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Research on The Container Runtime of The CERN EOS Distributed File System in a Kubernetes Environment

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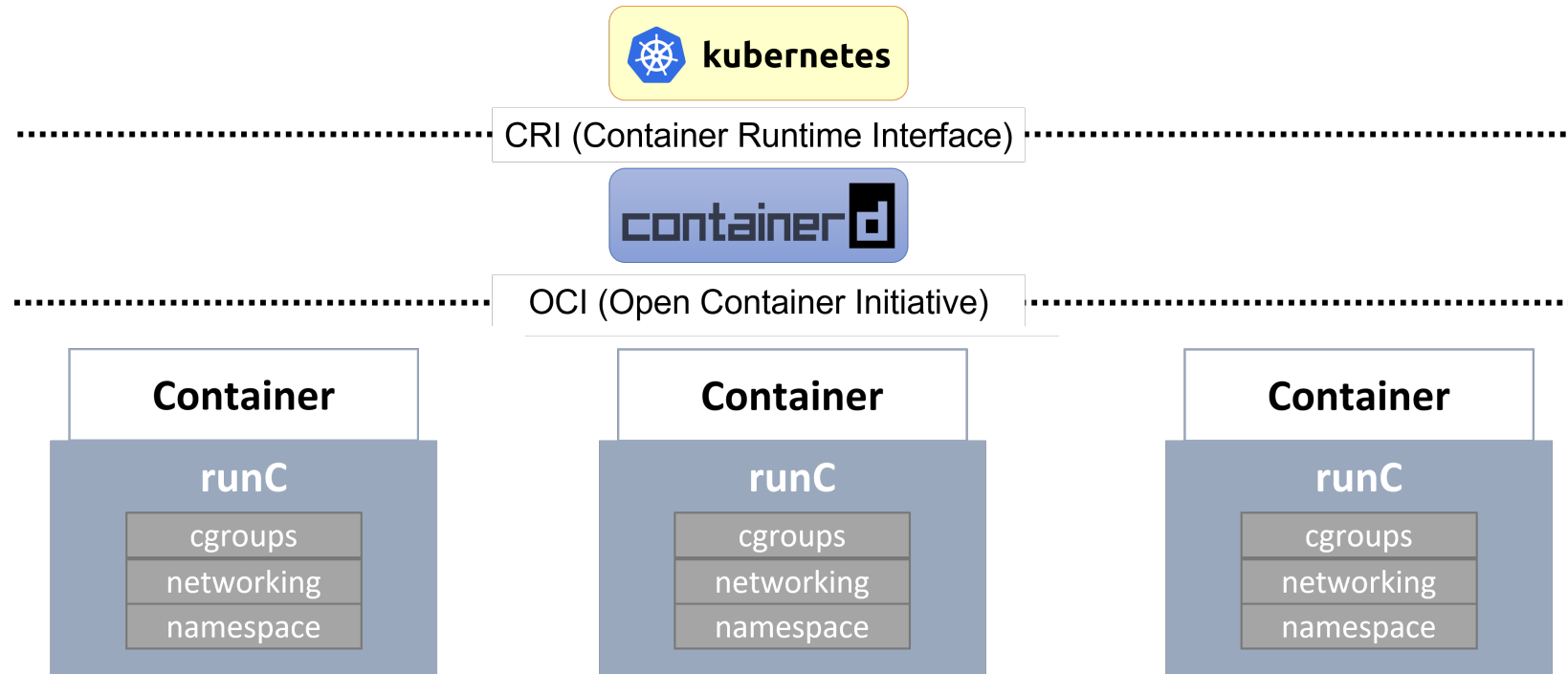
Container Runtime in K8S

- **The importance of choosing a container runtime in Kubernetes.**
  - In a Kubernetes configuration, the container runtime is one of the key elements responsible for executing and managing applications.
  - The choice of container runtime can impact the overall performance of both applications and the system.

Research Title
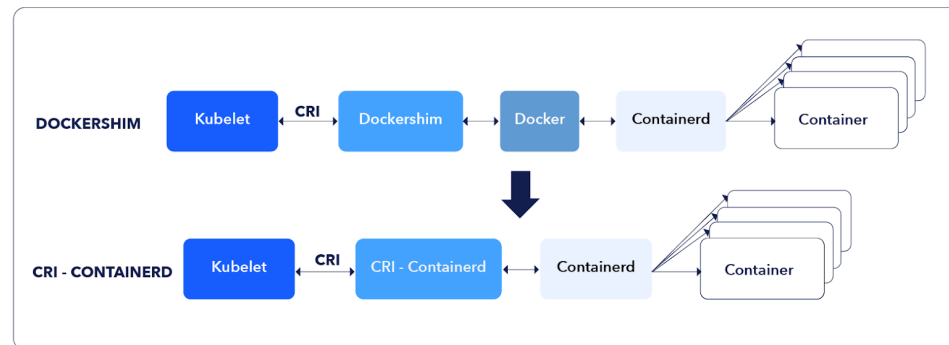
- **A Study of CERN EOS Distributed File System on Container Runtime Performance Analysis in a Kubernetes Environment**
    - The research goal is identifying a suitable container runtime for CERN EOS, which is used for large-scale scientific research.
    - So, we performed a performance evaluation of different container runtimes.
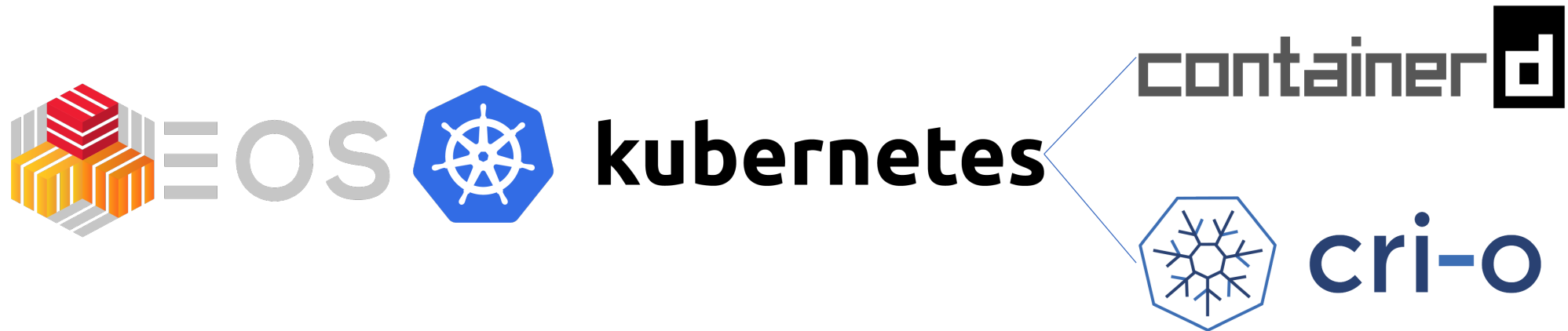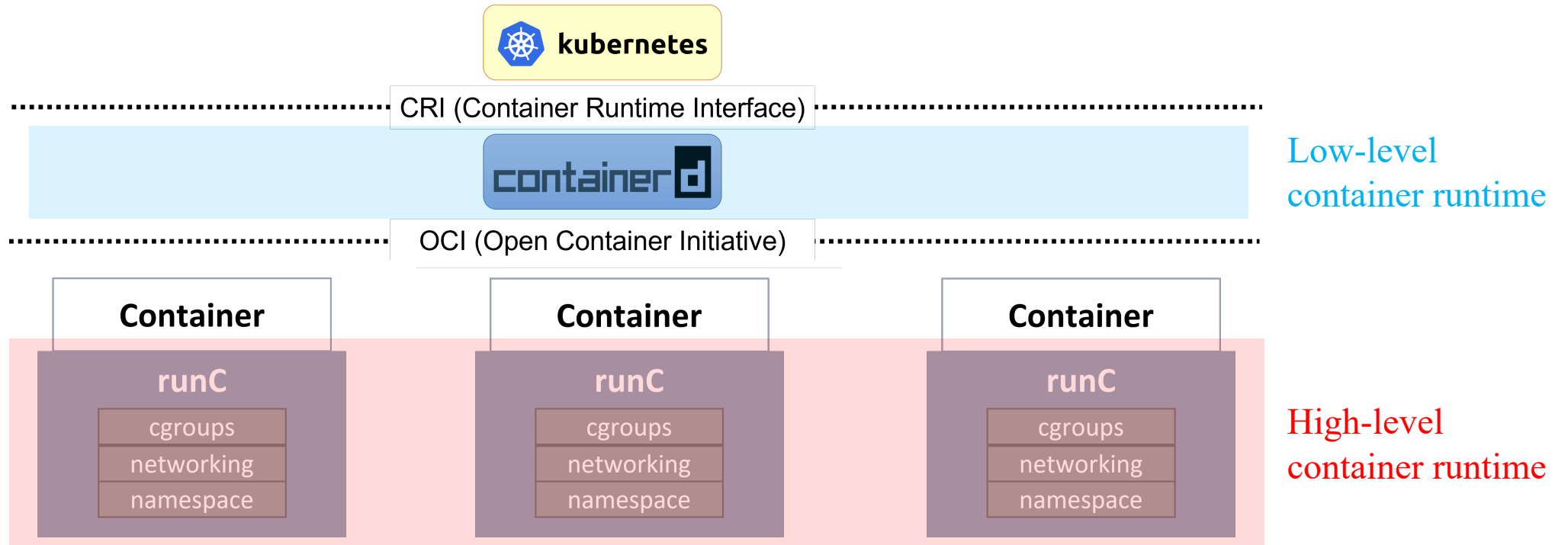
Container Runtime

- **The Architecture of Kubernetes :** Kubernetes – `containerd` – `runc`
  - `containerd` is a tool that manages container runtimes.
  - `runc` actually do performs tasks such as cgroups, networking, and namespace isolation.

Container Runtime

- **There are 2 type of the container runtime, High- and Low-level container runtime.**
- Which type of container runtime do the mentioned belong to?
  - containerd - High-level container runtime
  - runc - Low-level caontainer runtime

Container Runtime

- **Diverse container runtimes**
  - As shown in the picture, there are various container runtimes.
 - It is expected that each container runtime has distinct characteristics that impact the system differently.

High-Level Container Runtime
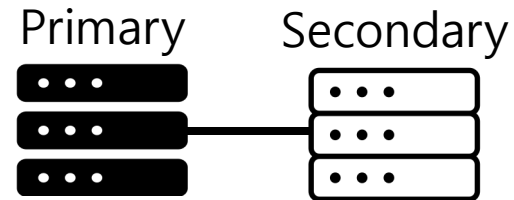
Low-Level Container Runtime

Analytics

- **Problems with Docker as a container runtime**
  - Compared to using `containerd` directly as the container runtime, `Docker-Engine` goes through an additional `Docker` intermediate layer.

Analytics
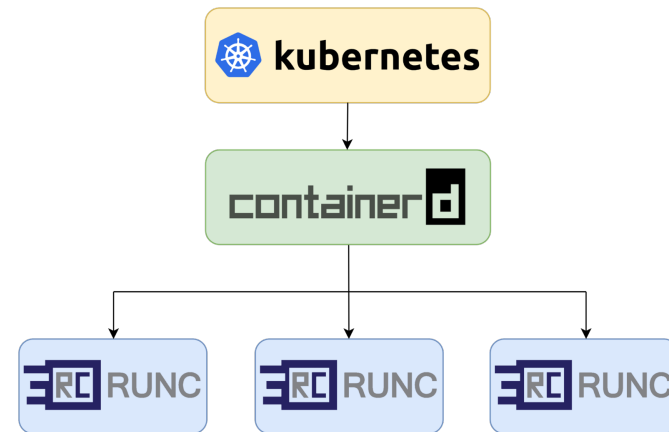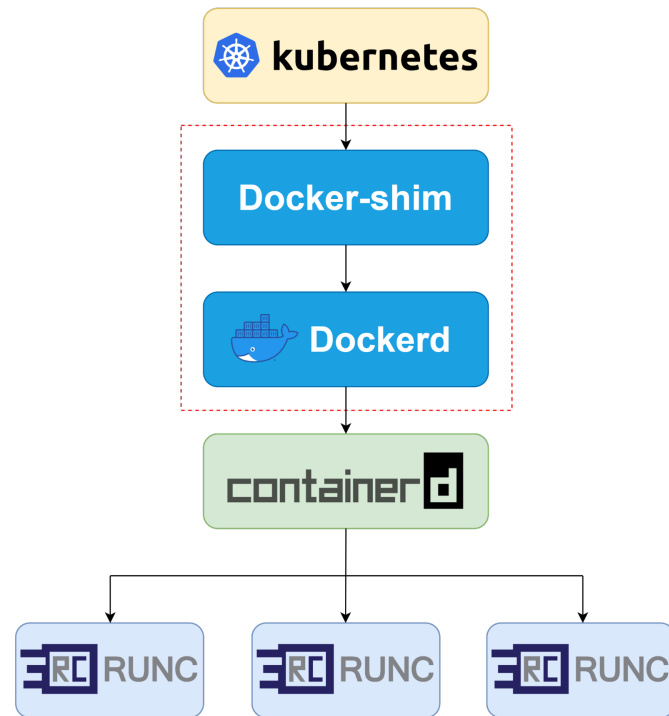
- **Experimental environment**
- The experiments were conducted on a typical Kubernetes cluster prior to evaluating the container runtime for CERN EOS.
  - Because of measuring how performance varies as the choice of container runtime.

Server Specification	
Chassis	Power Edge R440
OS	CentOS 7
CPU	Intel(R) Xeon(R) Silver 4208 CPU @ 2.10GHz
RAM	128GB
Disk	960 GB SSD (Boot), 2 TB HDD (Data)

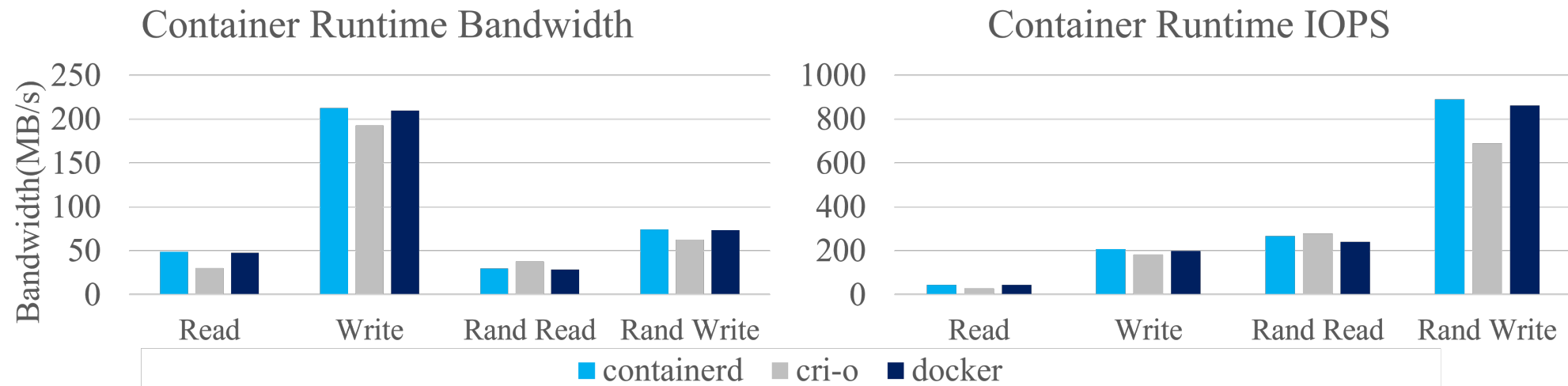| Container Runtime Version	
containerd	1.6.19
cri-o	1.26.1
Docker Engine	23.0.3

* To use `docker-shim`, we used version 1.23.0 of Kubernetes.

Analytics - typical Kubernetes cluster

- **Evaluation of Container Runtimes – Container Runtime**
  - containerd is generally stable and high performance.
  - Docker-Engine is similar to containerd.
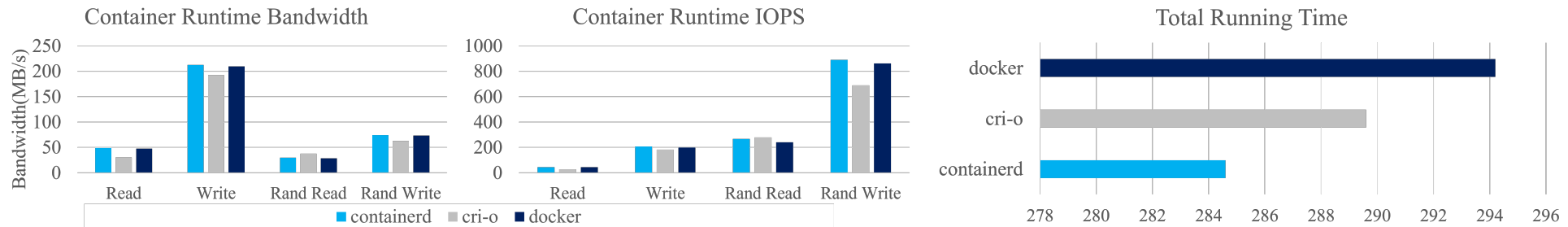 - CRI-O performs poorly compared to the other two container runtimes.

Container Runtime Bandwidth

Container Runtime IOPS

■ containerd ■ cri-o ■ docker

* Higher is good performed

Analytics - typical Kubernetes cluster

- **Evaluation of Container Runtimes – Total Running Time**
  - `containerd's` is 284 seconds and has the fastest running time
  - `Docker-Engine's` is 294 seconds and has the lowest running time
  - `CRI-O's` is 289 seconds and has the middle running time
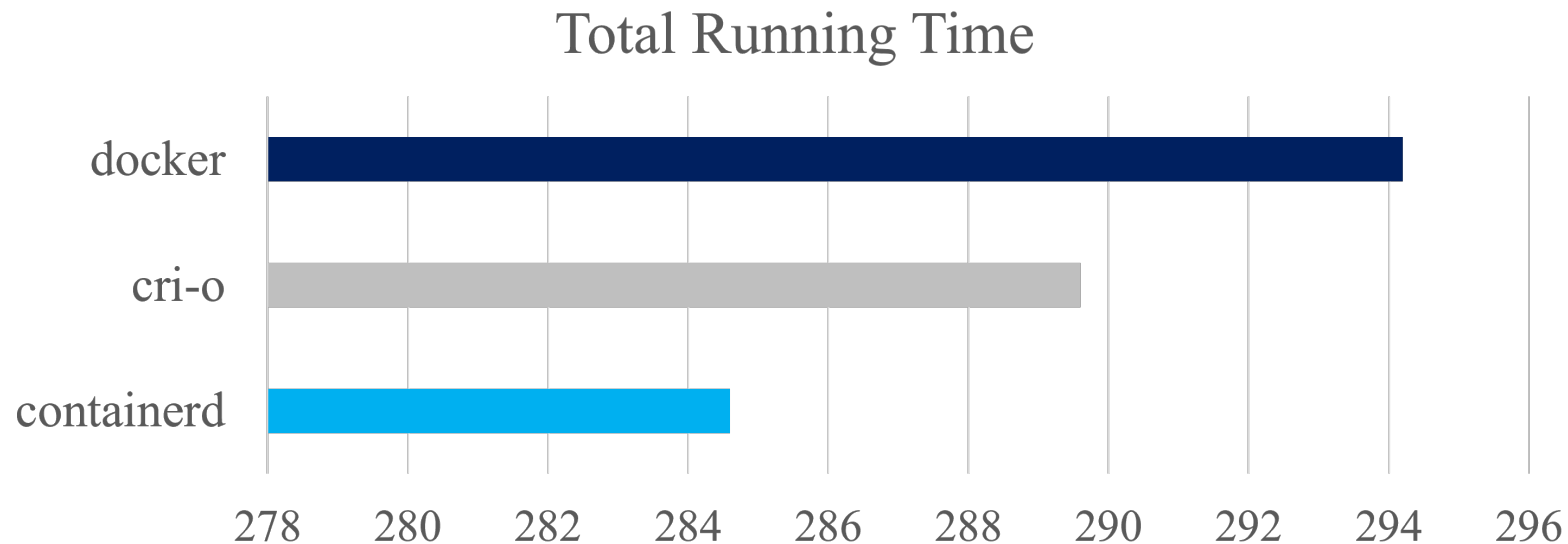
Total Running Time

* Lower is good performed

Analytics - typical Kubernetes cluster

- **The summary about Evaluation of Container Runtimes**

Container Runtime Bandwidth

Container Runtime IOPS

Total Running Time

|	**Bandwidth and IOPS**	**Total Running Time**
	containerd > Docker-Engine > CRI-O	containerd < CRI-O < Docker-Engine

- Total running time is not always proportional to bandwidth and IOPS.
  - Docker-Engine has higher bandwidth than CRI-O, but higher total execution time.

- Docker-Engine and containerd are similar in bandwidth and IOPS, but has relatively large differences in total running time.
  - This is likely due to the overhead of Docker-Engine actually using containerd.
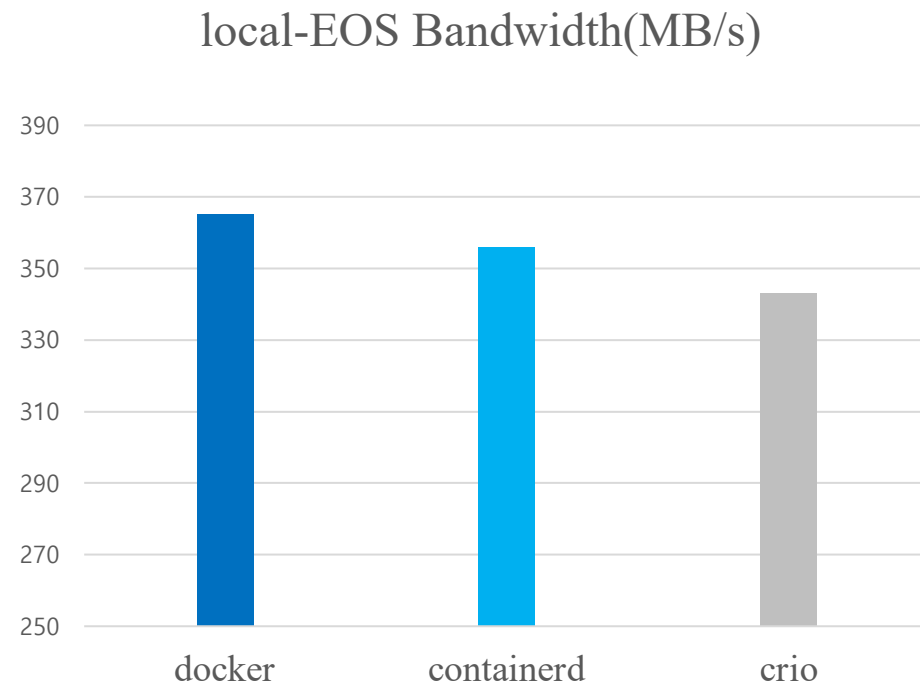
Analytics

- **Experimental environment for CERN EOS K8S Cluster**
  - To evaluate the container runtime for CERN EOS, experiments were designed with a different environment from the previous ones.
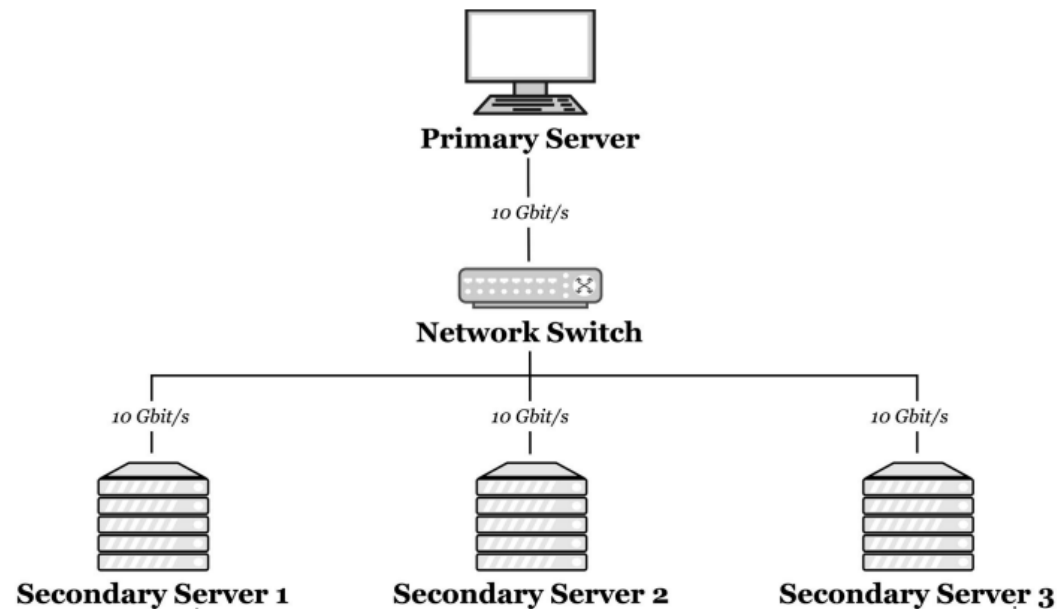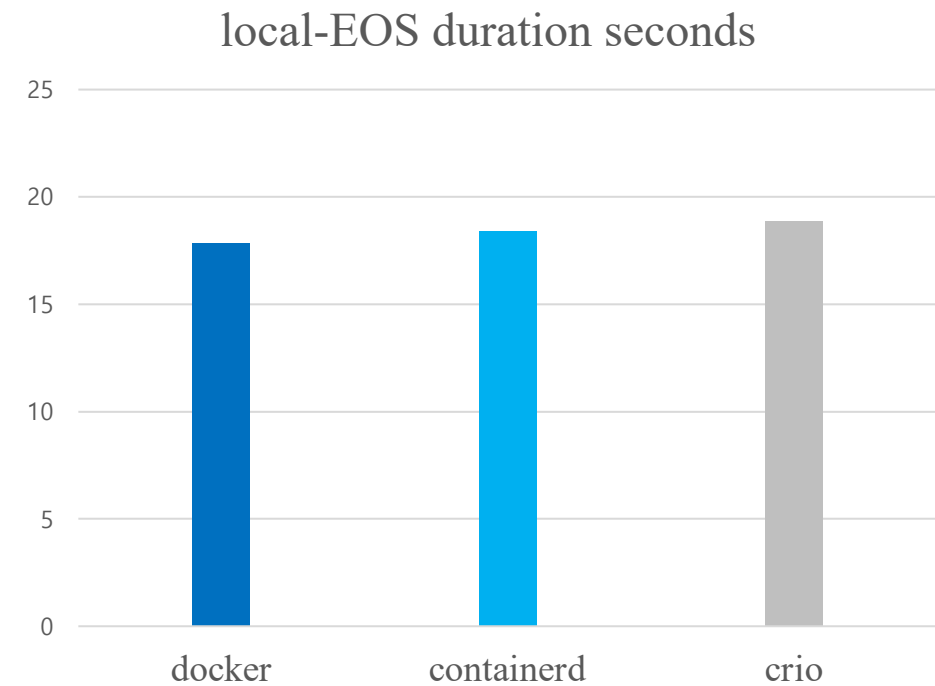

Server Specification	
OS	CentOS 7
CPU	Intel(R) Xeon(R) CPU E5-2680 2.70GHz
RAM	96GB
Disk	600GB HDD(Boot), 2.7 TB RAID Volume * 2
Network	10Gbit/s

Analytics - CERN EOS K8S Cluster

- **Evaluation of Container Runtimes – Uploading files from the local system to EOS**
  - The bandwidth - `Docker-Engine` > `containerd` > `CRI-O`
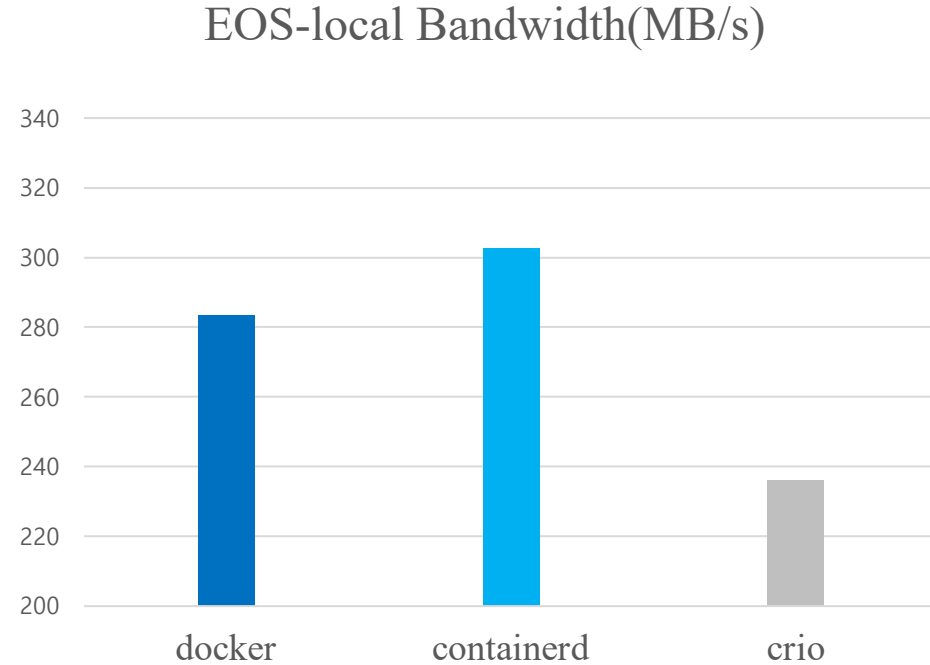 - The execution time - `Docker-Engine` < `containerd` < `CRI-O`

local-EOS Bandwidth(MB/s)

local-EOS duration seconds

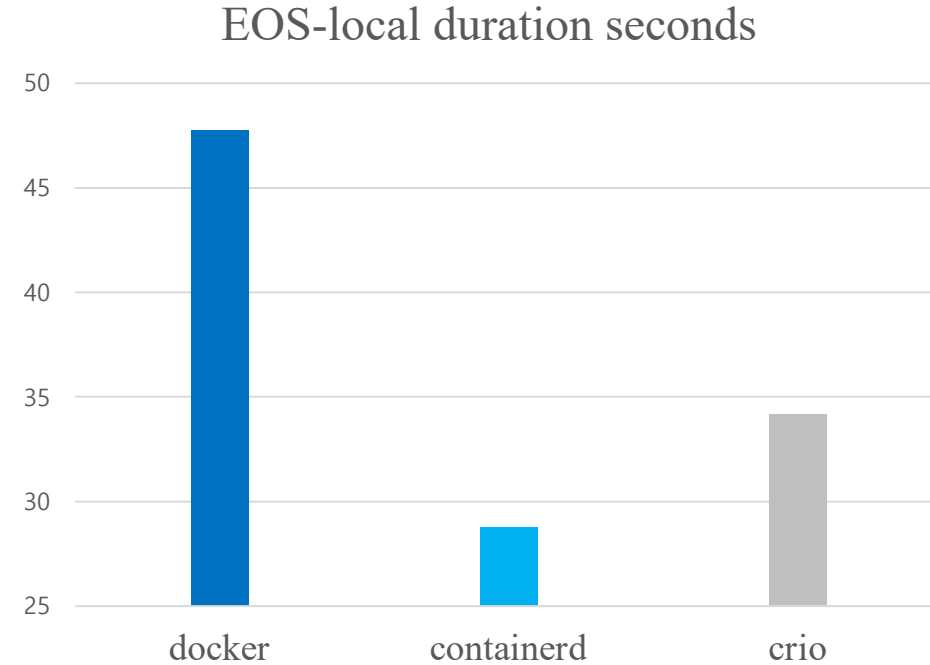** Higher is better*

Lower is better *

Analytics - CERN EOS K8S Cluster

- **Evaluation of Container Runtimes – Downloading files from EOS to the local system**
  - The bandwidth - `containerd` > `Docker-Engine` > `CRI-O`
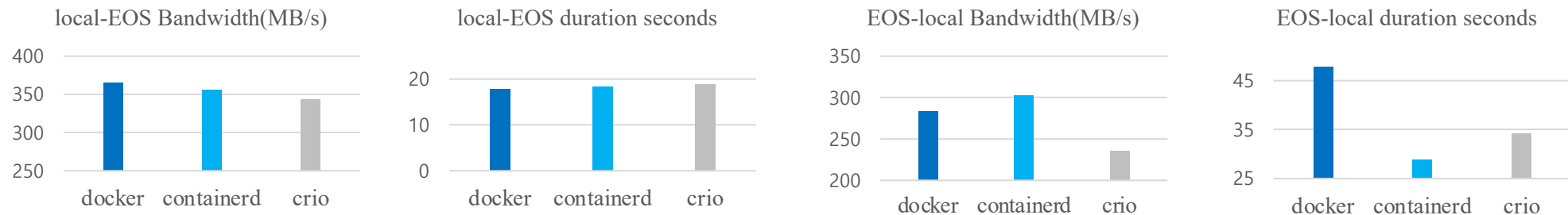 - The execution time - `containerd` < `CRI-O` < `Docker-Engine`

EOS-local Bandwidth(MB/s)

EOS-local duration seconds

* Higher is better

Lower is better *

Analytics - CERN EOS K8S Cluster

- **The summary about Evaluation of Container Runtimes**
  - It is concluded that integrating CERN EOS into Kubernetes using `containerd` is the most stable option.

local-EOS Bandwidth(MB/s)

local-EOS duration seconds

EOS-local Bandwidth(MB/s)

EOS-local duration seconds

| **Average Bandwidth**	**Duration Time**
containerd > Docker-Engine > CRI-O	containerd < CRI-O < Docker-Engine

- In the scenario of uploading files from the local system to EOS,
  - `Docker-Engine` unexpectedly shows the best performance with marginal differences.
- In the scenario of downloading files from EOS to the local system,
  - `Docker-Engine` shows a notably unstable behavior and persists even in subsequent evaluations

Conclusion

- **What shows the result of this research?**
  - The performance of various metrics changes depending on the container runtime in a Kubernetes environment.
  - It demonstrates the need to choose the appropriate container runtime for the situation.
  - It provides performance evaluations to help users choose the appropriate container runtime.

- **What is future plans?**
  - we will do performance analysis with more rigorous evaluation using precise criteria.
  - We will analyze more container runtimes with various benchmark tools to provide users with practical performance evaluations.

[Runtime − Container Runtime, CNCF Cloud Native Interactive Landscape]
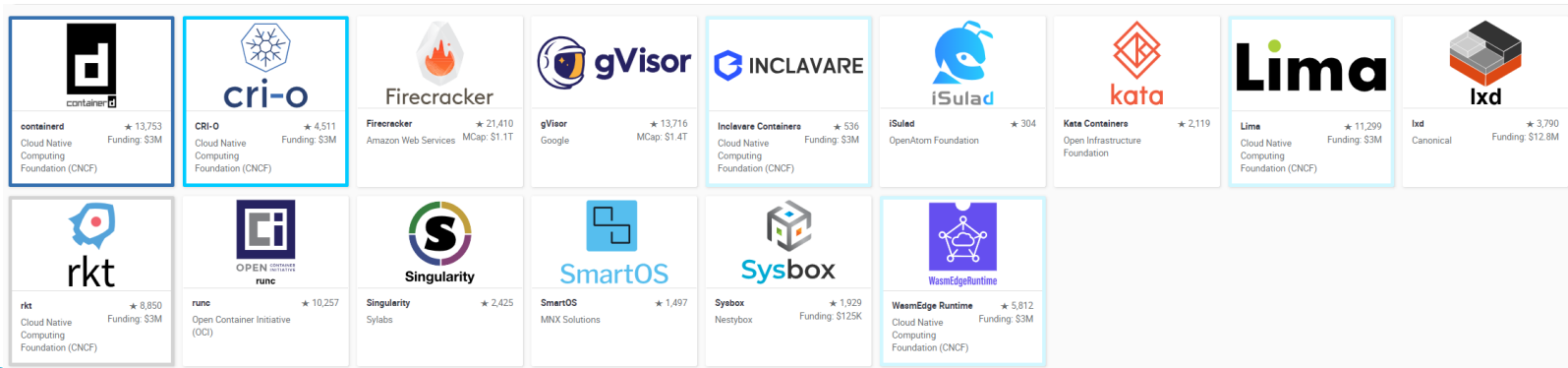
Thank you!

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