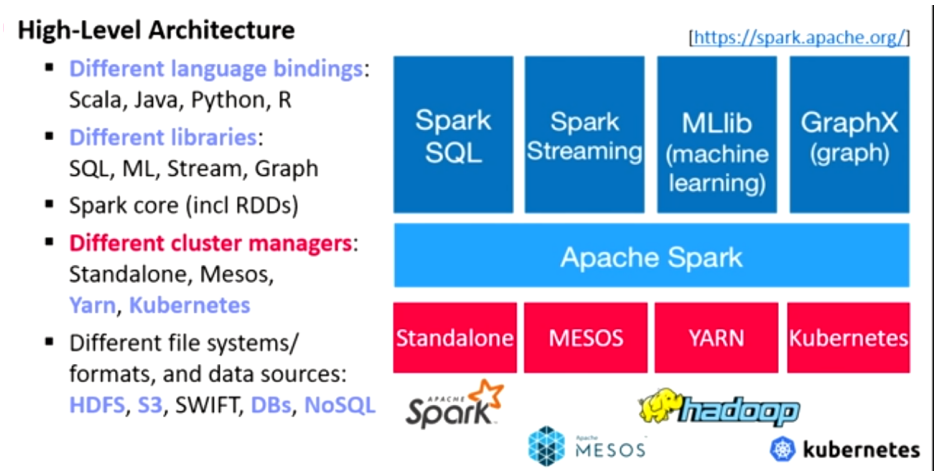
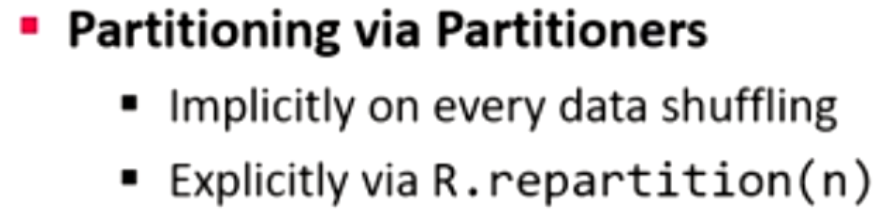
Overview

- alternative to [[MapReduce]]
  - many shared concepts
- executors with in-memory storage
  - lazy evaluation
  - fault tolerance via [[RDD]] lineage
- high performance
  - in-memory storage
  - fast job scheduling
- rich, functional high-level [[API]]
  - general computation DAGs
  - unified platform

Architecture

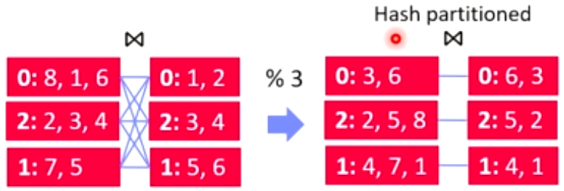


Spark Partitions

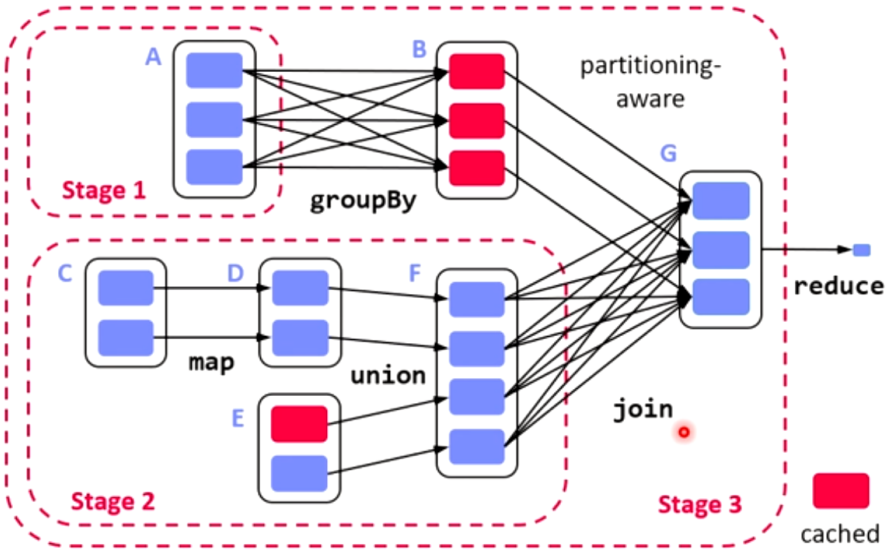
- logical key-value collections split into physical partitions 128MB
- partitiions are granularity of tasks, I/O, shuffling, evictions
- 

- partitioning preserving
  - operations which keep keys unchanged do no change partitions

- **Partitioning-Exploiting**
  - Join: R3 = R1.join(R2)
  - Lookups:
    `v = C.lookup(k)`



Lazy Evaluation, Caching and Lineage



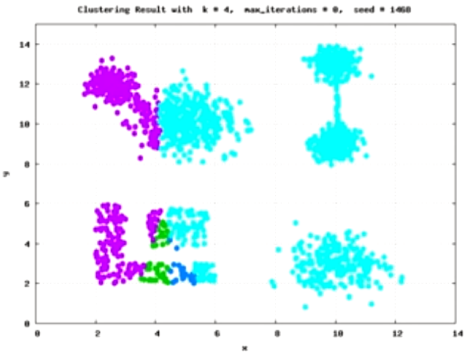
- example: k-means clustering

k-Means Algorithm

- Given dataset D and number of clusters k, find cluster centroids ("mean" of assigned points) that minimize within-cluster variance
- Euclidean distance: **sqrt(sum((a-b)^2))**

Pseudo Code

```
function Kmeans(D, k, maxiter) {
  C' = randCentroids(D, k);
  C = {};
  i = 0; //until convergence
  while( C' != C & i<=maxiter ) {
    C = C';
    i = i + 1;
    A = getAssignments(D, C);
    C' = getCentroids(D, A, k);
  }
  return C'
}
```



Example: K-Means Clustering in Spark

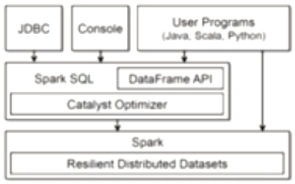
```
// create spark context (allocate configured executors)
JavaSparkContext sc = new JavaSparkContext();

// read and cache data, initialize centroids
JavaRDD<Row> D = sc.textFile("hdfs:/user/mboehm/data/D.csv")
  .map(new ParseRow()).cache(); // cache data in spark executors
Map<Integer,Mean> C = asCentroidMap(D.takeSample(false, k));

// until convergence
while( !equals(C, C2) & i<=maxiter ) {
  C2 = C; i++;
  // assign points to closest centroid, recompute centroid
  Broadcast<Map<Integer,Row>> bC = sc.broadcast(C)
  C = D.mapToPair(new NearestAssignment(bC))
       .foldByKey(new Mean(0), new IncComputeCentroids())
       .collectAsMap();
}

return C;
```

Note: Existing library algorithm
[https://github.com/apache/spark/blob/master/mllib/src/main/scala/org/apache/spark/mllib/clustering/KMeans.scala]

Spark DataFrames and DataSets

Overview Spark DataFrame

- DataFrame is **distributed collection of rows** with named/typed columns
- **Relational operations** (e.g., projection, selection, joins, grouping, aggregation)
- **DataSources** (e.g., json, jdbc, parquet, hdfs, s3, avro, hbase, csv, cassandra)

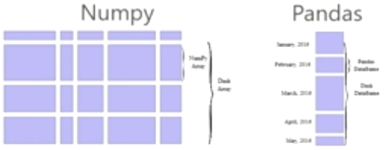


- example

```
logs = spark.read.format("json").open("s3://logs")
logs.groupBy(logs.user_id).agg(sum(logs.time))
  .write.format("jdbc").save("jdbc:mysql//...")
```

Dask

- **Overview Dask**
  - Multi-threaded and distributed operations for arrays, bags, and dataframes
  - `dask.array:`
    list of numpy n-dim arrays
  - `dask.dataframe:`
    list of pandas data frames



  - `dask.bag:` unordered list of tuples (second order functions)
  - Local and distributed schedulers:
    threads, processes, YARN, Kubernetes, containers, HPC, and cloud, GPUs

- **Execution**
  - Lazy evaluation
  - Limitation: requires **static size inference**
  - Triggered via `compute()`

```
import dask.array as da

x = da.random.random(
  (10000,10000), chunks=(1000,1000))
y = x + x.T
y.persist() # cache in memory
z = y[::2, 5000:].mean(axis=1) # colMeans
ret = z.compute() # returns NumPy array
```