Overview of Spark and its ecosystem

CS3678 Big Data and Hadoop

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Overview of Apache Spark

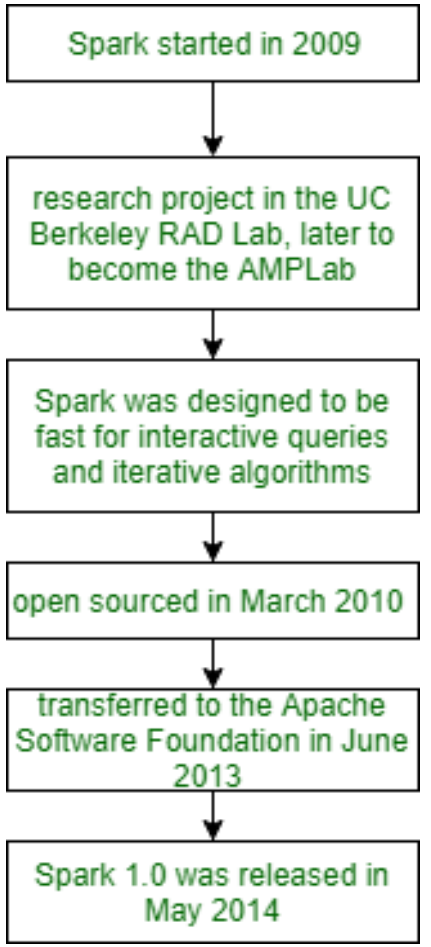
Developed in 2009 at UC Berkeley's AMP Lab for **fast iterative processing.**

Apache Spark

- **Open-source**
- **Distributed computing framework** for big data processing and analytics.
- **Faster In-memory computation**
- Supports **batch processing, real-time streaming, machine learning, and graph processing**.

How Spark Works

- Uses **in-memory computation** - reduce disk I/O, makes it faster than Hadoop.
- **Resilient Distributed Datasets (RDDs)** - Parallel processing & Fault tolerance
- **Data Frames** and **Datasets** optimize query execution.
- Supports various **storage** systems like
  - HDFS
  - Amazon S3
  - Cassandra
  - Redshift.



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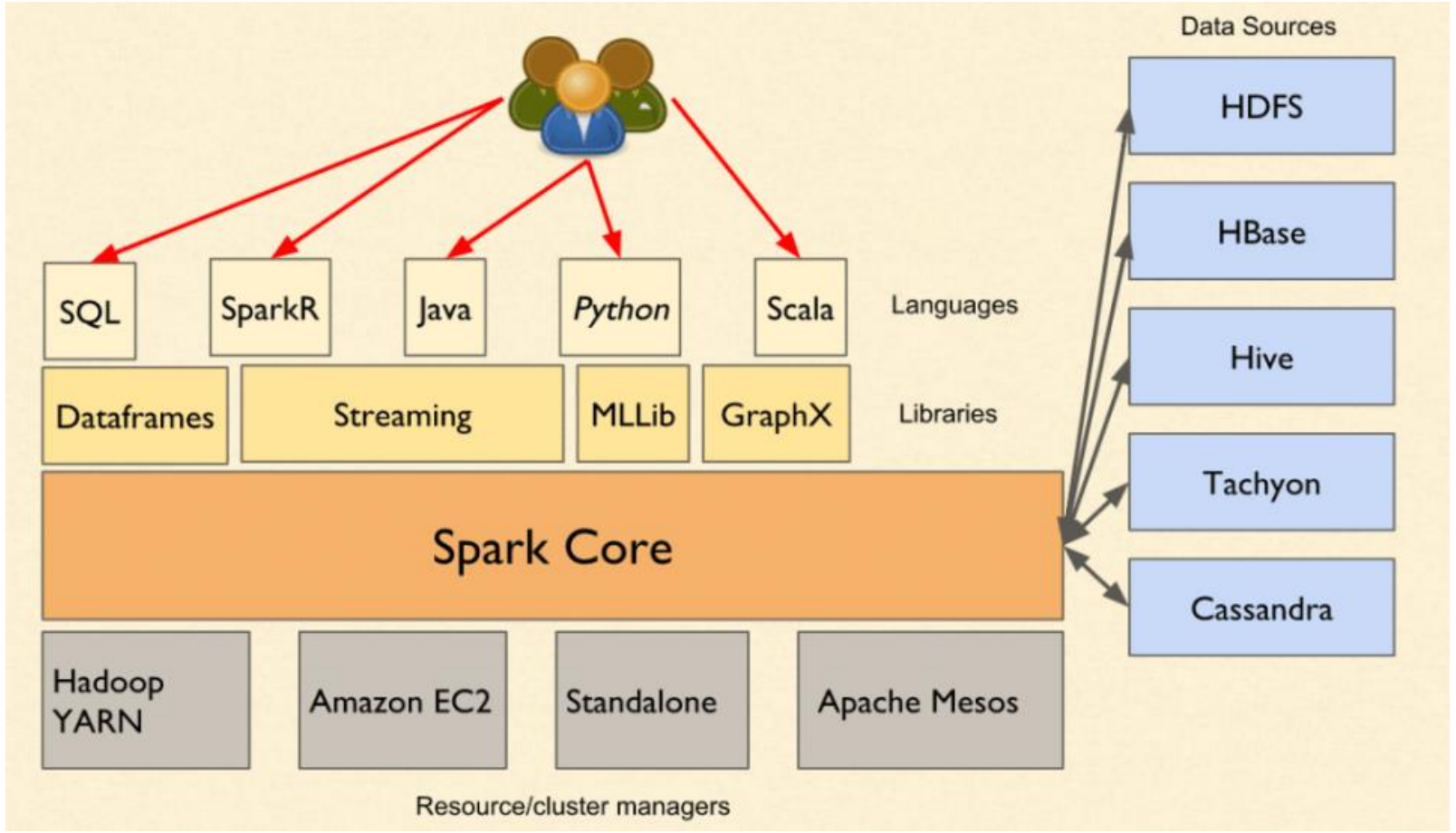
Spark Core and Architecture

Master-slave Architecture



Components:

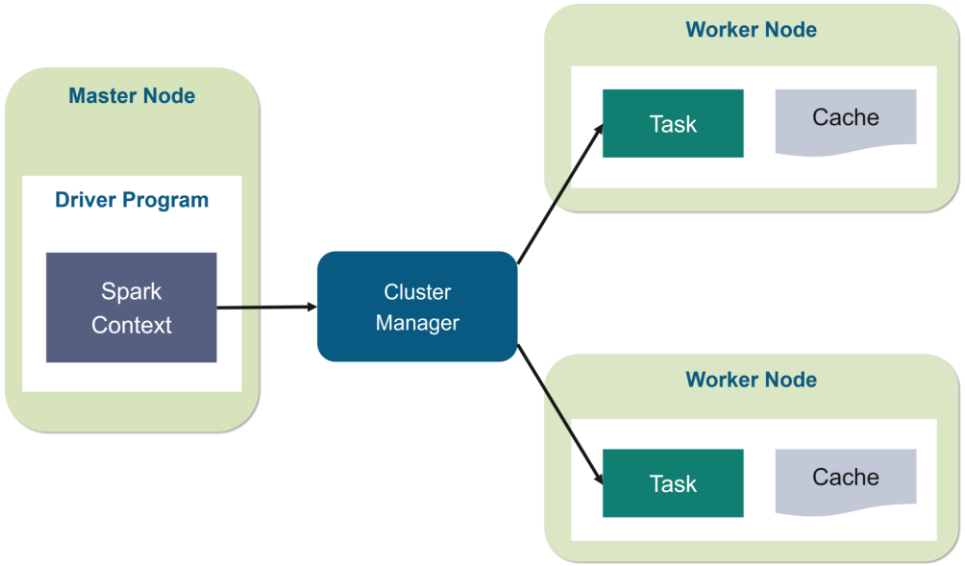
1. Scheduler or Resource Manager
2. Spark Driver & Executors
3. Spark Core (RDD)
4. Spark Libraries
5. API Bindings & Interactive Shells

- **RDD (Resilient Distributed Dataset)** is a fundamental, immutable, partitioned, fault-tolerant data structure that supports parallel processing.
- It enables in-memory computation, lazy evaluation, & transformations like map() and filter().

Spark Core and Architecture

Components:

1. **Scheduler or Resource Manager**
   - Manages cluster resources.
   - Can be **YARN, Mesos, cluster manager**.
2. **Spark Driver & Executors**
   - **Driver**:
     - Runs the main() method of the Spark application.
     - Creates **RDDs, transformations, and actions**.
     - Converts jobs into a **Directed Acyclic Graph** for execution.
   - **Executors**: Runs task assigned in driver & store data in memory for faster execution
3. **Spark Core (RDD)**
   - **Resilient Distributed Datasets (RDDs)**
     - Immutable, distributed data collection.
   - Supports transformations (map, filter) and actions (count, collect).
4. **Spark Libraries:**
   - Spark SQL, Spark Streaming, MLlib, GraphX
5. **API Bindings & Interactive Shells:**
   - APIs in Scala, Java, Python, R & SQL.
   - PySpark for Interactive data analysis.



How Spark Applications Run on a Cluster:

- User submits the Spark job
- Spark Driver starts and requests resources from Cluster Manager.
- Cluster Manager allocates resources, launches executors on workers.
- Driver schedules tasks and sends them to executors.
- Executors process data in parallel and store results in memory / disk
- Results are returned to the driver.

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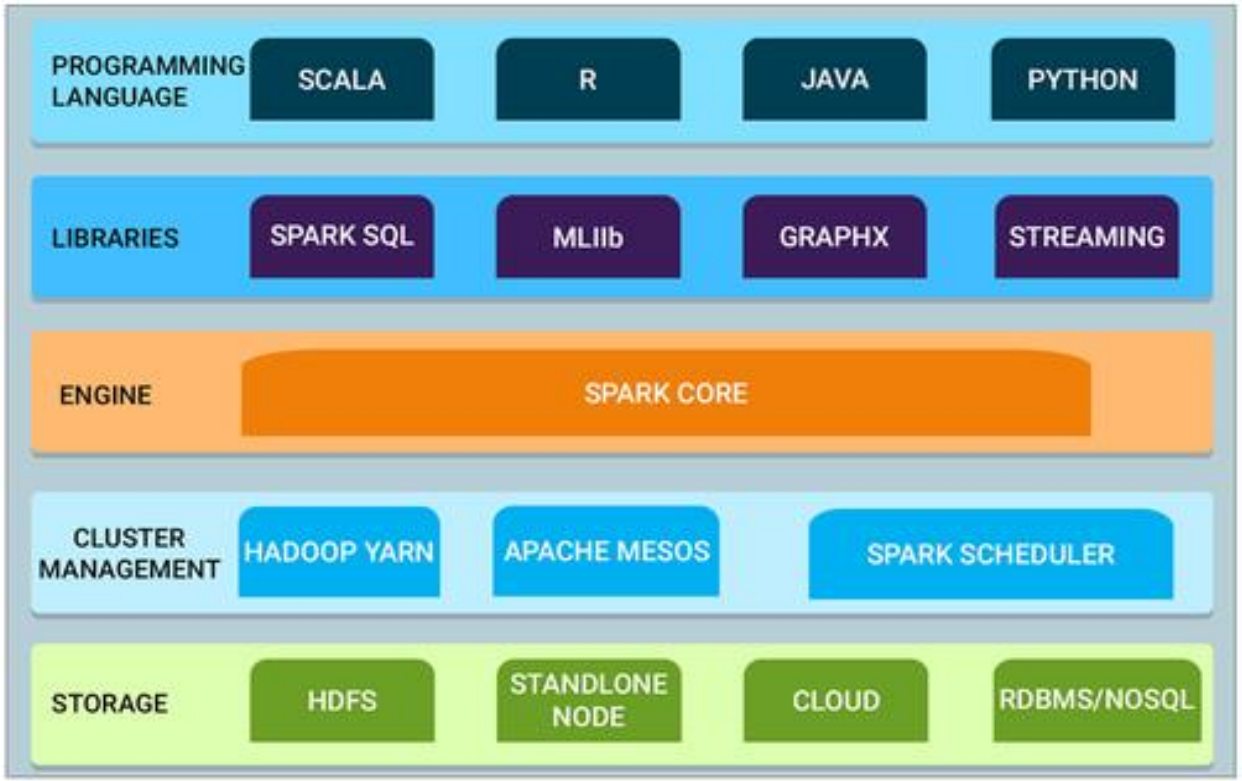
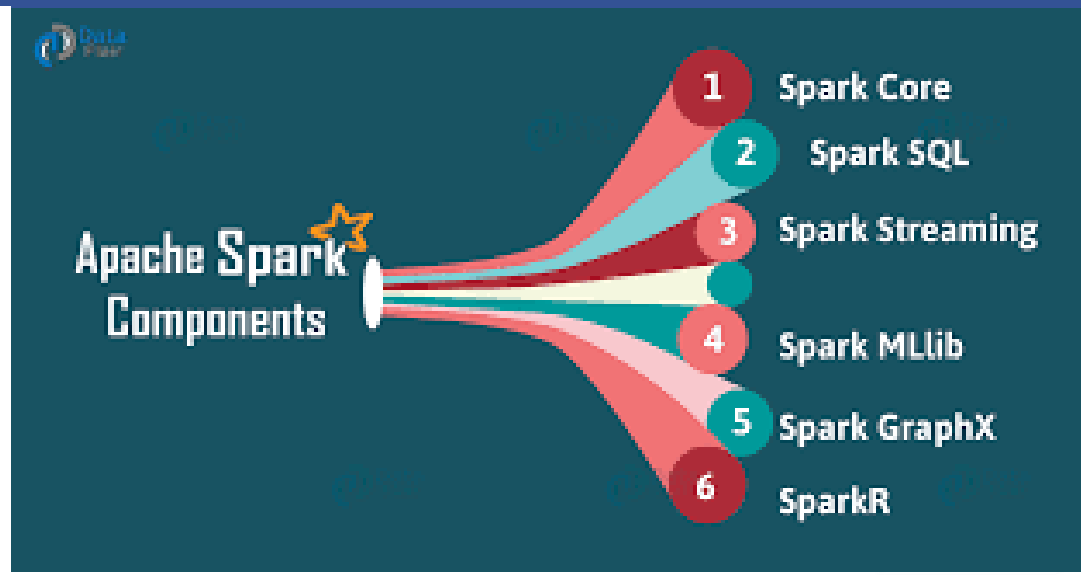
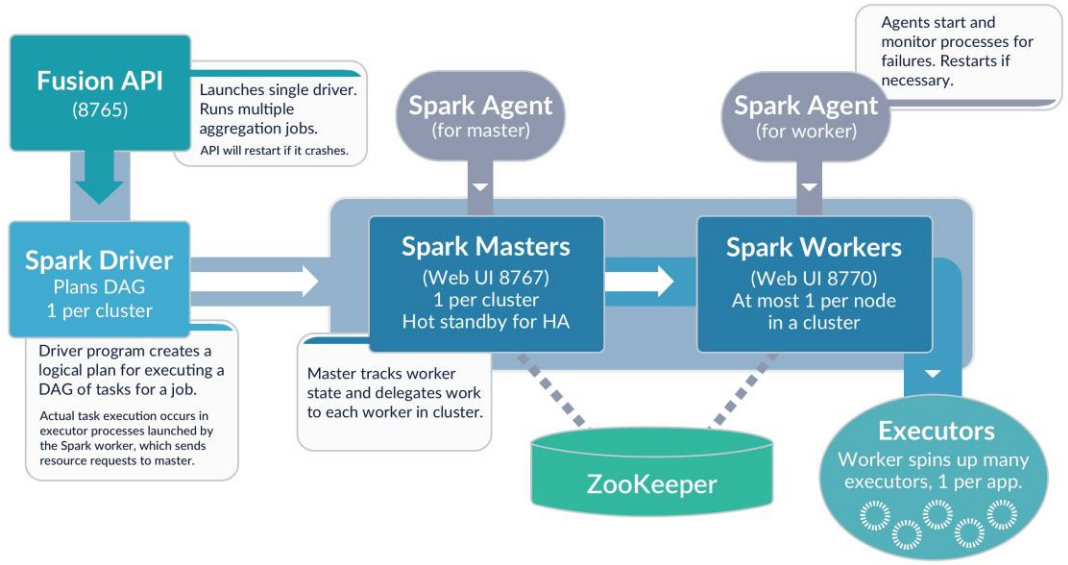
Spark Ecosystem Components







Spark Programming and APIs

- Scaladoc- Spark Scala Api
- Javadoc - Spark Java Api
- Sphinx - Spark Python Api
- Roxygen2- Spark R api

Spark commands

```
scala> :help
All commands can be abbreviated, e.g., :he instead of :help.
:completions <string>    output completions for the given string
:edit <id>|<line>        edit history
:help [command]          print this summary or command-specific help
:history [num]           show the history (optional num is commands to show)
:h? <string>             search the history
:imports [name name ...] show import history, identifying sources of names
:implicits [-v]          show the implicits in scope
:javap <path|class>      disassemble a file or class name
:line <id>|<line>        place line(s) at the end of history
:load <path>             interpret lines in a file
:paste [-raw] [path]     enter paste mode or paste a file
:power                   enable power user mode
:quit                    exit the interpreter
:replay [options]        reset the repl and replay all previous commands
:require <path>          add a jar to the classpath
:reset [options]         reset the repl to its initial state, forgetting all session entries
:save <path>             save replayable session to a file
:sh <command line>       run a shell command (result is implicitly => List[String])
:setting <options>       update compiler options, if possible; see reset
:silent                  disable/enable automatic printing of results
:type [-v] <expr>        display the type of an expression without evaluating it
:kind [-v] <type>        display the kind of a type. see also :help kind
:warnings                show the suppressed warnings from the most recent line which had any
```

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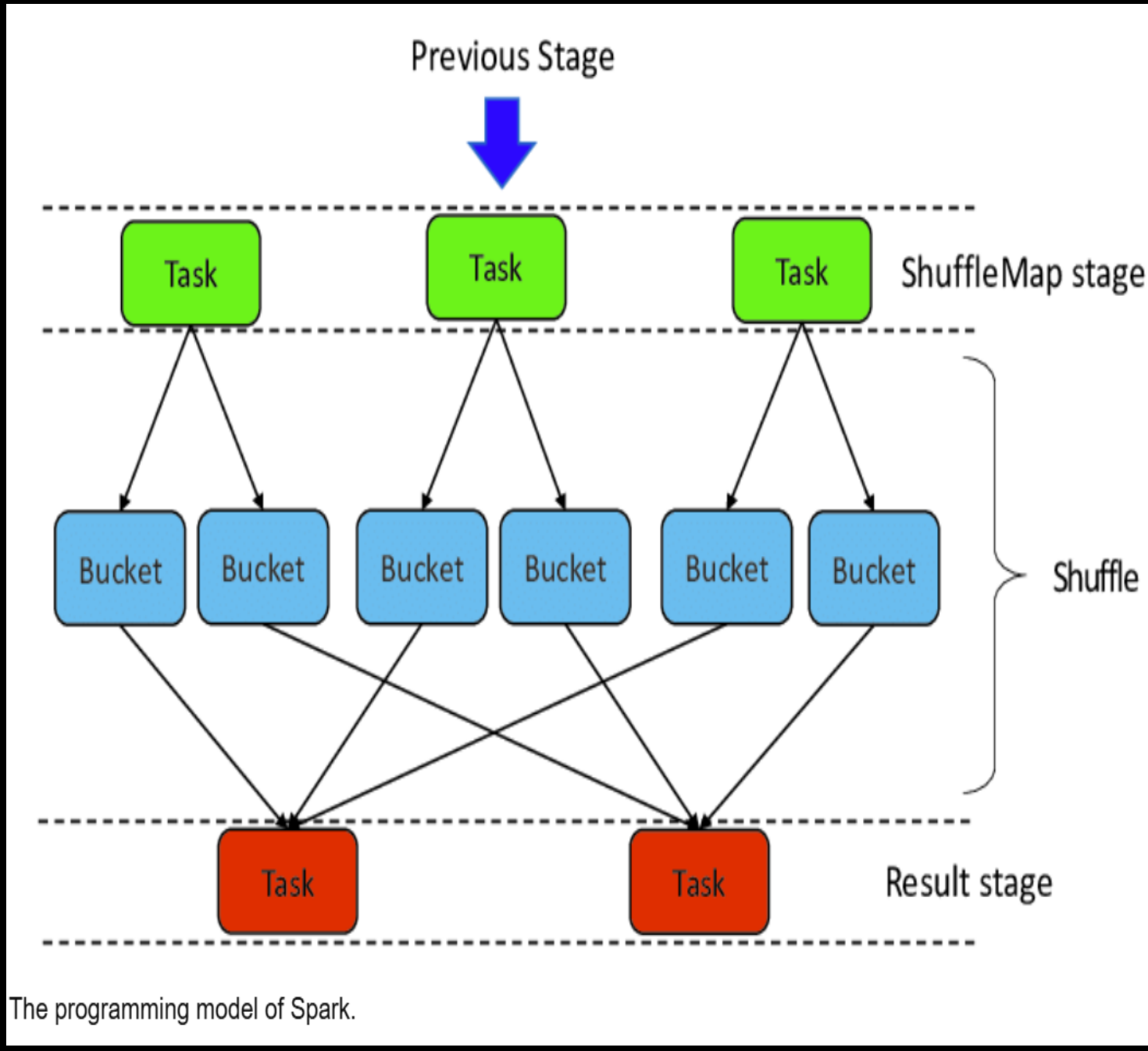
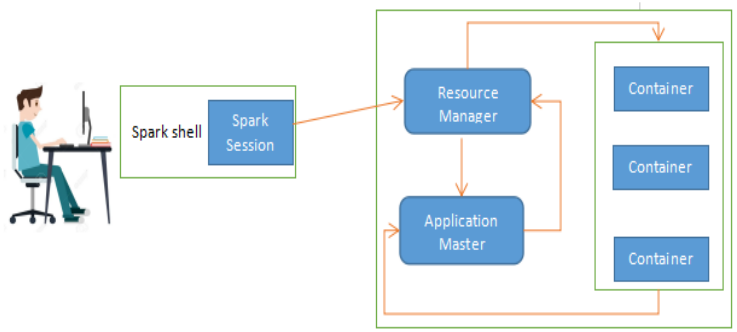
Spark programming model



The programming model of Spark.

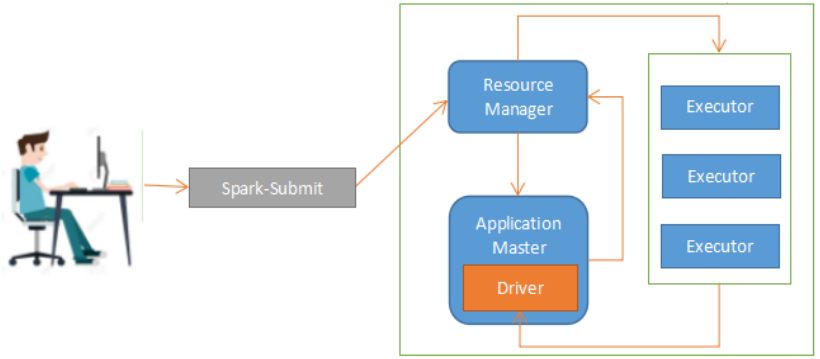
Spark Deployment

CLIENT MODE:



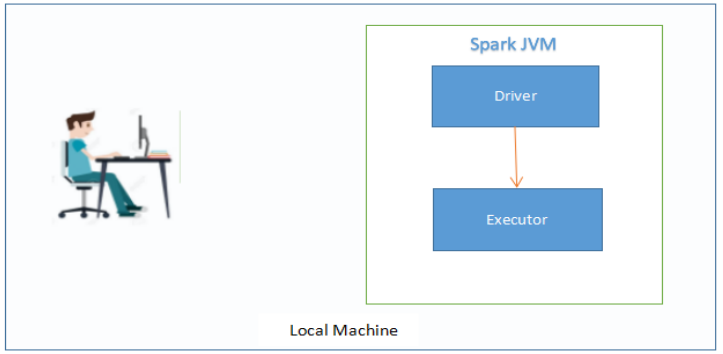
- Spark driver runs within the client machine from which you submit your Spark application.
- The client communicates directly with the cluster manager to request resources and execute tasks.
- Suitable for interactive environments (e.g., Jupyter notebooks) but **not recommended for production** due to dependency on the client machine.

CLUSTER MODE:



- Spark driver runs on one of the cluster nodes rather than on the client machine.
- The client submits the Spark application to the Resource manager, which launches the driver within one of its worker nodes.
- Ideal for **production** as it is more stable and scalable.

LOCAL MODE:



- Spark runs on a single machine, using all the cores of the machine.
- Best for **testing and debugging**, requiring minimal setup.

Cluster mode *is best for production,* ***client mode*** *is useful for debugging, and* ***local mode*** *is ideal for small-scale testing.*

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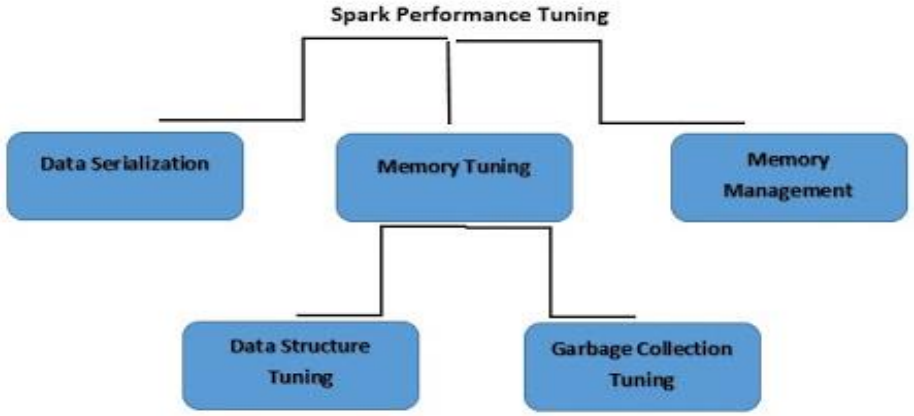
Performance Tuning

1. Data Serialization:
Serialization reduces memory usage and improves network performance in Spark. It enhances system efficiency by optimizing job execution and resource utilization. Spark supports:

- **Java Serialization** (default but slower)
- **Kryo Serialization** (faster and more memory-efficient)

2. Memory Tuning:
To optimize Spark's memory usage:

- Ensure the dataset fits in memory.
- Manage garbage collection efficiently.
- Minimize the cost of object access.



3. Data Structure Tuning:
To reduce memory consumption:

- For RAM < 32GB, enable `-XX:+UseCompressedOops` to reduce pointer size from 8 bytes to 4 bytes, optimizing memory usage.
- Avoid deeply nested structures.
- Prefer numeric IDs over strings.

4. Garbage Collection Tuning:
Efficient garbage collection minimizes overhead by:

- Using arrays instead of linked lists.
- Storing objects in serialized form to reduce memory fragmentation.

5. Memory Management:
Spark divides memory into:

- **Storage Memory:** Caches reusable data.
- **Execution Memory:** Used for computations (shuffles, sorts, joins).
  Challenges include balancing memory between execution, storage, and concurrent tasks.

Future of Spark and Emerging Trends

- **Serverless Computing**
  - Growing adoption of Spark in serverless architectures for better resource efficiency
- **AutoML & AI Integration**
  - Enhanced machine learning automation and integration with AI frameworks
- **Multi-Cloud & Hybrid Deployments**
  - Increased support for multi-cloud and hybrid cloud environments
- **Quantum Computing & Advanced Processing**
  - Potential applications of Spark in next-gen computing paradigms

THANK YOU !

References

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