MapReduce on Apache Hadoop (using Java)

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Hadoop Map-Reduce Inputs and Outputs

- The Map/Reduce framework operates exclusively on $<key, value>$ pairs, that is, the framework views the input to the job as a set of $<key, value>$ pairs and produces a set of $<key, value>$ pairs as the output of the job, but the key and value may be of different types.
- The key and value classes have to be serializable by the framework and hence need to implement the Writable interface. Additionally, the key classes have to implement the WritableComparable interface to facilitate sorting by the framework.
- The user needs to implement a Mapper class as well as a Reducer class. Optionally, the user can also write a Combiner class.

$$(\text{input}) < k1, v1 > \rightarrow \text{map} \rightarrow < k2, v2 > \rightarrow \text{combine} \rightarrow < k2, v2 >$$

$$\rightarrow \text{reduce} \rightarrow < k3, v3 > (\text{output})$$

MapReduce API

```
public class MyMapper extends
    Mapper<KEYIN, VALUEIN, KEYOUT, VALUEOUT> { ... }

protected void map(KEYIN key,
                   VALUEIN value,
                   Mapper.Context context)
            throws IOException,
                   InterruptedException

public class MyReducer extends
    Reducer<KEYIN, VALUEIN, KEYOUT, VALUEOUT> { ... }

protected void reduce(KEYIN key,
                      Iterable<VALUEIN> values,
                      Reducer.Context context)
              throws IOException,
                      InterruptedException
```

WordCount example with Hadoop API

Problem: To count the number of occurrences of each word in a large collection of documents.

```
/**
 * Counts the words in each line.
 * For each line of input, break the line into words
 * and emit them as (word, 1).
 */
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);
    }
  }
}
```

See full code here: WordCount.java

WordCount Example with Hadoop API (contd.)

```
/**
 * A reducer class that just emits the sum of the input
   values.
 */
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);
    }
 }
```

WordCount Example with Hadoop API (contd.)

```
public static void main(String[] args) throws Exception {
    Configuration conf = new Configuration();
    Job job = Job.getInstance(conf, "word count");
    job.setNumReduceTasks(8); // we can control it

    job.setJarByClass(WordCount.class);
    job.setMapperClass(TokenizerMapper.class);
    job.setCombinerClass(IntSumReducer.class);
    job.setReducerClass(IntSumReducer.class);

    job.setOutputKeyClass(Text.class);
    job.setOutputValueClass(IntWritable.class);

    FileInputFormat.addInputPath(job, new Path(args[0]));
    FileOutputFormat.setOutputPath(job, new Path(args[1]));

    System.exit(job.waitForCompletion(true) ? 0 : 1);
  }
```

Case Analysis Example

See full code here: CaseAnalysis.java

```
public class CaseAnalysis {
public static class Map extends Mapper<LongWritable, Text, Text,
    IntWritable> {
  private final static IntWritable one = new IntWritable(1);
  private final static IntWritable zero = new IntWritable(0);
  private Text word = new Text();

  public void map(LongWritable key, Text value,
                  Context context)
  throws IOException, InterruptedException
  {
    String line = value.toString();

    for (int i = 0; i < line.length(); i++) {
      if (Character.isLowerCase(line.charAt(i))) {
        word.set(String.valueOf(line.charAt(i)).toUpperCase());
        context.write(word, zero);
      } else if (Character.isUpperCase(line.charAt(i))) {
        word.set(String.valueOf(line.charAt(i)));
        context.write(word, one);
      } else {
          word.set("other");
          context.write(word, one);
      }
    }
   }
}
```

Case Analysis Example (contd.)

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

  public void reduce(Text key, Iterable<IntWritable> values,
      Context context) throws IOException, InterruptedException
  {
    long total = 0;
    int upper = 0;

    for (IntWritable val: values) {
        upper += val.get();
        total++;
    }
    result.set(String.format("%16d %16d %16d %16.2f", total, upper,
            (total - upper), ((double) upper / total)));
    context.write(key, result);
  }
}
```

Case Analysis Example (contd.)

```
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: hadoop jar caseanalysis.jar <in>
     <out>");
    System.exit(2);
  }

  Job job = Job.getInstance(conf, "case analysis");
  job.setJarByClass(CaseAnalysis.class);
  job.setMapperClass(Map.class);
  job.setReducerClass(Reduce.class);

  job.setOutputKeyClass(Text.class);
  job.setOutputValueClass(Text.class);
  job.setOutputKeyClass(Text.class);
  job.setOutputValueClass(IntWritable.class);

  FileInputFormat.addInputPath(job, new Path(otherArgs[0]));
  FileOutputFormat.setOutputPath(job, new Path(otherArgs[1]));

  System.exit(job.waitForCompletion(true) ? 0 : 1);
}
```

Inverted Index Example

Given an input text, an inverted index program uses MapReduce to produce an index of all the words in the text. For each word, the index has a list of all the files where the word appears. See full code here: InvertedIndex.java

```
public static class InvertedIndexMapper extends
    Mapper<LongWritable, Text, Text, Text>
{
  private final static Text word = new Text();
  private final static Text location = new Text();

  public void map(LongWritable key, Text val, Context context)
    throws IOException, InterruptedException
  {
    FileSplit fileSplit = (FileSplit) context.getInputSplit();
    String fileName = fileSplit.getPath().getName();
    location.set(fileName);

    String line = val.toString();
    StringTokenizer itr = new StringTokenizer(line.toLowerCase());
    while (itr.hasMoreTokens()) {
        word.set(itr.nextToken());
        context.write(word, location);
    }
  }
}
```

Inverted Index Example (contd.)

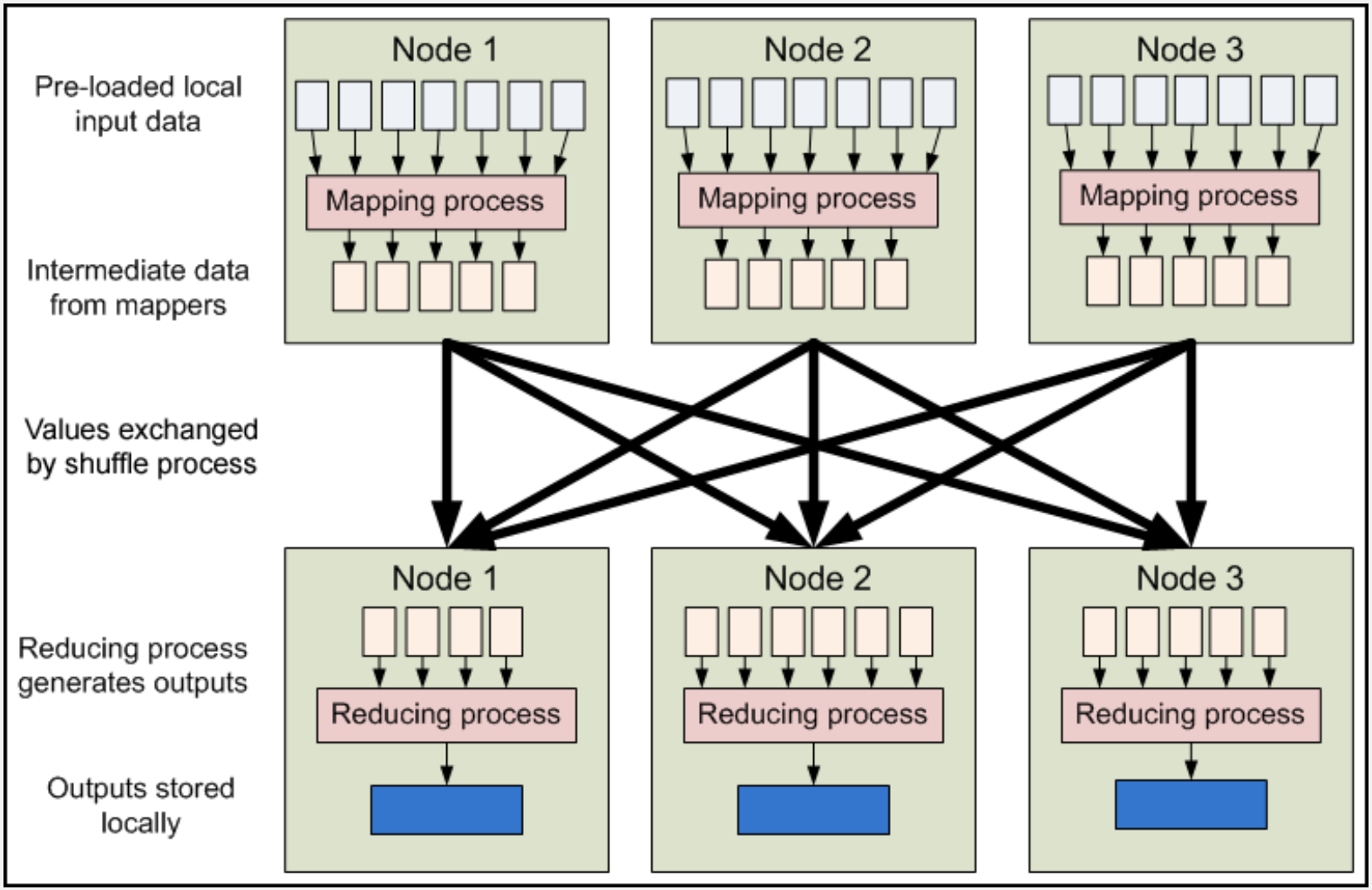
The reduce method is shown below.

```
public static class InvertedIndexReducer extends
                    Reducer<Text, Text, Text, Text>
{
    public void reduce(Text key, Iterable<Text> values, Context
    context)
    throws IOException, InterruptedException
    {
        boolean first = true;
        StringBuilder toReturn = new StringBuilder();
        while (values.hasNext()) {
            if (!first)
                toReturn.append(", ");
            first = false;
            toReturn.append(values.next().toString());
        }
        context.write(key, new Text(toReturn.toString()));
    }
}
```

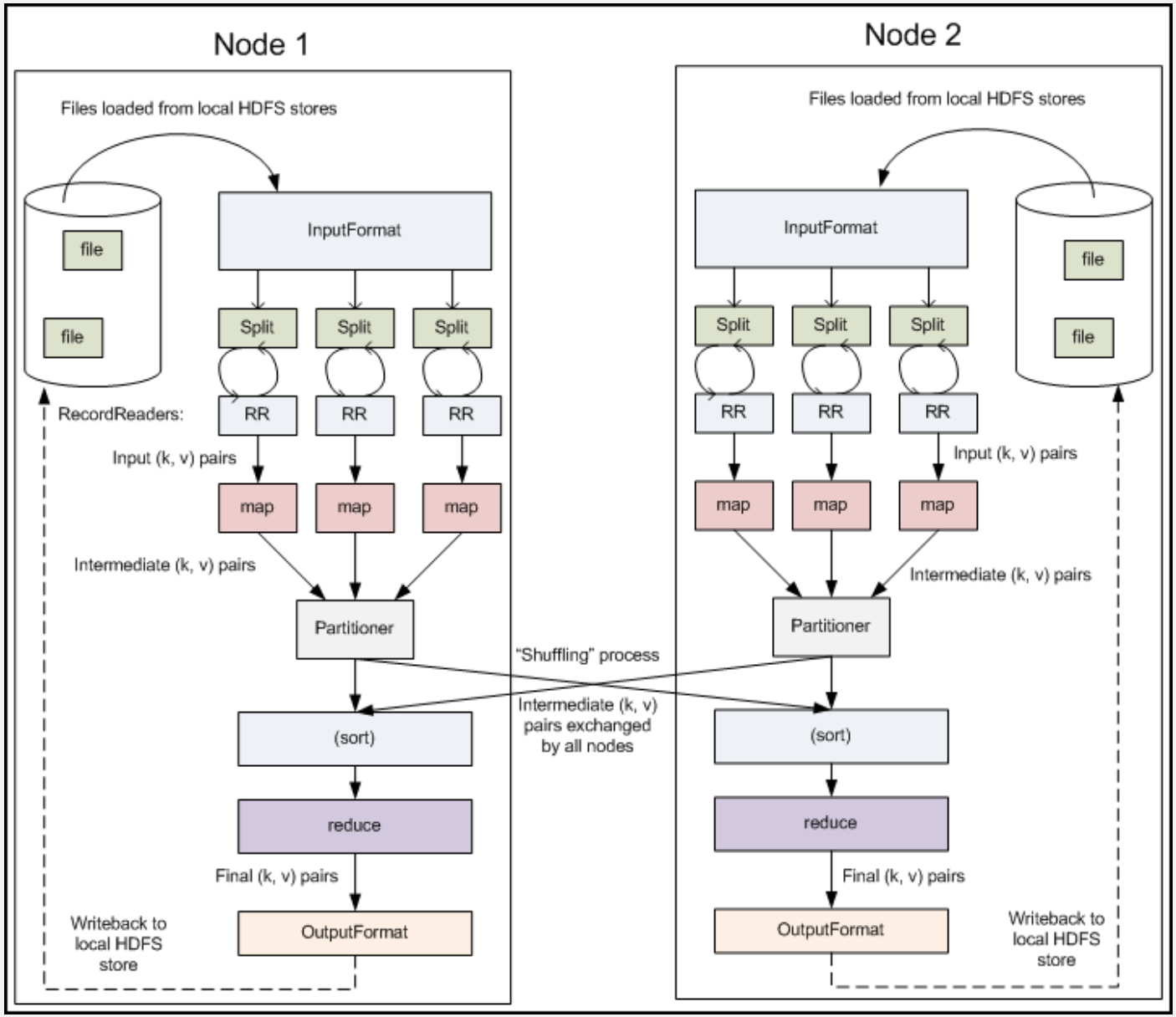
Inverted Index Example (contd)

```
public static void main(String[] args) throws IOException
{
  Configuration conf = new Configuration();
  String[] otherArgs = new GenericOptionsParser(conf,
                           args).getRemainingArgs();

  if (args.length < 2) {
    System.out
    println("Usage: InvertedIndex <input path> <output path>");
    System.exit(1);
  }
  Job job = Job.getInstance(conf, "InvertedIndex");
  job.setJarByClass(InvertedIndex.class);
  job.setMapperClass(InvertedIndexMapper.class);
  job.setReducerClass(InvertedIndexReducer.class);
  job.setOutputKeyClass(Text.class);
  job.setOutputValueClass(Text.class);

  FileInputFormat.addInputPath(job, new Path(args[0]));
  FileOutputFormat.setOutputPath(job, new Path(args[1]));
  System.exit(job.waitForCompletion(true) ? 0 : 1);
}
```

MapReduce: High-Level Data Flow



MapReduce: Detailed Data Flow



Top-N Example

- Given a list of movies with the number of views, find the top 10 movies by number of views (assume that the number of views is unique)
- See example code: hadoop/top-n-movies-v1
- Illustrates the setup/cleanup technique where we can take only one action for a map and reduce.
- What if we have multiple movies with the same number of views? See the example below for a sample solution.
- See example code: hadoop/top-n-movies-v2

Exercises

- Modify WordCount to not set number of reducers or change it to something different. Generate the jar file again and test to see if it does what you expected.
- Modify Case Analysis to skip the other non characters. Generate the jar file and run it to test it.

References

- Overall documentation for Hadoop 3.3.6:
  https://hadoop.apache.org/docs/r3.3.6/
- MapReduce API (Hadoop 3.3.6):
  https://hadoop.apache.org/docs/stable/api
- MapReduce Tutorial (for Java)