Investigating the Performance and Scalability of Kubernetes on Distributed Cluster of Resource-Constrained Edge Devices

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Background and Motivations

Edge Computing is pushing the bounds of computing away from centralized nodes to the logical verge of a network. Even though using container technologies and container orchestration platforms have several benefits especially for scalability of widely distributed edge nodes, it is still unpopular among resource-constrained edge devices, and the behavior of Kubernetes in such an environment is not apparent. This work is an attempt to set up a distributed testbed for edge computing using single-board Raspberry Pi computers and examines the performance and scalability of Kubernetes on the platform.

Distributed Testbed for Edge Computing

The initial setup of the distributed testbed for edge computing consists of 24 Raspberry Pi 3B+ nodes on two sites: 16 nodes at University of Florida, USA, and 8 nodes at Nara Institute of Science and Technology, Japan. Docker containers are used for application deployment and Kubernetes for container orchestration. The connection among the cluster nodes is facilitated and secured by IPOP Virtual Private Network.

Kubernetes Cluster Benchmarking

To measure the performance of Kubernetes, we developed **kbench***, a Kubernetes benchmarking test suite containing three tests.

pod-throughput Test:
Launches multiple pods in parallel and measures their start-up and clean-up time.

pod-latency Test:
Launches multiple pods sequentially and measures their start-up and clean-up time.

deployment-scaling Test:
Creates a deployment and measures scale-up/down latency. First, a deployment with *m* pods is created. Then, the deployment is scaled-up to *n* pods. Once the scale-up is completed, the deployment is scaled-down to *m* pods, again.

*https://github.com/keichi/kbench

Experiment Methodology

For the first set of experiments, the goal is to compare pod start-up/clean-up time in the Kubernetes cluster while all the nodes are either local to the master node or in a different network. So we run the experiments on 8 local nodes at UF (UF-8) versus 8 non-local nodes at NAIST (NAIST-8). Each experiment is executed on 16, 32, and 48 Kubernetes pods for four different-size Docker images:

- Tiny Image: hello-world (1.64kB)
- Small Image: eclipse-mosquitto (4.6MB)
- Medium Image: ubuntu (46.7MB), nginx (97.6MB)
- Large Image: python (708MB)

We repeat the experiments for 3 times and then calculate the average results.

The second set of experiments is similar to the first one, except that it applies to 16 local nodes at UF (UF-16) versus a hybrid setup of 8 local nodes at UF plus 8 non-local nodes at NAIST (UF-NAIST-16).

Contact

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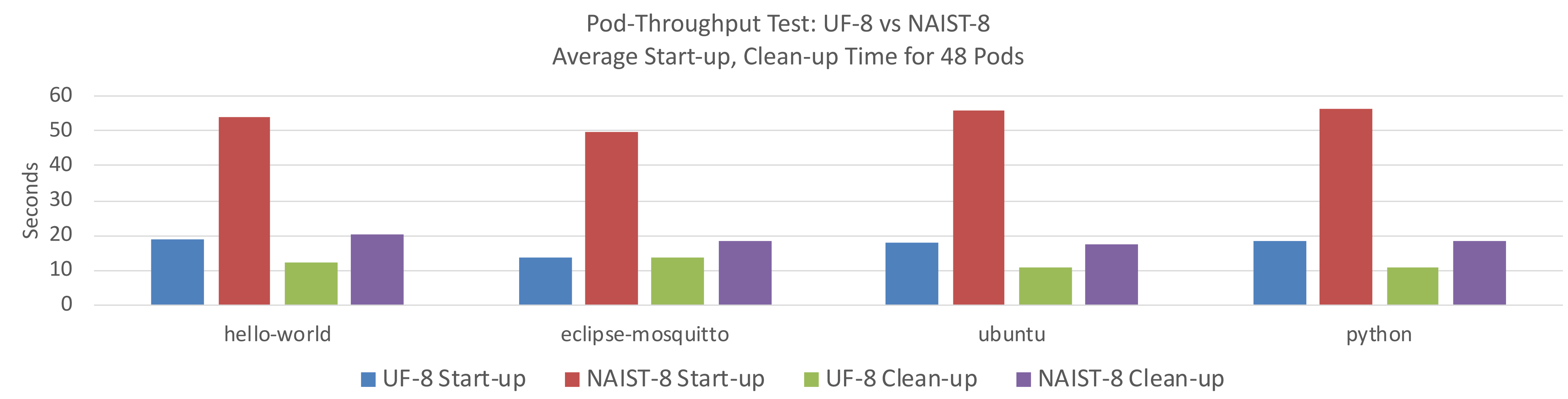
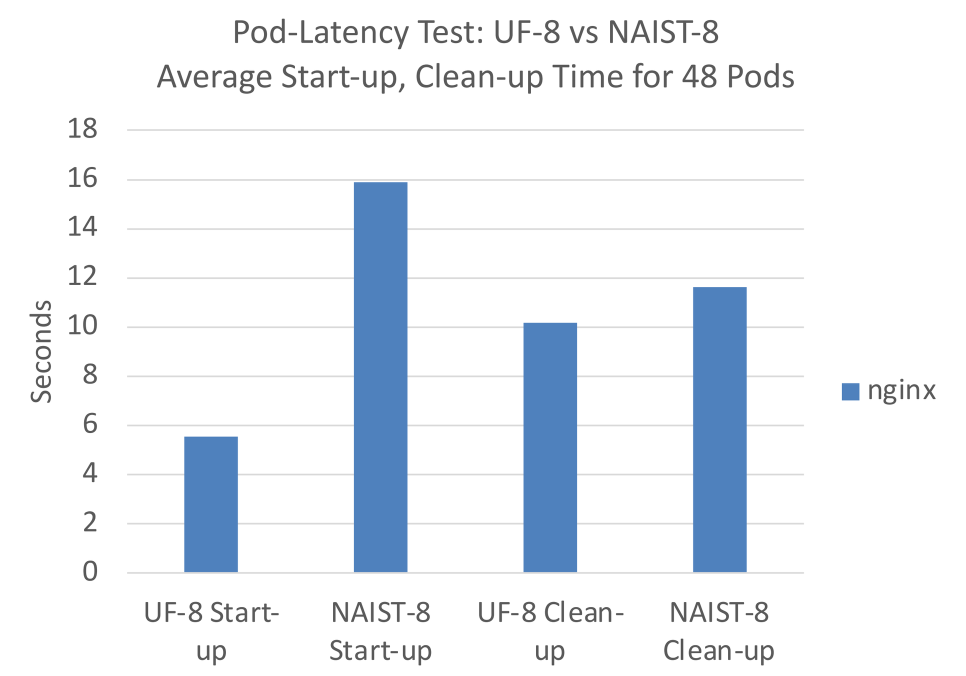
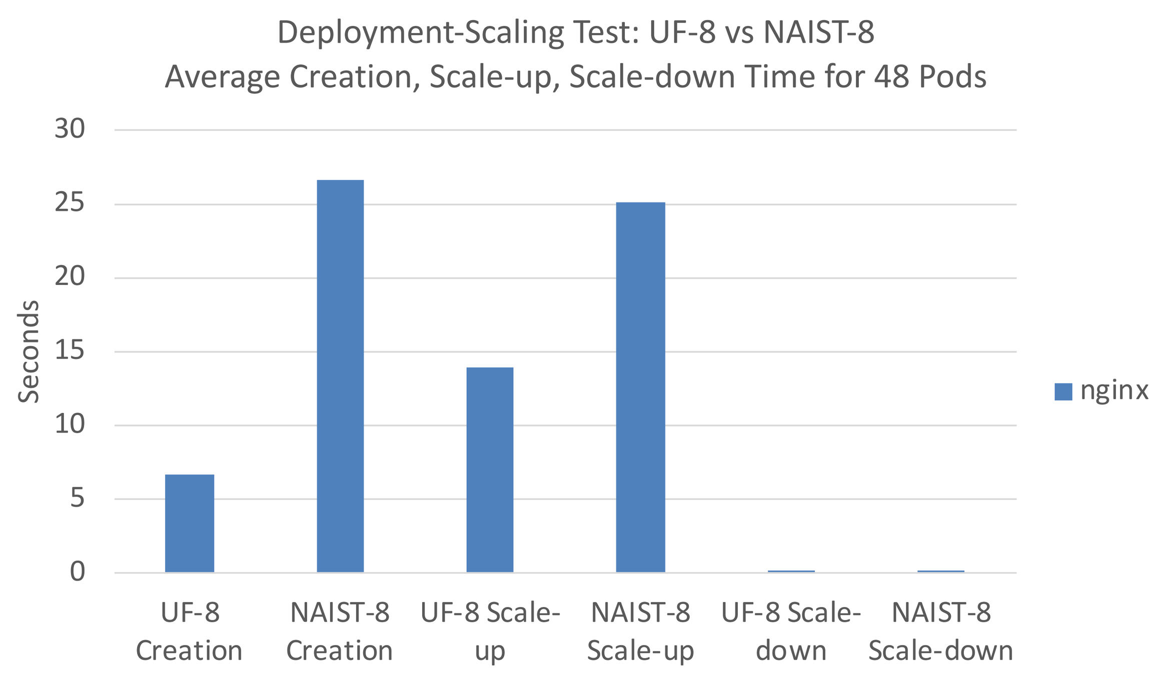
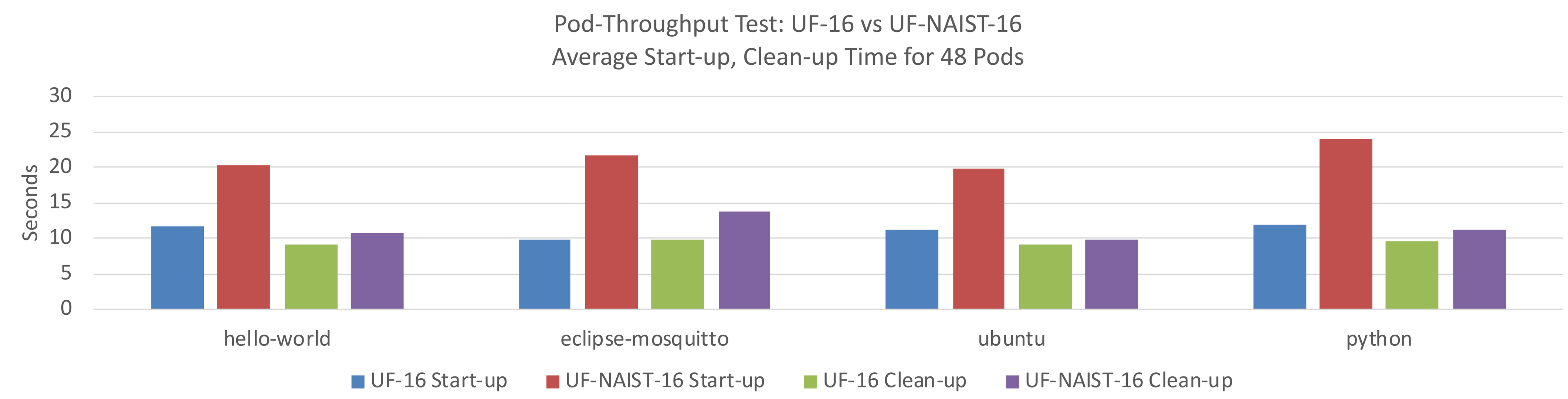
Selected Results – Local vs Non-local Nodes

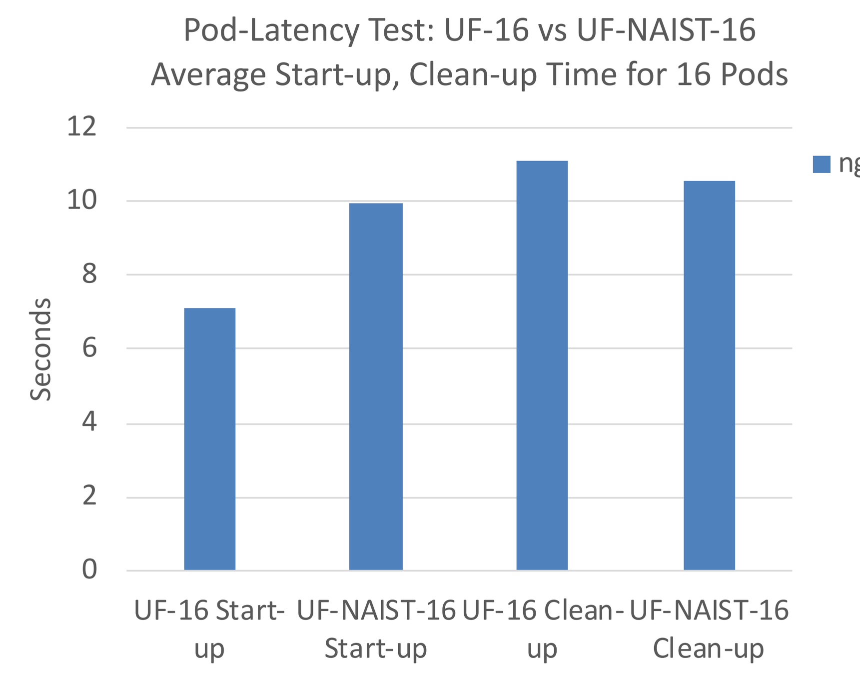


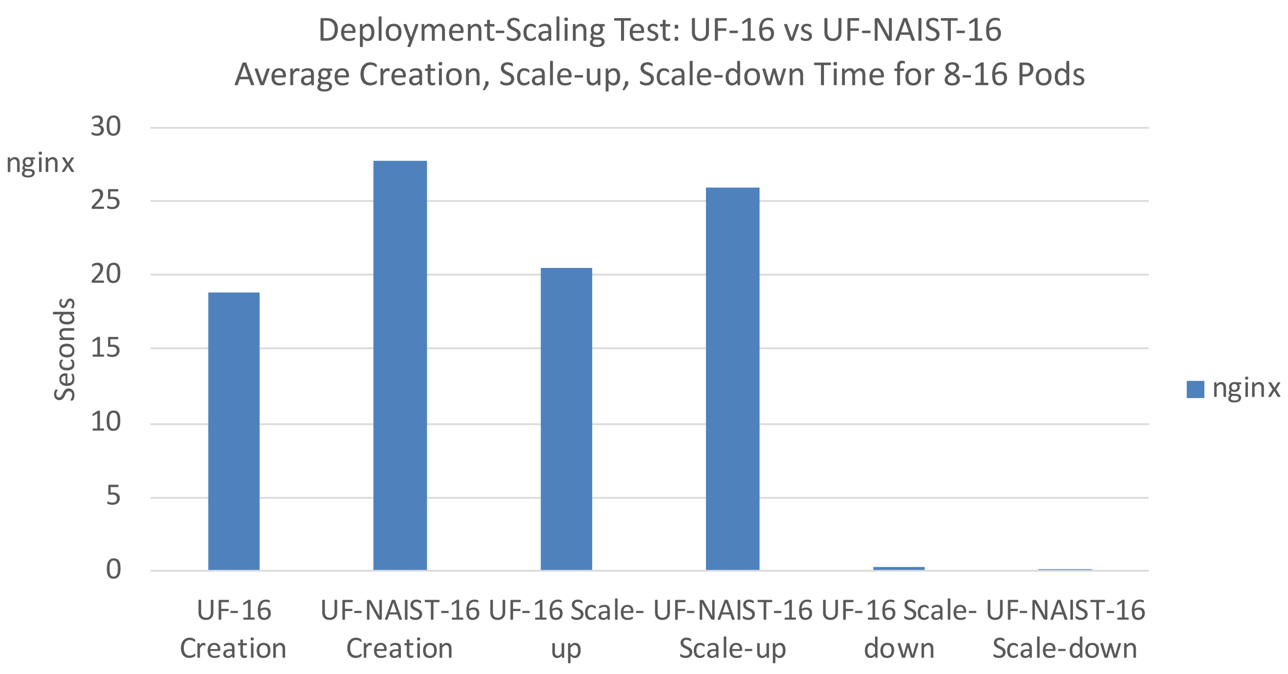




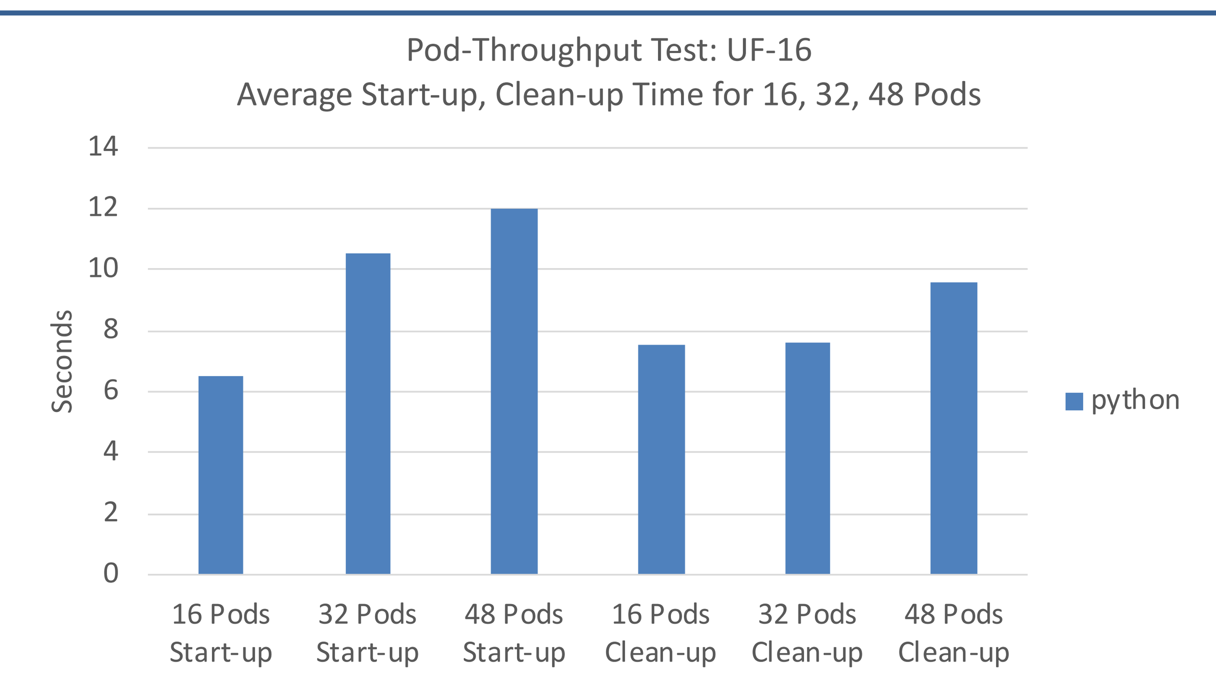
Selected Results – Local Nodes vs Local and Non-local Nodes







Selected Results – Cluster Size Effect



Conclusion

The results show that the average pod start-up time is vastly lower in the Kubernetes cluster when all the nodes are local to the master node compare to the case that the nodes are in a non-local site or distributed among local and non-local sites. For the clean-up time, this difference is much less notable.

While the Docker images are already pulled on the nodes, there is no correlation between the size of the Docker image and the pod start-up and clean-up time.

The average start-up and clean-up time for pods increases with the rise of the total number of pods in the cluster. This growth is more notable for the start-up time than the clean-up time.

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