Amirkabir University of Technology
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Cloud Computing

MapReduce Programming Model

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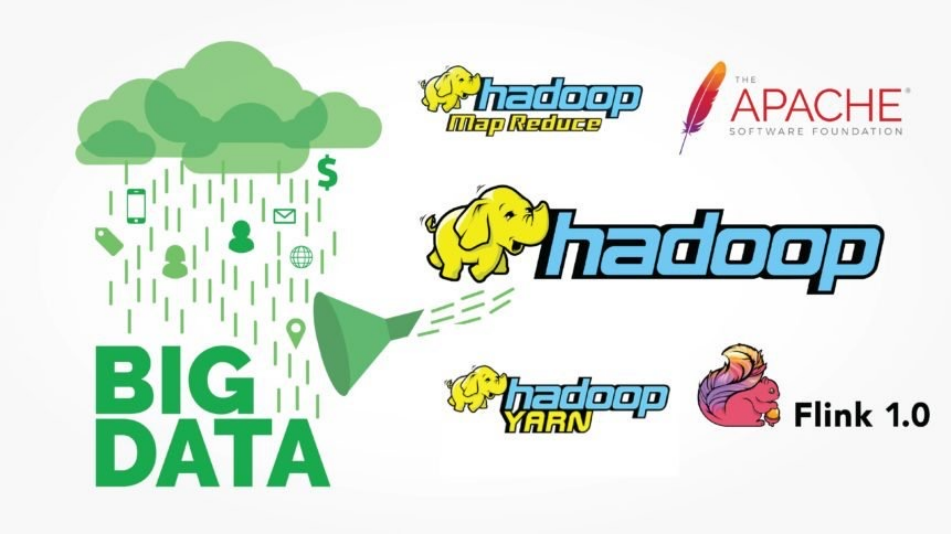
Programming Platforms for Big Data

- Map-Reduce: **Apache Hadoop**, Aneka
- Stream Processing: Heron, Apache Storm, Apache Spark
- Graph Processing: Pregel, Apache Giraph

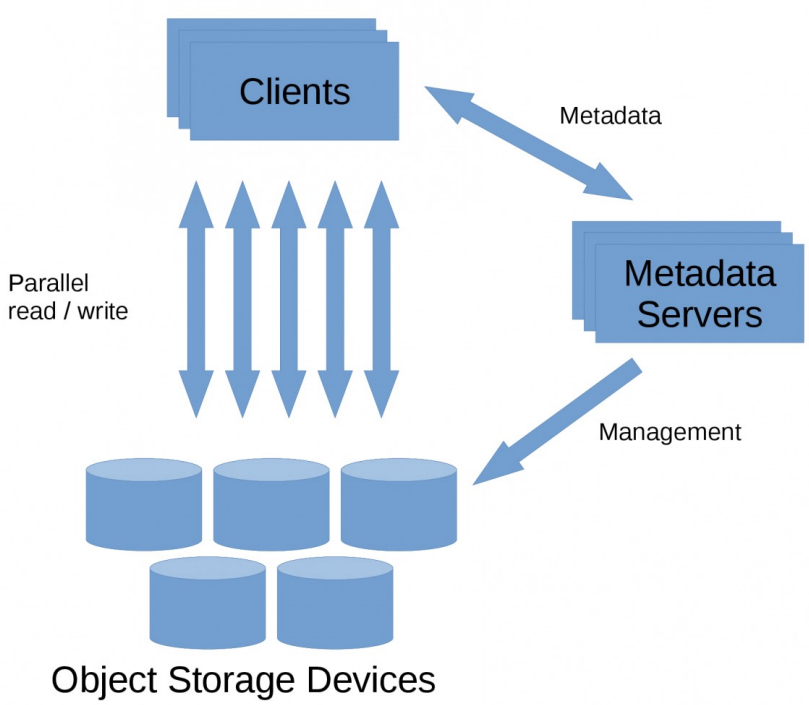


The MapReduce Programming Model

- Introduced by Google for processing large quantities of data.
- It expresses the computational logic of an application in two simple functions:
  - **map**
  - **reduce**

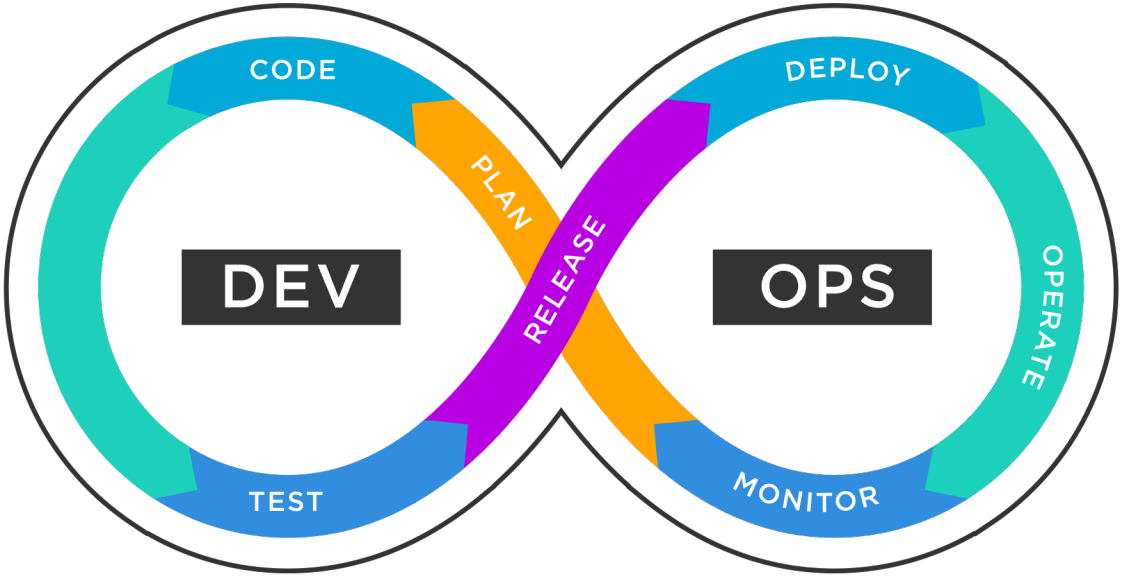
The MapReduce Programming Model

- Data transfer and management are completely handled by the Distributed Storage Infrastructure.
  - E.g., the Google File System
- Distributed Storage is in charge of providing access to data, replicating files, and eventually moving them where needed.



The MapReduce Programming Model

- Developers no longer have to handle storage issues.
- Developers are provided with an interface that presents data at a higher level: **as a collection of key-value pairs.**



The MapReduce Programming Model

- The computation of MapReduce applications is then organized into a workflow of **map** and **reduce** operations that is entirely controlled by the runtime system.

- Developers need only specify how the map and reduce functions operate on the key-value pairs.

The MapReduce Programming Model

- MapReduce model is expressed in the form of the two functions:
  - map(k_1, v_1) → list(k_2, v_2)
  - Reduce(k_2, list(v_2)) → list(v_3)

The MapReduce Programming Model

- Map takes an input pair and produces a set of intermediate key/value pairs.

- The MapReduce library **groups together all intermediate values associated with the same intermediate key** / and passes them to the Reduce function.

The MapReduce Programming Model

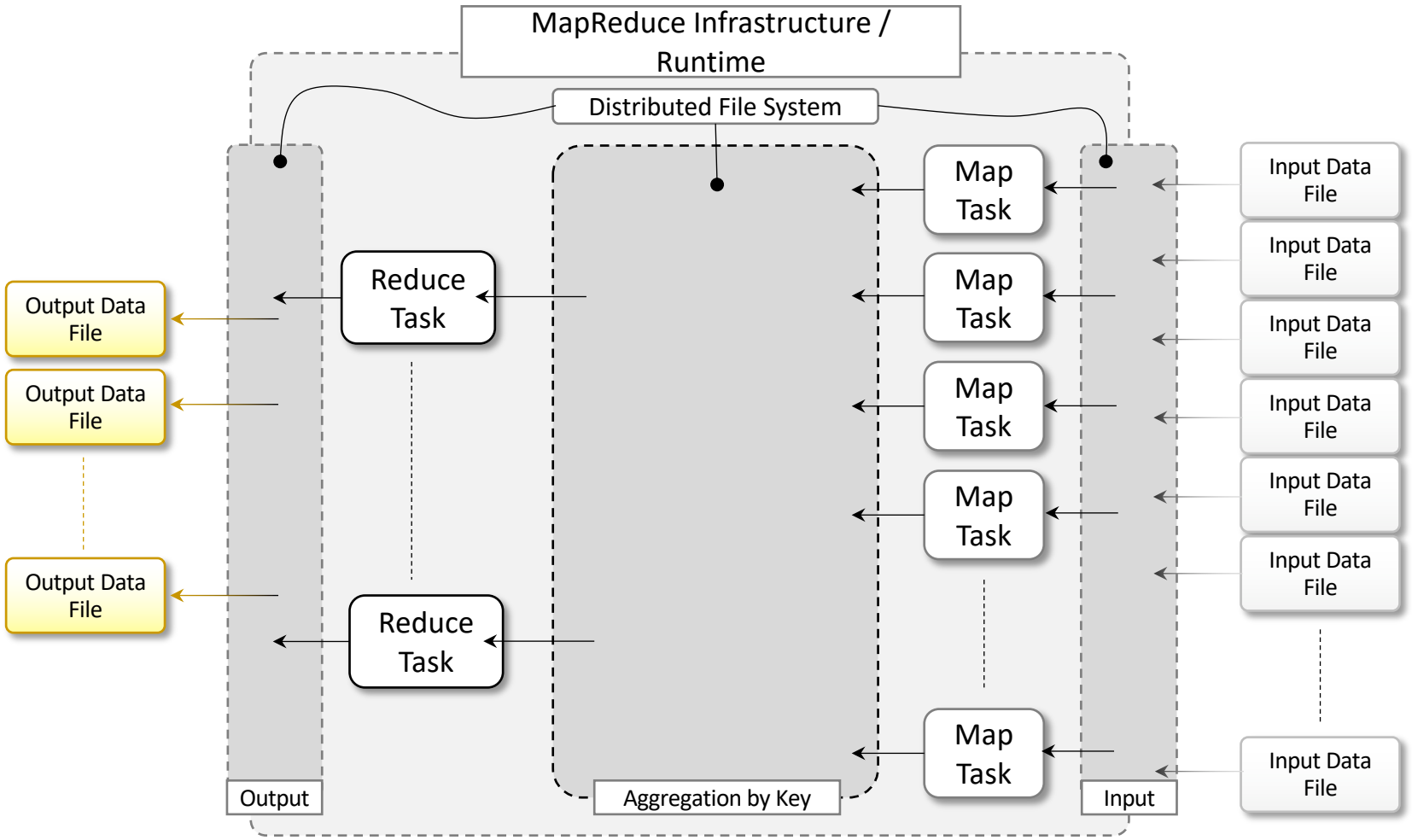
- The Reduce function accepts an intermediate key *I* and a set of values for that key.

- It **merges** together these values to form a possibly smaller set of values.
  - Typically just zero or one output value is produced per Reduce invocation.

The MapReduce Programming Model

- **The framework signature is**:
  - computation: list(k1, v1) → list(k2, v2)
- **Map Phase**
  - MapPhase: list(k1, v1) → list(k2, v2)
- **Reduce Phase**
  - ReducePhase = preparation; reduction
  - Preparation: list(k2, v2) → list(k2, list(v2))
  - Reduction: list(k2, list(v2)) → list(k2, v3)

MapReduce Framework



MapReduce Example

Problem: counting the number of occurrences of each word in a large collection of documents

```
map(String key, String value):
    // key: document name
    // value: document contents
     for each word w in value:
         EmitIntermediate(w, "1")
```

```
reduce(String key, Iterator values):
    // key: a word
    // values: a list of counts
    int result = 0;
    for each v in values:
        result += ParseInt(v);
    Emit(AsString(result));
```

More MapReduce Examples (Cont.)

- **Distributed Grep:**
  - Looking for a string in several files
  - Print name of files that contains a string
- **Distributed Grep (Solution)**
  - The map function emits a line if it matches a supplied pattern.
  - The reduce function is an identity function that just copies the supplied intermediate data to the output.

More MapReduce Examples (Cont.)

- **Count of URL Access Frequency:**
  - **How many time a URL is accessed given many web logs?**

- **Count of URL Access Frequency (solution)**
  - The map function processes logs of web page requests and outputs <URL,1>.
  - The reduce function adds together all values for the same URL and emits a <URL, total count> pair.

More MapReduce Examples (Cont.)

- **Inverted index:**
  - **Given a set of documents, create the set of {word → list of documents containing the word}.**
- **Inverted Index (Solution)**
  - The map function parses each document, and emits a sequence of <word, document ID> pairs.
  - The reduce function accepts all pairs for a given word, sorts the corresponding document IDs and emits a <word, list(document ID)> pair.
  - The set of all output pairs forms a simple inverted index.

The MapReduce Programming Model

- In general, any computation that can be expressed in the form of two major stages can be represented in the terms of **MapReduce computation**:
  - **Analysis**
  - **Aggregation**

Analysis

- **Analysis** operates directly on the data input file and corresponds to the operation performed by the map task.

- The computation at this stage is expected to be embarrassingly **parallel**, since map tasks are executed without any sequencing or ordering.

Aggregation

- **Aggregation** operates on the intermediate results and is characterized by operations that are aimed at aggregating, summing, and/or elaborating the data obtained at the previous stage to present the data in their final form.

- This is the task performed by the reduce function.

Sample MapReduce problem

- https://medium.com/@aw.shubh/join-algorithm-using-map-reduce-941f3437b483