CSE 4/587
Data Intensive Computing

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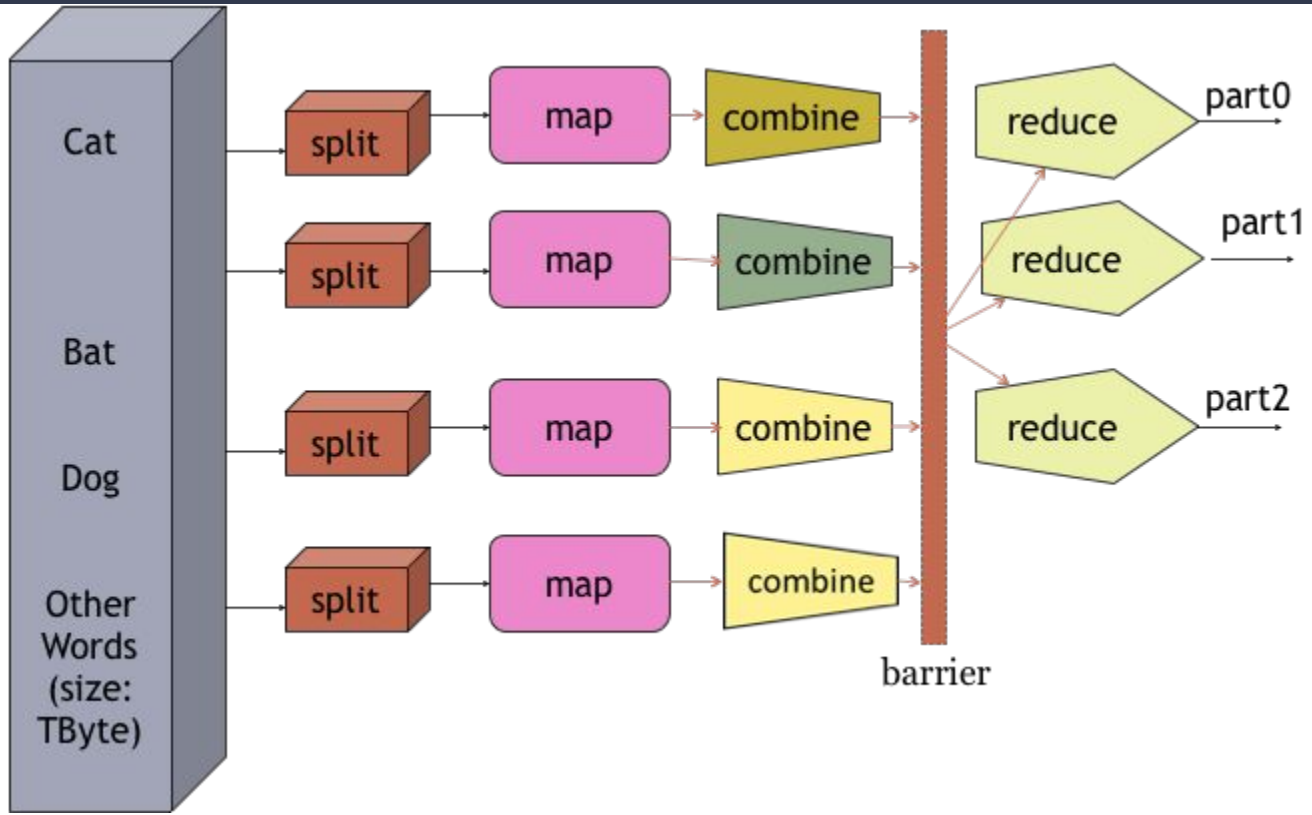
MapReduce Demo

Recap from Last Class

- Introduced MapReduce as a technique for handling large amounts of data on HDFS
  - "Unreasonable effectiveness of data" — Simple algorithms with more data can be more effective than sophisticated algorithms with less data
  - Applications consist of *mappers* and *reducers*
    - Mappers take input and map it to a set of key-value pairs
    - Reducers take multiple key-value pairs and reduce them to a single key-value pair

The Big Picture



Plan for Today

Today we will do a demonstration of MapReduce in Java

1. Set up our data in a local Hadoop instance and view it in a browser
2. Write a mapper, and a reducer
3. Configure our job
4. Compile and run our MapReduce code as a job in Hadoop
5. Explore the output of our job
6. Extend our example based on our observations

Setting up Hadoop

- Today we'll be running a single node instance of Hadoop
  - For installation I used Homebrew (brew install hadoop)
  - Directions for setup can be found at [1]
- Once we've done all the setup we'll need to create our directories and add our files to the instance
- We can also look at our instance via web browser

[1] https://hadoop.apache.org/docs/stable/hadoop-project-dist/hadoop-common/SingleCluster.html

Some Useful Commands

```
hadoop fs -mkdir
hadoop fs -ls
hadoop fs -mv
hadoop fs -rm
```

```
hadoop fs -touch
hadoop fs -put
hadoop fs -cp
hadoop fs -cat
```

```
hadoop fs -mkdir /user/epmikida
hadoop fs -mkdir input
hadoop fs -put <path>/pride_and_prejudice.txt input/
hadoop fs -cat input/pride_and_prejudice.txt
```

Some Useful Commands

```
hadoop fs -mkdir
hadoop fs -ls
hadoop fs -mv
hadoop fs -rm
```

```
hadoop fs -touch
hadoop fs -put
hadoop fs -cp
hadoop fs -cat
```

```
hadoop fs -mkdir /user/epmikida
hadoop fs -mkdir input
hadoop fs -put <path>/pride_and_prejudice.txt input/
hadoop fs -cat input/pride_and_prejudice.txt
```

←Create our home directory

Some Useful Commands

```
hadoop fs -mkdir
hadoop fs -ls
hadoop fs -mv
hadoop fs -rm
```

```
hadoop fs -touch
hadoop fs -put
hadoop fs -cp
hadoop fs -cat
```

```
hadoop fs -mkdir /user/epmikida          ←Create our home directory
hadoop fs -mkdir input                   ←Create a directory for input
hadoop fs -put <path>/pride_and_prejudice.txt input/
hadoop fs -cat input/pride_and_prejudice.txt
```

Some Useful Commands

```
hadoop fs -mkdir
hadoop fs -ls
hadoop fs -mv
hadoop fs -rm
```

```
hadoop fs -touch
hadoop fs -put
hadoop fs -cp
hadoop fs -cat
```

```
hadoop fs -mkdir /user/epmikida                          ←Create our home directory
hadoop fs -mkdir input                                   ←Create a directory for input
hadoop fs -put <path>/pride_and_prejudice.txt input/     ←Add a local file to HDFS
hadoop fs -cat input/pride_and_prejudice.txt
```

Some Useful Commands

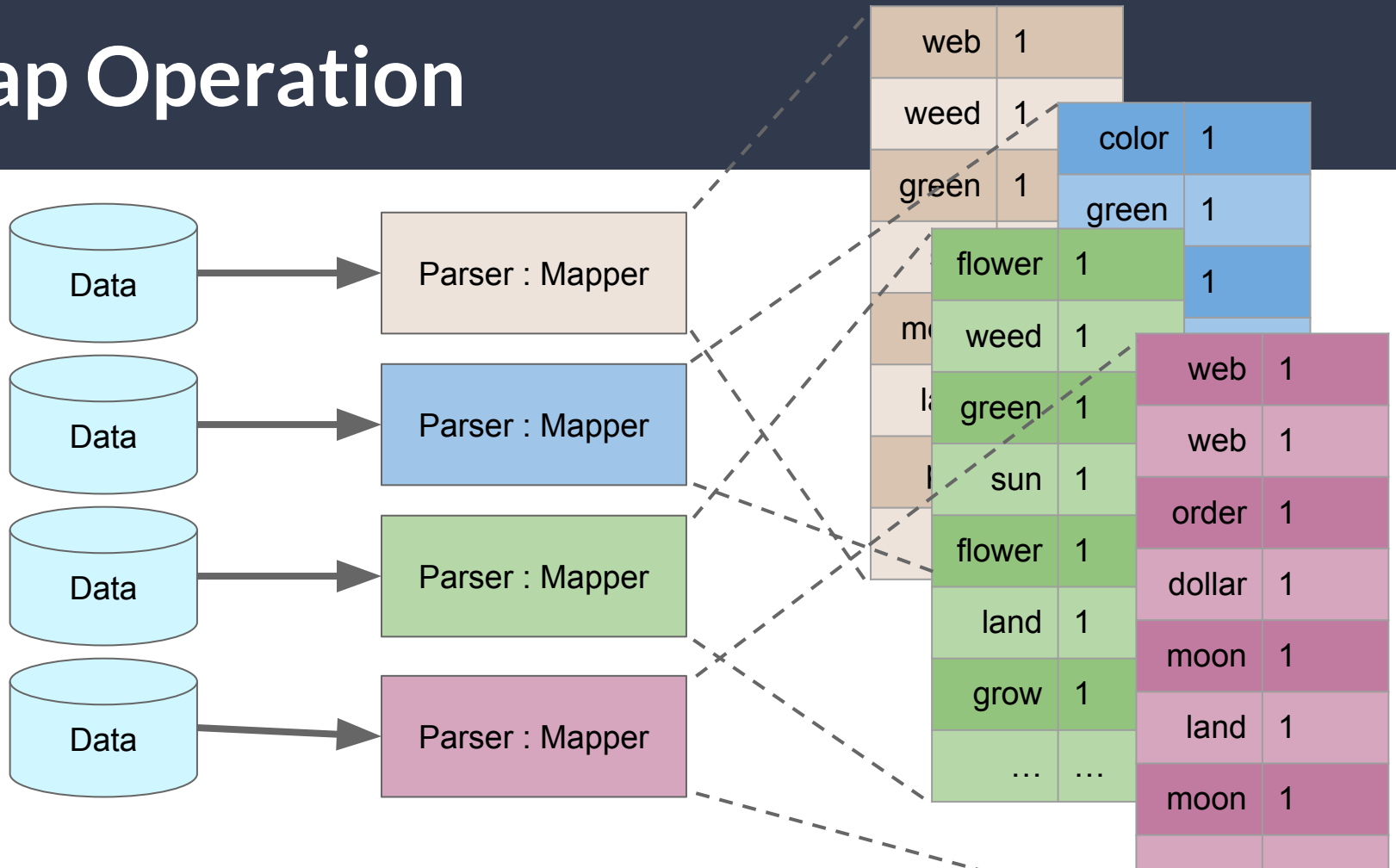
```
hadoop fs -mkdir
hadoop fs -ls
hadoop fs -mv
hadoop fs -rm
```

```
hadoop fs -touch
hadoop fs -put
hadoop fs -cp
hadoop fs -cat
```

```
hadoop fs -mkdir /user/epmikida                          ←Create our home directory
hadoop fs -mkdir input                                   ←Create a directory for input
hadoop fs -put <path>/pride_and_prejudice.txt input/     ←Add a local file to HDFS
hadoop fs -cat input/pride_and_prejudice.txt             ←Check contents of the file
```

HDFS Demo

Map Operation



Mapper Java Code

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3
4    private final static IntWritable one = new IntWritable(1);
5    private Text word = new Text();
6
7    public void map(Object key, Text value, Context context)
8        throws IOException, InterruptedException {
9      StringTokenizer itr = new StringTokenizer(value.toString());
10     while (itr.hasMoreTokens()) {
11       word.set(itr.nextToken());
12       context.write(word, one);
13     }
14   }
15 }
```

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11       word.set(itr.nextToken());
12       context.write(word, one);
13     }
14   }
15 }
```

Input Key type and Input Value type

Mapper Java Code

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3
4    private final static Int                          ;
5    private Text word = new Text();
6
7    public void map(Object key, Text value, Context context)
8        throws IOException, InterruptedException {
9      StringTokenizer itr = new StringTokenizer(value.toString());
10     while (itr.hasMoreTokens()) {
11       word.set(itr.nextToken());
12       context.write(word, one);
13     }
14   }
15 }
```

Output Key type and Output Value type

Mapper Java Code

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3
4    private final static IntWritable one = new IntWritable(1);
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6
7    public void map(Object key, Text value, Context context)
8        throws IOException, InterruptedException {
9      StringTokenizer itr = new StringTokenizer(value.toString());
10     while (itr.hasMoreTokens()) {
11       word.set(itr.nextToken());
12       context.write(word, one);
13     }
14   }
15 }
```

This is our input text that we are parsing

Mapper Java Code

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3
4    private final static IntWritable one = new IntWritable(1);
5    private Text word = new Text();
6
7    public void map(Object key, Text value, Context context)
8        throws IOException, InterruptedException {
9      StringTokenizer itr = new StringTokenizer(value.toString());
10     while (itr.hasMoreTokens()) {
11       word.set(itr.nextToken());
12       context.write(word, one);
13     }
14   }
15 }
```

Write out a key-value pair for the word we found, with a count of one.

Mapper Notes

- The MapReduce framework will spawn one Mapper per input split
  - Usually this is the number of blocks
  - Mappers are expensive to startup — choose granularity wisely
- Key types and value types must be serializable (Writable interface)
- Output will be grouped by key by the system
  - Optionally can be combined if a **`Combiner`** is also defined

Reducer Java Code

```
1  public static class IntSumReducer
2      extends Reducer<Text,IntWritable,Text,IntWritable> {
3
4    private IntWritable result = new IntWritable();
5
6    public void reduce(Text key, Iterable<IntWritable> values, Context context)
7        throws IOException, InterruptedException {
8      int sum = 0;
9      for (IntWritable val : values) {
10       sum += val.get();
11     }
12     result.set(sum);
13     context.write(key, result);
14   }
15 }
```

Reducer Java Code

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1  public static class IntSumReducer
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11     }
12     result.set(sum);
13     context.write(key, result);
14   }
15 }
```

Input Key type and Input Value type

Reducer Java Code

```
1  public static class IntSumReducer
2      extends Reducer<Text,IntWritable,Text,IntWritable> {
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4    private IntWritable result = new
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6    public void reduce(Text key, Iterable<IntWritable> values, Context context)
7        throws IOException, InterruptedException {
8      int sum = 0;
9      for (IntWritable val : values) {
10       sum += val.get();
11     }
12     result.set(sum);
13     context.write(key, result);
14   }
15 }
```

Output Key type and Output Value type

Reducer Java Code

```
1  public static class IntSumReducer
2      extends Reducer<Text,IntWritable,Text,IntWritable> {
3
4    private IntWritable result =
5
6    public void reduce(Text key, Iterable<IntWritable> values, Context context)
7        throws IOException, InterruptedException {
8      int sum = 0;
9      for (IntWritable val : values) {
10       sum += val.get();
11     }
12     result.set(sum);
13     context.write(key, result);
14   }
15 }
```

A single input key, and a list of values to be reduced

Reducer Java Code

```
1  public static class IntSumReducer
2      extends Reducer<Text,IntWritable,Text,IntWritable> {
3
4    private IntWritable result = new IntWritable();
5
6    public void reduce(Text key, Iterable<IntWritable> values, Context context)
7        throws IOException, InterruptedException {
8      int sum = 0;
9      for (IntWritable val : values) {
10       sum += val.get();
11     }
12     result.set(sum);
13     context.write(key, result);
14   }
15 }
```

Write out our reduced key-value pair

Reducer Notes

- The number of reducers is set in job configuration
  - Rule of thumb is either 0.95 or 1.75…but this can vary
  - Overhead vs Load balance is an important trade-off
- Output of mapping is sorted before reducing begins
- The framework passes each key and its values to a reducer
  - Which keys go to which reducer can be controlled with a partitioner

Job Configuration

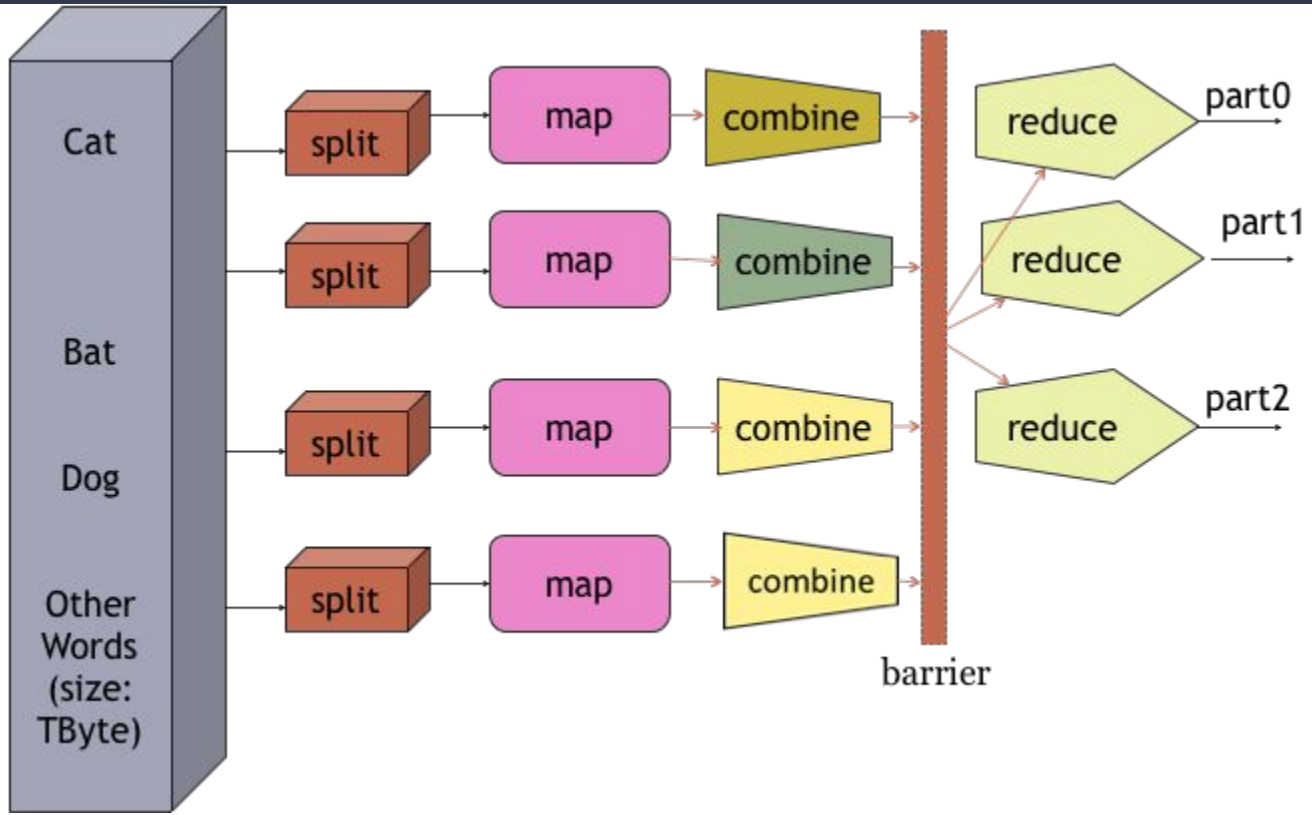
```
1  public static void main(String[] args) throws Exception {
2      Configuration conf = new Configuration();
3      Job job = Job.getInstance(conf, "word count");
4      job.setJarByClass(WordCount.class);
5      job.setMapperClass(TokenizerMapper.class);
6      job.setCombinerClass(IntSumReducer.class);
7      job.setReducerClass(IntSumReducer.class);
8      job.setOutputKeyClass(Text.class);
9      job.setOutputValueClass(IntWritable.class);
10     FileInputFormat.addInputPath(job, new Path(args[0]));
11     FileOutputFormat.setOutputPath(job, new Path(args[1]));
12     System.exit(job.waitForCompletion(true) ? 0 : 1);
13   }
```

Job Configuration

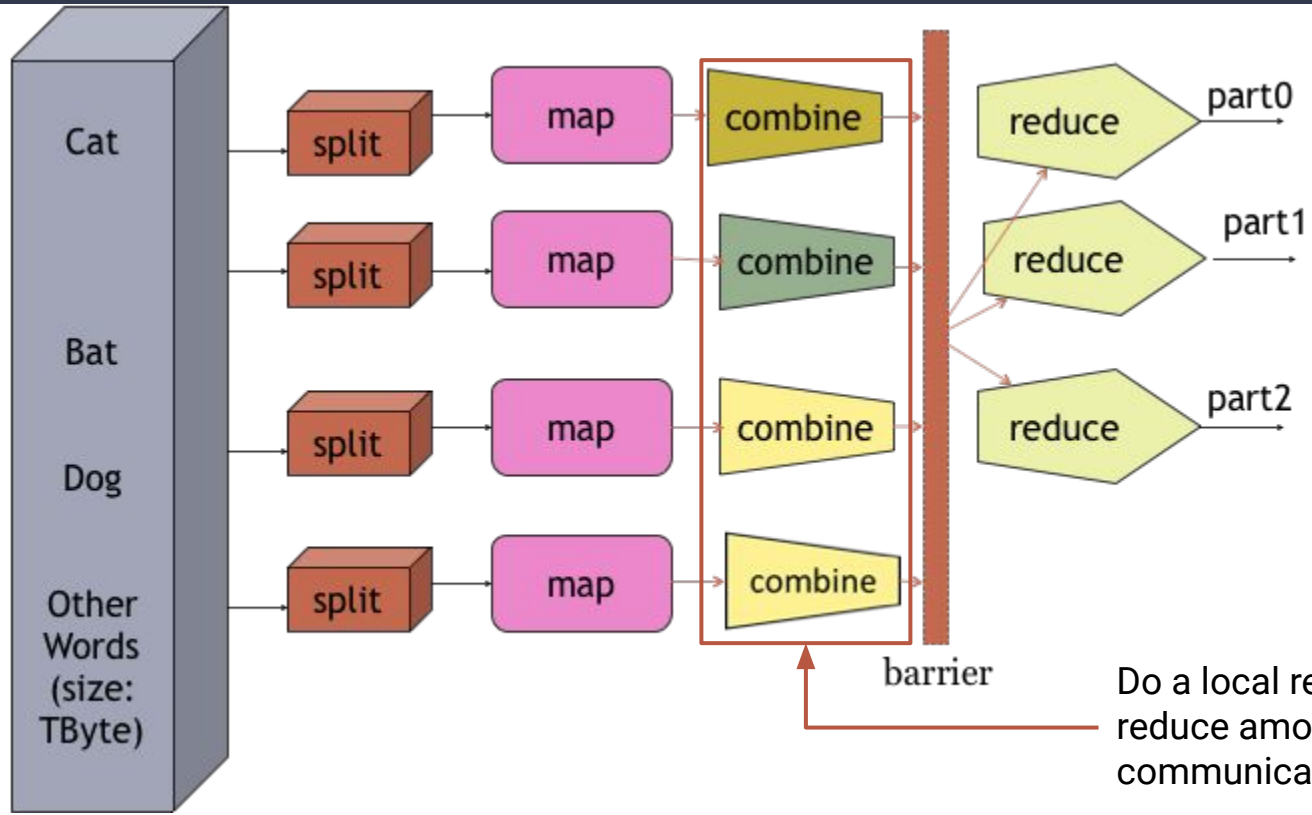
```
1  public static void main(String[] args) throws Exception {
2      Configuration conf = new Configuration();
3      Job job = Job.getInstance(conf, "word count");
4      job.setJarByClass(WordCount.class);
5      job.setMapperClass(TokenizerMapper.class);
6      job.setCombinerClass(IntSumReducer.class);
7      job.setReducerClass(IntSumReducer.class);
8      job.setOutputKeyClass(Text.class);
9      job.setOutputValueClass(IntWritable.class);
10     FileInputFormat.addInputPath(job, new Path(args[0]));
11     FileOutputFormat.setOutputPath(job, new Path(args[1]));
12     System.exit(job.waitForCompletion(true) ? 0 : 1);
13   }
```

Set types of Mappers and Reducers (and Combiners)

What's A Combiner?



What's A Combiner?



MapReduce Demo

Other Useful Components

- Argument Parsing - Get command line arguments and set global configuration parameters
- Distributed Cache - Allows for data sharing between components
- Counter - Allows for status information to be reported
- Partitioner - Allows for control of how keys are distributed to reducers

Generic Argument Parsing

```
 1 Configuration conf = new Configuration();
 2 GenericOptionsParser optionParser = new GenericOptionsParser(conf, args);
 3 String[] remainingArgs = optionParser.getRemainingArgs();
 4 if ((remainingArgs.length!=2) && (remainingArgs.length!=4)) { System.exit(2); }
 5
 6 List<String> otherArgs = new ArrayList<String>();
 7 for (int i=0; i < remainingArgs.length; ++i) {
 8   if ("-skip".equals(remainingArgs[i])) {
 9     job.addCacheFile(new Path(remainingArgs[++i]).toUri());
10     job.getConfiguration().setBoolean("wordcount.skip.patterns", true);
11   } else {
12     otherArgs.add(remainingArgs[i]);
13   }
14 }
```

Generic Argument Parsing

```
1  Configuration conf = new Configuration();
2  GenericOptionsParser optionParser = new GenericOptionsParser(conf, args);
3  String[] remainingArgs = optionParser.get
4  if ((remainingArgs.length!=2) && (remain                    2); }
5
6  List<String> otherArgs = new ArrayList<String>();
7  for (int i=0; i < remainingArgs.length; ++i) {
8    if ("-skip".equals(remainingArgs[i])) {
9      job.addCacheFile(new Path(remainingArgs[++i]).toUri());
10     job.getConfiguration().setBoolean("wordcount.skip.patterns", true);
11   } else {
12     otherArgs.add(remainingArgs[i]);
13   }
14 }
```

Get generic arguments and set them in our job configuration

Generic Argument Parsing

```
 1 Configuration conf = new Configuration();
 2 GenericOptionsParser optionParser = new GenericOptionsParser(conf, args);
 3 String[] remainingArgs = optionParser.getRemainingArgs();
 4 if ((remainingArgs.length!=2) && (remainingArgs.length!=4)) { System.exit(2); }
 5
 6 List<String> otherArgs = new ArrayList<Stri
 7 for (int i=0; i < remainingArgs.length; ++i
 8   if ("-skip".equals(remainingArgs[i])) {
 9     job.addCacheFile(new Path(remainingArgs[++i]).toUri());
10     job.getConfiguration().setBoolean("wordcount.skip.patterns", true);
11   } else {
12     otherArgs.add(remainingArgs[i]);
13   }
14 }
```

Check for non-generic arguments

Generic Argument Parsing

```
1  Configuration conf = new Configuration();
2  GenericOptionsParser optionParser = new GenericOptionsParser(conf, args);
3  String[] remainingArgs = optionParser.getRemainingArgs();
4  if ((remainingArgs.length!=2) && (remainingArgs.length!=4)) { System.exit(2); }
5
6  List<String> otherArgs = new ArrayLis
7  for (int i=0; i < remainingArgs.lengt
8    if ("-skip".equals(remainingArgs[i]
9      job.addCacheFile(new Path(remainingArgs[++i]).toUri());
10     job.getConfiguration().setBoolean("wordcount.skip.patterns", true);
11   } else {
12     otherArgs.add(remainingArgs[i]);
13   }
14 }
```

Load a skip file into the distributed cache and set a configuration parameter

Generic Argument Parsing

- Generic arguments can be passed to the MapReduce job with -D
  - ie: `-Dwordcount.case.sensitive=false`
- Mappers/Reducers can access configuration values and cache files via the `Context` object
  - They can also define a `setup` method which is called before mapping/reducing begins

Augmenting Our Mapper

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3    ...
4    public void setup(Context context) throws IOException, InterruptedException {
5      conf = context.getConfiguration();
6      caseSensitive = conf.getBoolean("wordcount.case.sensitive", true);
7      if (conf.getBoolean("wordcount.skip.patterns", false)) {
8        URI[] patternsURIs = Job.getInstance(conf).getCacheFiles();
9        for (URI patternsURI : patternsURIs) {
10         Path patternsPath = new Path(patternsURI.getPath());
11         String patternsFileName = patternsPath.getName().toString();
12         parseSkipFile(patternsFileName);
13       }
14     }
15   }
16
```

Augmenting Our Mapper

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3    ...
4    public void setup(Context context) throws IOException, InterruptedException {
5      conf = context.getConfiguration()
6      caseSensitive = conf.getBoolean('
7      if (conf.getBoolean("wordcount.sk
8        URI[] patternsURIs = Job.getInstance(conf).getCacheFiles();
9        for (URI patternsURI : patternsURIs) {
10         Path patternsPath = new Path(patternsURI.getPath());
11         String patternsFileName = patternsPath.getName().toString();
12         parseSkipFile(patternsFileName);
13       }
14     }
15   }
```

Setup function allows our mapper to do some initial setup based on global configuration

Augmenting Our Mapper

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3    ...
4    public void setup(Context context) throws IOException, InterruptedException {
5      conf = context.getConfiguration();
6      caseSensitive = conf.getBoolean("wordcount.case.sensitive", true);
7      if (conf.getBoolean("wordcount.skip.patterns", false)) {
8        URI[] patternsURIs = Job.getInstance(conf).getCacheFiles();
9        for (URI patternsURI : patternsURIs) {
10         Path patternsPath = new Path(patterns
11         String patternsFileName = patternsPath.getName().toString();
12         parseSkipFile(patternsFileName);
13       }
14     }
15   }
```

Read in configuration values

Augmenting Our Mapper

```
1  public static class TokenizerMapper
2      extends Mapper<Object, Text, Text, IntWritable> {
3    ...
4    public void setup(Context context) throws IOException, InterruptedException {
5      conf = context.getConfiguration();
6      caseSensitive = conf.getBoolean("wordcount.case.sensitive", true);
7      if (conf.getBoolean("wordcount.skip.patterns", false)) {
8        URI[] patternsURIs = Job.getInstance(conf).getCacheFiles();
9        for (URI patternsURI : patternsURIs) {
10         Path patternsPath = new Path(patternsURI.getPath());
11         String patternsFileName = patternsPath.getName().toString();
12         parseSkipFile(patternsFileName);
13       }
14     }
15   }
```

Access files from the distributed cache

Augmenting our Mapper

We can now use this information inside our `map` function

Augmenting Our map Function

```
1  static enum CountersEnum { INPUT_WORDS }
2  public void map(Object key, Text value, Context context)
3      throws IOException, InterruptedException {
4    String line=(caseSensitive)?value.toString():value.toString().toLowerCase();
5    for (String pattern : patternsToSkip) { line = line.replaceAll(pattern, ""); }
6
7    StringTokenizer itr = new StringTokenizer(line);
8    while (itr.hasMoreTokens()) {
9      word.set(itr.nextToken());
10     context.write(word, one);
11     Counter counter = context.getCounter(CountersEnum.class.getName(),
12         CountersEnum.INPUT_WORDS.toString());
13     counter.increment(1);
14   }
15 }
```

Augmenting Our map Function

```
1  static enum CountersEnum { INPUT_WORDS }
2  public void map(Object key, Text value, Context context)
3      throws IOException, InterruptedException {
4    String line=(caseSensitive)?value.toString():value.toString().toLowerCase();
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8    while (itr.hasMoreTokens()) {
9      word.set(itr.nextToken());
10     context.write(word, one);
11     Counter counter = context.getCounter(CountersEnum.class.getName(),
12         CountersEnum.INPUT_WORDS.toString());
13     counter.increment(1);
14   }
15 }
```

Use our configuration from setup

Augmenting Our map Function

```
1  static enum CountersEnum { INPUT_WORDS }
2  public void map(Object key, Text value, Context context)
3      throws IOException, Inte
4    String line=(caseSensitive)?value.toString():value.toString().toLowerCase();
5    for (String pattern : patternsToSkip) { line = line.replaceAll(pattern, ""); }
6
7    StringTokenizer itr = new StringTokenizer(line);
8    while (itr.hasMoreTokens()) {
9      word.set(itr.nextToken());
10     context.write(word, one);
11     Counter counter = context.getCounter(CountersEnum.class.getName(),
12         CountersEnum.INPUT_WORDS.toString());
13     counter.increment(1);
14   }
15 }
```

Define a Counter (as an Enum)

Augmenting Our map Function

```
1  static enum CountersEnum { INPUT_WORDS }
2  public void map(Object key, Text value, Context context)
3      throws IOException, InterruptedException {
4    String line=(caseSensitive)?value.toString():value.toString().toLowerCase();
5    for (String pattern : patternsToSkip) { line = line.replaceAll(pattern, ""); }
6
7    StringTokenizer itr = new StringTokenizer(line);
8    while (itr.hasMoreTokens()) {
9      word.set(itr.nextToken());
10     context.write(word, one);
11     Counter counter = context.getCounter(CountersEnum.class.getName(),
12         CountersEnum.INPUT_WORDS.toString());
13     counter.increment(1);
14   }
15 }
```

Use our Counter to count the number of words we parsed

Improved MapReduce Demo

References

Setting up Hadoop

https://hadoop.apache.org/docs/stable/hadoop-project-dist/hadoop-common/SingleCluster.html

MapReduce Tutorial

https://hadoop.apache.org/docs/stable/hadoop-mapreduce-client/hadoop-mapreduce-client-core/MapReduceTutorial.html