COMP9313: Big Data Management

Introduction to MapReduce and Spark

Motivation of MapReduce

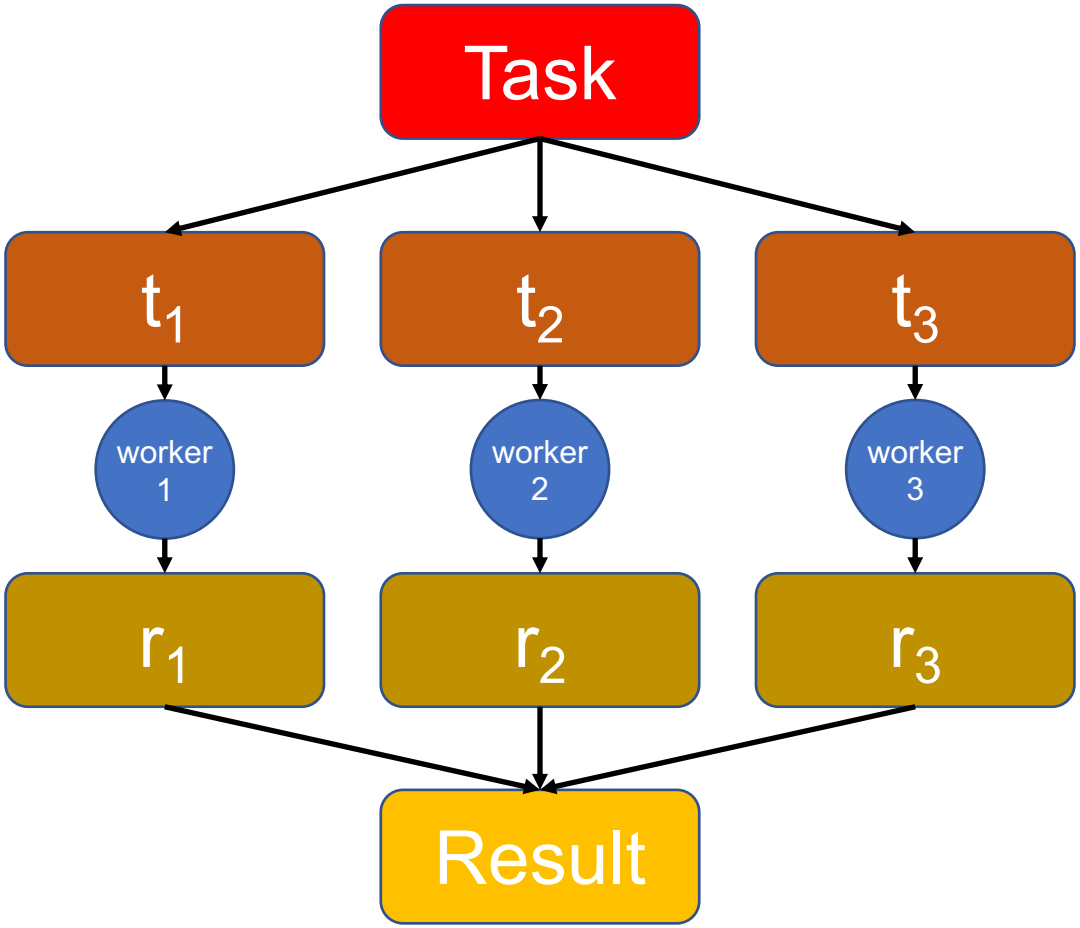
- Word count
  - output the number of occurrence for each word in the dataset.
- Naïve solution:

```
word_count(D):
    H = new dict
    For each w in D:
        H[w] += 1
    For each w in H:
        print (w, H[w])
```

- How to speed up?

Motivation of MapReduce

- Make use of multiple workers



There are some problems…

- Data reliability
- Equal split of data
- Delay of worker
- Failure of worker
- Aggregation the result

- We need to handle them all! In traditional way of parallel and distributed processing.

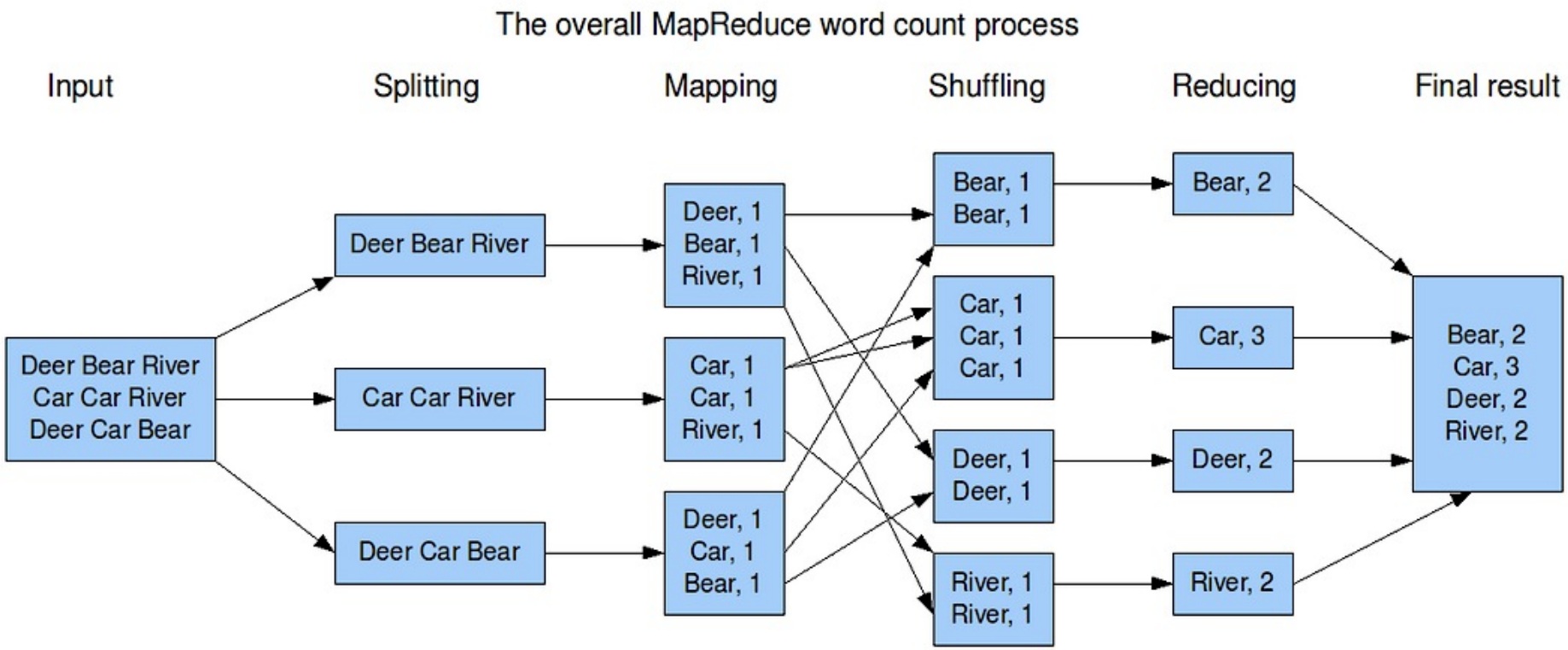
MapReduce

- MapReduce is a programming framework that
  - allows us to perform distributed and parallel processing on large data sets in a distributed environment
  - no need to bother about the issues like reliability, fault tolerance etc
  - offers the flexibility to write code logic without caring about the design issues of the system

Map Reduce

- MapReduce consists of Map and Reduce
- Map
  - Reads a block of data
  - Produces key-value pairs as intermediate outputs
- Reduce
  - Receive key-value pairs from multiple map jobs
  - aggregates the intermediate data tuples to the final output

A Simple MapReduce Example



Pseudo Code of Word Count

```
Map(D):
        for each w in D:
                emit(w, 1)


Reduce(t, counts): # e.g., bear, [1, 1]
        sum = 0
        for c in counts:
                sum = sum + c
        emit (t, sum)
```

Advantages of MapReduce

- Parallel processing
  - Jobs are divided to multiple nodes
  - Nodes work simultaneously
  - Processing time reduced

- Data locality
  - Moving processing to the data
    - Opposite from traditional way

We will discuss more on MapReduce, but not now…

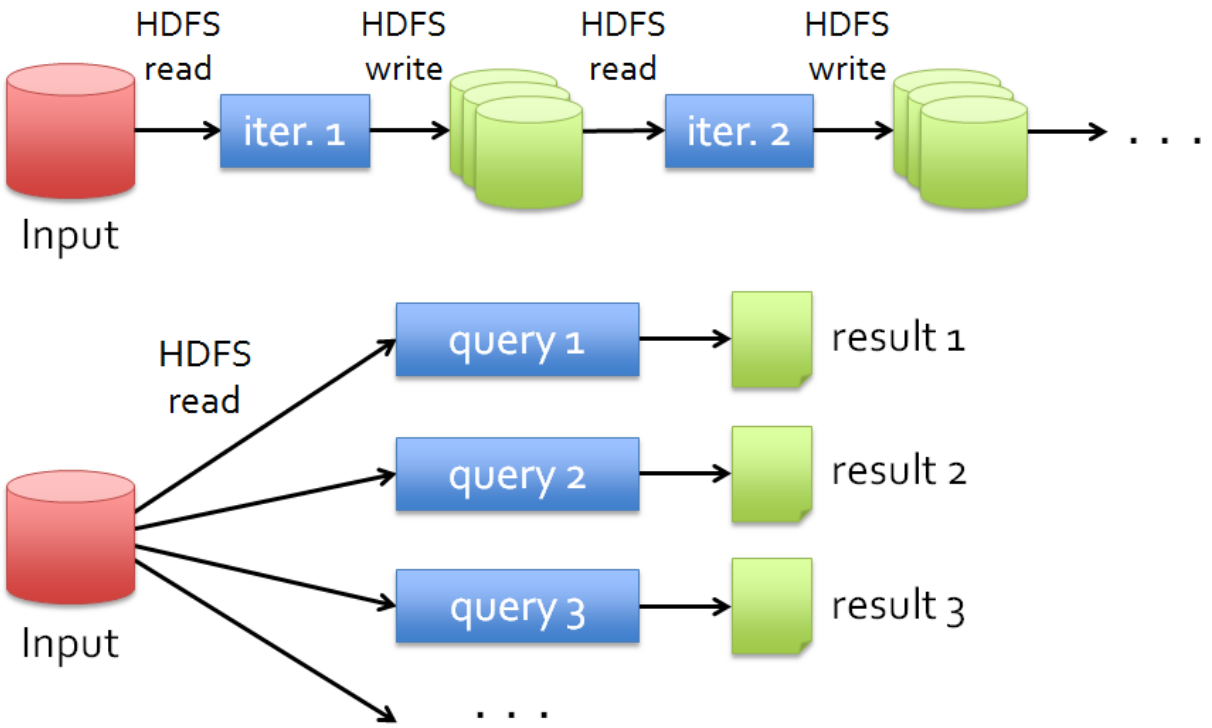
Motivation of Spark

- MapReduce greatly simplified big data analysis on large, unreliable clusters. It is great at one-pass computation.
- But as soon as it got popular, users wanted more:
  - more **complex**, multi-pass analytics (e.g. ML, graph)
  - more **interactive** ad-hoc queries
  - more **real-time** stream processing

Limitations of MapReduce

- As a general programming model:
  - more suitable for one-pass computation on a large dataset
  - hard to compose and nest multiple operations
  - no means of expressing iterative operations
- As implemented in Hadoop
  - all datasets are read from disk, then stored back on to disk
  - all data is (usually) triple-replicated for reliability

Data Sharing in Hadoop MapReduce



- **Slow** due to replication, serialization, and disk IO
- Complex apps, streaming, and interactive queries all need one thing that MapReduce lacks:
  - Efficient primitives for **data sharing**

What is Spark?

- Apache Spark is an open-source cluster computing framework for real-time processing.
- Spark provides an interface for programming entire clusters with
  - implicit data parallelism
  - fault-tolerance
- Built on top of Hadoop MapReduce
  - extends the MapReduce model to efficiently use more types of computations

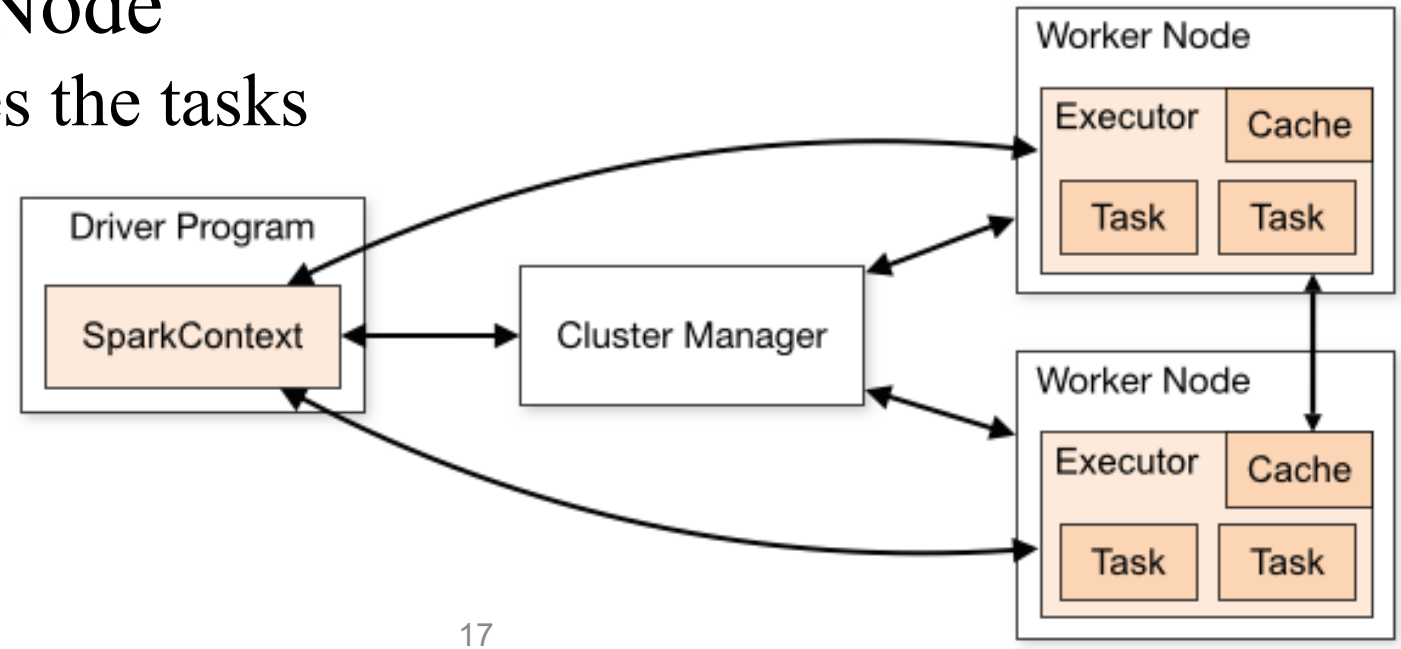
Spark Features

- Polyglot
- Speed
- Multiple formats
- Lazy evaluation
- Real time computation
- Hadoop integration
- Machine learning

Spark Eco-System

Spark Architecture

- Master Node
  - takes care of the job execution within the cluster
- Cluster Manager
  - allocates resources across applications
- Worker Node
  - executes the tasks



Resilient Distributed Dataset (RDD)

- RDD is where the data stays
- RDD is the fundamental data structure of Apache Spark
  - is a collection of elements
    - Dataset
  - can be operated on in parallel
    - Distributed
  - fault tolerant
    - Resilient

Features of Spark RDD

- In memory computation
- Partitioning
- Fault tolerance
- Immutability
- Persistence
- Coarse-grained operations
- Location-stickiness

Create RDDs

- Parallelizing an existing collection in your driver program
  - Normally, Spark tries to set the number of partitions automatically based on your cluster
- Referencing a dataset in an external storage system
  - HDFS, HBase, or any data source offering a Hadoop InputFormat
  - By default, Spark creates one partition for each block of the file

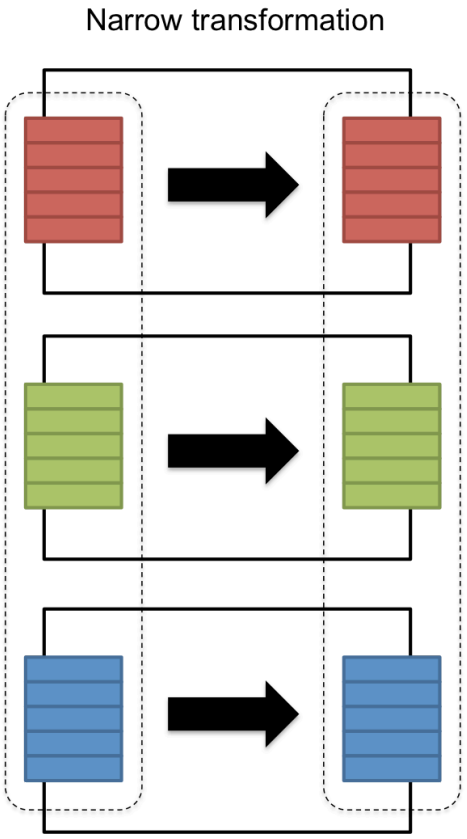
RDD Operations

- Transformations
  - functions that take an RDD as the input and produce one or many RDDs as the output
  - Narrow Transformation
  - Wide Transformation
- Actions
  - RDD operations that produce non-RDD values.
  - returns final result of RDD computations

Narrow and Wide Transformations

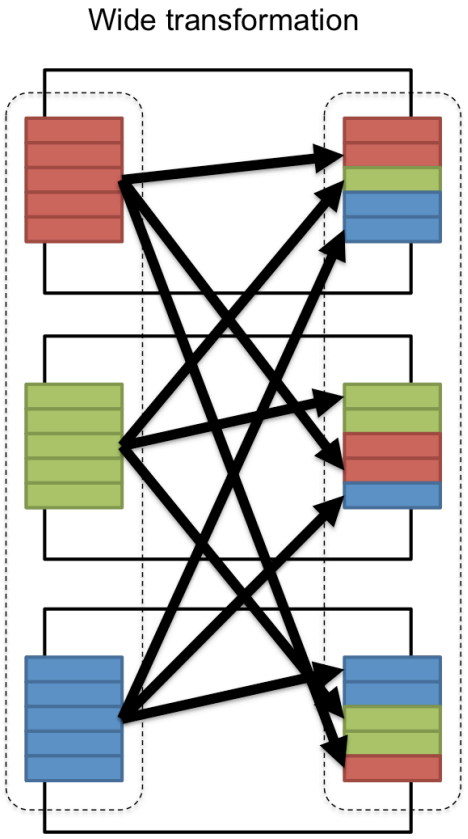
Narrow transformation involves no data shuffling

- map
- flatMap
- filter
- sample



Wide transformation involves data shuffling

- sortByKey
- reduceByKey
- groupByKey
- join



Action

- Actions are the operations which are applied on an RDD to instruct Apache Spark to apply computation and pass the result back to the driver
  - collect
  - take
  - reduce
  - forEach
  - count
  - save

Lineage

- RDD lineage is the graph of all the ancestor RDDs of an RDD
  - Also called RDD operator graph or RDD dependency graph
- Nodes: RDDs
- Edges: dependencies between RDDs

Fault tolerance of RDD

- All the RDDs generated from fault tolerant data are fault tolerant
- If a worker fails, and any partition of an RDD is lost
  - the partition can be re-computed from the original fault-tolerant dataset using the lineage
  - task will be assigned to another worker

DAG in Spark

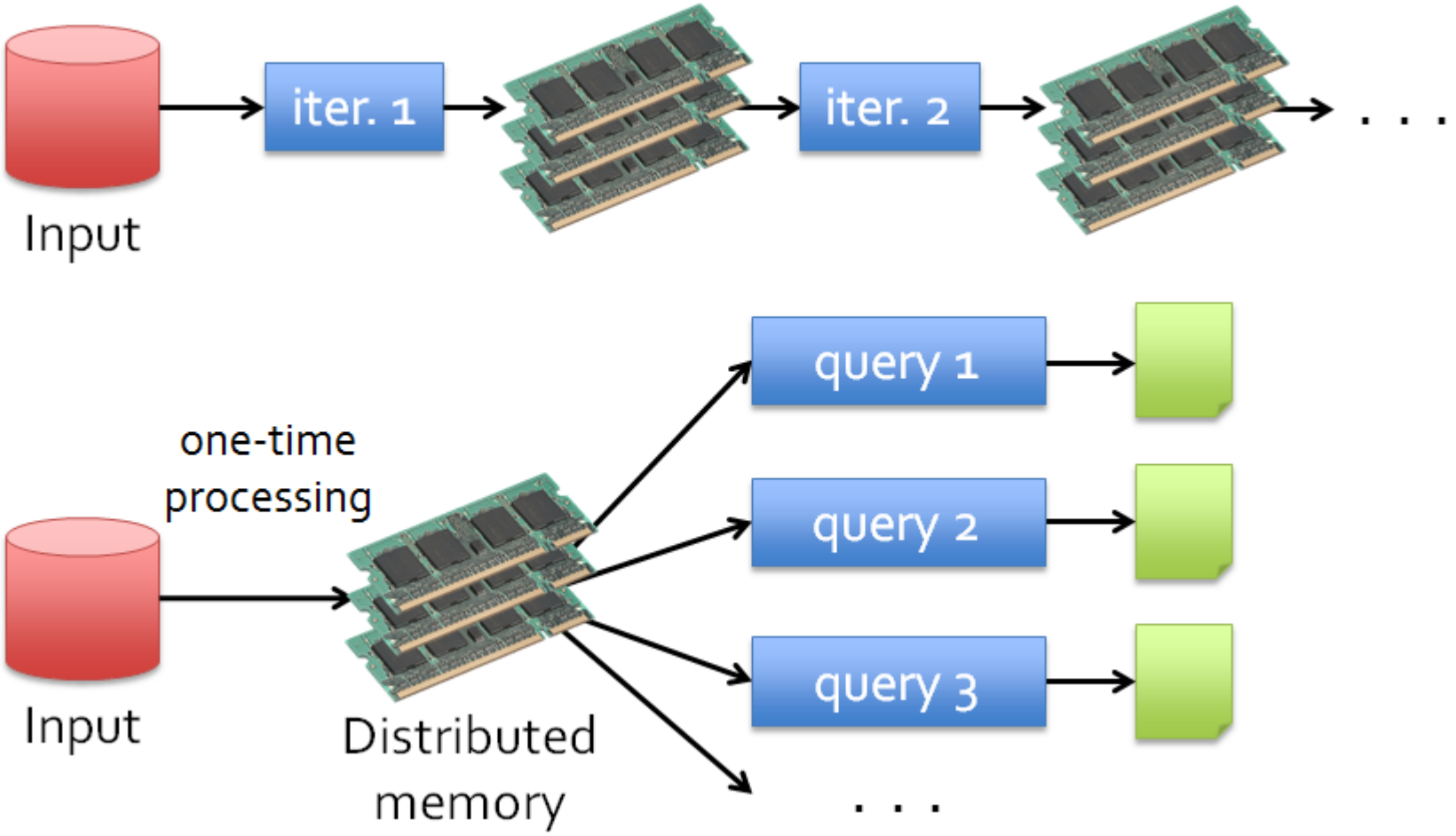
- DAG is a direct graph with no cycle
  - Node: RDDs, results
  - Edge: Operations to be applied on RDD
- On the calling of Action, the created DAG submits to DAG Scheduler which further splits the graph into the stages of the task
- DAG operations can do better global optimization than other systems like MapReduce

DAG, Stages and Tasks

- DAG Scheduler splits the graph into multiple stages
- Stages are created based on transformations
  - The narrow transformations will be grouped together into a single stage
  - Wide transformation define the boundary of 2 stages
- DAG scheduler will then submit the stages into the task scheduler
  - Number of tasks depends on the number of partitions
  - The stages that are not interdependent may be submitted to the cluster for execution in parallel

Lineage vs. DAG

Data Sharing in Spark Using RDD



100x faster than network and disk