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AGENDA

BACKGROUND

SPARK ON KUBERNETES
- Why use Spark-on-K8s
- How it works

JD.COM CASE STUDY
- JD.com's MoonShot
- Network Choice
- Storage Choice

SUMMARY
BACKGROUND
ABOUT SPARK-ON-KUBERNETES

https://github.com/apache-spark-on-k8s/spark

Spark* on Kubernetes*(K8s) is a new project proposed by the companies including Bloomberg, Google, Intel, Palantir, Pepperdata, and Red Hat.

The goal is to bring native support for Spark to use Kubernetes as a cluster manager like Spark Standalone, YARN*, or Mesos*.

The feature has been merged into Spark 2.3.0 release(SPARK-18278).
Customers are asking to use an unified cloud platform to manage their applications. Based on Kubernetes*, we can ease to set up a platform to support CPU, GPU, as well as FPGA resources for Big Data/AI workloads.
SPARK ON KUBERNETES
SPARK ON DOCKER SOLUTIONS

Solution1 - Spark* Standalone on Docker*
- Run Spark standalone cluster in Docker.
- Two-tiers resource allocation(K8s->Spark Cluster->Spark Applications).
- Less efforts to migrate existing architecture into container environment.

Solution2 - Spark on Kubernetes*
- Use native way to run Spark on Kubernetes like Spark Standalone, YARN, or Mesos.
- Single tier resource allocation(K8s->Spark Applications) for higher utilization.
- Must re-write the entire logical program for resource allocation via K8s.
SOLUTION1 - SPARK STANDALONE ON DOCKER

1. **Step 1:** Kubelet sends a request to submit App1 to Kubernetes Master.
2. **Step 2:** Kubernetes Master forwards the request to the Spark Master.
3. **Step 3:** Spark Master receives the request and starts the App1 Executor on Spark Slave Pod.
4. **Step 4:** Spark Slave Pod sends the completed App1 to the Spark Master, which then forwards it to Kubernetes Master.

Other components include:
- **Spark Slave Pod:** Hosts App1 and App2 Executors.
- **App1 Executor:** Processes data and sends results to Spark Slave Pod.
- **App2 Executor:** Processes data and sends results to Spark Slave Pod.

*Other names and brands may be claimed as the property of others.*
HOW TO USE SPARK ON K8S

bin/spark-submit \
  --deploy-mode cluster \
  --class org.apache.spark.examples.SparkPi \
  --master k8s://http://127.0.0.1:8080 \
  --kubernetes-namespace default \
  --conf spark.executor.instances=5 \
  --conf spark.executor.cores=4 \
  --conf spark.executor.memory=4g \
  --conf spark.app.name=spark-pi \
  --conf spark.kubernetes.driver.docker.image=localhost:5000/spark-driver \
  --conf spark.kubernetes.executor.docker.image=localhost:5000/spark-executor \
  --conf spark.kubernetes.initcontainer.docker.image=localhost:5000/spark-init \
  --conf spark.kubernetes.resourceStagingServer.uri=http://$ip:31000 \
hdfs://examples/jars/spark-examples_2.11-2.1.0-k8s-0.1.0-SNAPSHOT.jar
**DATA PROCESSING MODEL**

**PATTERN 1: Internal HDFS**
- **Virtual Cluster**
  - **Docker1**
  - **Docker2**
- **Host**

Use HDFS as file sharing server. HDFS runs in the same host to give elasticity to add/reduce compute nodes by request.

Please refer to Spark and HDFS.

**PATTERN 2: External HDFS**
- **Virtual Cluster**
  - **Docker1**
- **Host**

Use HDFS as file sharing server. HDFS runs outside in a long-running cluster to make sure data is persisted.

Please refer to PR-350

**PATTERN 3: Object Store**
- **Virtual Cluster**
  - **Docker1**
  - **Object Store**
- **Host**

Launch a File Staging Server to share data between nodes. Input and Output data can put in an object store. Streaming data directly via object level storage like Amazon S3, Swift.

**Storage Plan for Spark on K8s**

The design rule is based on “whether the data must be persisted”.

**spark.local.dir:**
For Spark Data Shuffling. Use Ephemeral Volume. Now it uses docker-storage with diff. storage backend. EmptyDir is WIP.

**File Staging Server:**
For sharing data such as Jar or dependence file between computing nodes. Now it uses docker-storage. Local Storage support in Persist Volume(PV) is WIP.
KEY FEATURES

- Support Cluster Mode
- Client Mode Support is under reviewing.
- Support File Staging in local, HDFS, or running a File Stage Server container.
- Support Scala, Java, and PySpark.
- Support Static and Dynamic Allocation for Executors.
- Support running HDFS inside K8s or externally.
- Support for Spark 2.3
- Pre-built docker images
The resources are allocated in the beginning and cannot change during the executors are running. Static resource allocation uses local storage (docker-storage) for data shuffle.

Use EmptyDir in K8s for this temporary data shuffle.
The resources are allocated in the beginning, but applications can change the resource in run time. Dynamic resource allocation uses shuffle service container for data shuffle.

There are two methods:
1\textsuperscript{st} method is to run shuffle service in a pod.
2\textsuperscript{nd} method is to run shuffle service as a container with an executor.
JD.COM CASE STUDY
JD.com (NASDAQ: JD)

Founded in 2004 in Beijing by CEO, Richard Liu.

Largest online retailer in China

Member of the Fortune Global 500

Business including e-commerce, Internet finance, logistics, cloud computing and smart technology

Technology-driven company, ABC strategy

Joybuy.com for US customers - affiliate to JD.com
JD.com MOONSHOT

JD has used K8s* as cloud infrastructure management for several years.

JD would like to use K8s to manage all the computing resources including CPU, GPU, FPGA, ...etc.

Target for all AI workloads; Using the same cluster for training/inference.

Across multiple Machine Learning framework including Caffe, TensorFlow, XGBoost, MXNet, BigDL ...etc.

To optimize workloads for different resource allocation.

Multi-tenancy support by different user accounts and resource pool.
## MOONSHOT ARCHITECTURE

<table>
<thead>
<tr>
<th>Applications</th>
<th>Management Center</th>
</tr>
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<tbody>
<tr>
<td>Image Recognition</td>
<td>Authority Mgmt.</td>
</tr>
<tr>
<td>NLP</td>
<td>Task Mgmt.</td>
</tr>
<tr>
<td>Security Solutions</td>
<td>Procedure Mgmt.</td>
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<tr>
<td>Finance</td>
<td>Monitor Center</td>
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<td>Public Cloud</td>
<td>Logging Center</td>
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<table>
<thead>
<tr>
<th>Computing Engine</th>
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</thead>
<tbody>
<tr>
<td>TensorFlow*</td>
<td>Spark</td>
</tr>
<tr>
<td>Caffe*</td>
<td>MLib</td>
</tr>
<tr>
<td>MXNet*</td>
<td>Spark SQL</td>
</tr>
<tr>
<td>XGBoost*</td>
<td>Streaming</td>
</tr>
<tr>
<td></td>
<td>Deeplearn (mindj)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Container Cluster</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Docker* + Kubernetes*</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Ethernet</td>
</tr>
<tr>
<td>GPU</td>
<td>InfiniBand</td>
</tr>
<tr>
<td>FPGA</td>
<td>Omini-Path</td>
</tr>
<tr>
<td></td>
<td>SSD</td>
</tr>
<tr>
<td></td>
<td>HDD</td>
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</table>

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TYPES OF CONTAINER NETWORK

Bridge
Bridge is the default network (docker0) in Docker*. Linux bridge provides a host internal network for each host and leverages iptables for NAT and port mapping. It is simple and easy, but with bad performance.

Host
Container shares its network namespace with the host. This way provides high performance without NAT support, but limits with port conflict issue.

Overlays
Overlays use networking tunnels (such as VXLAN) to communicate across hosts. Overlay network provides the capability to separate the network by projects.

Underlays
Underlays expose host interfaces directly to containers running on the host. It supports many popular drivers like MACvlan, IPvlan, ...etc. Some other ways via Underlay network are Direct Routing, Fan Networking, Point-to-Point.
NETWORK SOLUTIONS

Flannel*
A simple and easy to configure layer 3 network fabric designed for K8s. It runs flanneld on each host to allocate subnet and uses etcd to store network configuration. Flannel supports several backends including VXLAN, host-gw, UDP, ...etc.

Weave*
Weave creates a virtual network that connects Docker containers across multiple hosts and enables their automatic discovery.

OpenVSwitch*

Calico*
An approach to virtual networking and network security for containers, VMs, and bare metal services, which provides a rich set of security enforcement capabilities running on top of a highly scalable and efficient virtual network fabric. Calico uses BGP to set up the network and it also supports IPIP methods to build up a tunnel network.
Why CALICO?

No overlay required
Little overhead comparing to bare metal. Sometimes, overlay network (encapsulating packets inside an extra IP header) is an option, not MUST. Using Calico with BGP is much faster.

Simple & Scalable
The architecture is simple, the deployment is simple as well. We can easily deploy thousands of nodes in k8s by using yaml file.

Policy-driven network security
In many scenarios of JD.com, for example, multi-tenancy is necessary to make network isolation. Calico enables developers and operators to easily define network policy with fine granularity such as allowed or blocked connections.

Widely deployed, and proven at scale
We leverage the experience from other big companies who share their issues in the community. These experience are very valuable for us at the very beginning of moonshot. Fortunately, Calico has passed the verified in our production environment.
## NETWORK PERFORMANCE RESULT

All scenarios use `ab` command to connect to nginx* server with different IP address. “ab -n 1000000 -c 100 -H"Host: nginx.jd.local" 172.20.141.72:80/index.html “

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario</th>
<th>Concurrency #</th>
<th>Total Time(s)</th>
<th>Request per Second</th>
<th>Response Time(ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Client -&gt; Nginx</td>
<td>50</td>
<td>50.044</td>
<td>19982</td>
<td>0.05</td>
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<tr>
<td>2</td>
<td>Weave: Client -&gt; iptables -&gt; Weave -&gt; Nginx container</td>
<td>50</td>
<td>132.839</td>
<td>7527</td>
<td>0.133</td>
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<tr>
<td>3</td>
<td>Calico with IPIP: Client -&gt; iptables -&gt; Calico -&gt; Nginx container</td>
<td>50</td>
<td>111.136</td>
<td>8998</td>
<td>0.111</td>
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<tr>
<td>4</td>
<td>Calico with BGP: Client -&gt; iptables -&gt; Calico -&gt; Nginx container</td>
<td>50</td>
<td>59.218</td>
<td>16886</td>
<td>0.059</td>
</tr>
</tbody>
</table>

JD.com decides to pick up Calico since Calico provides similar performance to Bare Metal.
STORAGE CHOICE BY JD.COM
STORAGE CHOICES

Separate Compute and Storage cluster

Use Kubernetes to allocate resources for compute

Use Stand-alone HDFS Cluster for data persistent

Data locality depends on the workload types
## DATA LOCALITY IMPACT

<table>
<thead>
<tr>
<th>Workloads</th>
<th>Types</th>
<th>Locality</th>
<th>Datasize</th>
<th>Cluster Size</th>
<th>Network</th>
<th>Execution Time</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terasort</td>
<td>IO</td>
<td>Local</td>
<td>320GB</td>
<td>5</td>
<td>1Gb</td>
<td>2119.926sec</td>
<td>1x</td>
</tr>
<tr>
<td>Terasort</td>
<td>IO</td>
<td>Remote</td>
<td>320GB</td>
<td>5 Spark + 3 Hadoop</td>
<td>1Gb</td>
<td>4212.029sec</td>
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<tr>
<td>Terasort</td>
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<td>5</td>
<td>10Gb</td>
<td>500.198sec</td>
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<tr>
<td>Terasort</td>
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<td>Remote</td>
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<td>5 Spark + 3 Hadoop</td>
<td>10Gb</td>
<td>548.549sec</td>
<td>1.10x</td>
</tr>
<tr>
<td>Kmeans</td>
<td>CPU</td>
<td>Local</td>
<td>240GB</td>
<td>5</td>
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<td>Kmeans</td>
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<td>5 Spark + 3 Hadoop</td>
<td>10Gb</td>
<td>1219.138sec</td>
<td>1.05x</td>
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</tbody>
</table>

Note1: This testing is using 5-nodes bare metal cluster.
Note2: 4 SATA SSD per Spark and Hadoop node
Note3: Performance may impact in different configuration including the number of disk, network bandwidth, as well as different platform.
SUMMARY
CURRENT STATUS & ISSUES

Spark* Shell for Client Mode hasn’t been merged and verified.

Data Locality Support

Storage Backend Support

Performance Issues for launching container via Kubernetes

Reliability: Need more verification in larger scale(current 300+ and moving to 1000+)
SUMMARY

Spark* on K8s* provides a cloud native way to run Spark on Cloud which not only can get better resource utilization but also integrate with more big data services.

JD.com’s MoonShot is a POC to prove Spark on K8s is good enough in a production environment.

JD.com next step is to scale up the size of cluster to thousand level.

Spark on K8s is still under developing and there are many issues/features are waiting to be fixed/implemented.