QCon 全球软件开发大会
INTERNATIONAL SOFTWARE DEVELOPMENT CONFERENCE

BEIJING 2018

京东如何基于容器
打造高性能及效率的大数据平台

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AGENDA

BACKGROUND

SPARK ON KUBERNETES
- Why use Spark-on-K8s
- How it works
- Current Status & Issues

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 is planning to be put into Spark 2.3.0 release(SPARK-18278).

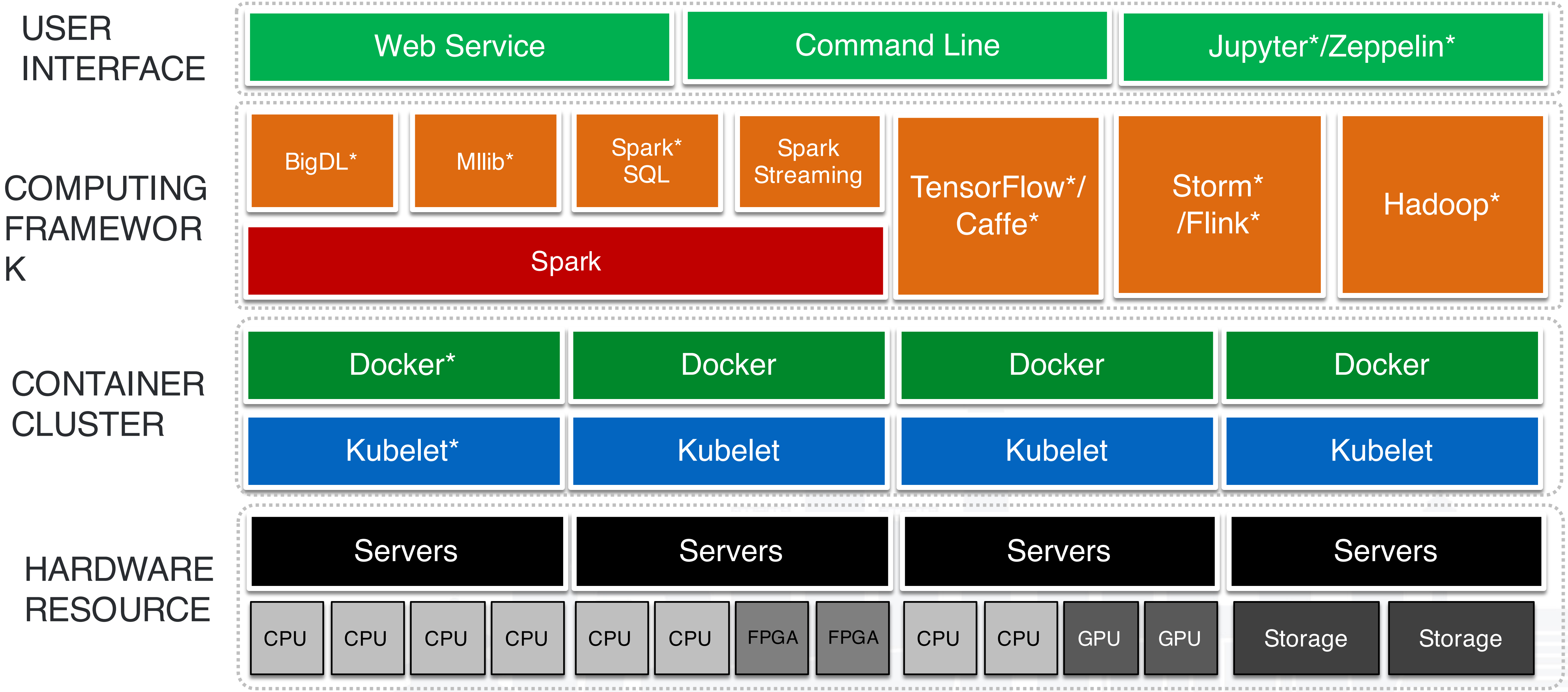
WHY JD.COM CHOOSE SPARK-ON-K8S

Heterogeneous Computing

CPU + GPU + FPGA

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.

HETEROGENEOUS CLOUD SOLUTION



USER INTERFACE

Web Service | Command Line | Jupyter*/Zeppelin*

COMPUTING FRAMEWORK

BigDL* | Mllib* | Spark* SQL | Spark Streaming

Spark

TensorFlow*/Caffe* | Storm*/Flink* | Hadoop*

CONTAINER CLUSTER

Docker* | Docker | Docker | Docker

Kubelet* | Kubelet | Kubelet | Kubelet

HARDWARE RESOURCE

Servers | Servers | Servers | Servers

CPU | CPU | CPU | CPU | CPU | CPU | FPGA | FPGA | CPU | CPU | GPU | GPU | Storage | Storage

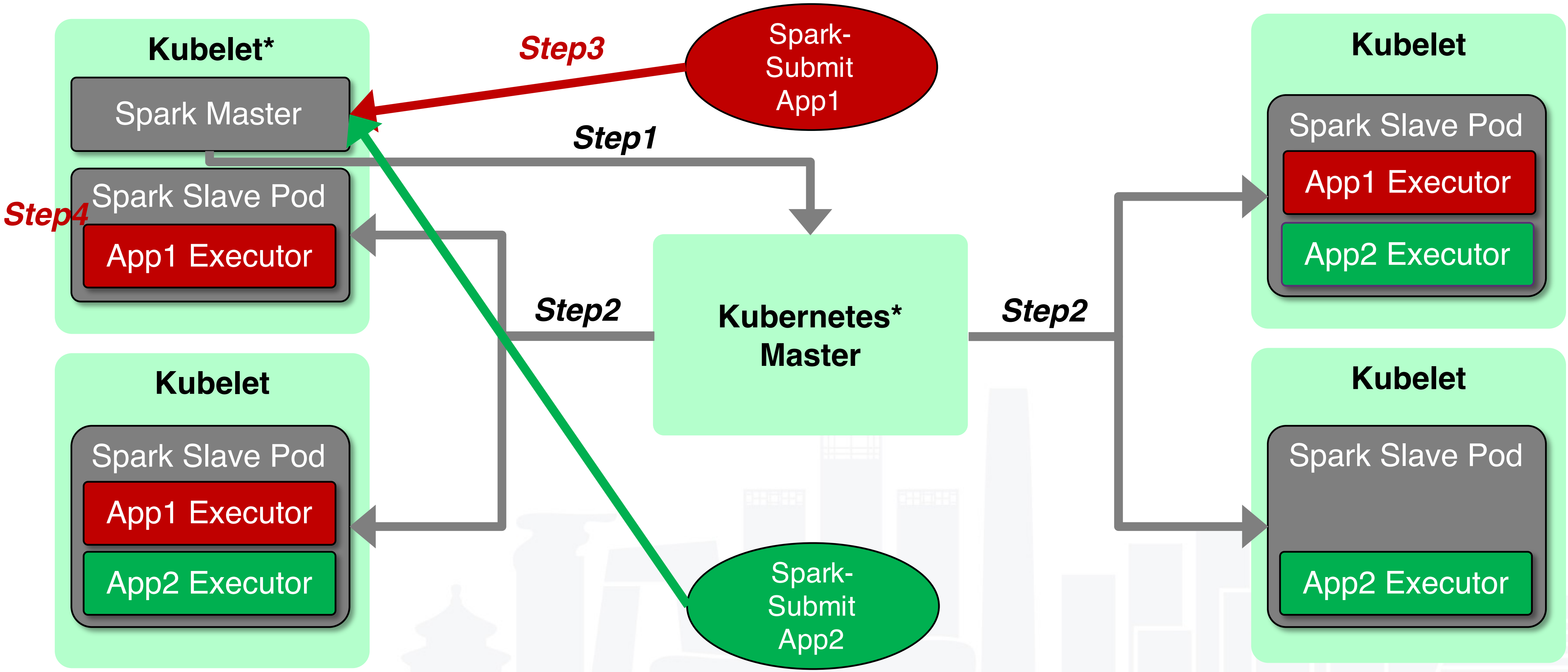
SPARK ON KUBERNETES

SPARK ON DOCKER SOLUTIONS

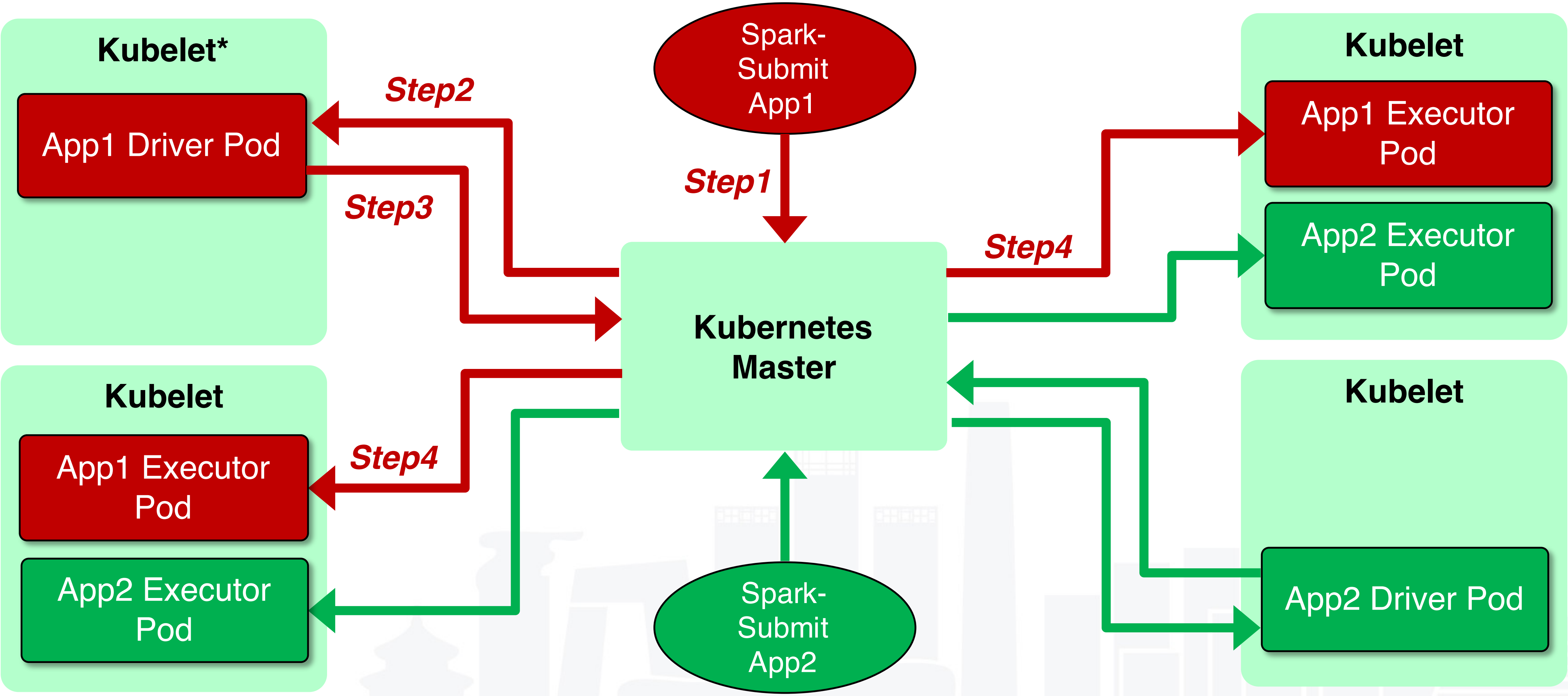
- **Solution1 - Spark* Standalone on Docker***
  - Run Spark standalone cluster in Docker.
  - Two-tiers resource allocation(K8s->Spark Cluster->Spark Applications).
  - Less efforts to migrate existing architecture into container environment.

- **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



SOLUTION2 - SPARK ON KUBERNETES



HOW TO USE SPARK ON K8S

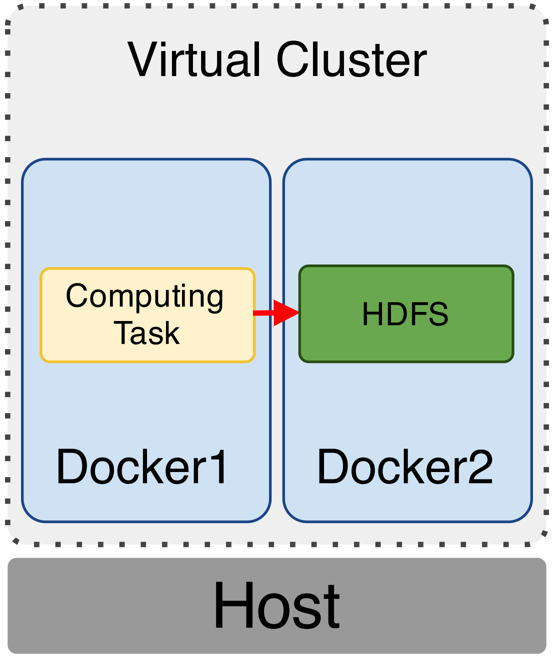
```
# bin/spark-submit \
  --deploy-mode cluster \
  --class org.apache.spark.examples.SparkPi \
  --master k8s://http://127.0.0.1:8080 \
  --kubernetes-namespace default \
  --conf spark.executor.instances=5 \
  --conf spark.executor.cores=4 \
  --conf spark.executor.memory=4g \
  --conf spark.app.name=spark-pi \
  --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
```

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 Kubernetes 1.6 - 1.7
- Pre-built docker images

DATA PROCESSING MODEL

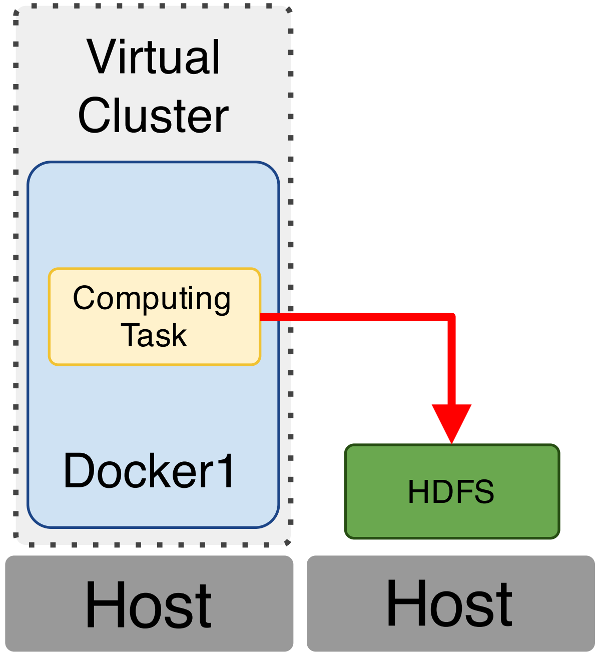
PATTERN 1: Internal HDFS*



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.

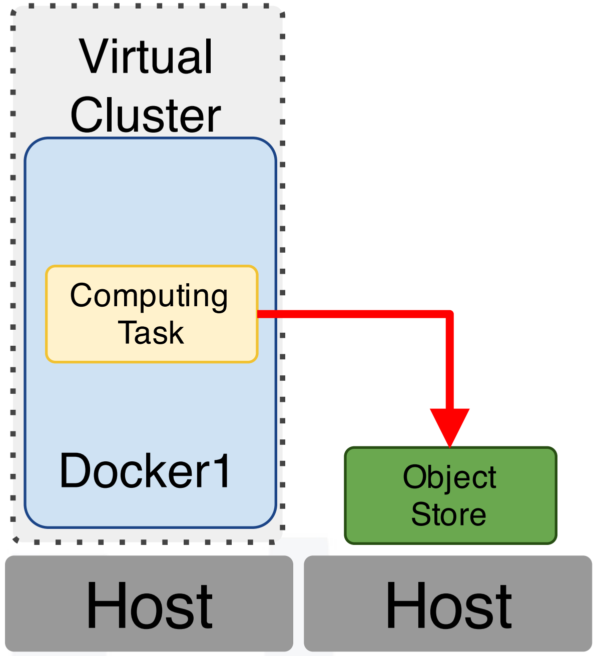
PATTERN 2: External HDFS



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



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.

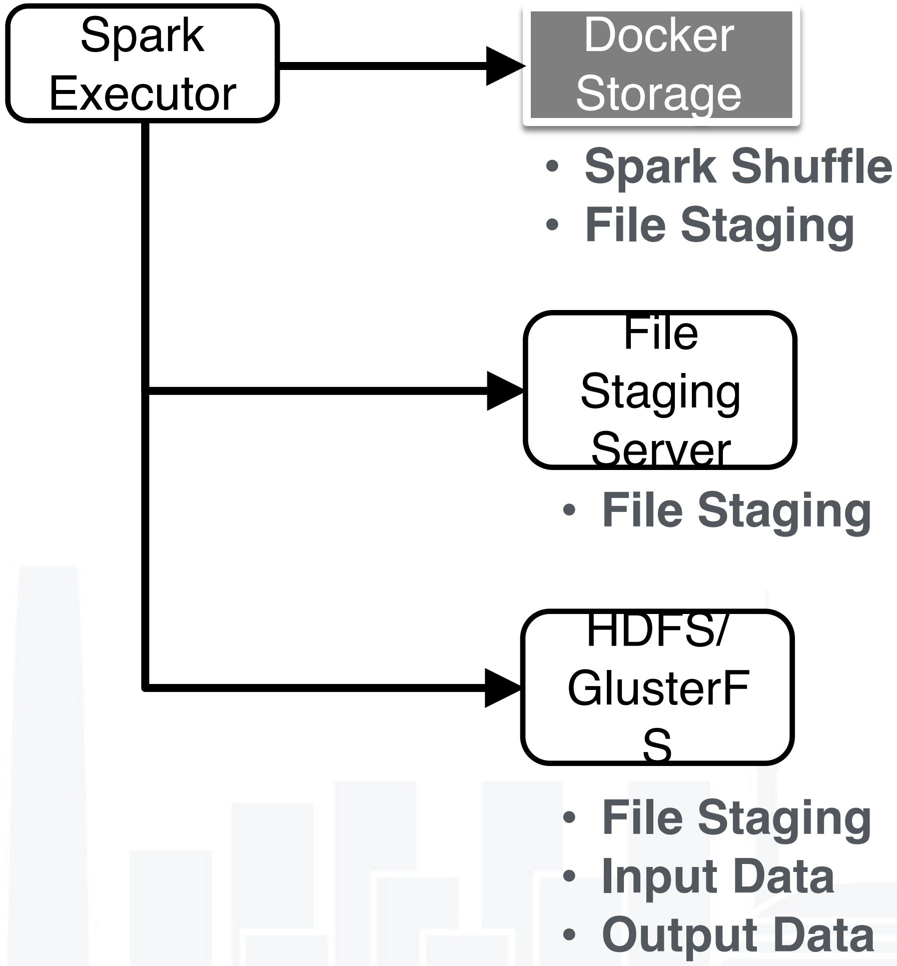
STORAGE SUPPORT

- Spark* Shuffle: Uses Ephemeral Volumes
- Docker* Storage: Use devicemapper
- Shared Volumes:

1. #439 Use EmptyDir for File Staging to share jar file.
2. Local in Spark Executors(Docker Storage)
3. Remote HDFS*
4. Create a Staging Server Container

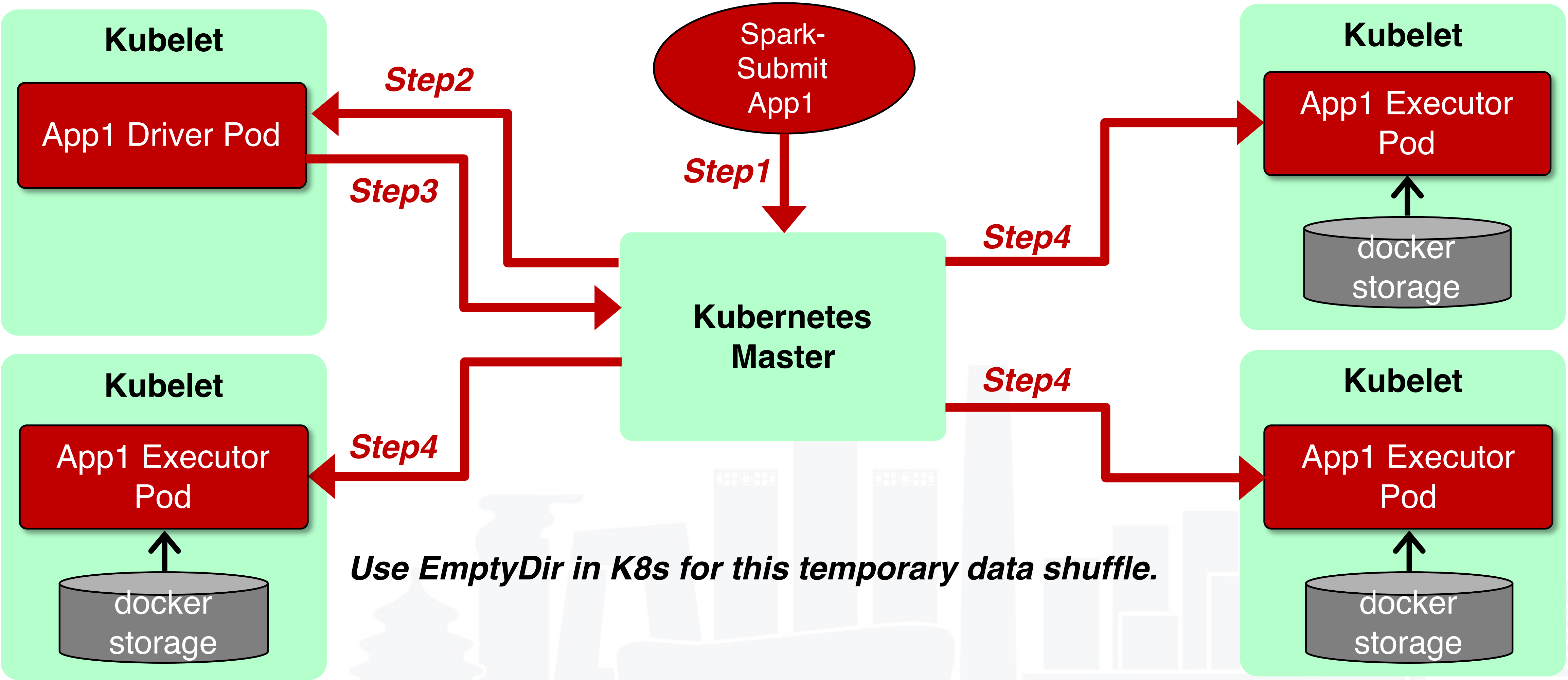
- Persistent Volumes(Ongoing):

1. #306 Use PV
2. Input/Output Data
3. Remote HDFS
4. Remote Object Storage such as GlusterFS*



STATIC RESOURCE ALLOCATION

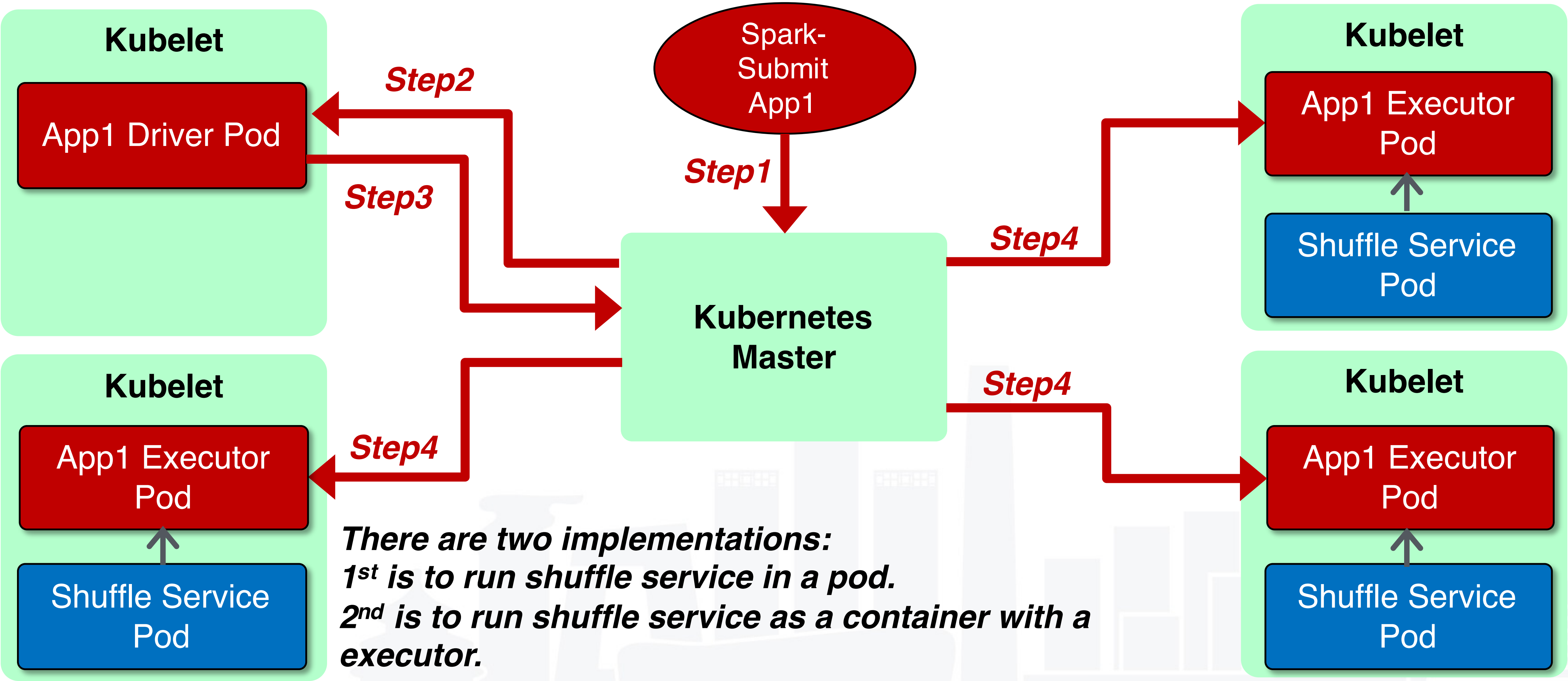
The resources are allocated in the beginning and cannot change during the executors are running. Static resource allocation uses local storage(docker-storage) for data shuffle.



Use EmptyDir in K8s for this temporary data shuffle.

DYNAMIC RESOURCE ALLOCATION

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 implementations:
1st is to run shuffle service in a pod.
2nd is to run shuffle service as a container with a executor.

CURRENT STATUS & ISSUES

- Spark* Shell for Client Mode hasn’t verified yet.
- Spark Cluster for Long Time Job
- Data Locality Support
- Storage Backend Support
- Container Launch Time may take too long
- Performance Issues
- Reliability

JD.COM CASE STUDY

JD.com (NASDAQ: JD)

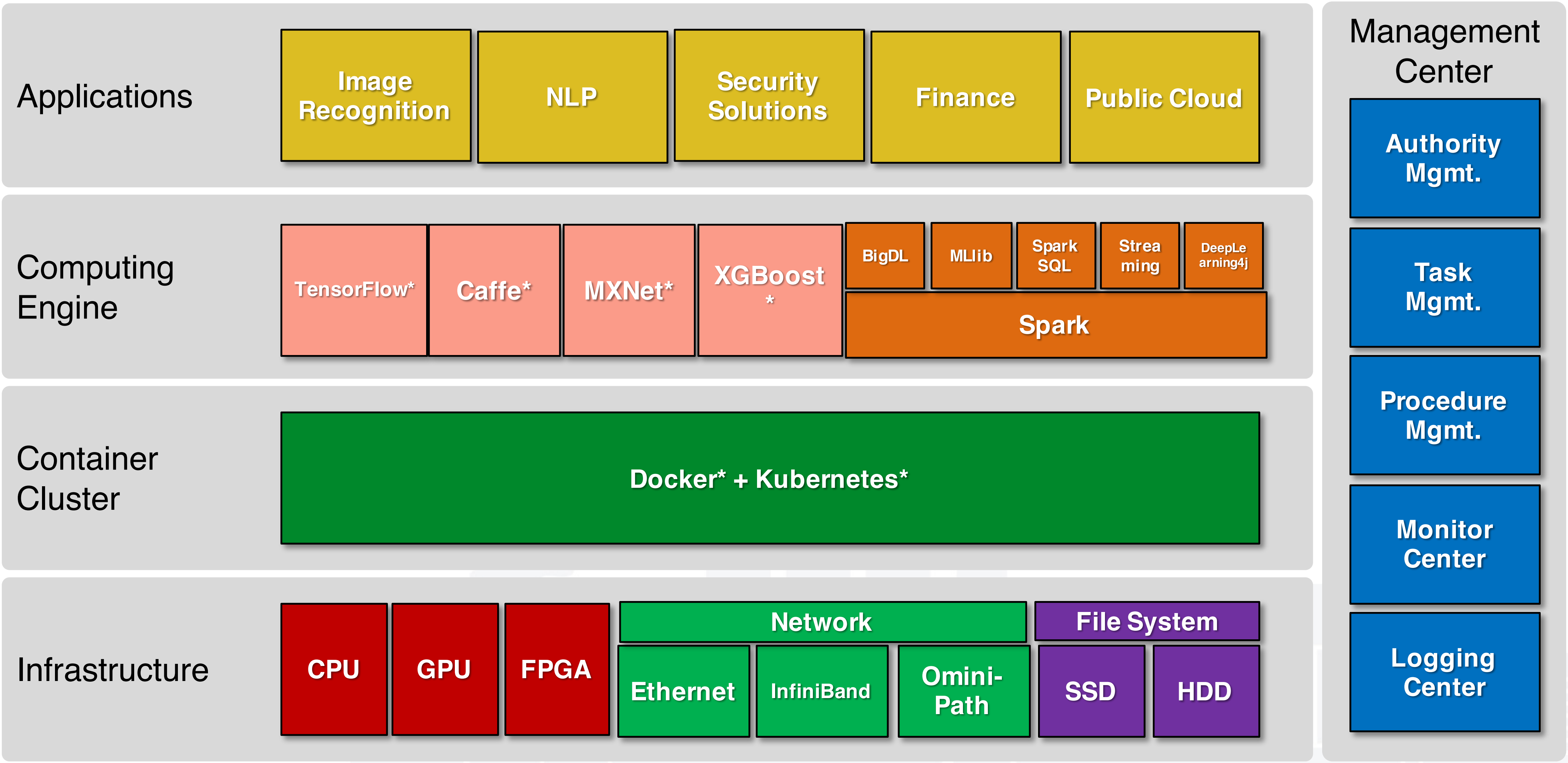
- Founded in 2004 in Beijing by CEO, Richard Liu.
- Largest online retailer in China
- Member of the Fortune Global 500
- Business including e-commerce, Internet finance, logistics, cloud computing and smart technology
- Technology-driven company, ABC strategy
- Joybuy.com for US customers - affiliate 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.

Reference: https://mp.weixin.qq.com/s?__biz=MzA5Nzc2NDAxMg%3D%3D&mid=2649864623&idx=1&sn=f476db89b3d0ec580e8a63ff78144a37

MOONSHOT ARCHITECTURE



Applications

Image Recognition

NLP

Security Solutions

Finance

Public Cloud

Computing Engine

TensorFlow*

Caffe*

MXNet*

XGBoost *

BigDL

MLlib

Spark SQL

Strea ming

DeepLe arning4j

Spark

Container Cluster

Docker* + Kubernetes*

Infrastructure

CPU

GPU

FPGA

Network

Ethernet

InfiniBand

Omini-Path

File System

SSD

HDD

Management Center

Authority Mgmt.

Task Mgmt.

Procedure Mgmt.

Monitor Center

Logging Center

NETWORK CHOICE by JD.com

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.

- 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.

- Weave*

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

- OpenVSwitch*
- Others

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.

- 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 “

No.	Scenario	Concurrency #	Total Time(s)	Request per Second	Waiting Time(ms)
1	Client -> Nginx	50	50.044	19982	0.05
2	Weave: Client -> iptables -> Weave -> Pod	50	132.839	7527	0.133
3	Calico with IPIP: Client -> iptables -> Calico -> Pod	50	111.136	8998	0.111
4	Calico with BGP: Client -> iptables -> Calico -> Pod	50	59.218	16886	0.059

JD.com decides to pick up Calico since Calico provides better performance than Weave and Calico can still provide tunnel method(via IPIP) to set up network.

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 ISSUE

- In cloud environment, compute and storage resource are separated. This could highlight data locality issue with performance drop.
- Some possible solutions can help to resolve data locality issues
- Choose right workloads, most workloads only need to read data and write data at beginning and end phase.
- HDFS* on Kubernetes
- Alluxio*

DATA LOCALITY IMPACT

Workloads	Types	Locality	Datasize	Cluster Size	Network	Execution Time	Notes
Terasort	IO	Local	320GB	5	1Gb	2119.926sec	1x
Terasort	IO	Remote	320GB	5 Spark + 3 Hadoop	1Gb	4212.029sec	1.98x
Terasort	IO	Local	320GB	5	10Gb	500.198sec	1x
Terasort	IO	Remote	320GB	5 Spark + 3 Hadoop	10Gb	548.549sec	1.10x
Kmeans	CPU	Local	240GB	5	10Gb	1156.235sec	1x
Kmeans	CPU	Remote	240GB	5 Spark + 3 Hadoop	10Gb	1219.138sec	1.05x

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.

SPARK PERFORMANCE COMPARISON

Task#	Remote in K8s (sec)	Remote in Yarn (sec)	Local in Yarn (sec)	1 - k8s/yarn local (X)	1 - k8s/yarn remote (X)
01. gdm_m12_pop_ord_sum_101_spark	424.33	600.33	398.33	-6.53%	29.32%
02. gdm_m12_pop_ord_sum_102_spark	996.00	1188.00	1155.67	13.82%	16.16%
03. odm_waybill_ord_sum_spark	420.67	517.33	391.33	-7.50%	18.69%
04. odm_jdorders_waybill_spark	399.67	573.67	413.33	3.31%	30.33%
05. tmp_d05_pre_sorting_da_spark	525.33	672.67	489.33	-7.36%	21.90%
06. odm_ord_det_basic_spark	659.67	1313.33	647.67	-1.85%	49.77%
08. fdm_bd_waybill_v_waybill_c_chain_spark	2224.33	2259.00	1717.67	-29.5%	1.53%
10. odm_m04_ord_amount_det_da_spark	1013.33	2019.00	958.00	-5.78%	49.81%
11. odm_product_pop_product_spark	1539.33	3540.33	1351.33	-13.91%	56.52%

Run 3 times per task and list result in average.
Separate compute and storage bring some performance loss compared to yarn local.
Spark on K8s(remote) provide better performance comparing to yarn remote.

SUMMARY

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 Moon Shot uses K8s to create a heterogeneous cloud infrastructure, it can support both CPU and GPU for their AI workloads.
- Spark on K8s is still under developing and there are many issues/features are waiting to be fixed/implemented.

FUTURE WORKS

- Intel RDT integration
  https://www.intel.com/content/www/us/en/architecture-and-technology/resource-director-technology.html
- Intel DPDK for Software Define Network(SDN)
- Intel HW Features Enabling
- Spark* on K8s* Feature Support
- Enable more customers to use Spark on K8s

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