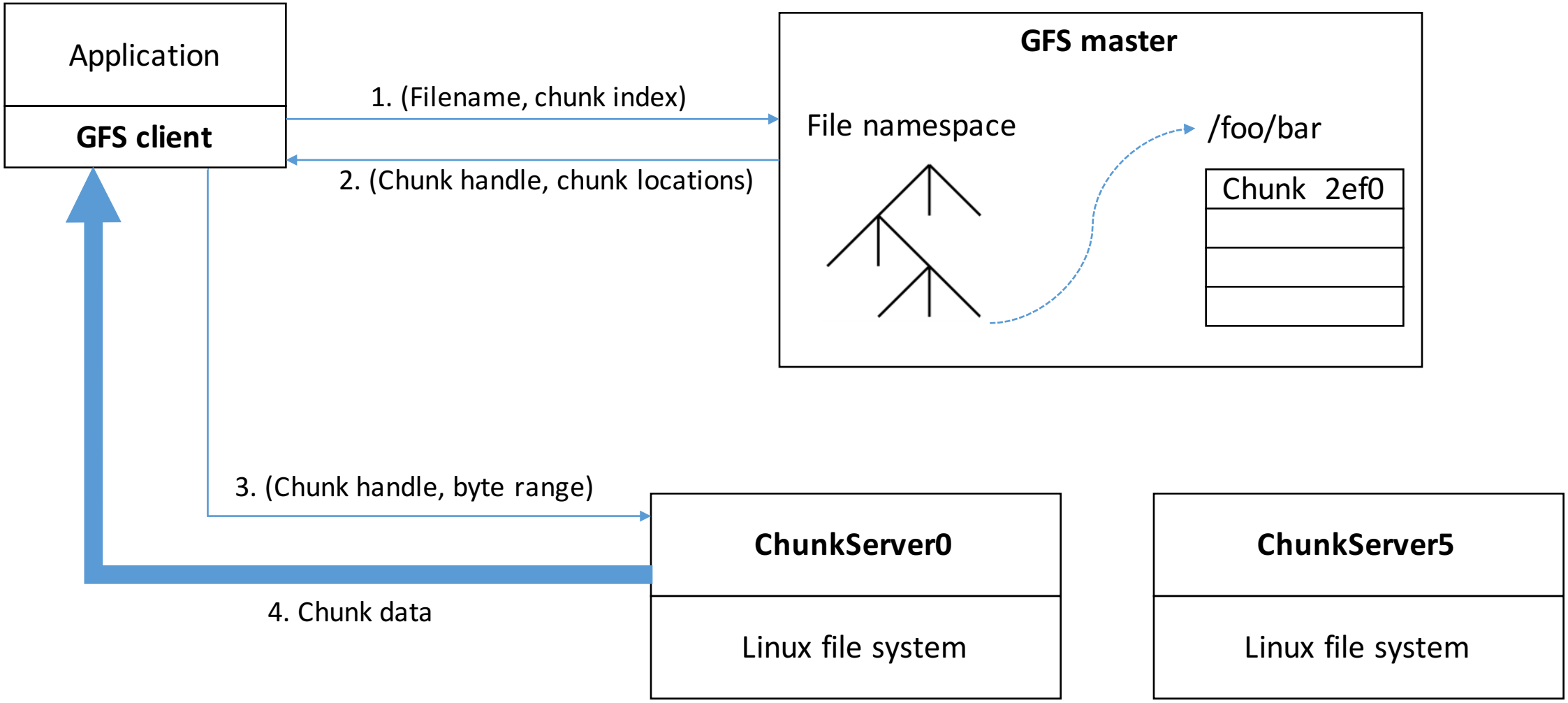
How to read from a file?



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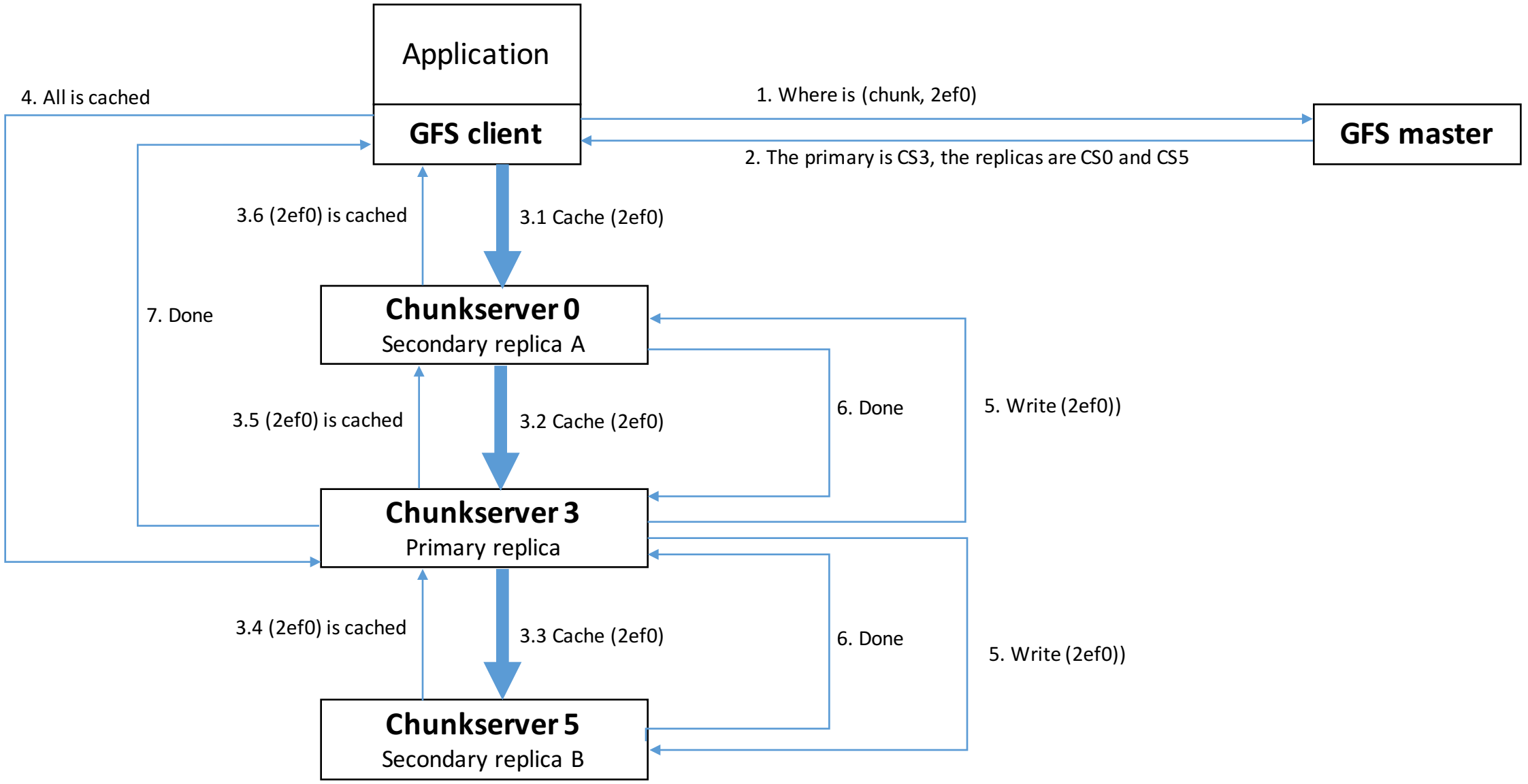
How to write into a file?



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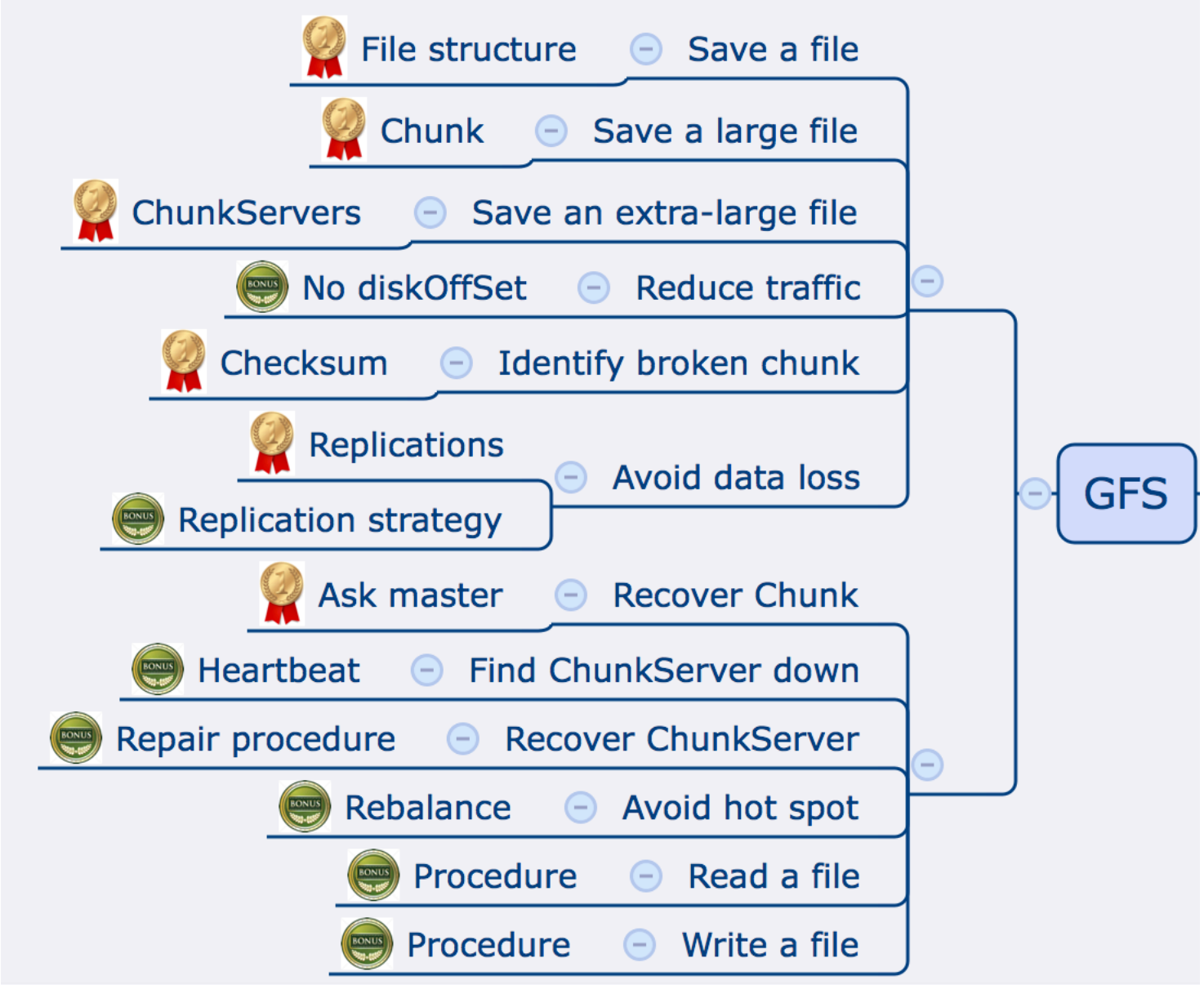
GFS Summary (6+7)



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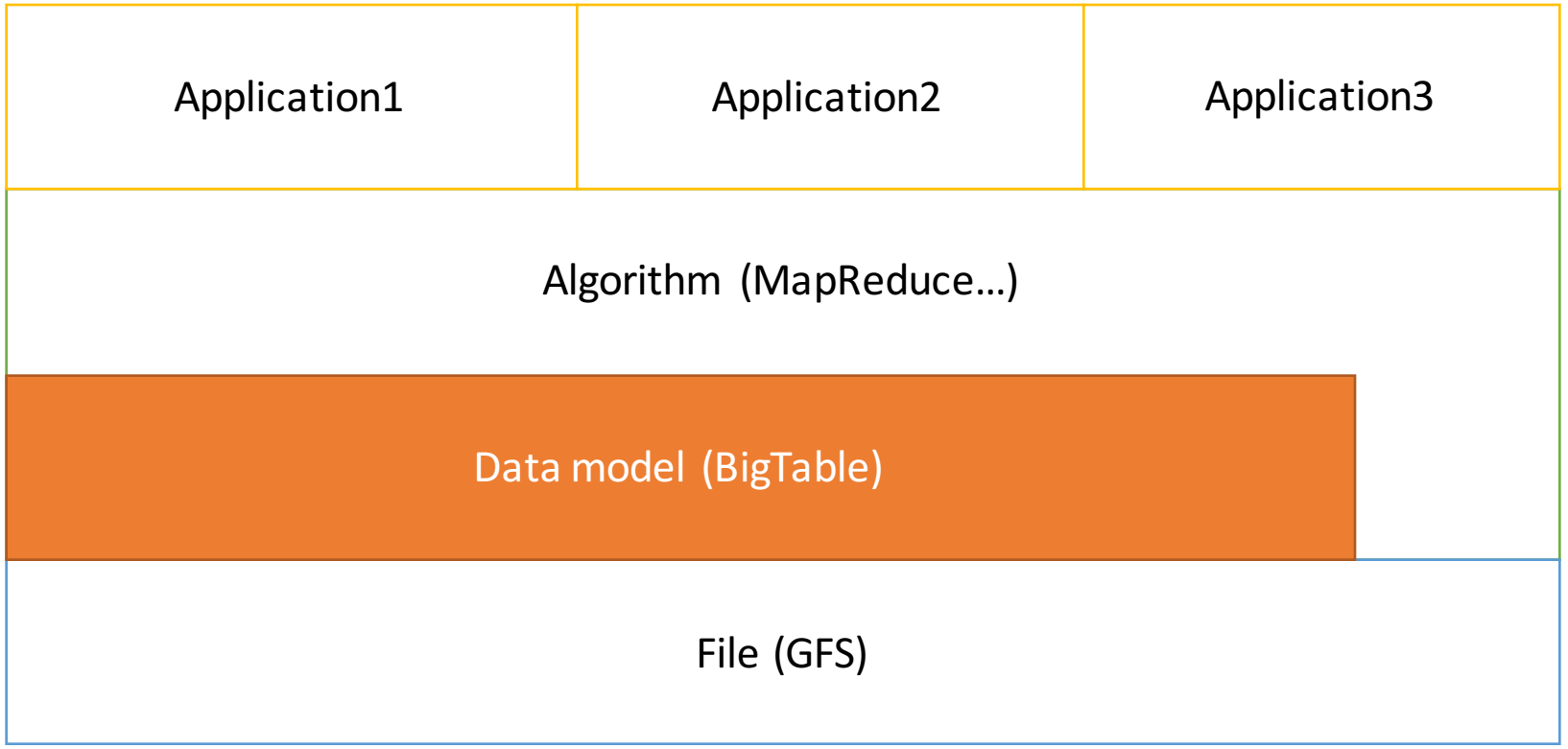
Layers of system



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我又不是因為想
得到你們的承認
才當英雄的
是因為
我想當才當的

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BigTable

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Interviewer: How to support lookup and range query on a file?

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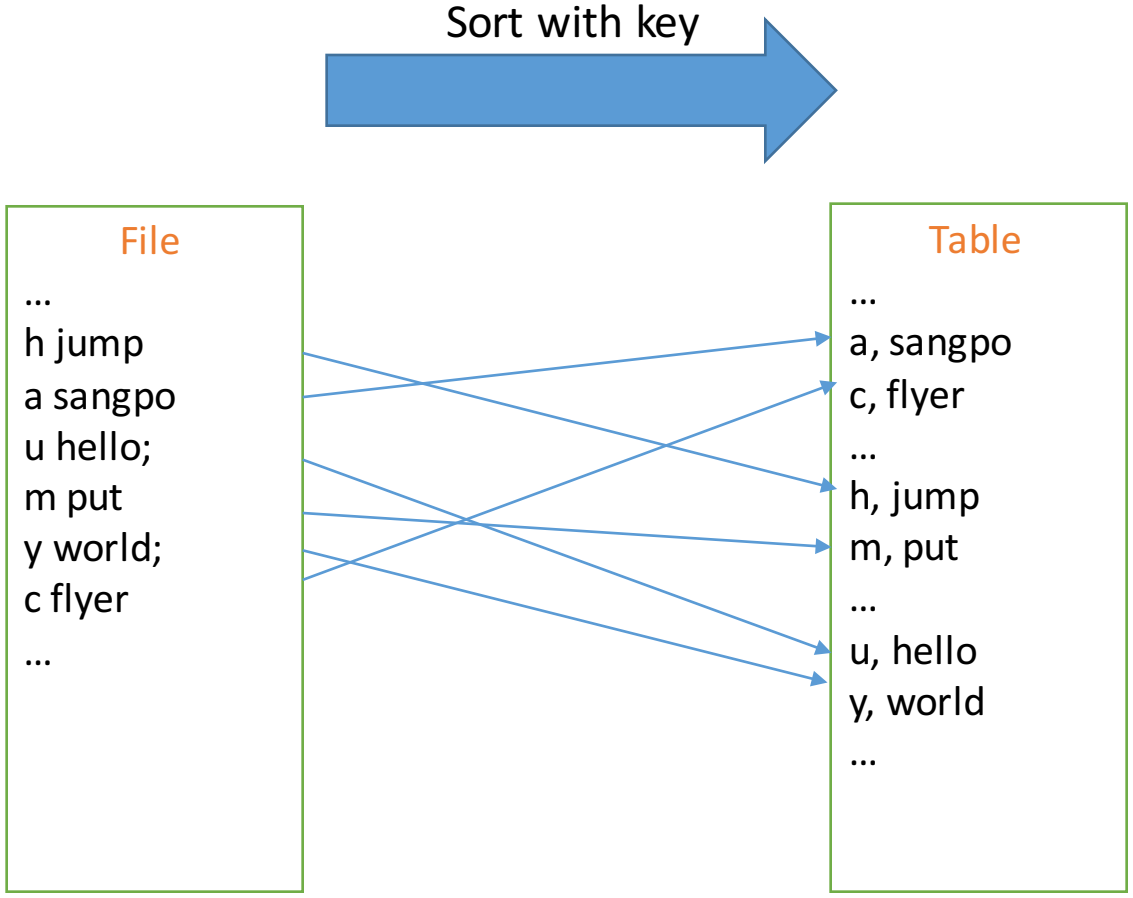
How to support lookup and range query on a file?



- Key point
  - Table = A list of sorted <key, value>

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Interviewer: How to save a large table?

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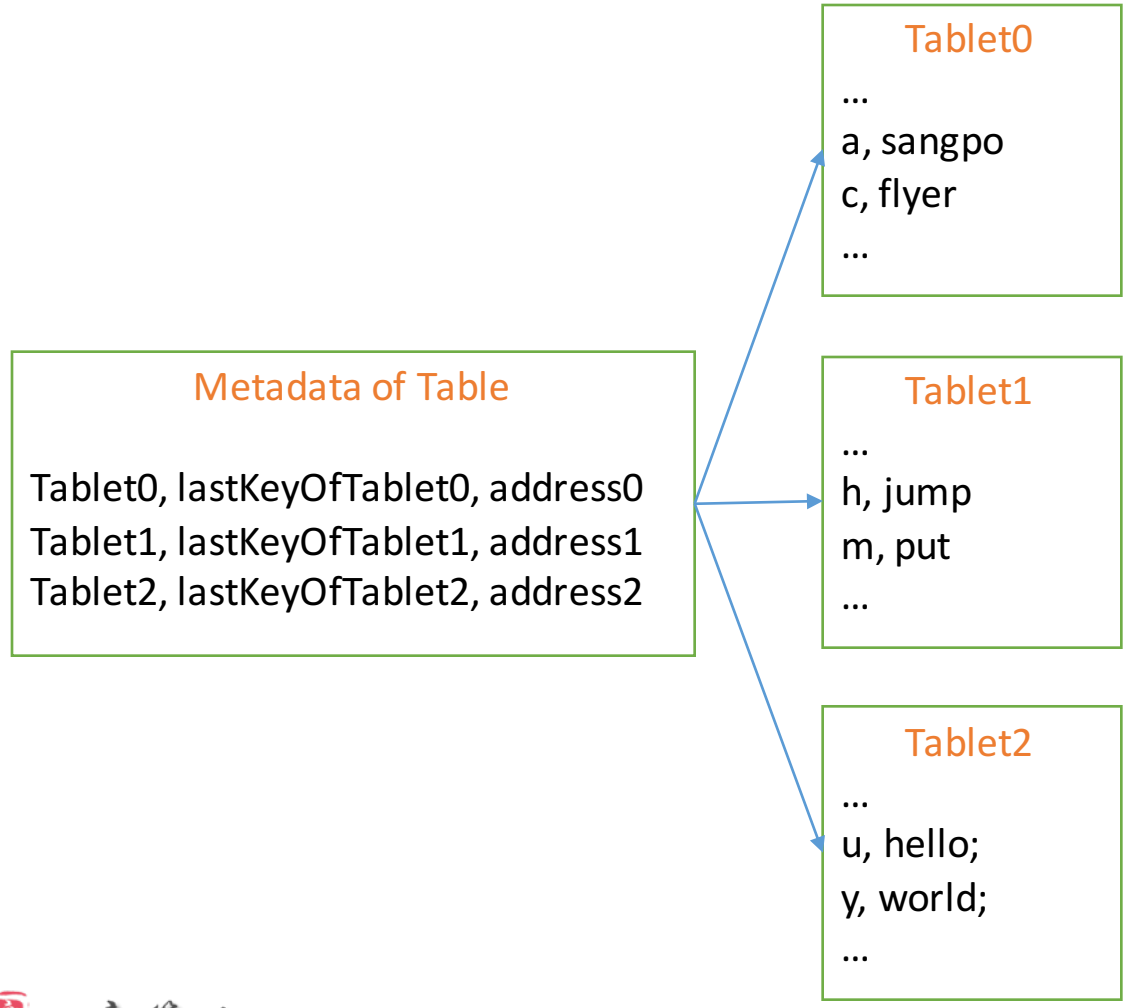
How to save a large table?



- Key point
  - A table = a list of tablets
  - A tablet = a list of sorted <key value>

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Interviewer: How to save an extra-large table?

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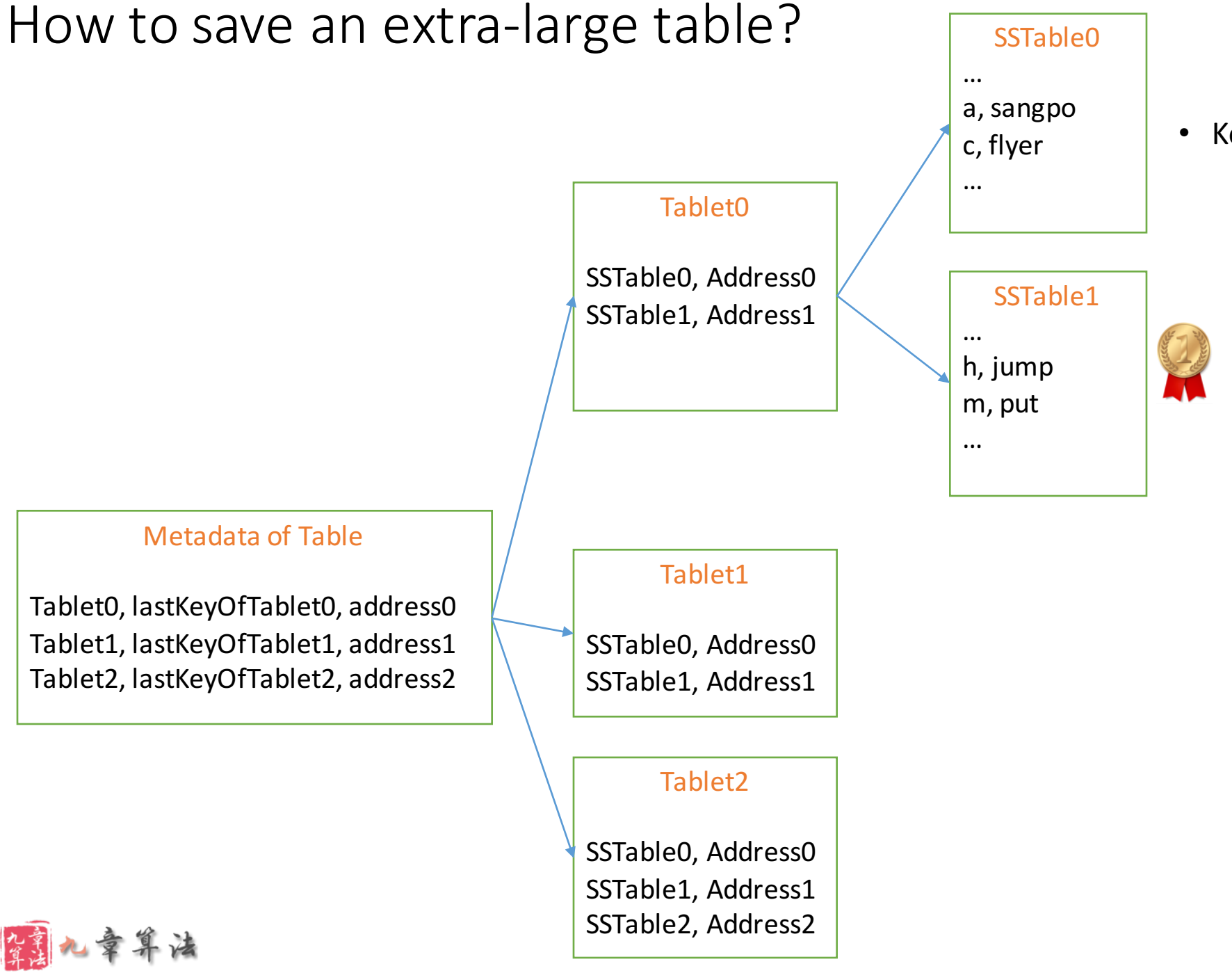
How to save an extra-large table?



- Key point
  - A table = a list of tablets
  - A tablet = a list of SSTables
  - A SSTable = a list of sorted <key, value>

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Interviewer: How to write into a table?

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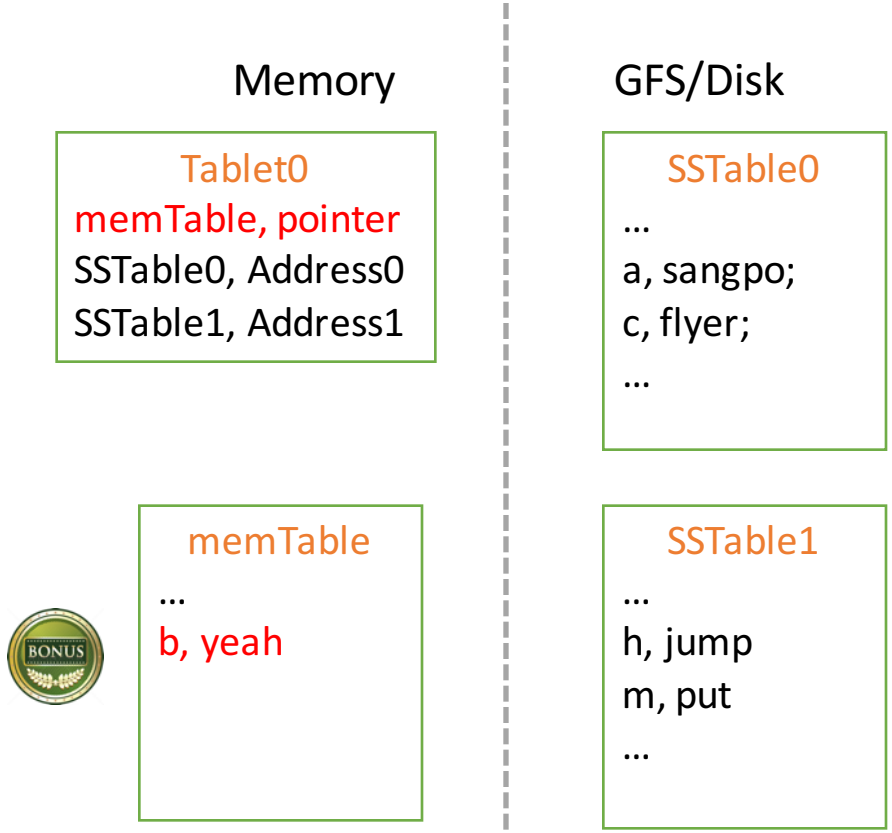
How to write into a table?

Task: add <b, yeah>



- Key point
  - Write into a memTable to increase speed
  - A tablet = memTable + a list of SSTables

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Interviewer: What if memTable is too large?

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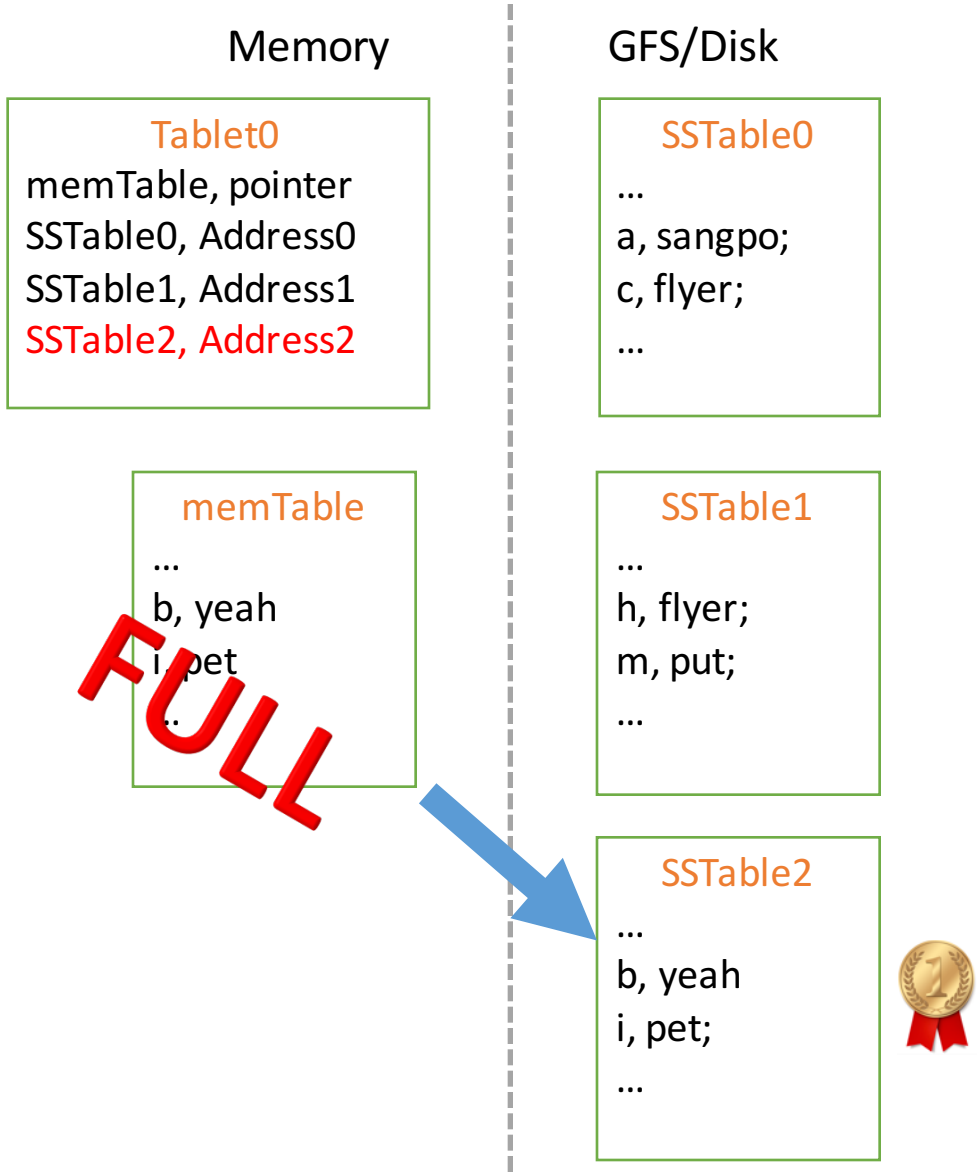
What if memTable is too large?



- Key point
  - Copy into a new SSTable in GFS/Disk when memTable is full

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Interviewer: How to avoid system failure?

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How to avoid system failure? Task: add <b, yeah>

Memory

Tablet0
memTable, pointer
SSTable0, Address0
SSTable1, Address1

memTable
...
b, yeah

GFS/Disk

SSTable0
...
a, sangpo;
c, flyer;
...

SSTable1
...
h, flyer;
m, put;
...
Index1 of blocks

tabletLog
...
Add <b,yeah>

- Key point
  - A tablet = memTable + a list of SSTables + log

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Interviewer: How to read data?

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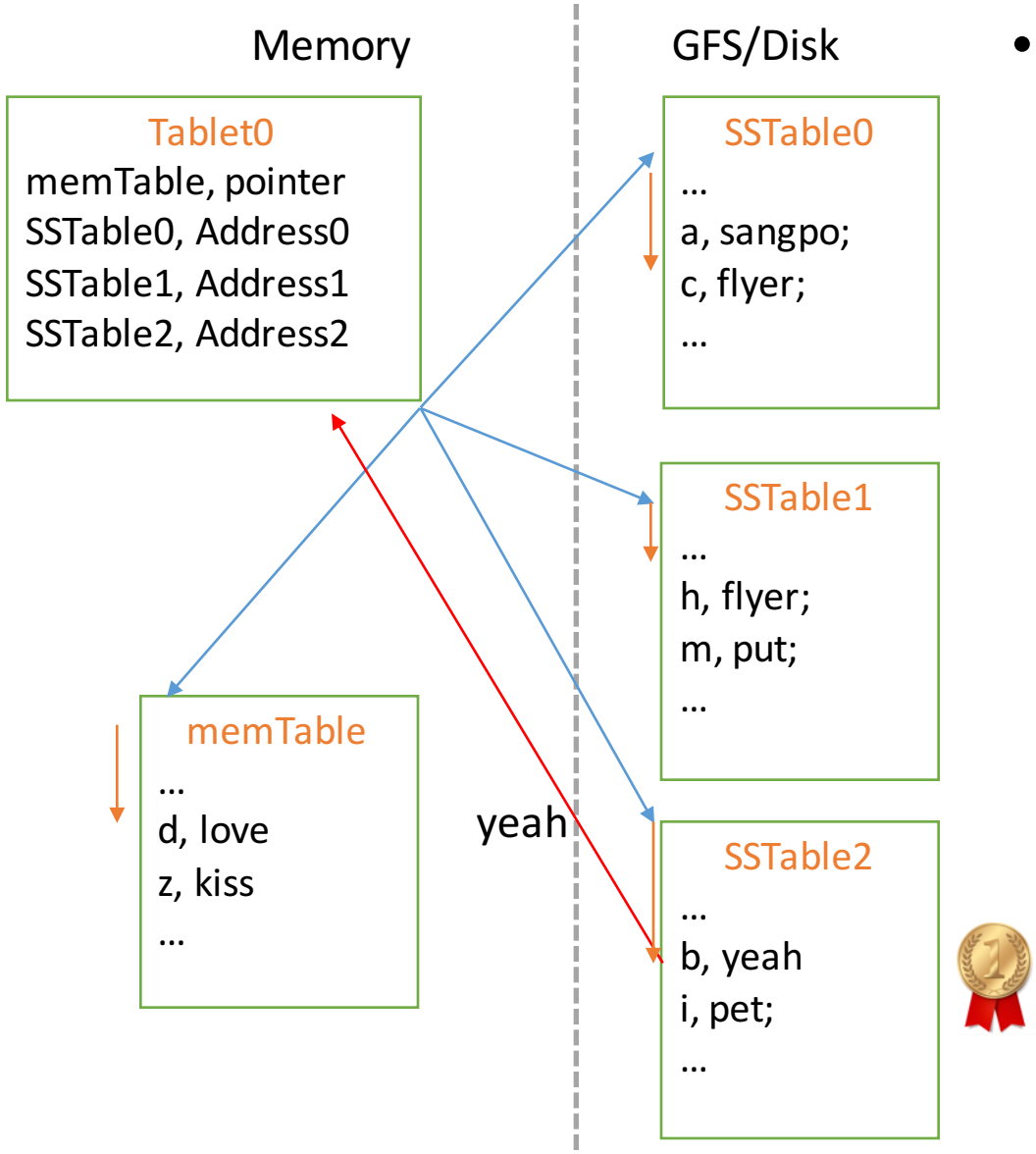
How to read data? Task: lookup(b)



- Key point
  - Due to our write strategy
    - Data is ordered inside a SSTable
    - Data is not ordered among SSTables
  - A read need to ask all SSTables and memTable
  - Each SSTable needs to use Disk search to find the element

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Interviewer: How to read data fast?

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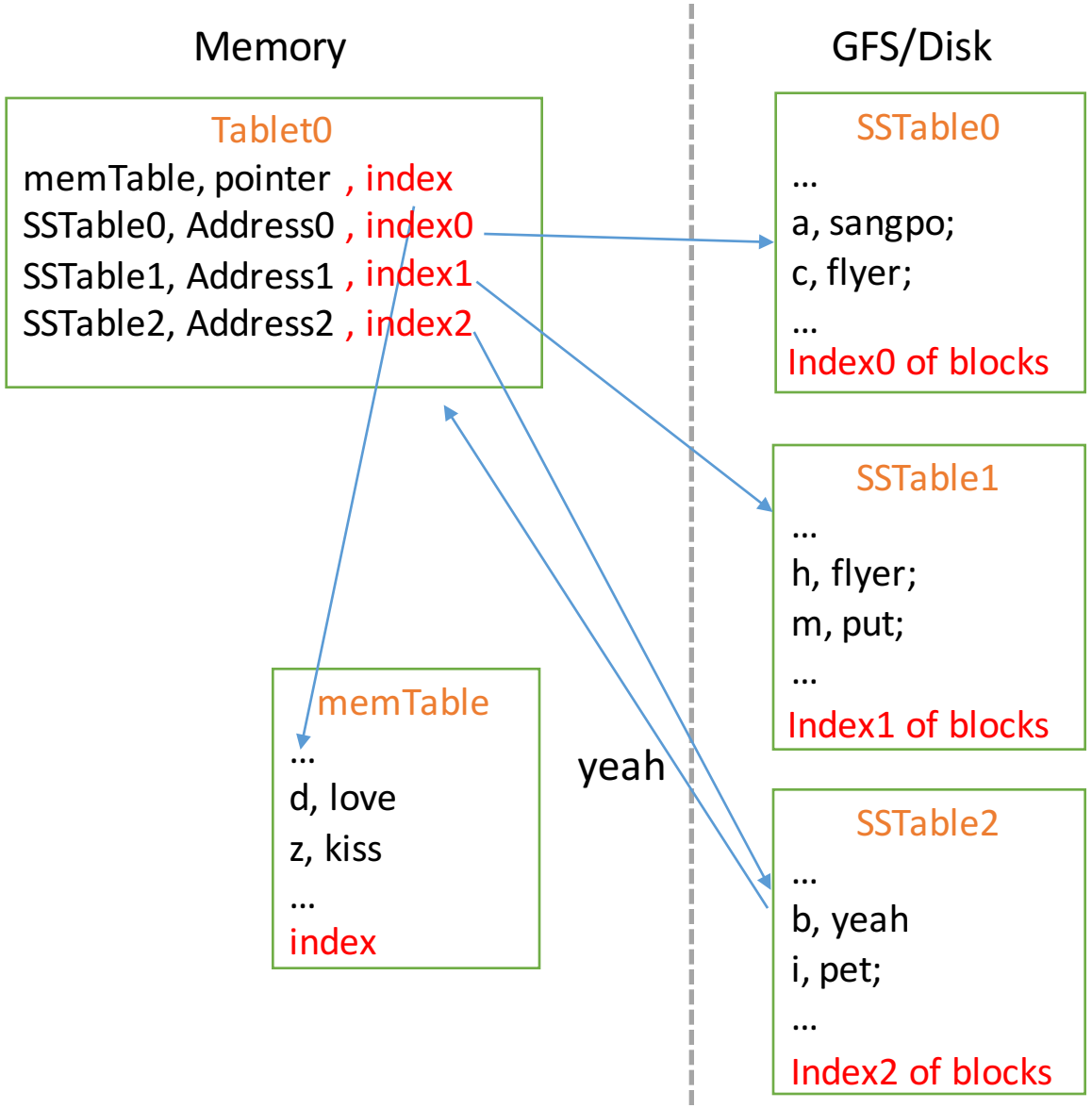
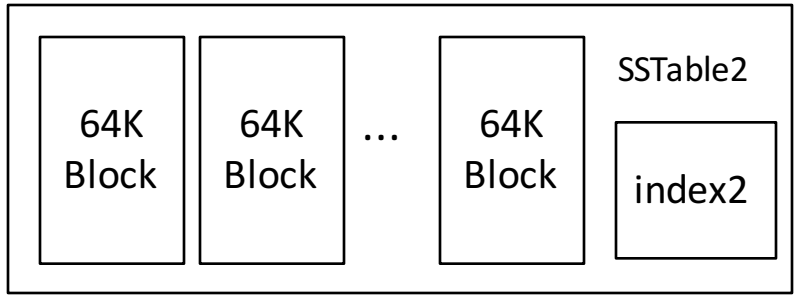
How to read data fast?

Task: lookup(b)?



- Key point
  - A SSTable = a list of sorted <key, value>
    = a list of 64K blocks + inde
  - Indices are pre-loaded into memory
  - Read fast by
    - Use indices to identify the place in disk



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Interviewer: Read faster?

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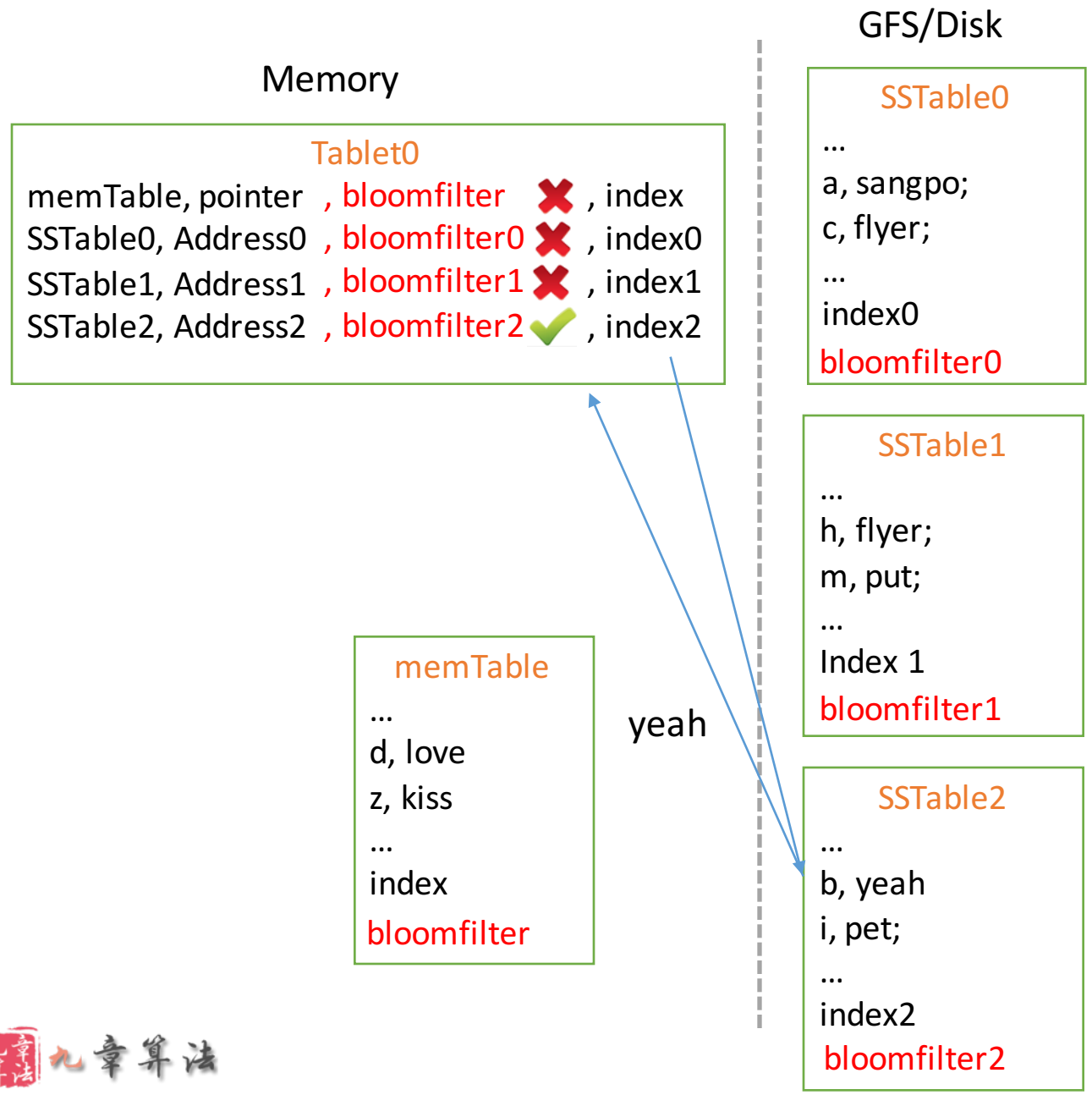
How to read data faster? Task: lookup(b)?



- Key point
  - A SSTable = a list of sorted <key, value>
    = a list of 64K blocks + index + bloomfilter
  - Bloomfilters are pre-loaded into memory
  - Read faster by
    - Check the existence of the element with bloomfilters

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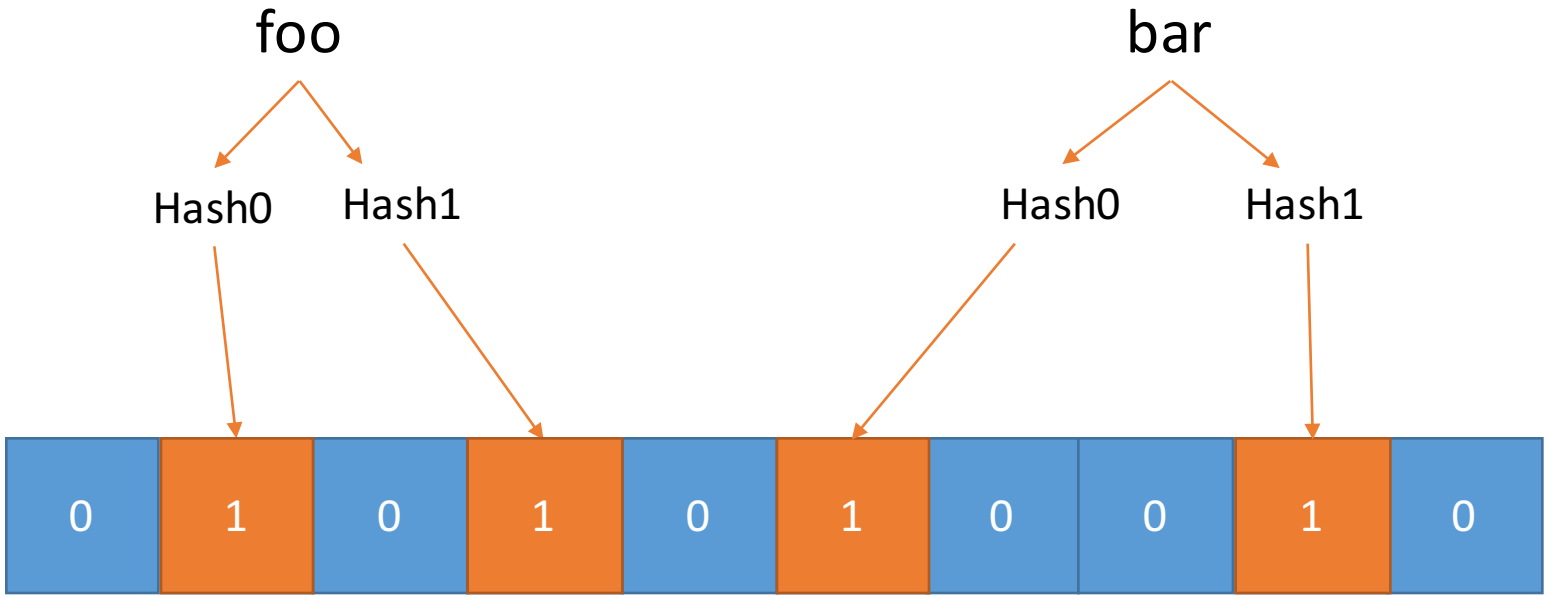
How to build bloom filter?



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Expert/Master, http://url.cn/aPCYvo
Expert/Master, http://url.cn/TkF35M

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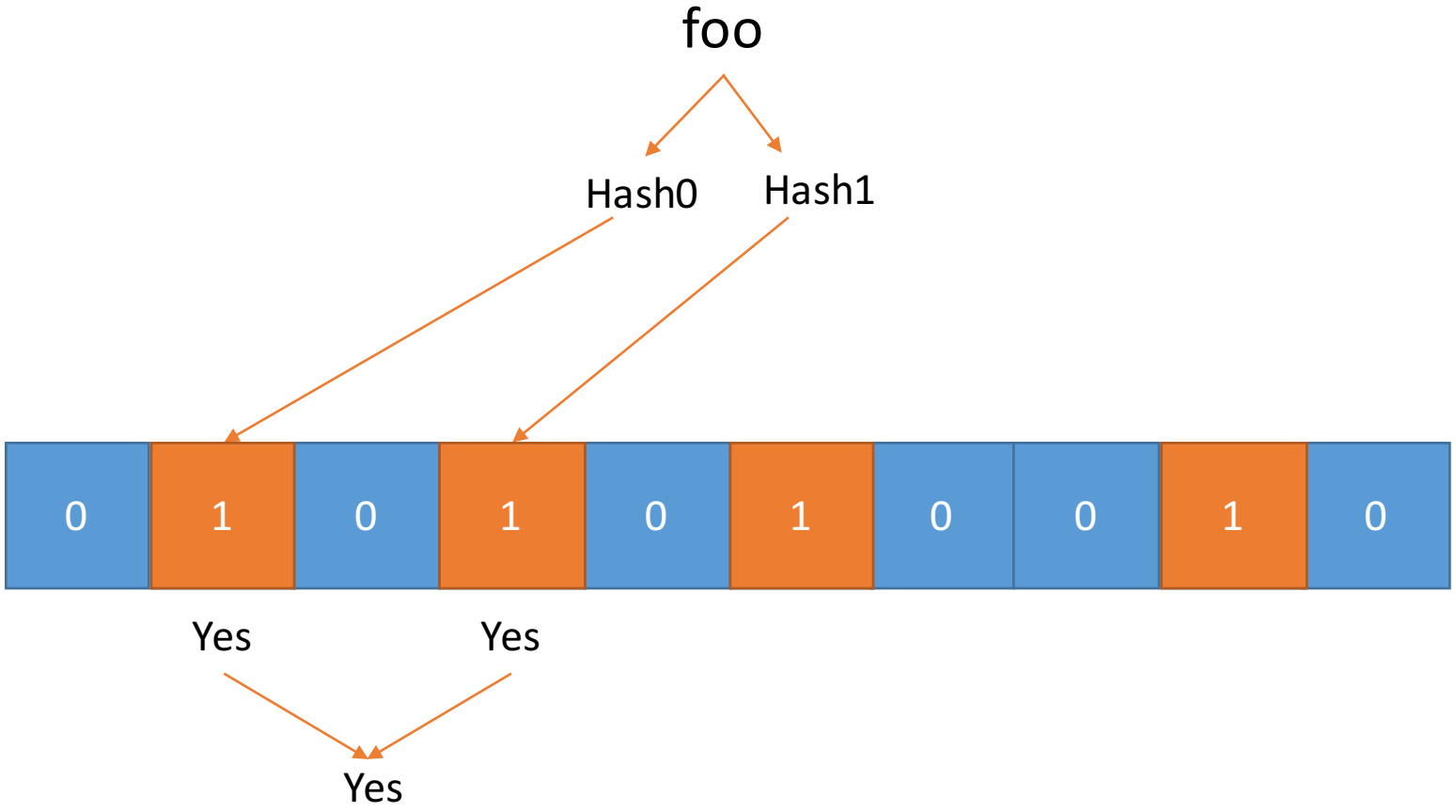
Lookup “foo”



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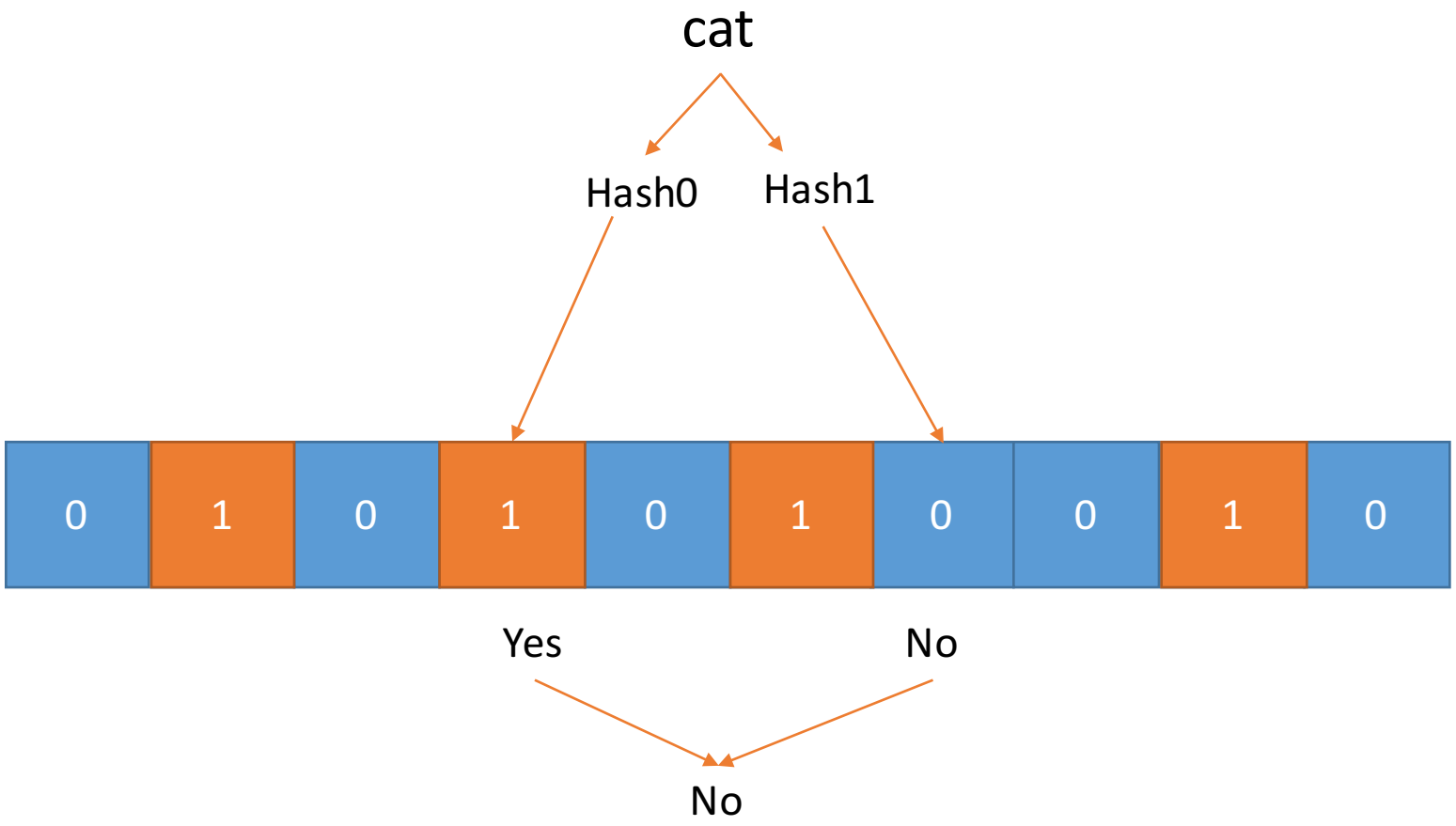
Lookup “cat”



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Interviewer: How to save a table into GFS?

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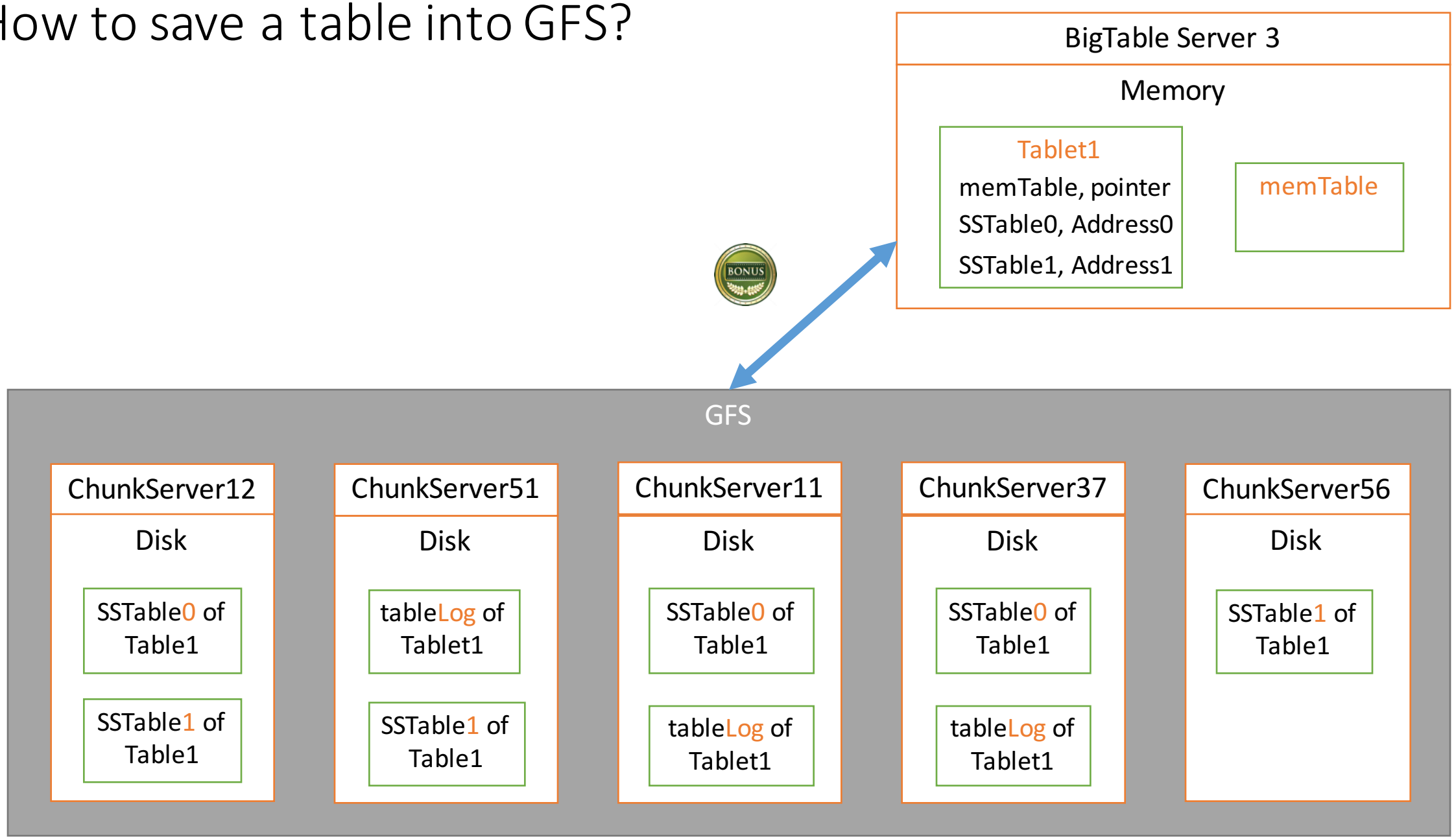
How to save a table into GFS?



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Interviewer: What is the logical view of table?

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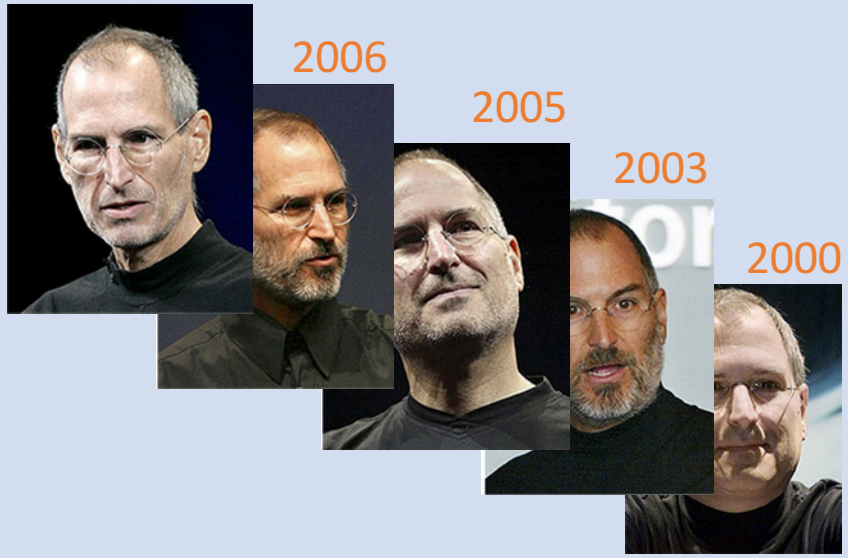
What is the logical view of table?

		Body	
Name	Photo	Weight	Height
Sangpo			
Steve		110lb, 2009 120lb, 2008 150lb, 1995	6'2", 2011 5'7", 1987
Tiger			

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Interviewer: How to transform logic view into physical storage?

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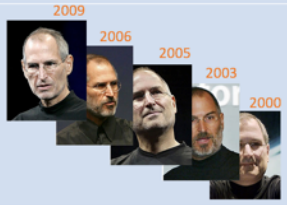
How to transform logic view into physical storage?

Logic view of Table

Name	Photo	Body	
		Weight	Height
Sangpo			
Steve		110lb, 2009 120lb, 2008 150lb, 1995	6'2", 2011 5'7", 1987
Tiger			

Key = string(row, column, time)

Physical storage of <Key, value>

Table

...
Steve;Body:Height;2011 -> 6'2"
Steve;Body:Height;1987 -> 5'7"
Steve;Photo;2009 -> 2009.JPG
Steve;Photo;2006 -> 2006.JPG
Steve;Photo;2005 -> 2005.JPG
...

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Interviewer: What is the architecture of BigTable?

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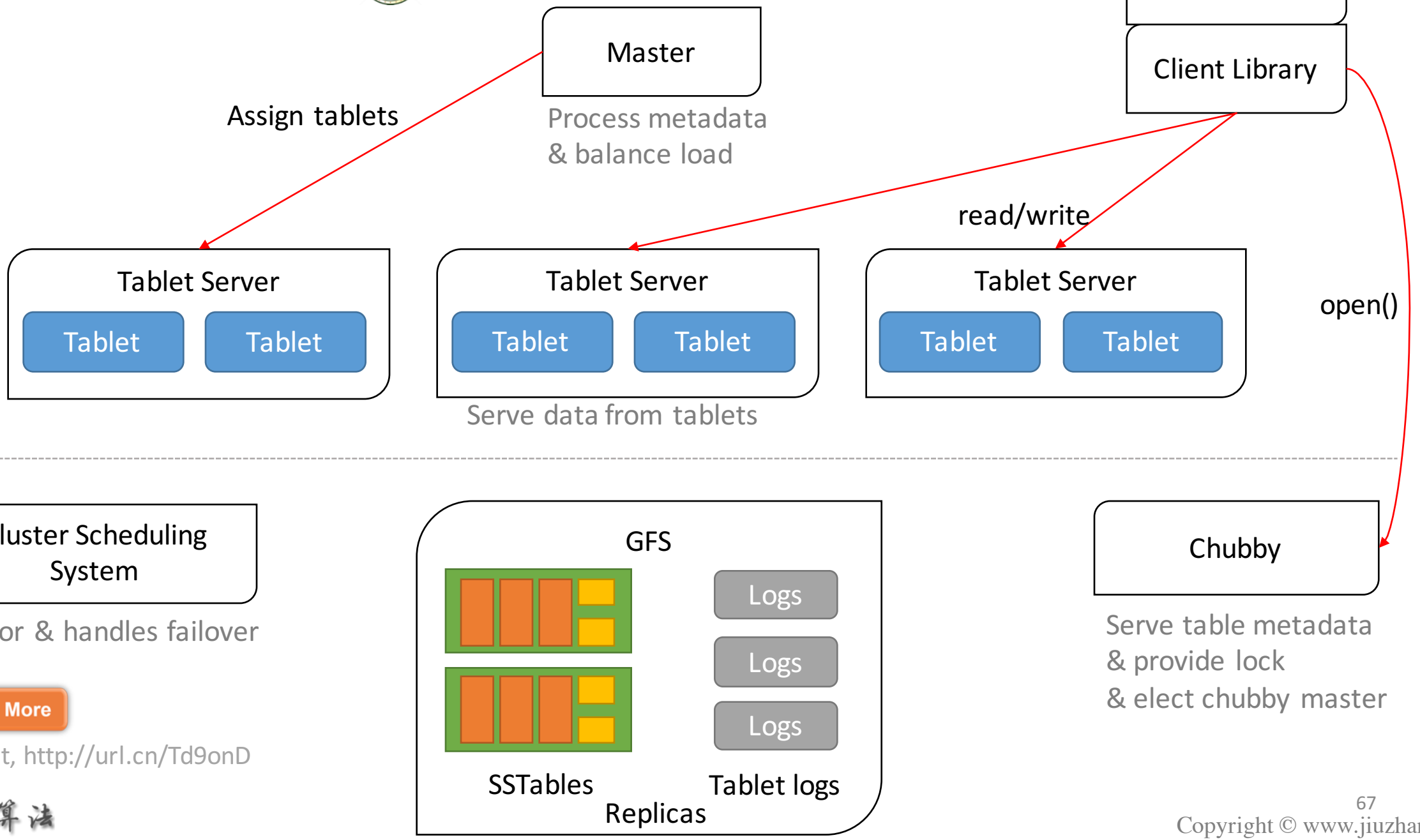
BigTable architecture



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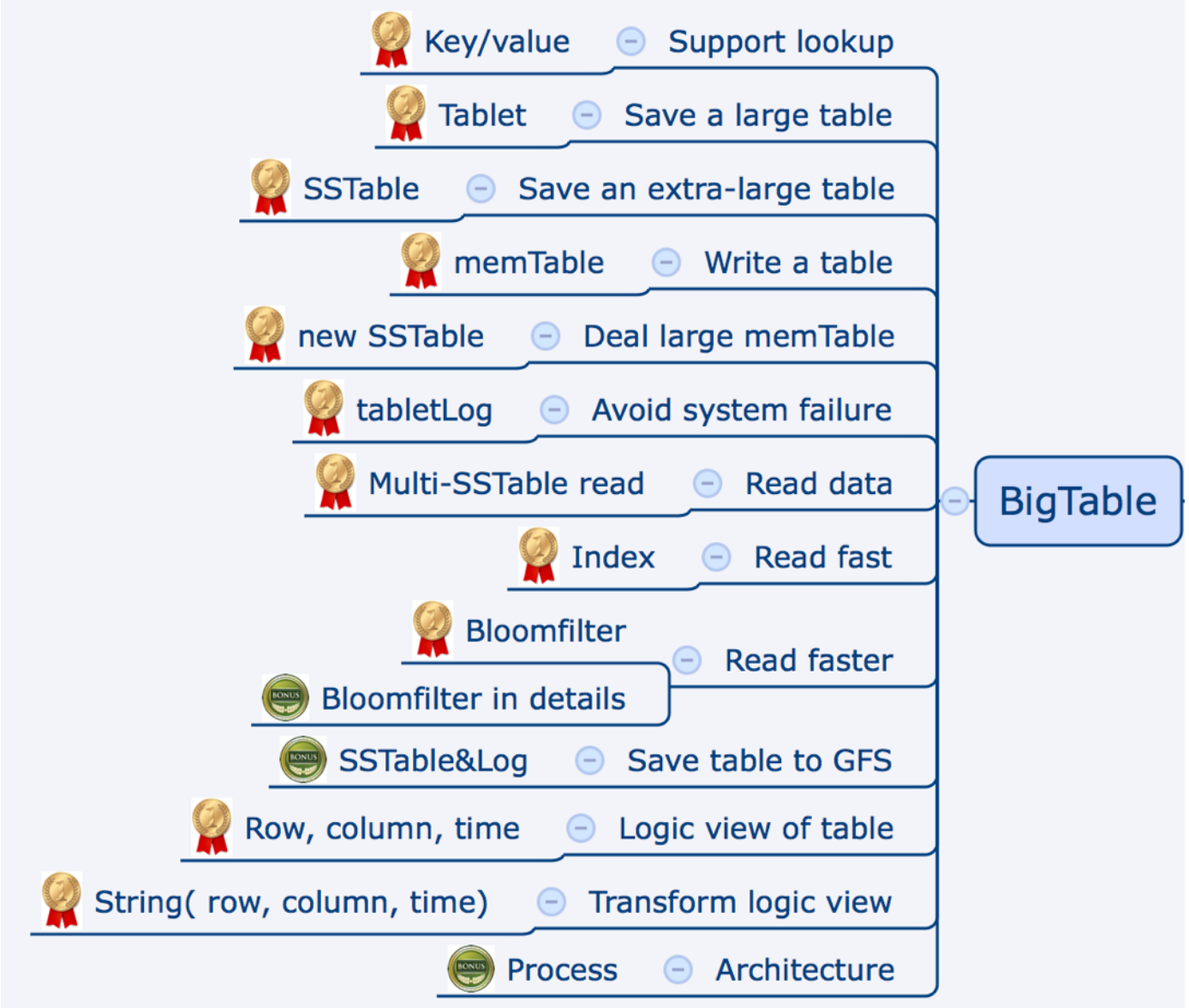
BigTable summary (11+3)



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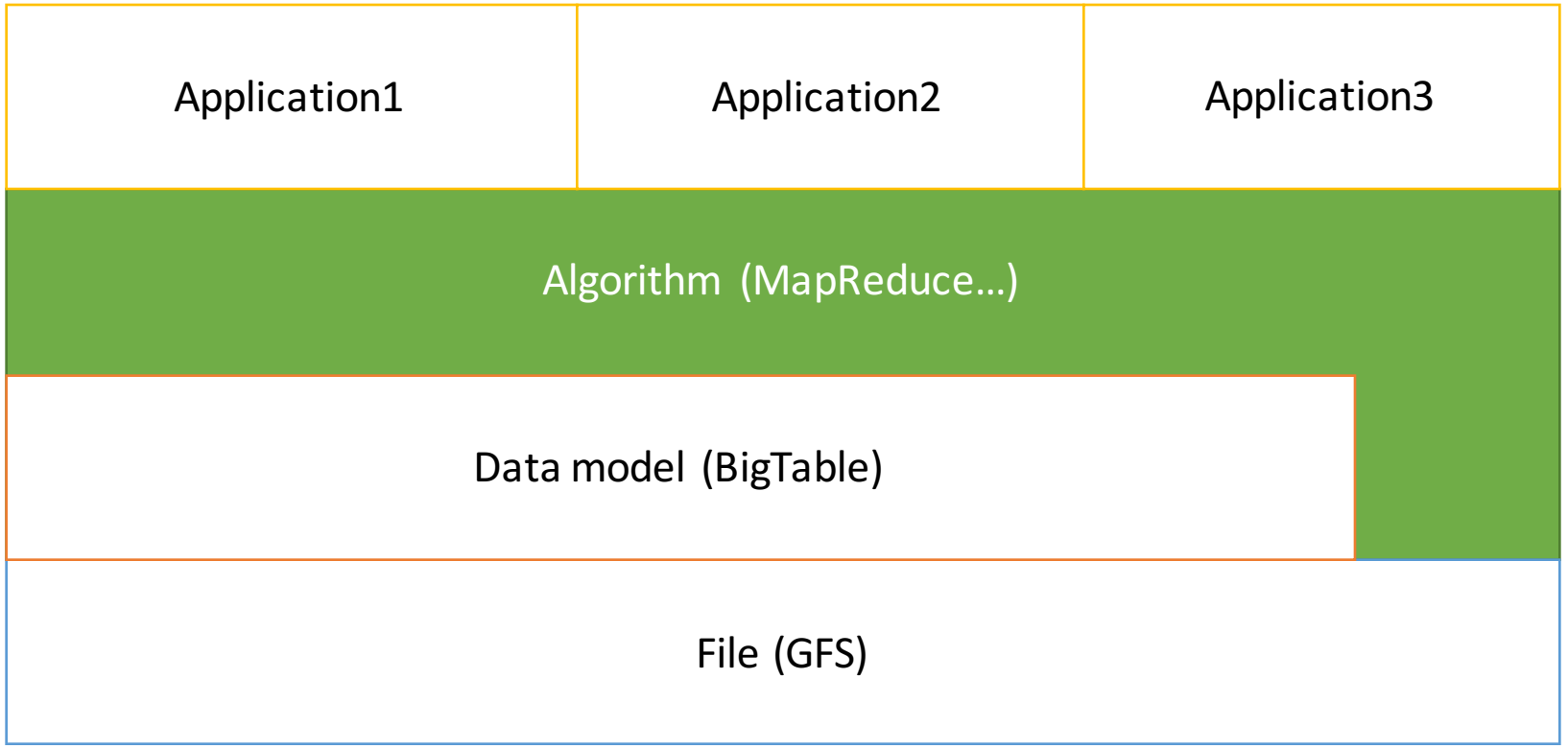
Layers of system



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MapReduce

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Expert, http://url.cn/b41Qzf
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For 1TB <key, value> data, how to compute

- appearances of words
- inverted index
- anagrams

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Interviewer: What is Map and Reduce?

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What is map?

Input

Map

Output

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What is reduce?

Input

Reduce

Output

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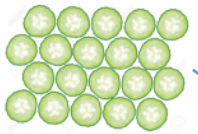
MapReduce

Input | Split | Map | Shuffle | Reduce | Finalize














Ticket 13

Ticket 14

Ticket 15

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Interviewer: Calculate word appearance with MapReduce

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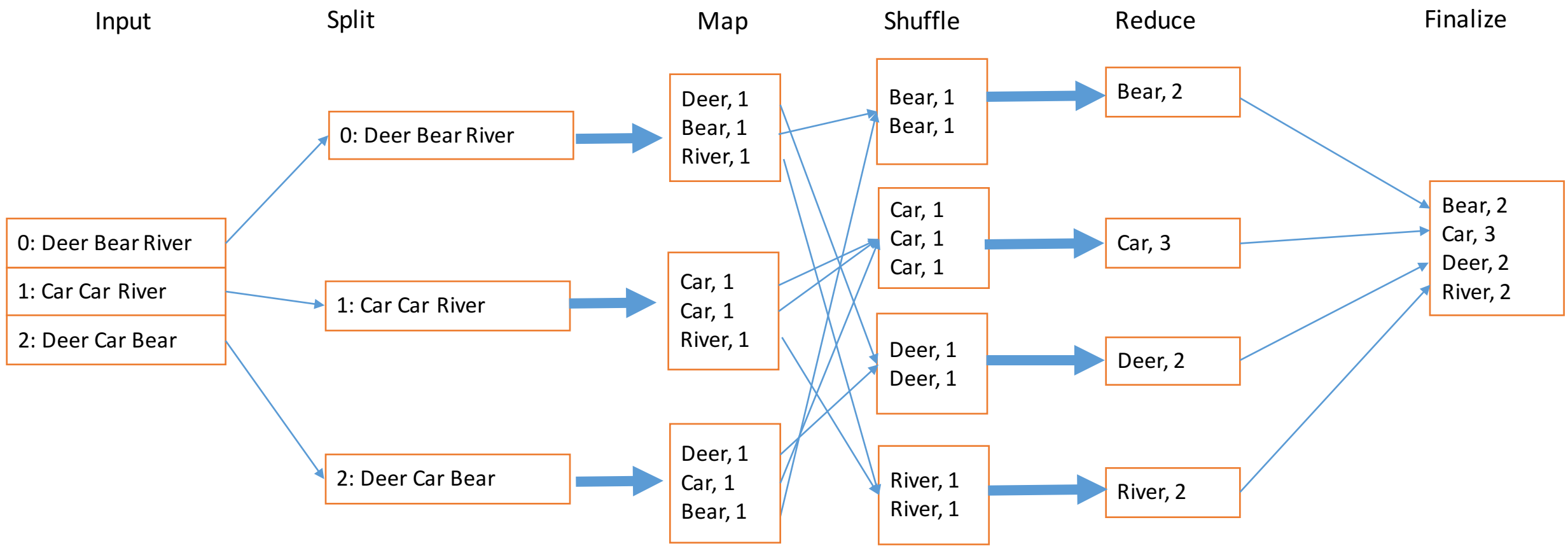
Calculate each word's number of appearance




```
Map( string key, string value)
    //key: the id of a line
    //value: the content of the line
    for each word in value:
        OutputTemp( word, 1);
```

```
Reduce( string key, list valueList)
    //key: the name of a word
    //valueList: the appearances of this word
    int sum = 0;
    for value in valueList:
        sum+=value;
    OutputFinal( key,sum);
```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Interviewer: Build inverted index with MapReduce?

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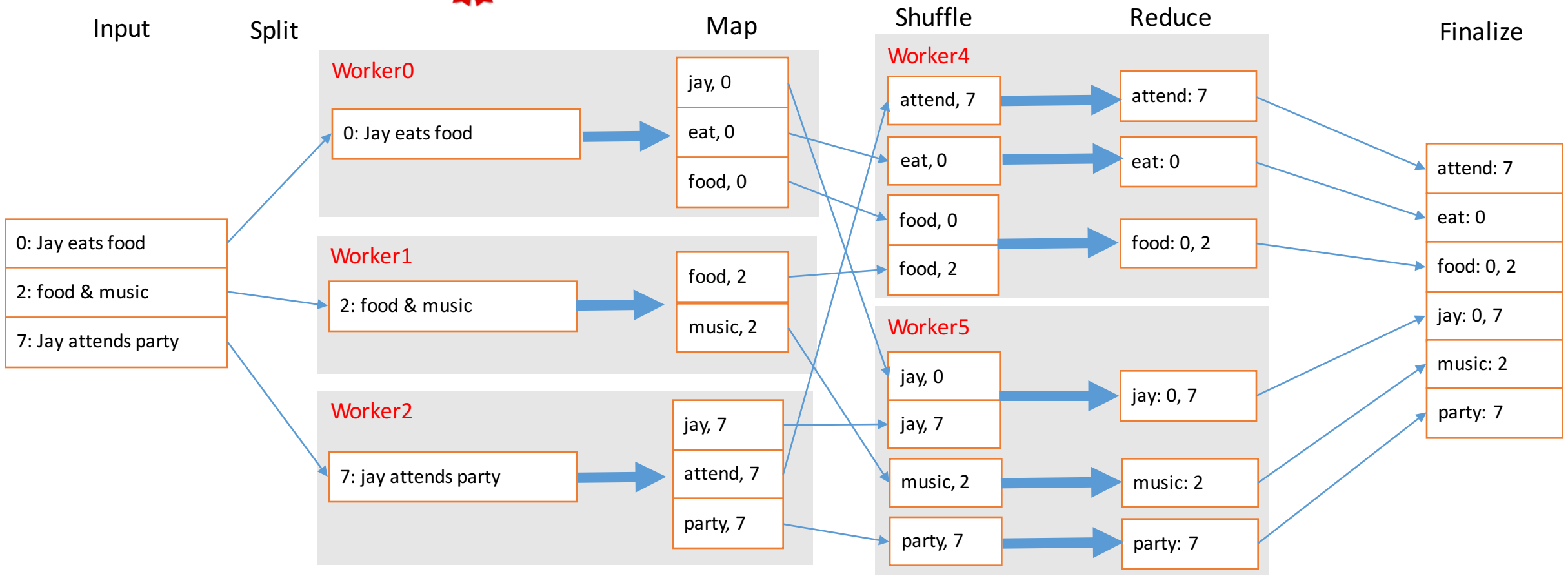
Build inverted index




```
Map( string key, string value )
    //key: the id of a document
    //value: the content of the document
    for each word in value:
        OutputTemp( word, key );
```

```
Reduce( string key, list valueList )
    //key: the name of a word
    //valueList: the appearances of this word in documents
    List sumList;
    for value in valueList:
        sumList.append(value);
    OutputFinal( key, sumList );
```

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Novice/Expert, http://url.cn/fsZ927

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Interviewer: Calculate anagrams with MapReduce?

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LintCode *Coding interview questions online training system*

Medium Anagrams

Given an array of strings, return all groups of strings that are anagrams.

Example

Given `["lint", "intl", "inlt", "code"]`, return `["lint", "inlt", "intl"]`.

Given `["ab", "ba", "cd", "dc", "e"]`, return `["ab", "ba", "cd", "dc"]`.

Anagram(lint) = { <i,1>, <l,1>, <n,1>, <t,1> }
Anagram(intl) = { <i,1>, <l,1>, <n,1>, <t,1> }
Anagram(inlt) = { <i,1>, <l,1>, <n,1>, <t,1> }

Anagram(code) = { <c,1>, <d,1>, <e,1>, <o,1>}

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Novice, http://url.cn/WGXjtQ
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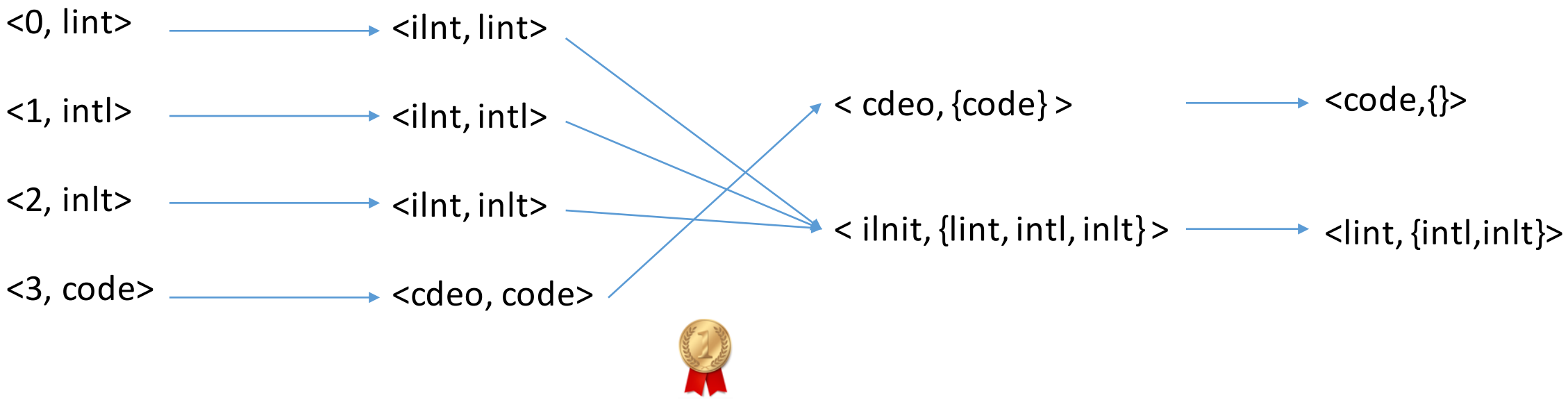

Map

Input
k = lineID
v = word

Output
k = sort(word)
v = word

Shuffle

Reduce

Input
k = sort(word)
v = {anagram0, anagram1, ...}

Output
k = anagram0
v = {anagram1, anagram2,...}

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Interviewer: What is the architecture of MapReduce?

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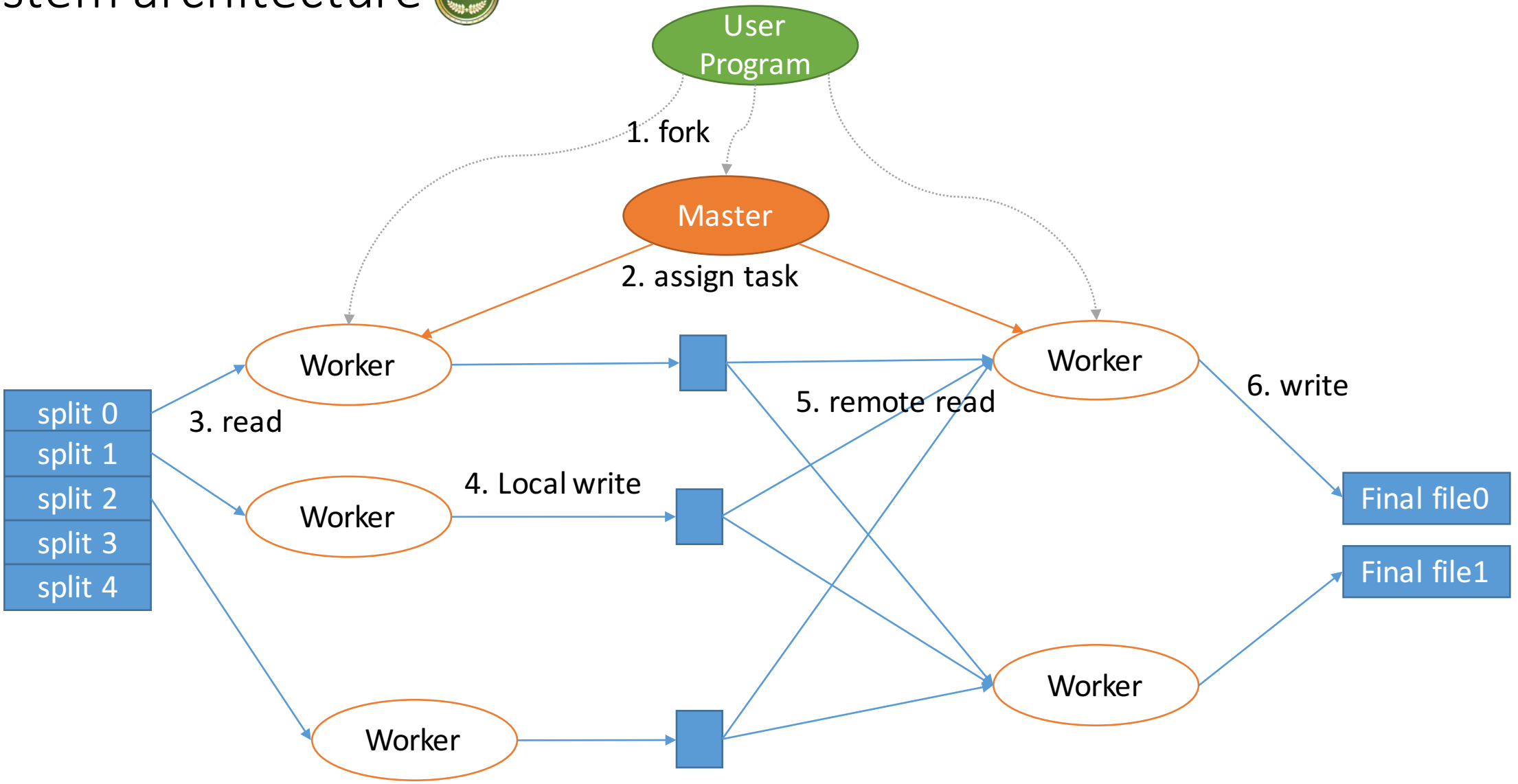
System architecture



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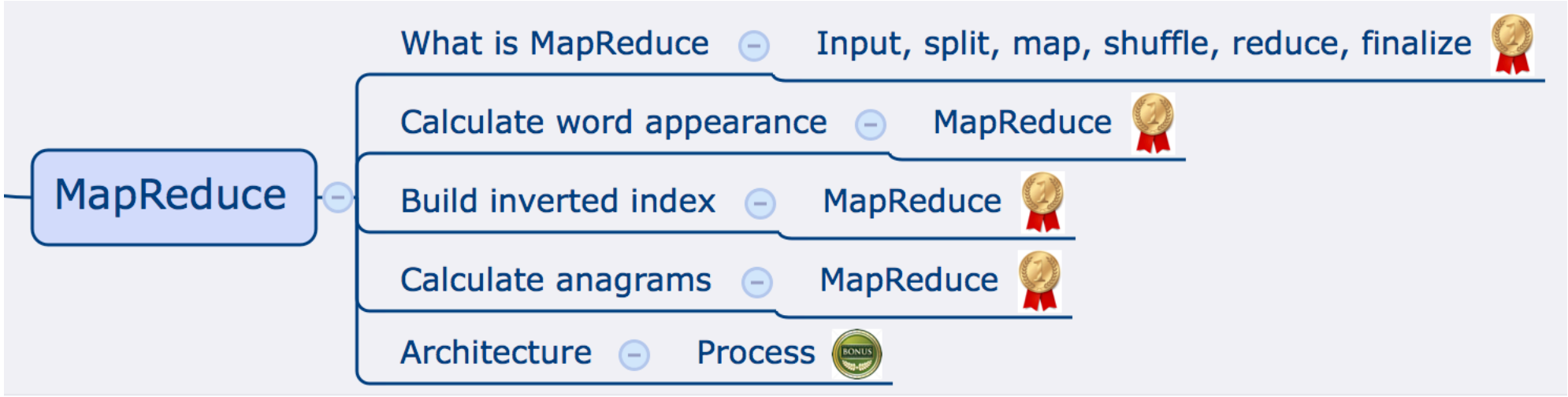
MapReduce summary (4+1)



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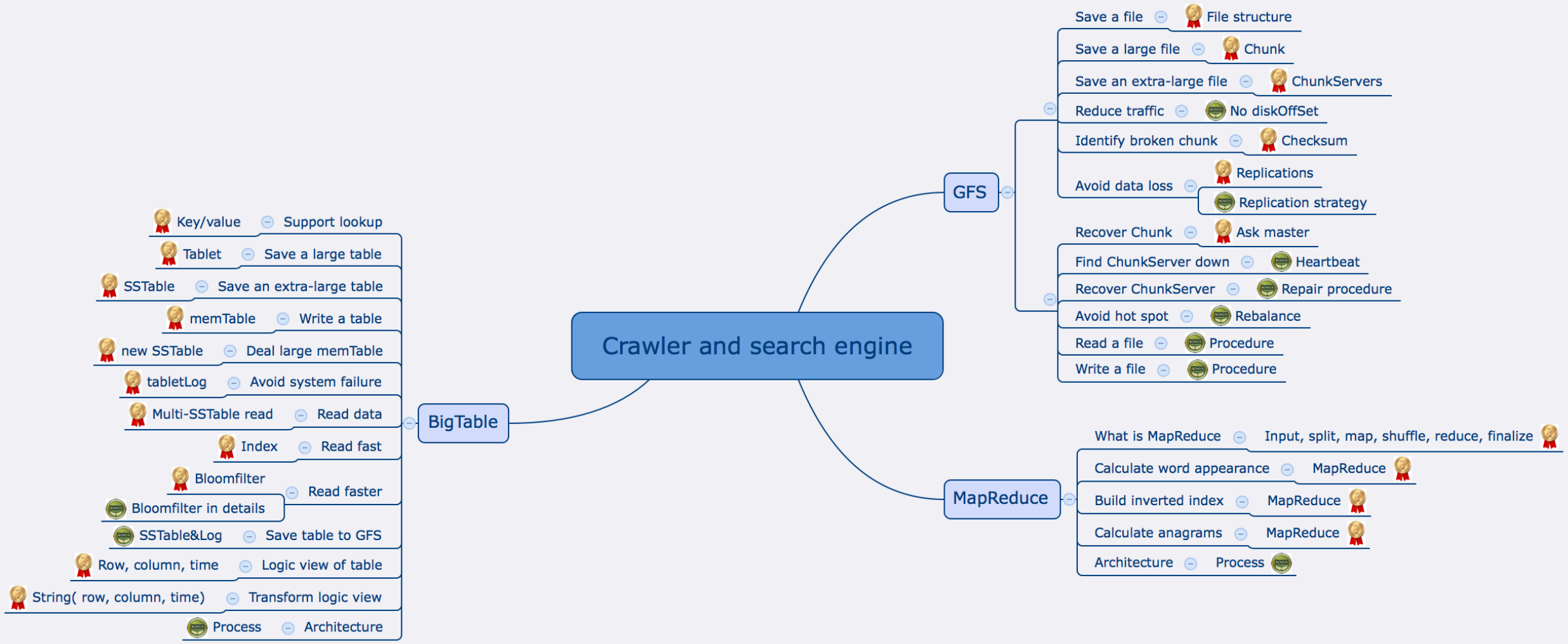
Class5 summary



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Keyword

- GFS
- BigTable
- MapReduce

- Bloom filter

- Log analysis

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Homework

- Output top10 IPs in the latest hour in real-time

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QA

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MR. Problem

Divide & Conquer

Map is disassemble;
Reduce is assemble.
Our life is a sequence of
assemble and disassemble.

You may wonder why!
Is it true?
But how to solve my job interview,
such a real problem?

Disassemble MR. problem again and again,
Until you can assemble the courage to face it.
Wish you, my friend,
Assemble all the pieces to win your job, hohoho!

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