Programming with Hadoop

Overview

- How to use Hadoop
  - Hadoop MapReduce
  - Hadoop Streaming

Some MapReduce Terminology

- *Job* – A "full program" - an execution of a Mapper and Reducer across a data set
- *Task* – An execution of a Mapper or a Reducer on a slice of data
  - a.k.a. Task-In-Progress (TIP)
- Task Attempt – A particular instance of an attempt to execute a task on a machine

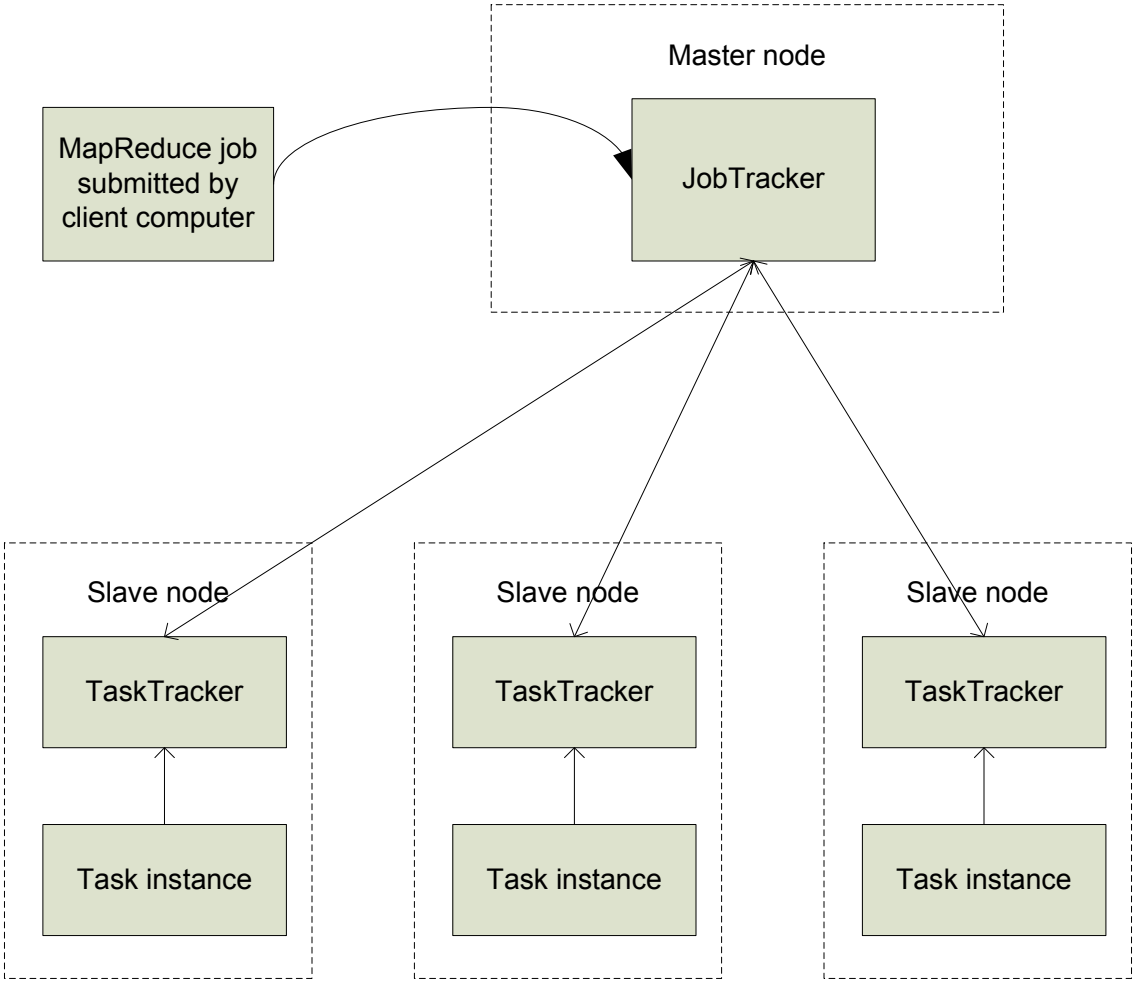
Terminology Example

- Running “Word Count” across 20 files is one *job*
- 20 files to be mapped imply 20 *map tasks* + some number of *reduce tasks*
- At least 20 map *task attempts* will be performed… more if a machine crashes, etc.

Task Attempts

- A particular task will be attempted at least once, possibly more times if it crashes
  - If the same input causes crashes over and over, that input will eventually be abandoned
- Multiple attempts at one task may occur in parallel with speculative execution turned on
  - Task ID from *TaskInProgress* is not a unique identifier; don't use it that way

MapReduce: High Level



Nodes, Trackers, Tasks

- Master node runs *JobTracker* instance, which accepts *Job* requests from clients
- *TaskTracker* instances run on slave nodes
- TaskTracker forks separate Java process for task instances

Job Distribution

- MapReduce programs are contained in a Java "jar" file + an XML file containing serialized program configuration options
- Running a MapReduce job places these files into the HDFS and notifies TaskTrackers where to retrieve the relevant program code
- … Where's the data distribution?

Data Distribution

- Implicit in design of MapReduce!
  - All mappers are equivalent; so map whatever data is local to a particular node in HDFS
- If lots of data does happen to pile up on the same node, nearby nodes will map instead
  - Data transfer is handled implicitly by HDFS

Configuring With JobConf

- MR Programs have many configurable options
- *JobConf* objects hold (key, value) components mapping String → 'a
  - e.g., "mapred.map.tasks" → 20
  - JobConf is serialized and distributed before running the job
- Objects implementing *JobConfigurable* can retrieve elements from a JobConf

What Happens In MapReduce? Depth First

Job Launch Process: Client

- Client program creates a *JobConf*
  - Identify classes implementing *Mapper* and *Reducer* interfaces
    - JobConf.setMapperClass(), setReducerClass()
  - Specify inputs, outputs
    - FileInputFormat.addInputPath(conf)
    - FileOutputFormat.setOutputPath(conf)
  - Optionally, other options too:
    - JobConf.setNumReduceTasks(), JobConf.setOutputFormat()…

Job Launch Process: *JobClient*

- Pass JobConf to JobClient.runJob() or submitJob()
  - runJob() blocks, submitJob() does not
- *JobClient*:
  - Determines proper division of input into *InputSplits*
  - Sends job data to master *JobTracker* server

Job Launch Process: *JobTracker*

- *JobTracker*:
  - Inserts jar and JobConf (serialized to XML) in shared location
  - Posts a *JobInProgress* to its run queue

Job Launch Process: *TaskTracker*

- *TaskTrackers* running on slave nodes periodically query *JobTracker* for work
- Retrieve job-specific jar and config
- Launch task in separate instance of Java
  - main() is provided by Hadoop

Job Launch Process: Task

- TaskTracker.Child.main():
  - Sets up the child *TaskInProgress* attempt
  - Reads XML configuration
  - Connects back to necessary MapReduce components via RPC
  - Uses *TaskRunner* to launch user process

Job Launch Process: *TaskRunner*

- *TaskRunner* launches your *Mapper*
  - Task knows ahead of time which *InputSplits* it should be mapping
  - Calls *Mapper* once for each record retrieved from the InputSplit
- Running the *Reducer* is much the same

Creating the *Mapper*

- You provide the instance of *Mapper*
  - Should extend *MapReduceBase*
- One instance of your Mapper is initialized per task
  - Exists in separate process from all other instances of Mapper – no data sharing!

Mapper

- void map(WritableComparable key,
  Writable value,
  OutputCollector output,
  Reporter reporter)

What is Writable?

- Hadoop defines its own “box” classes for strings *(Text)*, integers *(IntWritable)*, etc.
- All values are instances of *Writable*
- All keys are instances of *WritableComparable*

Writing For Cache Coherency

```
while (more input exists) {
   myIntermediate = new intermediate(input);
   myIntermediate.process();
   export outputs;
}
```

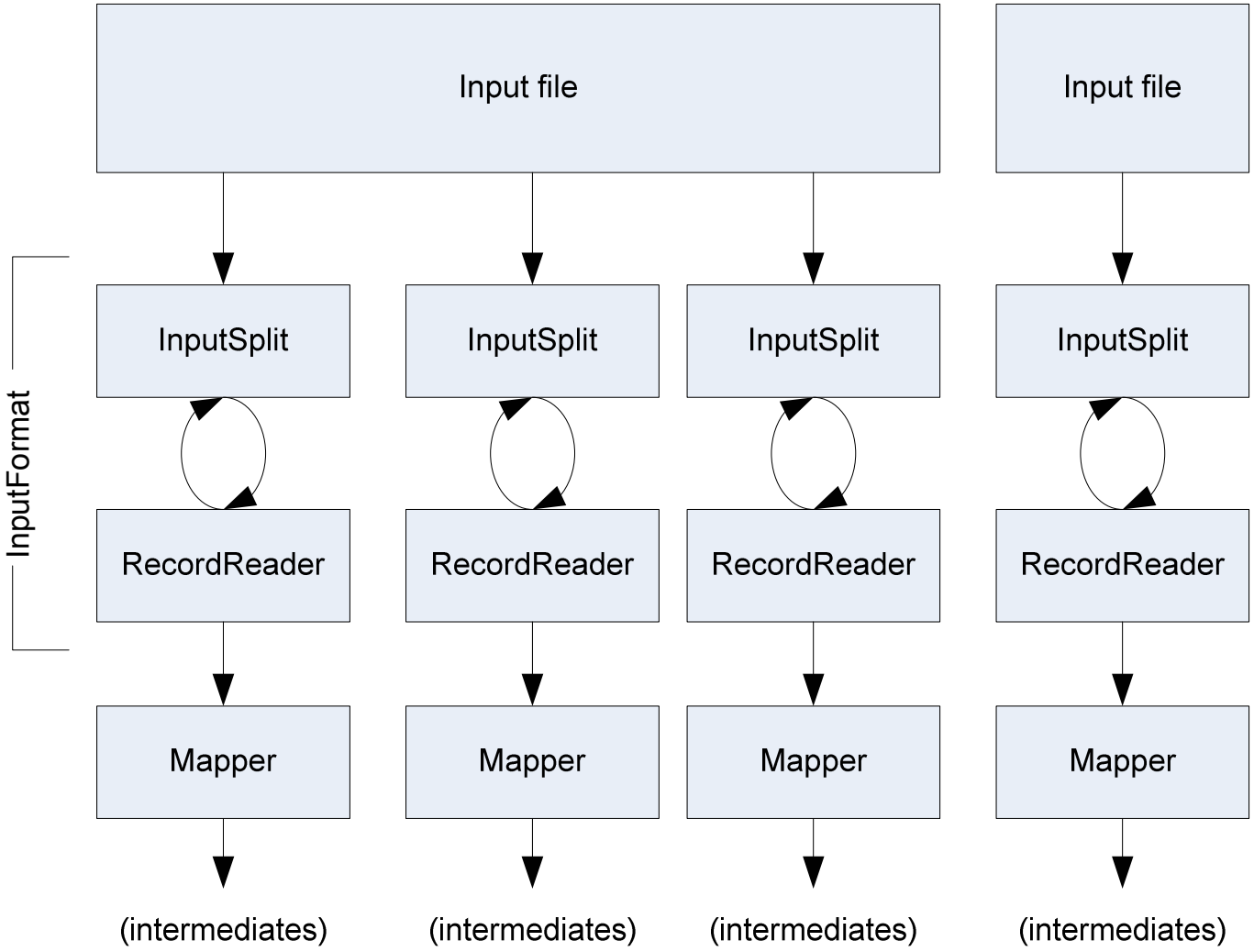
Writing For Cache Coherency

```
myIntermediate = new intermediate (junk);
while (more input exists) {
   myIntermediate.setupState(input);
   myIntermediate.process();
   export outputs;
}
```

Writing For Cache Coherency

- Running the GC takes time
- Reusing locations allows better cache usage (up to 2x performance benefit)
- All keys and values given to you by Hadoop use this model (share containiner objects)

Getting Data To The Mapper



Reading Data

- Data sets are specified by *InputFormats*
  - Defines input data (e.g., a directory)
  - Identifies partitions of the data that form an *InputSplit*
  - Factory for *RecordReader* objects to extract (k, v) records from the input source

FileInputFormat and Friends

- *TextInputFormat* – Treats each '\n'-terminated line of a file as a value
- *KeyValueTextInputFormat* – Maps '\n'-terminated text lines of "k SEP v"
- *SequenceFileInputFormat* – Binary file of (k, v) pairs with some add'l metadata
- *SequenceFileAsTextInputFormat* – Same, but maps (k.toString(), v.toString())

Filtering File Inputs

- *FileInputFormat* will read all files out of a specified directory and send them to the mapper
- Delegates filtering this file list to a method subclasses may override
  - *e.g.,* Create your own “xyzFileInputFormat” to read *.xyz from directory list

Record Readers

- Each *InputFormat* provides its own *RecordReader* implementation
  - Provides (unused?) capability multiplexing
- *LineRecordReader* – Reads a line from a text file
- *KeyValueRecordReader* – Used by *KeyValueTextInputFormat*

Input Split Size

- *FileInputFormat* will divide large files into chunks
  - Exact size controlled by mapred.min.split.size
- RecordReaders receive file, offset, and length of chunk
- Custom *InputFormat* implementations may override split size – e.g., “NeverChunkFile”

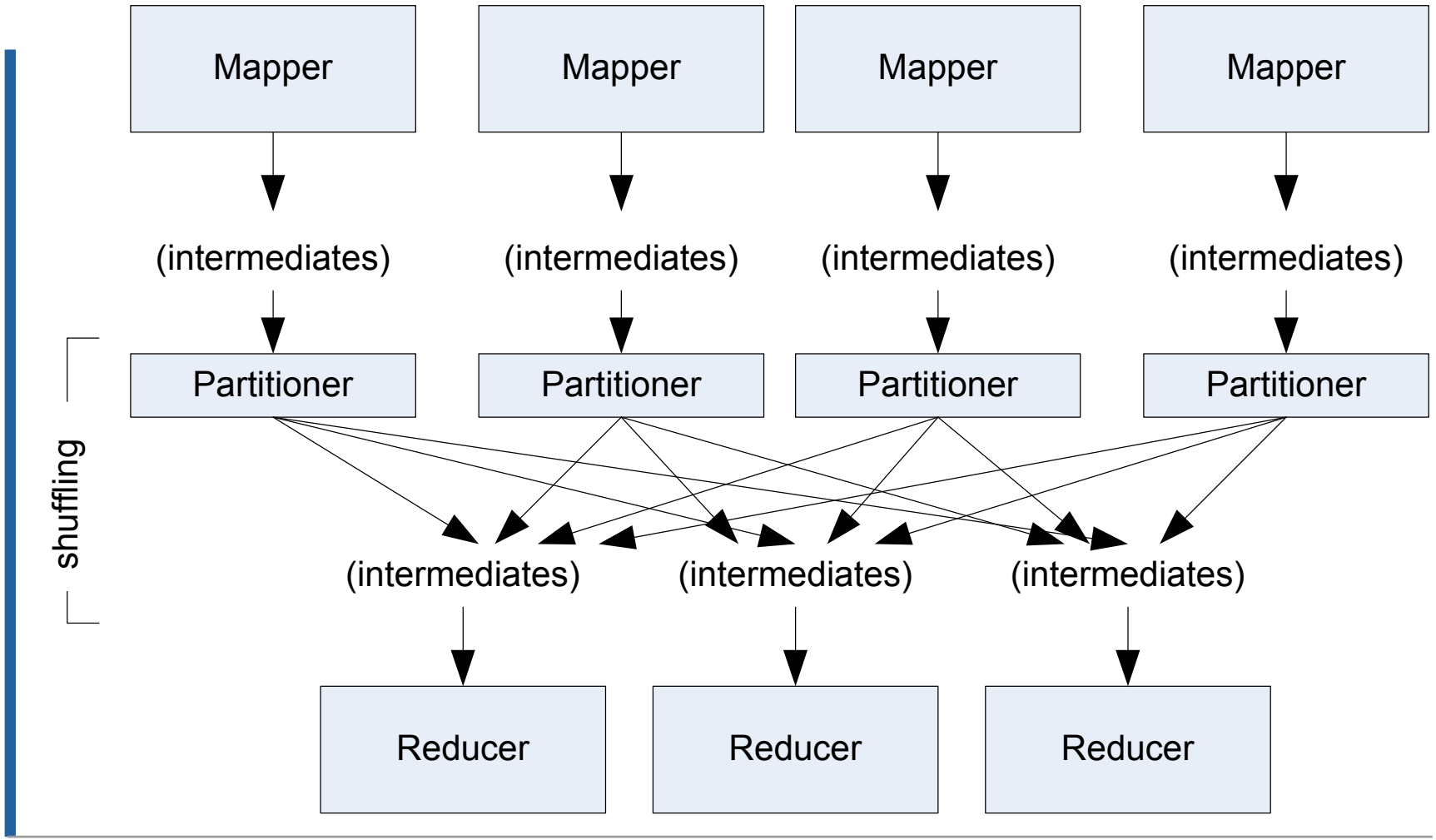
Sending Data To Reducers

- Map function receives *OutputCollector* object
  - OutputCollector.collect() takes (k, v) elements
- Any *(WritableComparable, Writable)* can be used

Sending Data To The Client

- *Reporter* object sent to Mapper allows simple asynchronous feedback
  - incrCounter(Enum key, long amount)
  - setStatus(String msg)
- Allows self-identification of input
  - InputSplit getInputSplit()

Partition And Shuffle



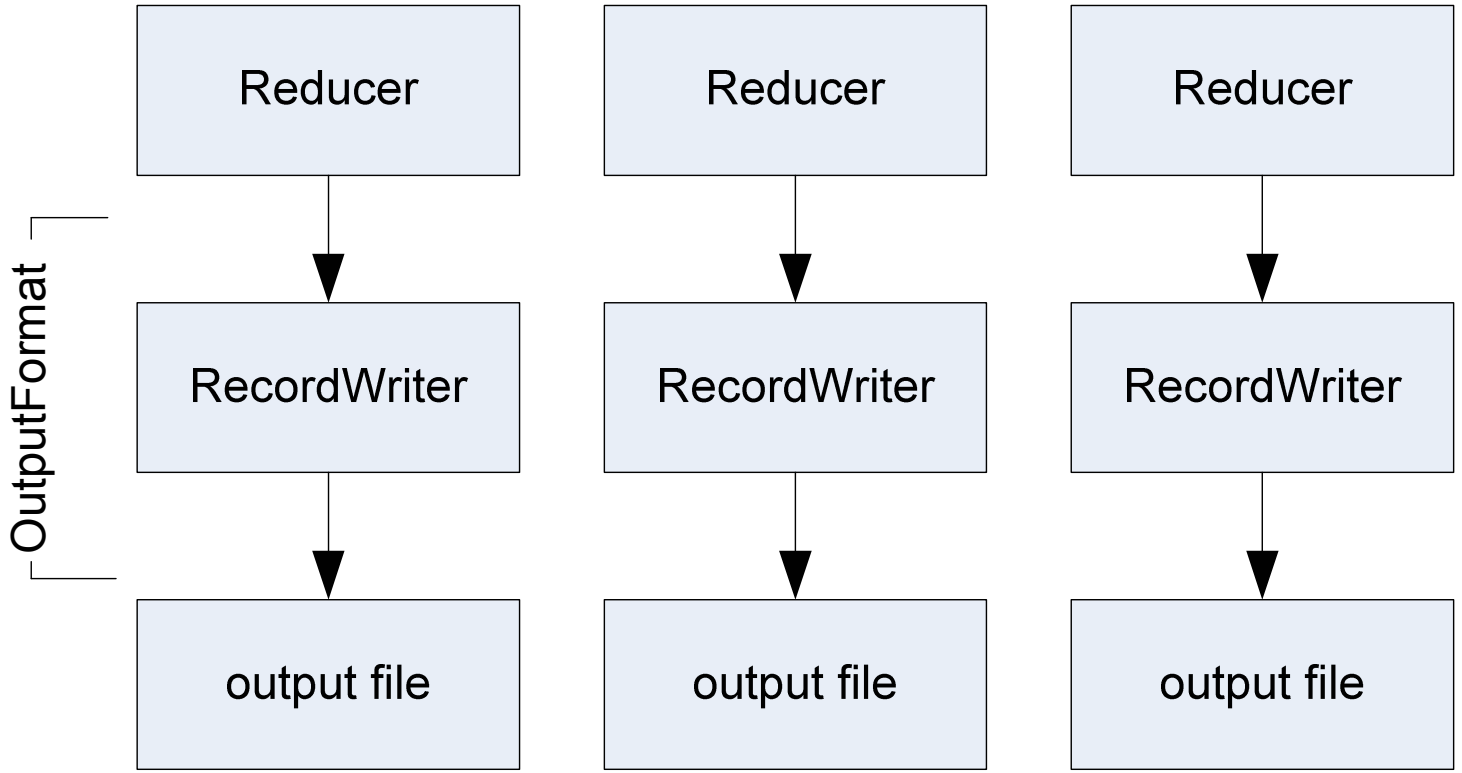
Partitioner

- int getPartition(key, val, numPartitions)
  - Outputs the partition number for a given key
  - One partition == values sent to one Reduce task
- *HashPartitioner* used by default
  - Uses key.hashCode() to return partition num
- *JobConf* sets *Partitioner* implementation

Reduction

- reduce(WritableComparable key,
  Iterator values,
  OutputCollector output,
  Reporter reporter)
- Keys & values sent to one partition all go to the same reduce task
- Calls are sorted by key – “earlier” keys are reduced and output before “later” keys
- Remember – values.next() always returns the same object, different data!

Finally: Writing The Output



OutputFormat

- Analogous to *InputFormat*
- *TextOutputFormat* – Writes “key val\n” strings to output file
- *SequenceFileOutputFormat* – Uses a binary format to pack (k, v) pairs
- *NullOutputFormat* – Discards output

Conclusions

- That's the Hadoop flow!
- Lots of flexibility to override components, customize inputs and outputs
- Using custom-built binary formats allows high-speed data movement

Hadoop Streaming

Motivation

- You want to use a scripting language
  - Faster development time
  - Easier to read, debug
  - Use existing libraries
- You (still) have lots of data

HadoopStreaming

- Interfaces Hadoop MapReduce with arbitrary program code
- Uses **`stdin`** and **`stdout`** for data flow
- You define a separate program for each of mapper, reducer

Data format

- Input (key, val) pairs sent in as lines of input

  key (tab) val (newline)

- Data naturally transmitted as text
- You emit lines of the same form on stdout for output (key, val) pairs.

Example: map (k, v) → (v, k)

```
#!/usr/bin/env python
import sys
while True:
  line = sys.stdin.readline()
  if len(line) == 0:
    break
  (k, v) = line.strip().split("\t")
  print v + "\t" + k
```

Launching Streaming Jobs

- Special jar contains streaming “job”
- Arguments select mapper, reducer, format…
- Can also specify Java classes
  - Note: must be in Hadoop “internal” library

Reusing programs

- Identity mapper/reducer: `cat`
- Summing: `wc`
- Field selection: `cut`
- Filtering: `awk`

Streaming Conclusions

- Fast, simple, powerful
- Low-overhead way to get started with Hadoop
- Resources:
  - http://wiki.apache.org/hadoop/HadoopStreaming
  - http://hadoop.apache.org/core/docs/current/streaming.html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