PES UNIVERSITY ONLINE

BIG DATA

Map Reduce Programming model and Architecture

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What we have learnt so far..

- Large amounts of data to be processed.
- We have HDFS as a distributed store.
- We need to distribute the processing also.

What is Map Reduce ?

Why Map-Reduce ?

- A new fundamental way to process extremely large data (?)
- We are going to
  - Study Map-Reduce paradigm
  - Study Hadoop architecture
    - Open Source implementation of Map-Reduce

What is MapReduce ?

- Origin from Google, [OSDI’04]
- A simple programming model
- Functional model
- For large-scale data processing
    - Exploits large set of commodity computers
    - Executes process in distributed manner
    - Offers high availability

Big Data: Map Reduce Motivating Example

Map Reduce - Motivation

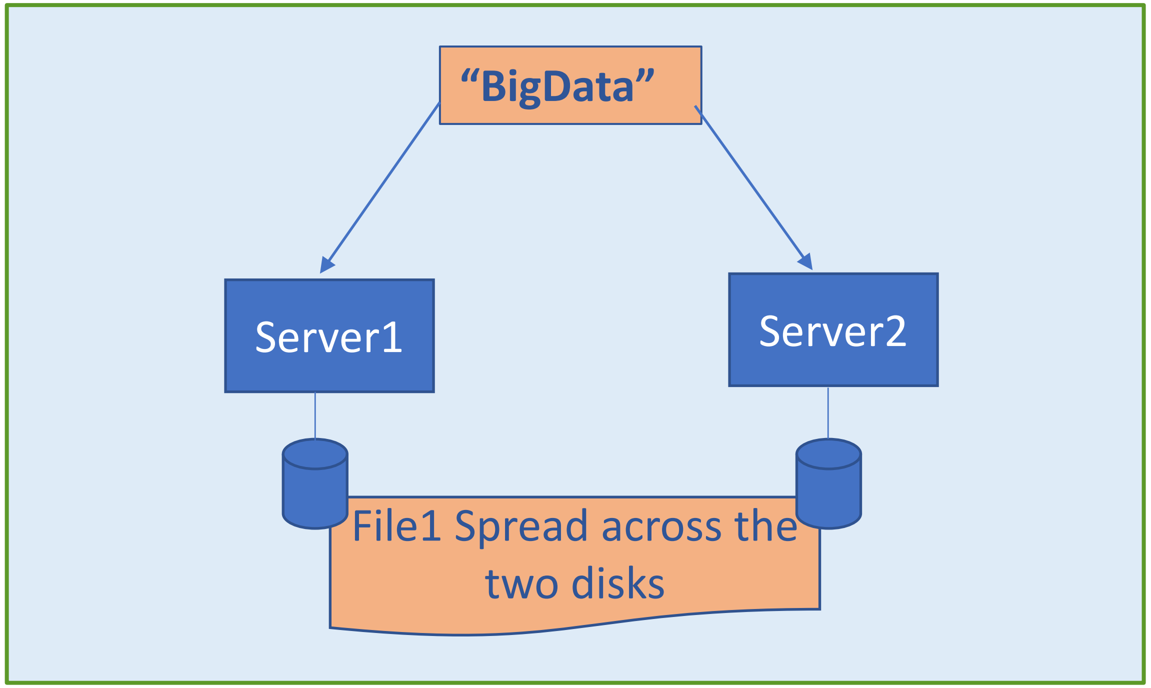
- Lots of demands for very large scale data processing

- Lots of machines needed (scaling)
- Two basic operations on the input
  - Map
  - Reduce

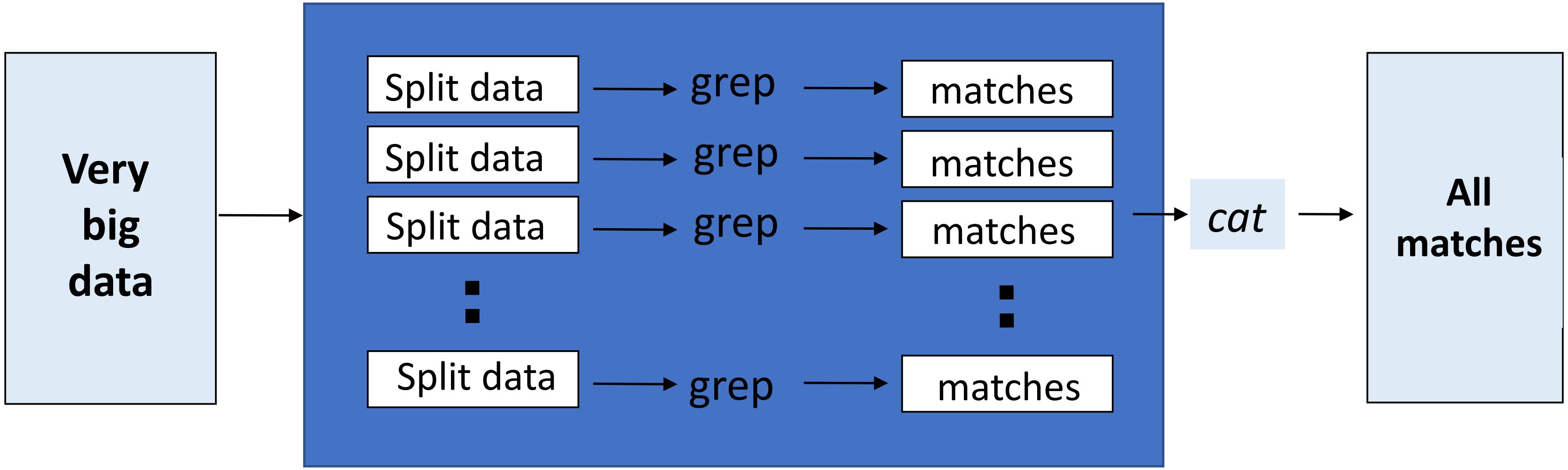
- To understand what Map/Reduce really are..

A MapReduce Example

- Consider a very large text file and you want to determine if a word exists in this file?
  - The file is stored in HDFS across two machines.
  - How will you search to check if the word "BigData" is present in the file?

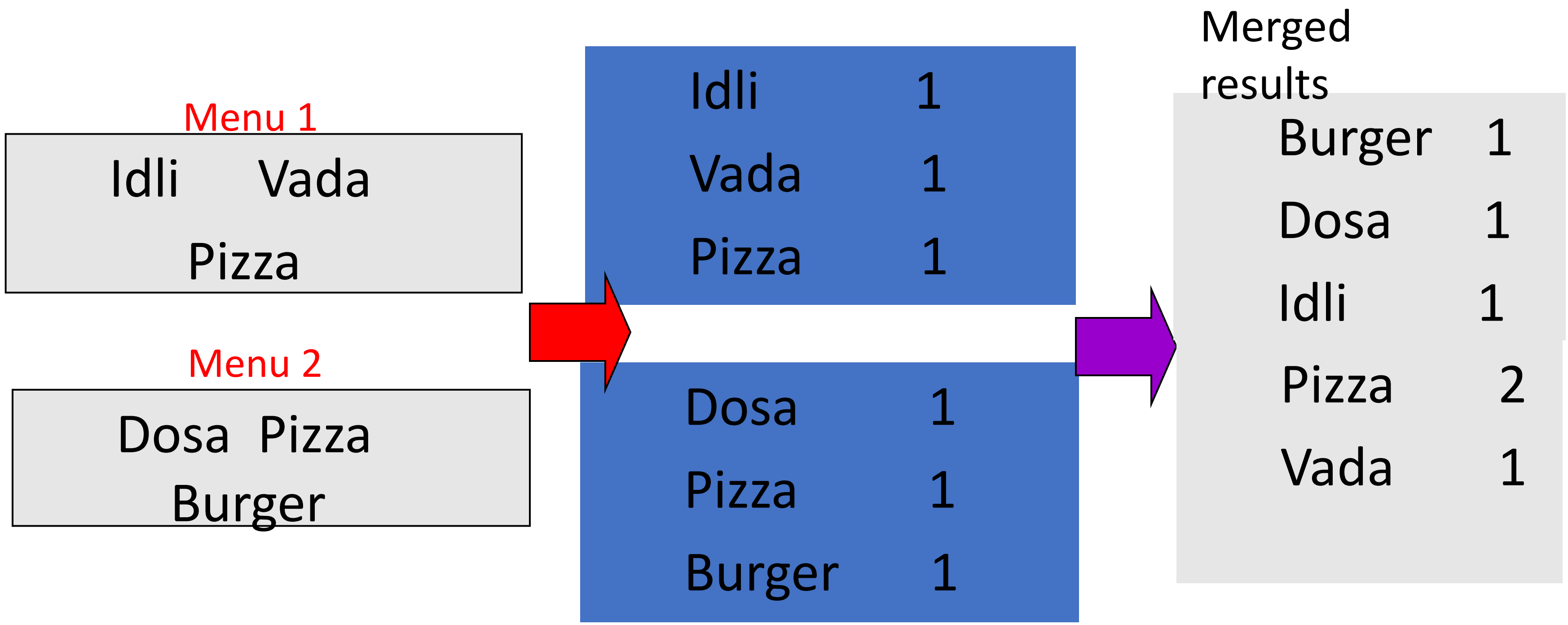


Map Reduce: Distributed Grep-Solution



Distributed Word Count

Example: find the number of restaurants offering each item?



Menu 1

Idli Vada
Pizza

Menu 2

Dosa Pizza
Burger

Idli 1
Vada 1
Pizza 1

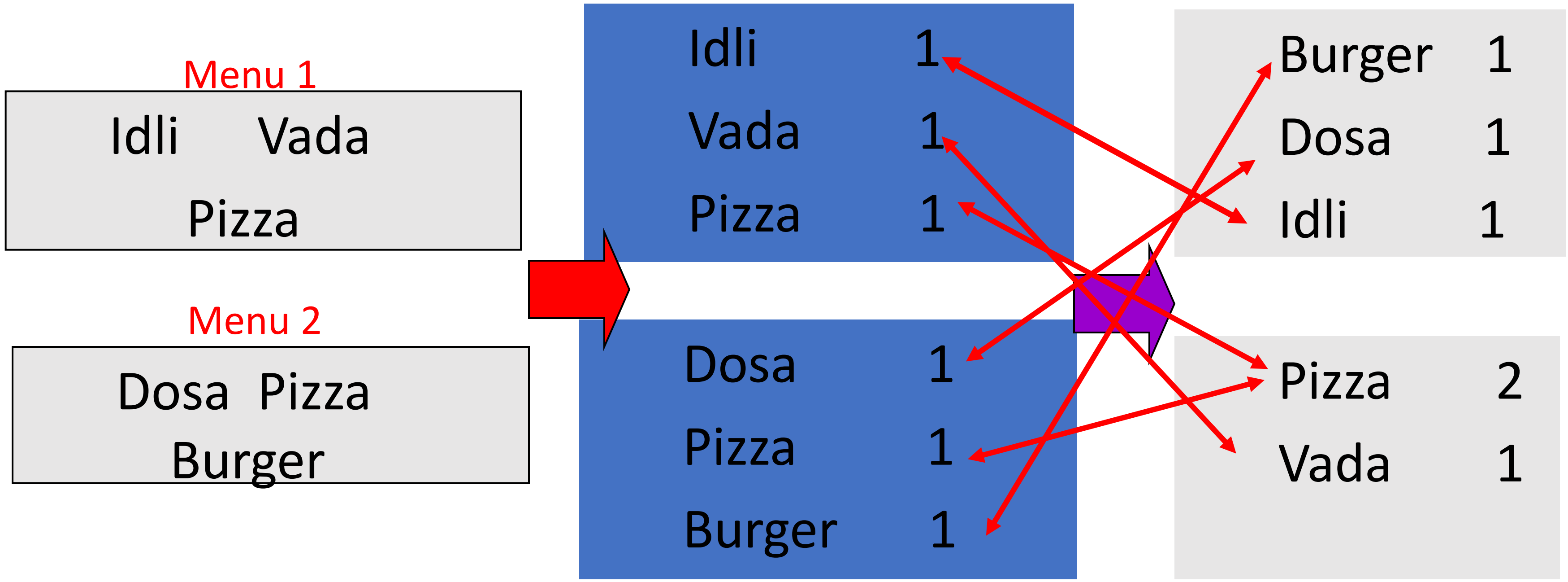
Dosa 1
Pizza 1
Burger 1

Merged results

Burger 1
Dosa 1
Idli 1
Pizza 2
Vada 1

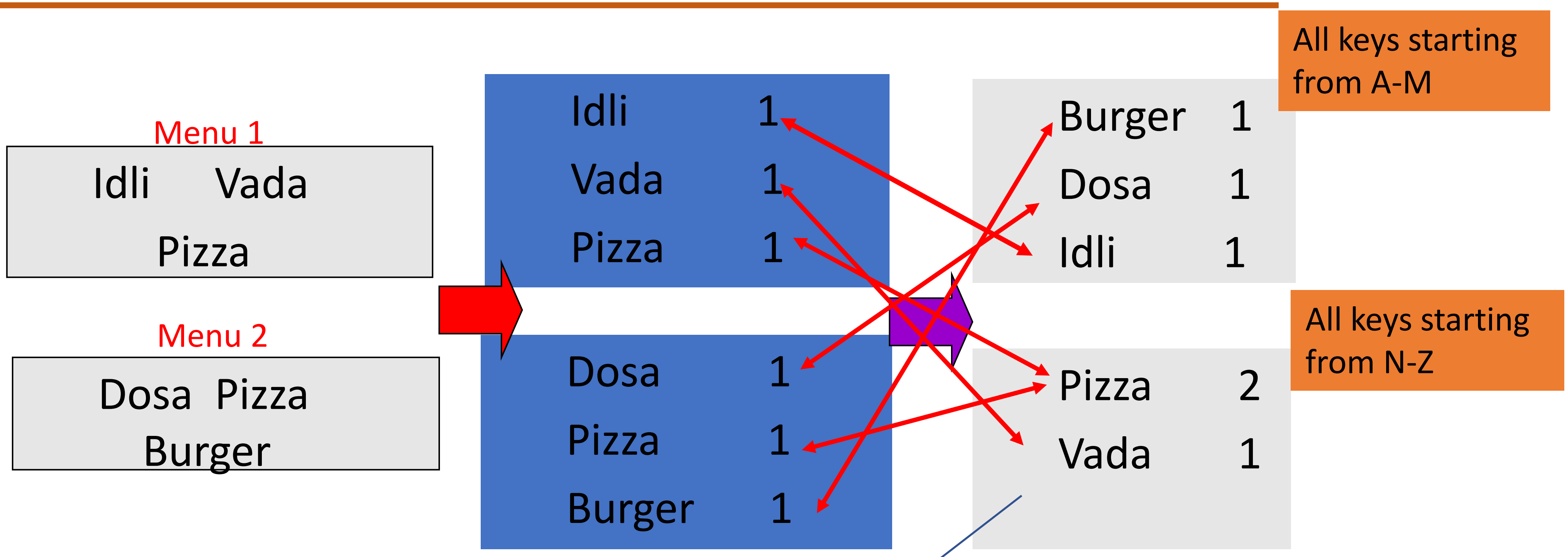
- Suppose we need parallelism of the merge program.
- Would the earlier approach work?
- What do we need to do?

Example: find the number of restaurants offering each item?



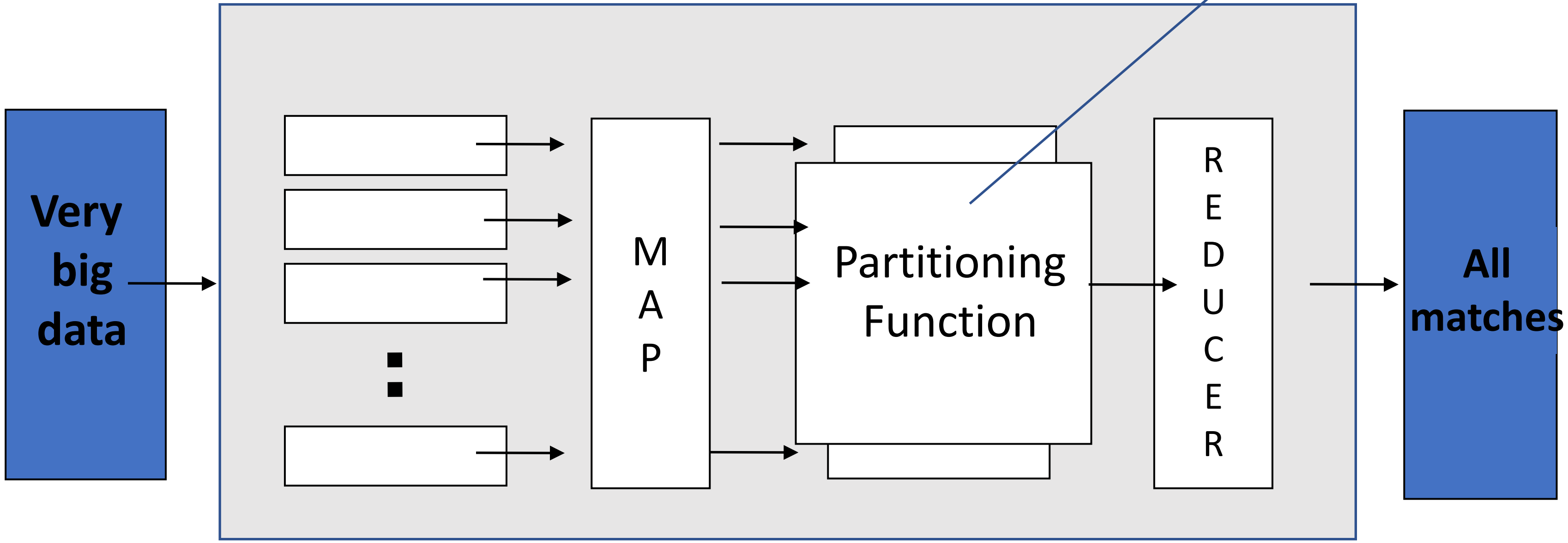
- Treat output of first program as a key value pair
- Partition the keys between the second program

Distributed Word Count



How do we know that all the “pizza” keys must be aggregated in server 2?

Map + Reduce



Ensures that all similar keys are aggregated at the same reducer. Each mapper has the same partition function

- Map:
  - Accepts *input* key/value pair
  - Emits *intermediate* key/value pair

- Reduce :
  - Accepts *intermediate* key/value* pair
  - Emits *output* key/value pair

Map Reduce: A look at the code

Map Reduce Programming model

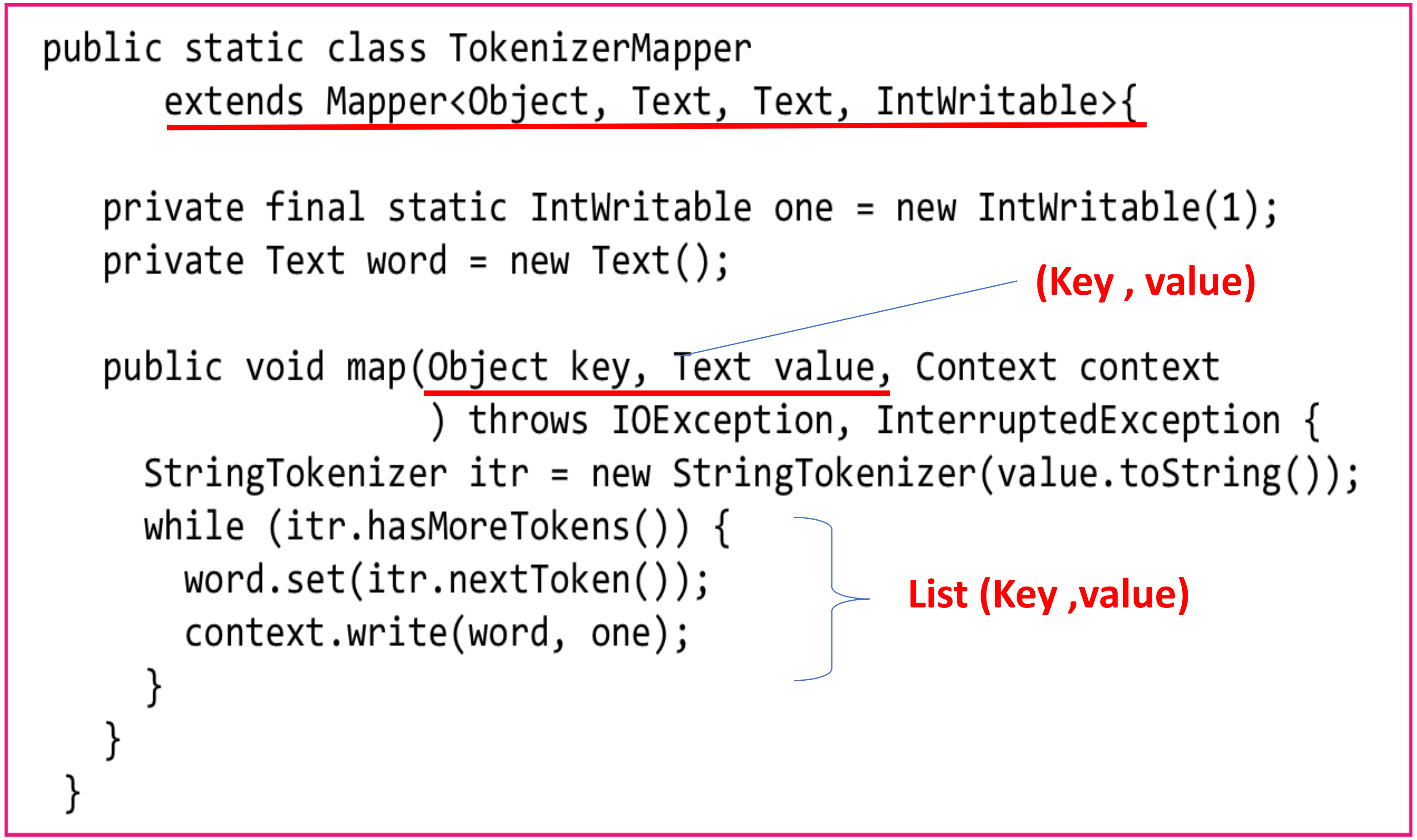
- **Data type:** key-value *records*
- **Map function:**

$$(K_{in}, V_{in}) \rightarrow list(K_{inter}, V_{inter})$$

- **Reduce function:**

$$(K_{inter}, list(V_{inter})) \rightarrow list(K_{out}, V_{out})$$

Map Reduce- Mapper for Word Count



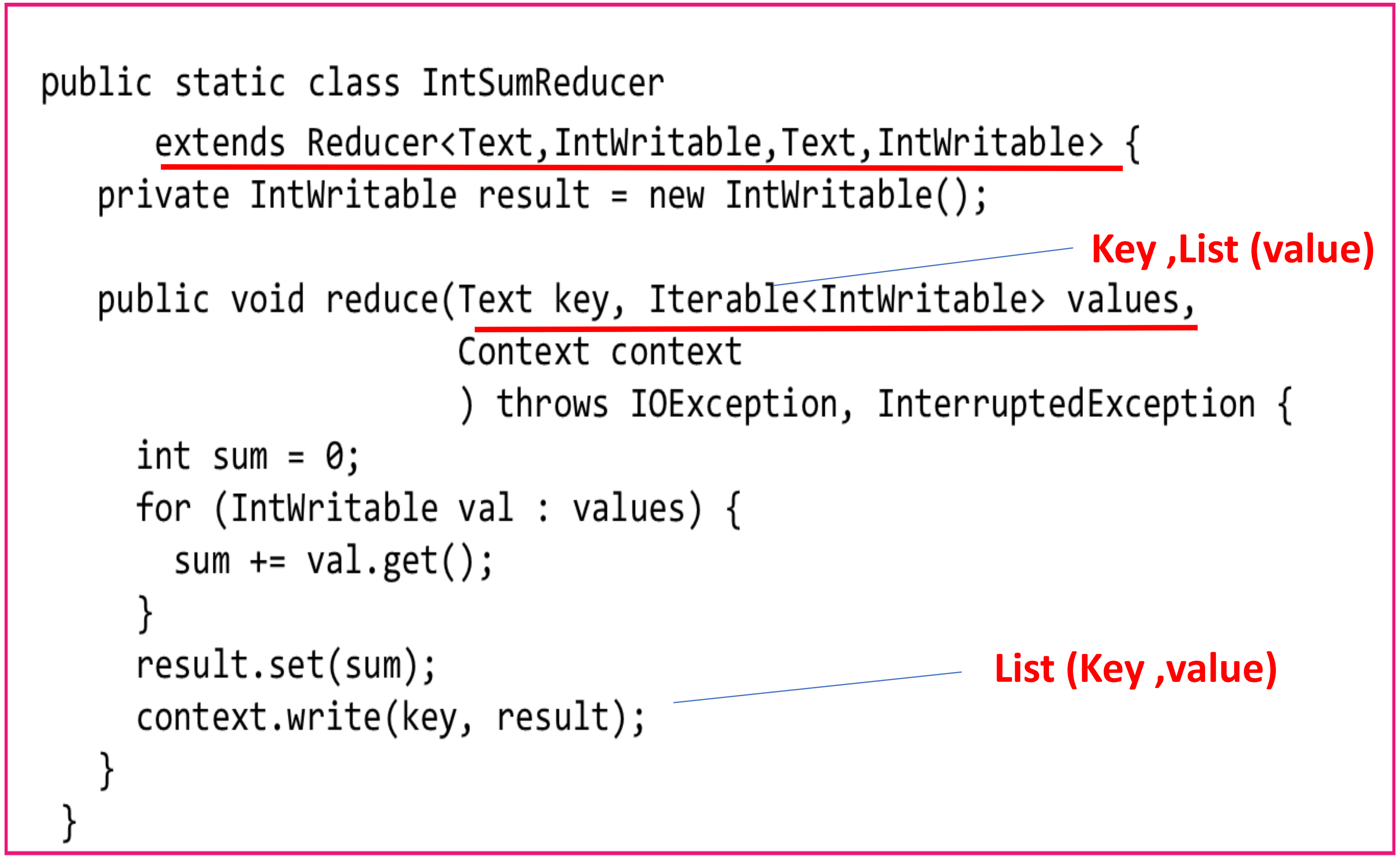
```
public static class TokenizerMapper
      extends Mapper<Object, Text, Text, IntWritable>{

   private final static IntWritable one = new IntWritable(1);
   private Text word = new Text();

   public void map(Object key, Text value, Context context
                   ) throws IOException, InterruptedException {
     StringTokenizer itr = new StringTokenizer(value.toString());
     while (itr.hasMoreTokens()) {
       word.set(itr.nextToken());
       context.write(word, one);
     }
   }
 }
```

(Key , value)

List (Key ,value)

$(K_{in}, V_{in}) \rightarrow list(K_{inter} , V_{inter})$

Map Reduce -Reducer for Word Count



```
public static class IntSumReducer
      extends Reducer<Text,IntWritable,Text,IntWritable> {
   private IntWritable result = new IntWritable();

   public void reduce(Text key, Iterable<IntWritable> values,
                      Context context
                      ) throws IOException, InterruptedException {
     int sum = 0;
     for (IntWritable val : values) {
       sum += val.get();
     }
     result.set(sum);
     context.write(key, result);
   }
 }
```

Key ,List (value)

List (Key ,value)

$(K_{inter}, list(V_{inter})) \rightarrow list(K_{out}, V_{out})$

Map Reduce - Main Program for Word Count

```
public static void main(String[] args) throws Exception {
  Configuration conf = new Configuration();
  String[] otherArgs = new GenericOptionsParser(conf, args).
                           getRemainingArgs();
  if (otherArgs.length < 2) {
    System.err.println("Usage: wordcount <in> [<in>...] <out>");
    System.exit(2);
  }
  Job job = new Job(conf, "word count");
  job.setJarByClass(WordCount.class);
  job.setMapperClass(TokenizerMapper.class);

  job.setReducerClass(IntSumReducer.class);
  job.setOutputKeyClass(Text.class);
  job.setOutputValueClass(IntWritable.class);
  for (int i = 0; i < otherArgs.length - 1; ++i) {
    FileInputFormat.addInputPath(job, new Path(otherArgs[i]));
  }
  FileOutputFormat.setOutputPath(job,
    new Path(otherArgs[otherArgs.length - 1]));
  System.exit(job.waitForCompletion(true) ? 0 : 1);
}
```

Set Mapper and Reducer class

Map Reduce: Sample Exercise

Map Reduce , Search

Input: file(lineNumber, line) records and pattern

Output: lines matching a given pattern

What will be the mapper and reducer? What will be the keys?

Map:

Reduce:

Map Reduce , Search - Solution

Input: file (lineNumber, line) records and pattern

Output: lines matching a given pattern

Map:

```
if(line matches pattern):
       output(line)
```

Reduce: identity function

–Alternative: no reducer (map-only job)

Map Reduce , Functions in the Model

- **Map**
  - Process a key/value pair to generate intermediate key/value pairs
  - Sorts all key/value pairs before sending to reducer
- **Reduce**
  - Merge all intermediate values associated with the same key
  - Runs after all Map tasks are finished (why?)
- **Partition**
  - By default : `hash(key) mod R` (Well balanced)
  - There are cases where this can be more complex

Map Reduce: Revision exercise

Map Reduce, Sort

Input: (key, value) records

Output: same records, sorted by key

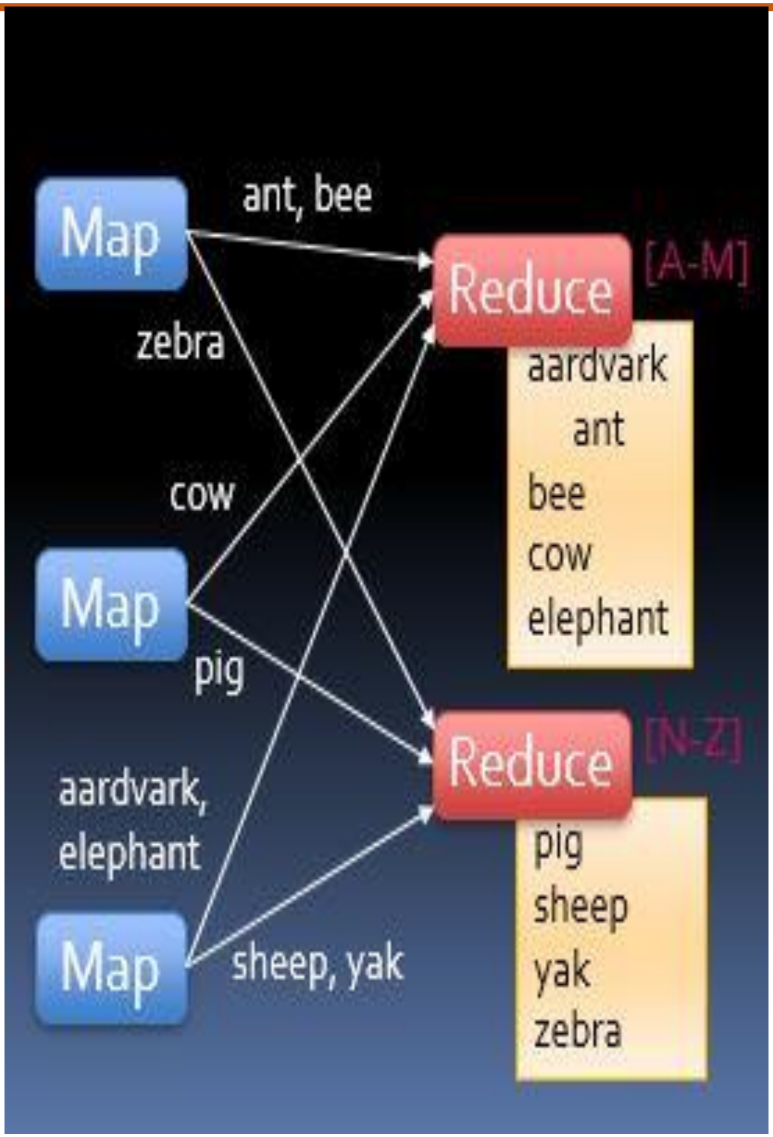
What will be the mapper and reducer?
What will be the partition function?

Map:

Reduce:

Map Reduce, Sort - Solution

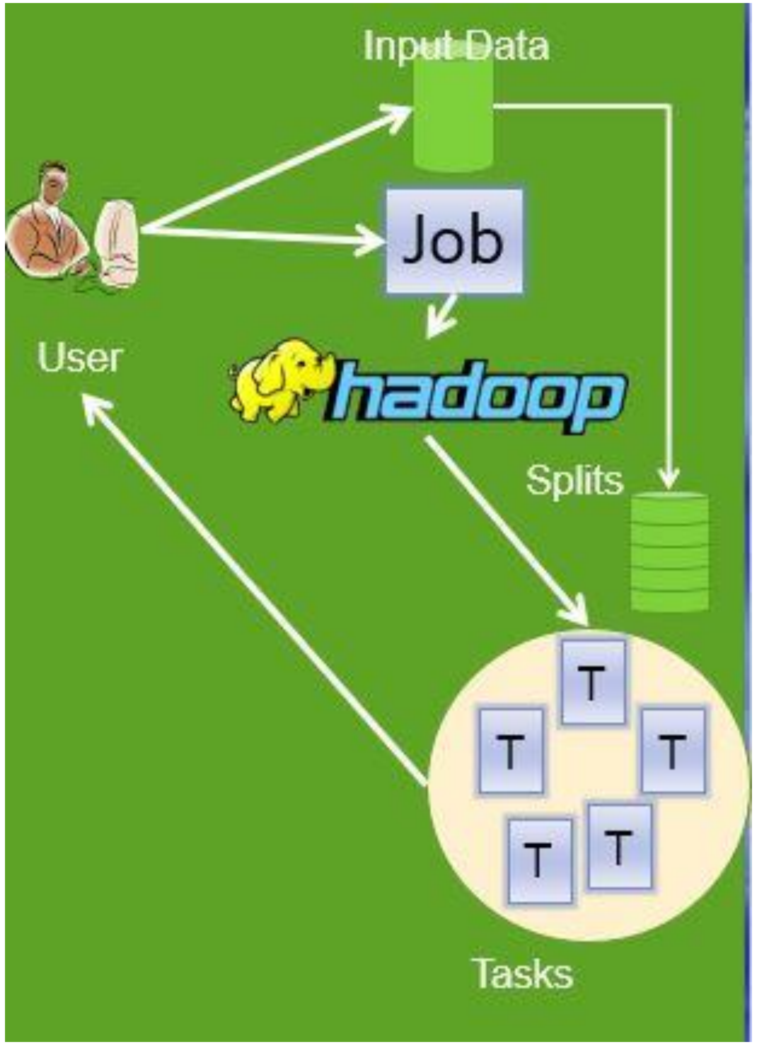
- **Input**: (key, value) records
- **Output**: same records, sorted by key
- **Map**: identity function
- **Reduce**: identity function
- **Trick**: Pick partitioning function *p* so that $k_1 < k_2 \Rightarrow p(k_1) < p(k_2)$
- Works because map sorts output keys.



Map Reduce: Job Submission Flow

Map Reduce , Hadoop Flow.

- User submits job
  - input data, MapReduce program, and configuration information
- How is parallelization achieved?
  - Divide input into smaller chunks – called **input splits**
- Hadoop divides jobs into tasks
  - Map tasks, reduce tasks
  - One map task per split
  - Tasks run in parallel



MapReduce Flow for A SINGLE REDUCE Task

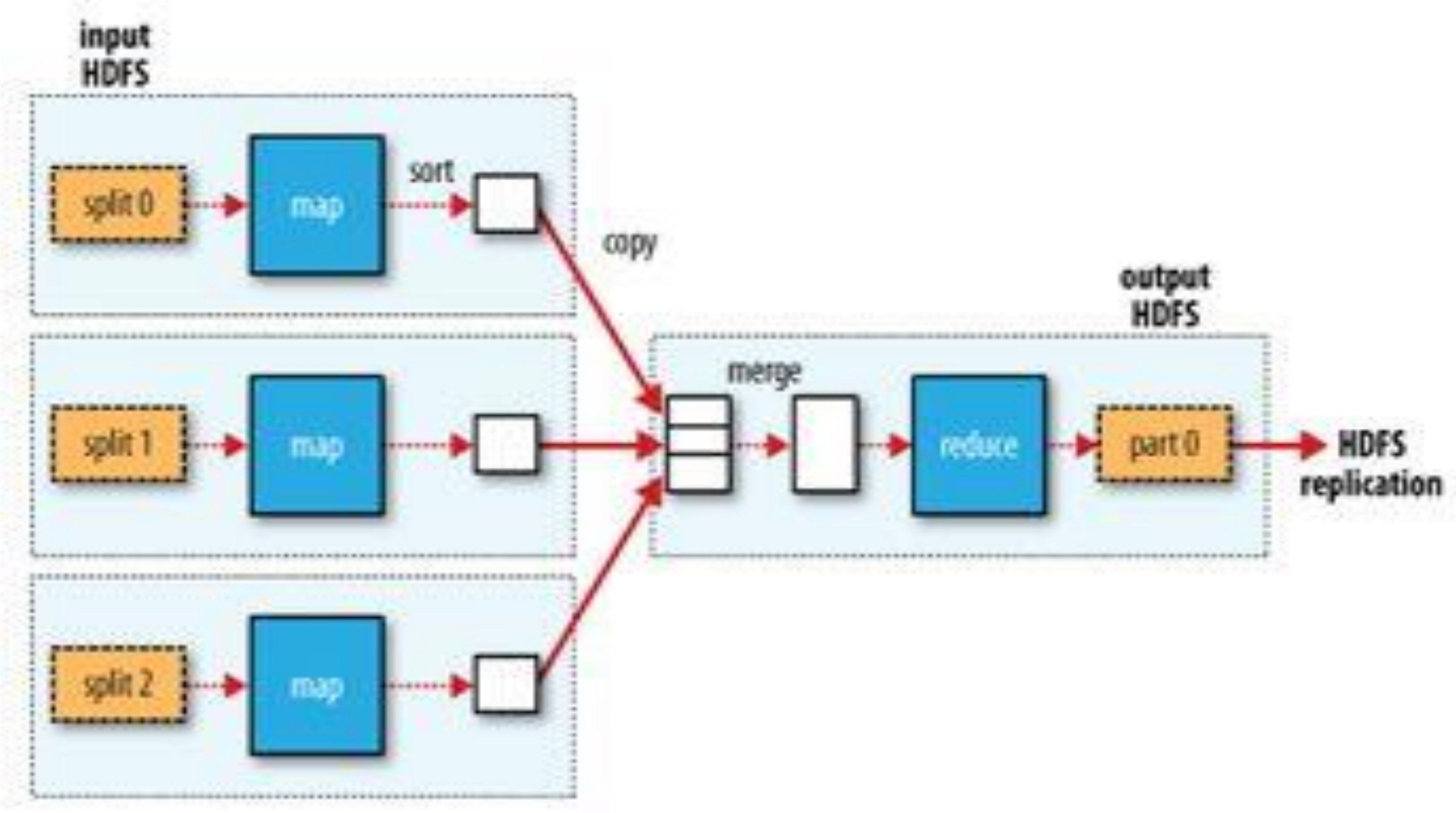


Figure: Map reduce data flow for single reducer task.

Map Reduce:
Exercise : Job Submission Flow with two Reducers

MapReduce Flow

- How will it work when there are two reducers?
- Where will the outputs be?

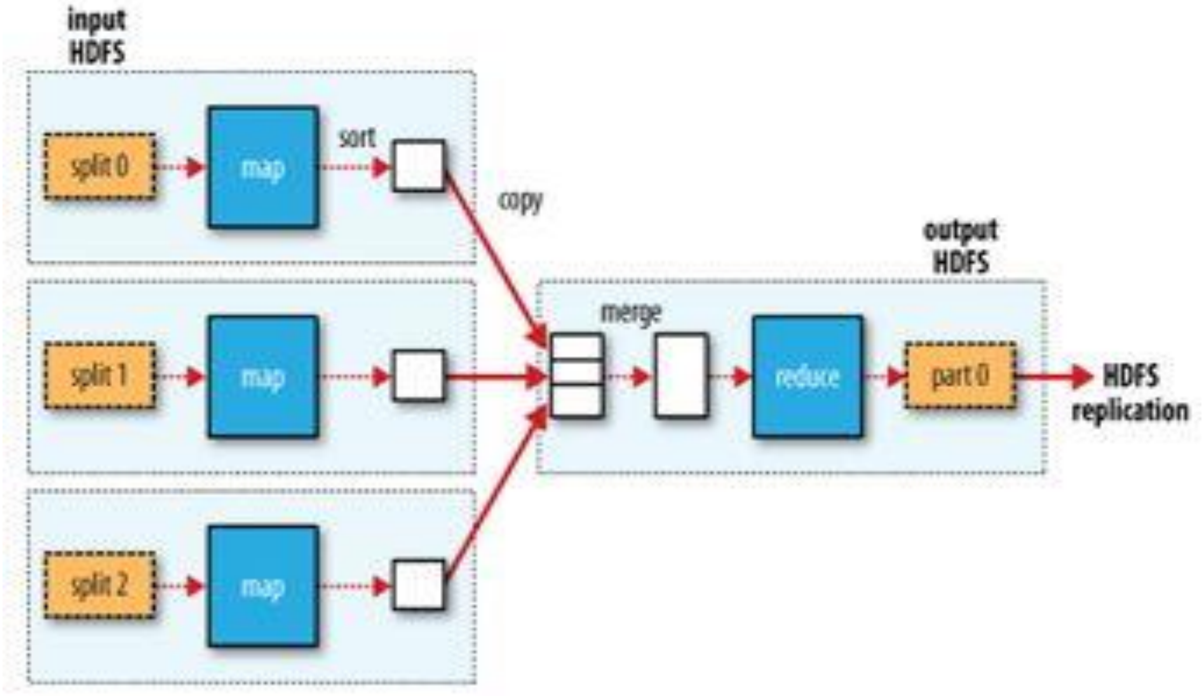
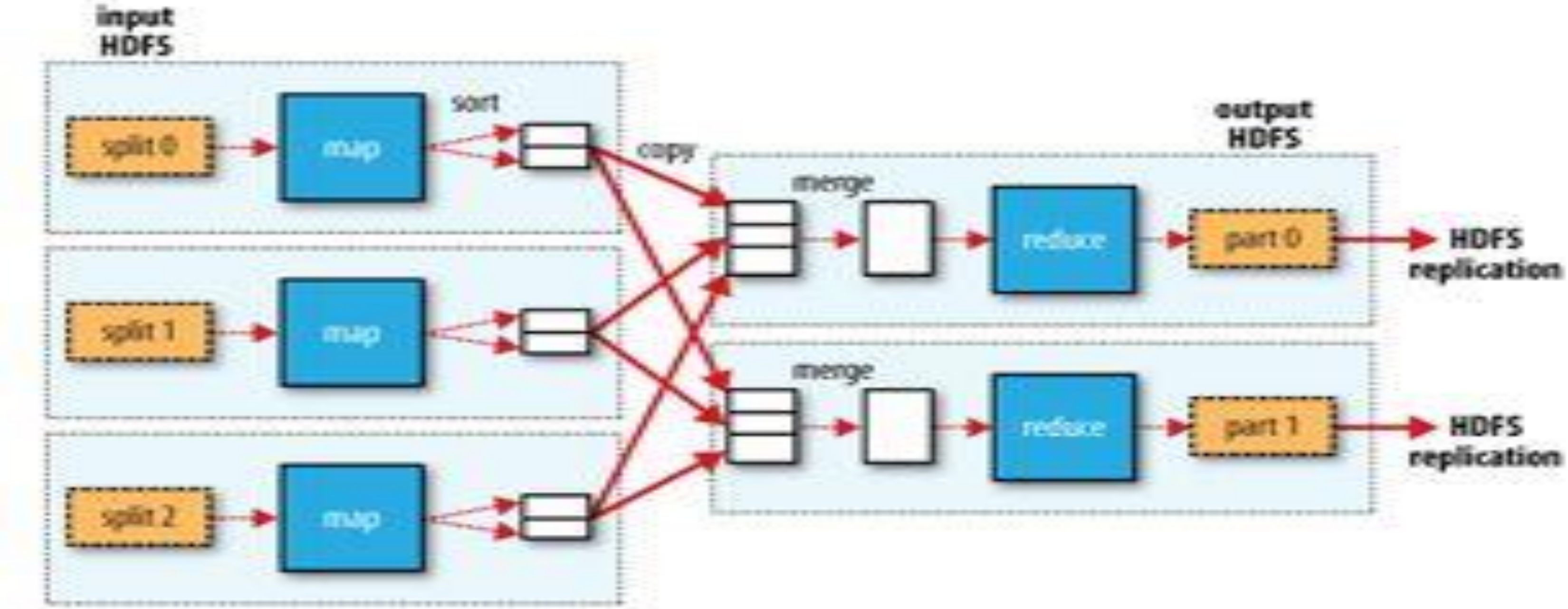


Figure: Map reduce data flow for single reducer task.

MapReduce Flow for MULTIPLE REDUCE Tasks



- Outputs are created on two different nodes and have to be merged.
- But available through HDFS on any node

Map Reduce: Splits

Map Reduce Split size considerations

- Split size proportional to parallelism
- Small split size
  - Advantages
    - Large #splits
    - Increased parallelism
    - Increased load balancing
  - Disadvantages
    - the overhead of managing the splits and of map task creation
    - begins to dominate the total job execution time.

Optimal split size == size of HDFS block (128MB) (default) on Hadoop v2

Map Output

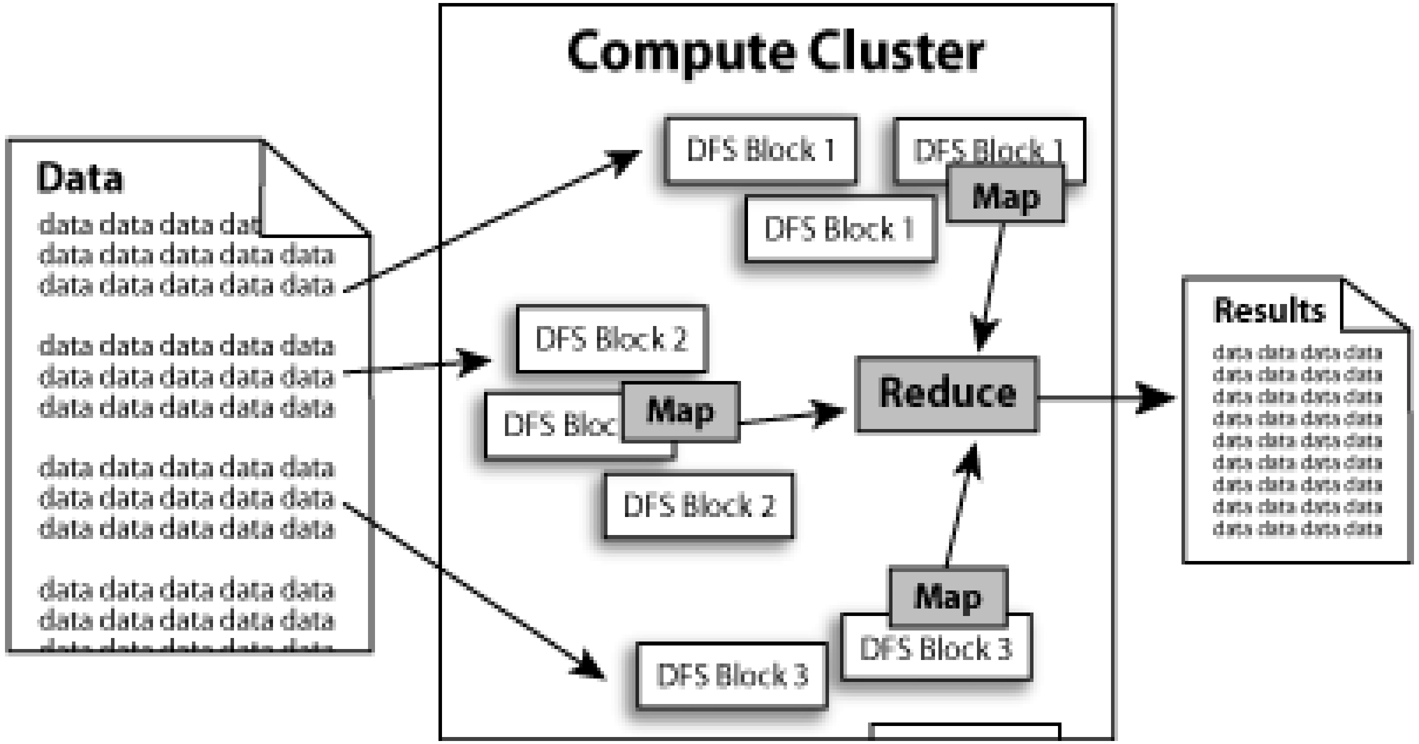
Split == Block size

- All data required for Map
  - In the same node
  - No inter-node data transfer is required

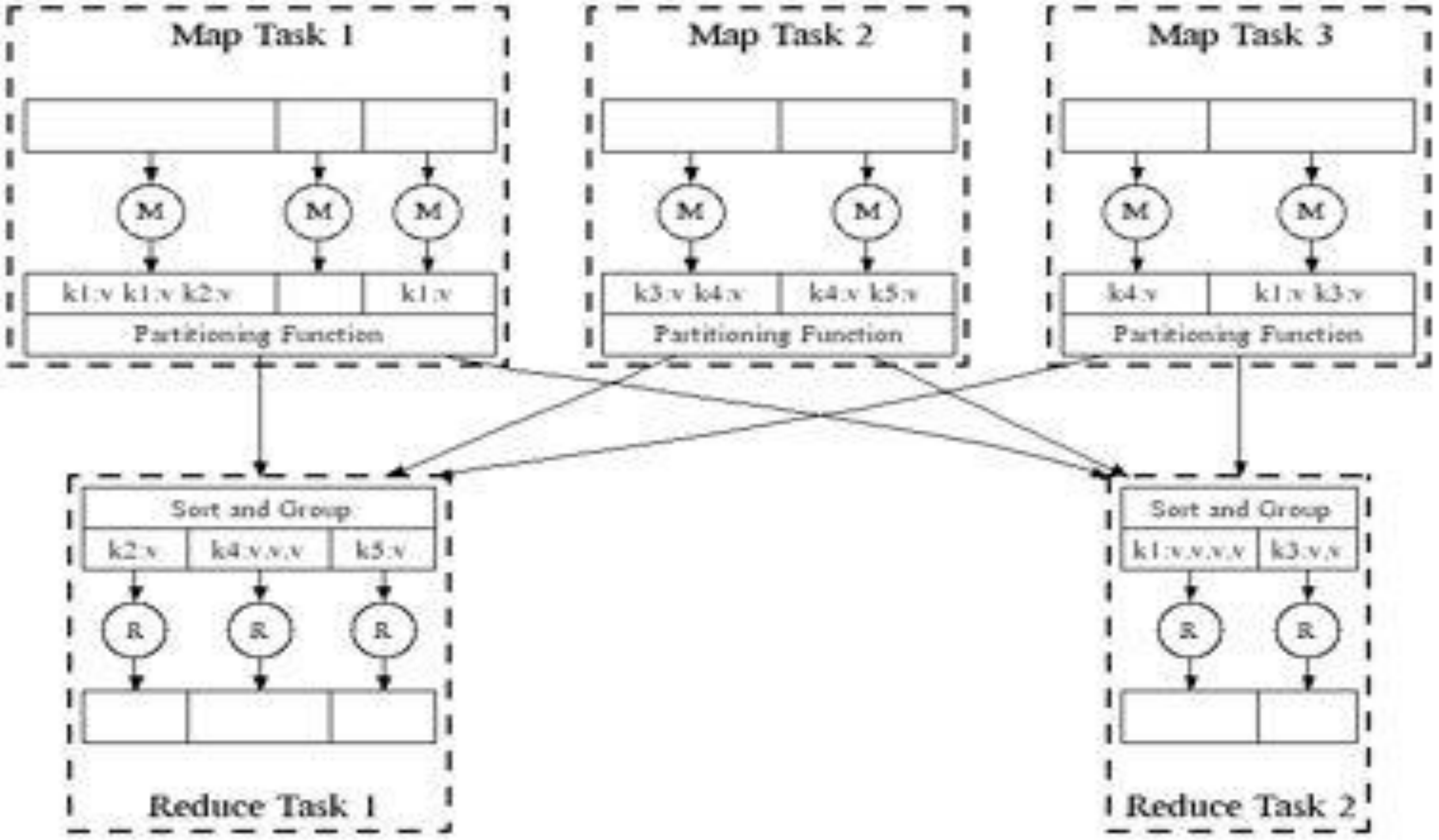
Split != block size

- Data transfer across multiple nodes
- Impacts performance

Traditional: Move Data to Compute



Big Data: Move Compute to Data



Parallel Execution

Map Output

- **Where is Map output written to?**
  - Local disk and not HDFS
  - Why? Temporary output to be discarded after reduce.

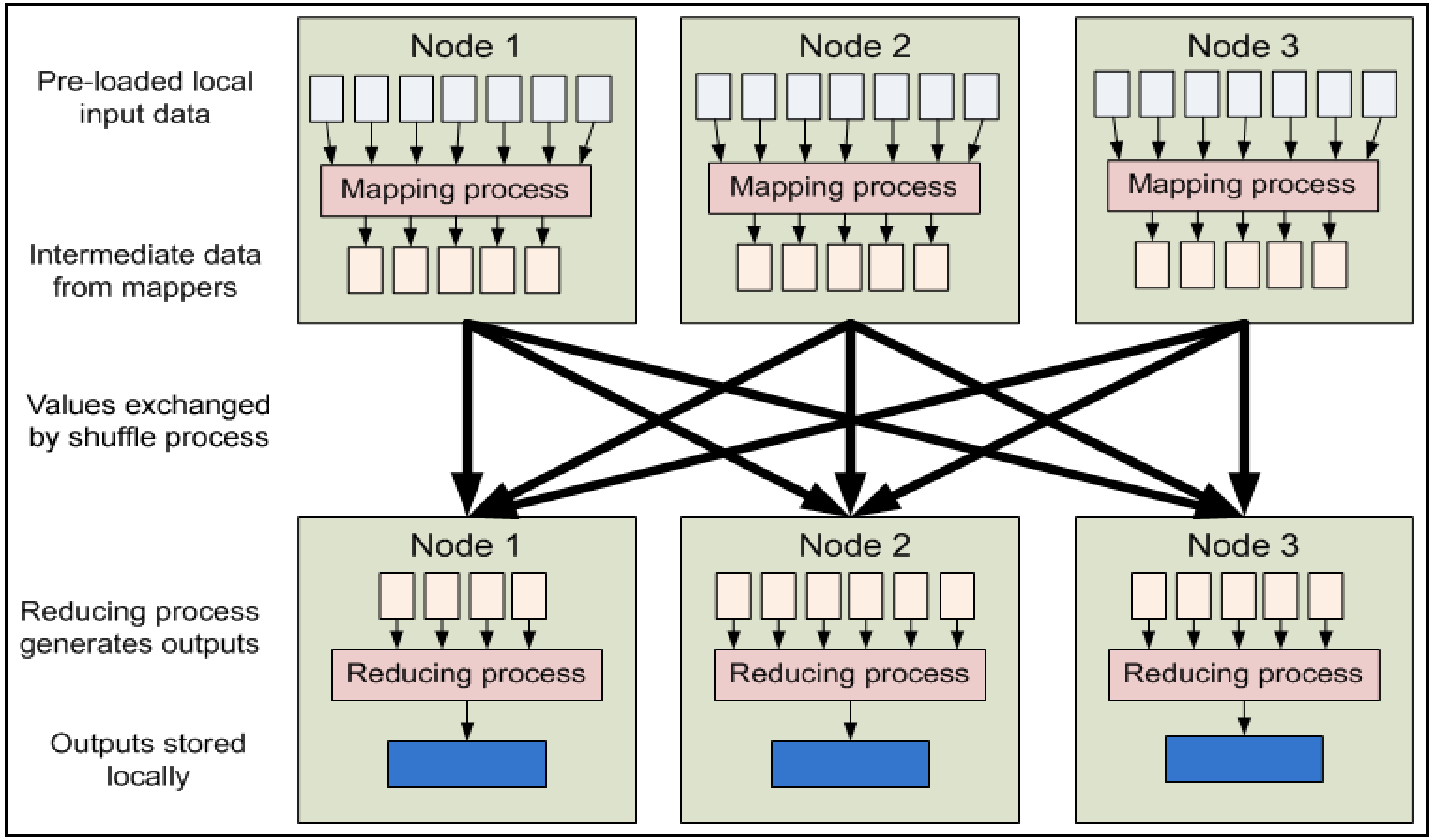
- **Failure**
  - If the node running the map task fails
    - before the output has been consumed by reducer
  - Automatically rerun map task on another node

Reduce Tasks

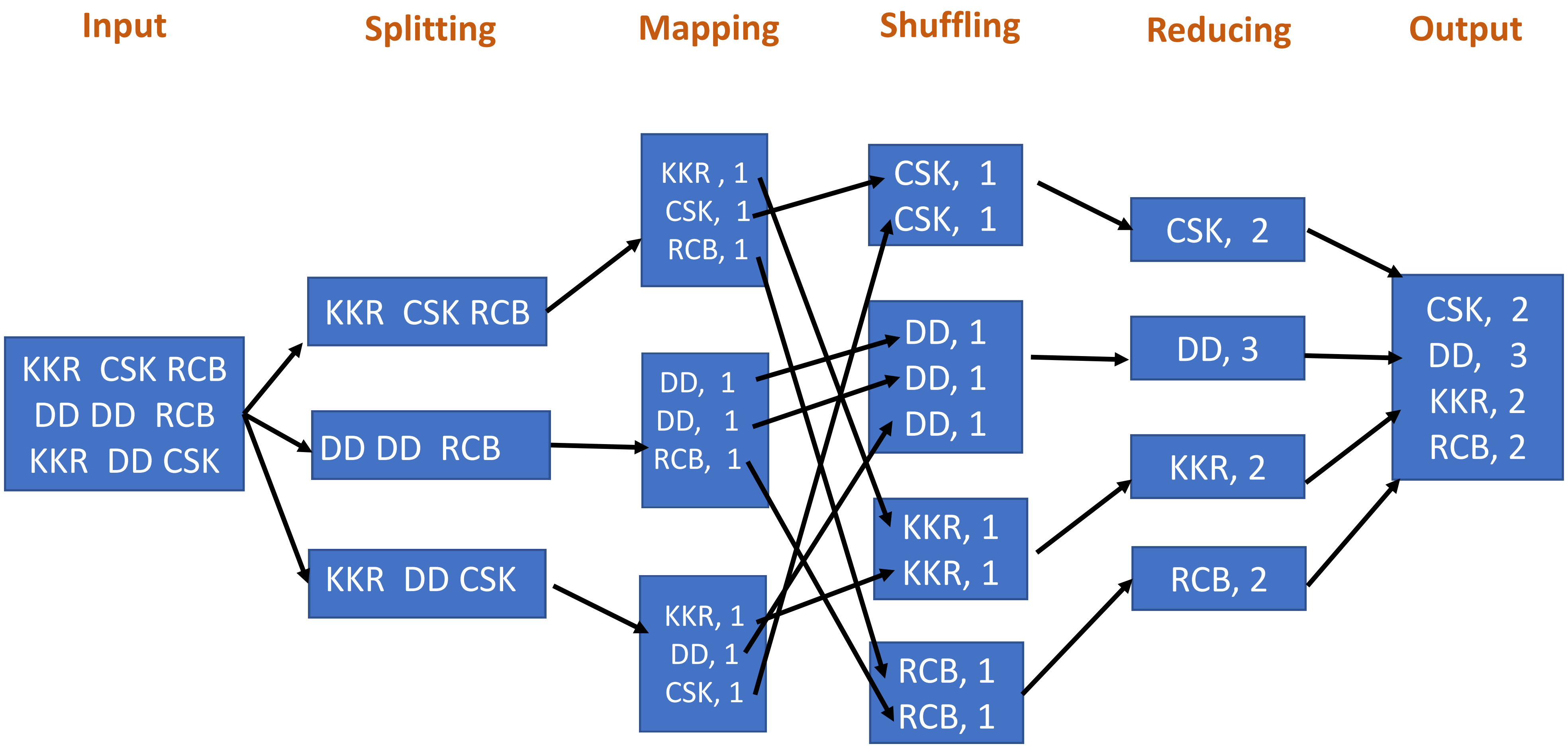
- Reduce tasks don't have the advantage of data locality
  - the input to a single reduce task is normally the output from all mappers.
- Sorted map outputs
  - have to be transferred across the network
  - Where to?
    - To the node where the reduce task is running
    - Merge data from different mappers
    - Then passed to the user-defined reduce function.
- The output of the reduce is normally stored in HDFS for reliability.
- Where is the reduce output stored
  - 1 on the local node where the reduce happens
  - Other replicas on off-rack nodes.
  - Consumes network bandwidth

Map Reduce: Working

High level view

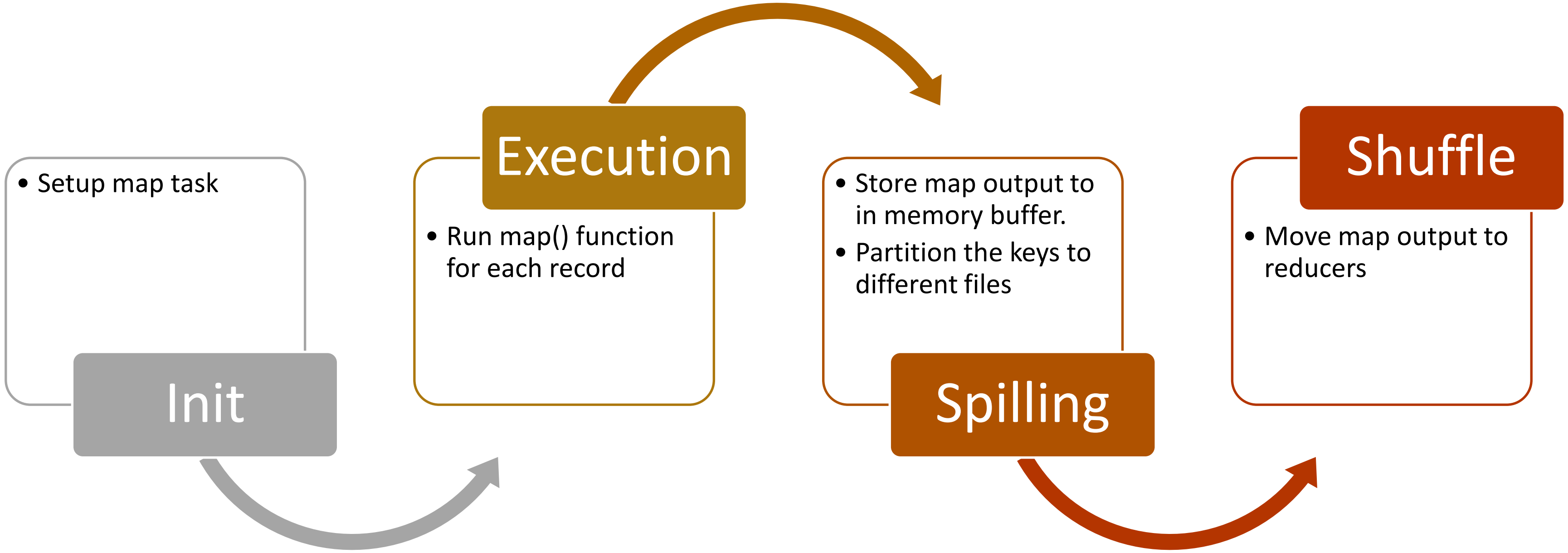


Shuffling - example



The overall Map-Reduce word count Process

Closer look - Map

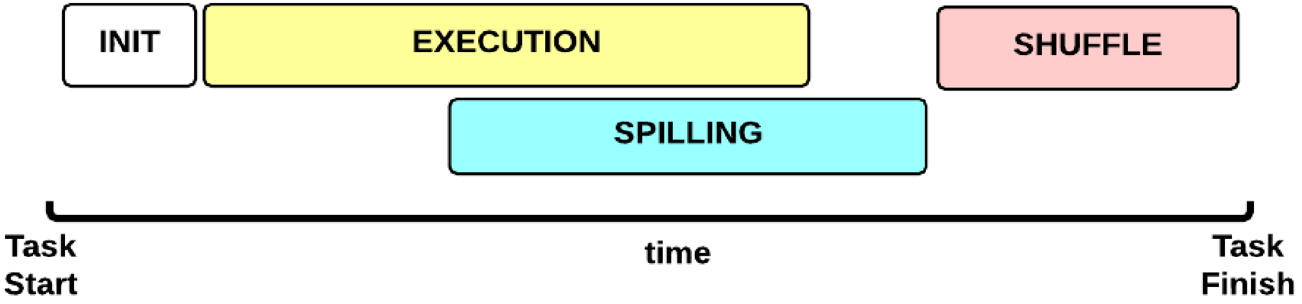


- Setup map task

- Run map() function for each record

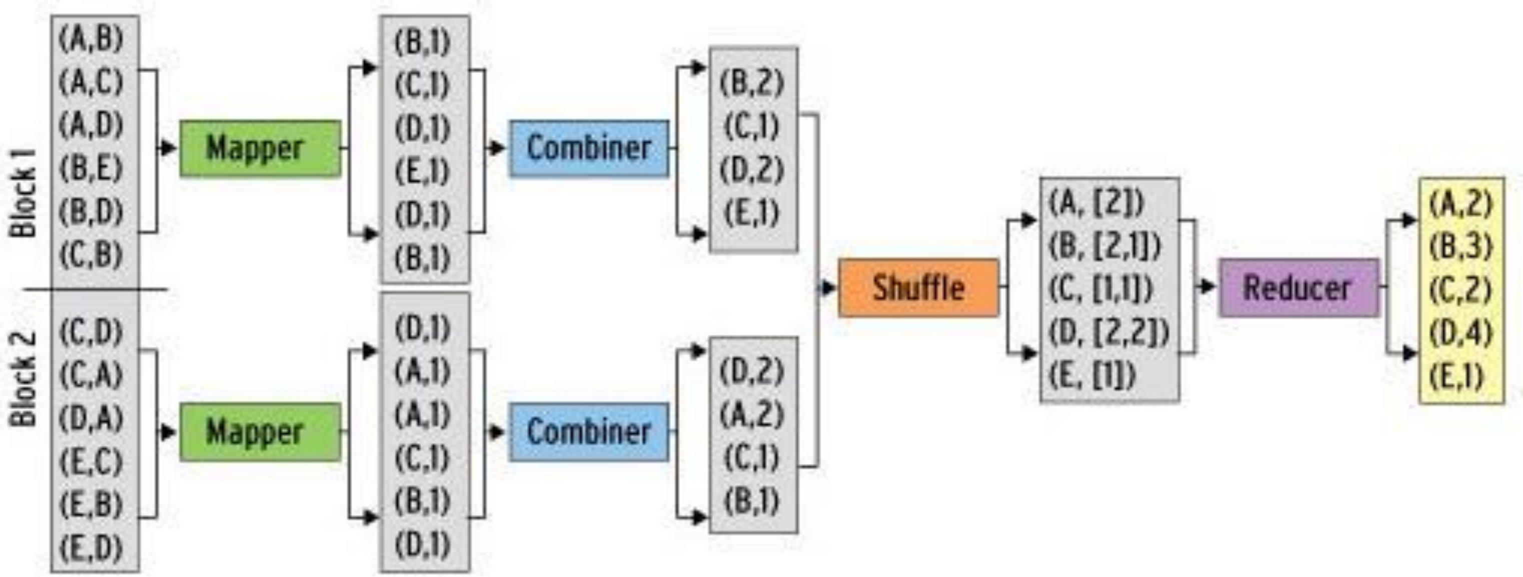
- Store map output to in memory buffer.
- Partition the keys to different files

- Move map output to reducers



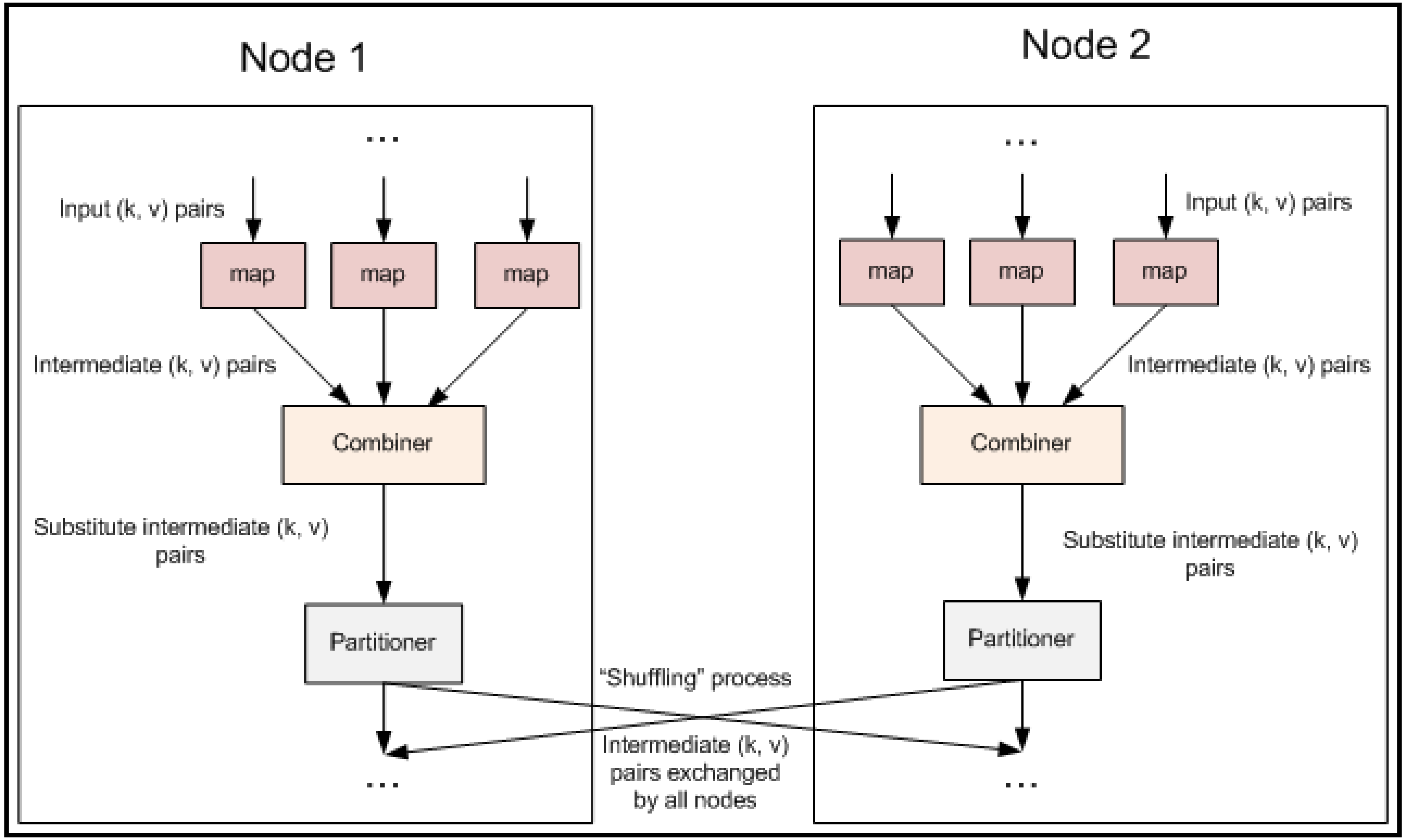
Map Reduce: Combiners

MapReduce – Combiners - motivation

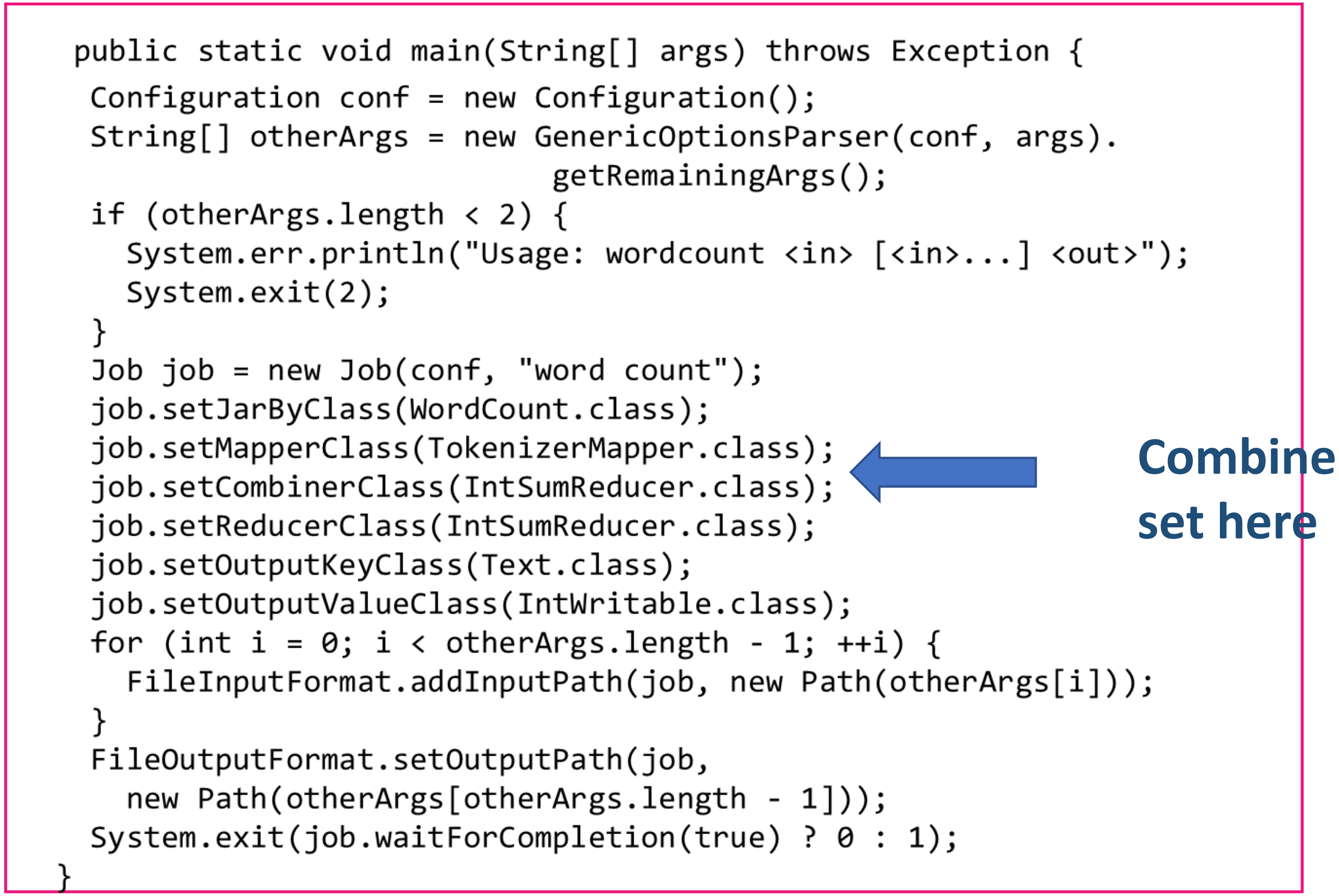


- Combine multiple map outputs before doing a reduce
- Can write a combiner function in program
  - Combiner will be run before reduce
- Mini-reducer

Combiner – when does it run?


Node 1
Node 2
...
Input (k, v) pairs
map
map
map
Intermediate (k, v) pairs
Combiner
Substitute intermediate (k, v) pairs
Partitioner
...
Input (k, v) pairs
map
map
map
Intermediate (k, v) pairs
Combiner
Substitute intermediate (k, v) pairs
Partitioner
"Shuffling" process
Intermediate (k, v) pairs exchanged by all nodes
...
...

Map Reduce - Main Program for Word Count



```
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  Configuration conf = new Configuration();
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  if (otherArgs.length < 2) {
    System.err.println("Usage: wordcount <in> [<in>...] <out>");
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  Job job = new Job(conf, "word count");
  job.setJarByClass(WordCount.class);
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  job.setReducerClass(IntSumReducer.class);
  job.setOutputKeyClass(Text.class);
  job.setOutputValueClass(IntWritable.class);
  for (int i = 0; i < otherArgs.length - 1; ++i) {
    FileInputFormat.addInputPath(job, new Path(otherArgs[i]));
  }
  FileOutputFormat.setOutputPath(job,
    new Path(otherArgs[otherArgs.length - 1]));
  System.exit(job.waitForCompletion(true) ? 0 : 1);
}
```

Combiner is set here

Review Questions

Review Questions

- Questions from T1, LOR 2.4

Sample questions

- How many mappers and reducers will get started when trying to process a 230 MB file with Hadoop v2?
  - Ans: Block size = 128MB, so there will be two blocks. Assuming one block per split there will be 2 mappers
    - #reducers is configurable.
- Where is a combiner executed?
  - On the mapper.
- Write mappers and reducer pseudo code showing keys for counting #unique words in a file?
  - Similar to word count. Just that reducer does not have to write the count.

Additional Notes, References and Videos

Notes

- Chapter 2.4 from T1 – Rajkamal
- Tom whites book is an excellent reference for the programming component.

THANK YOU

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