Chair of Communication Networks
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# Towards Data-Driven Approaches for Network Digital Twins of Microservice-Based Architectures

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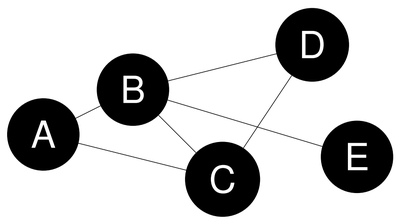
## Motivation

**Web Service**

**Core Network**

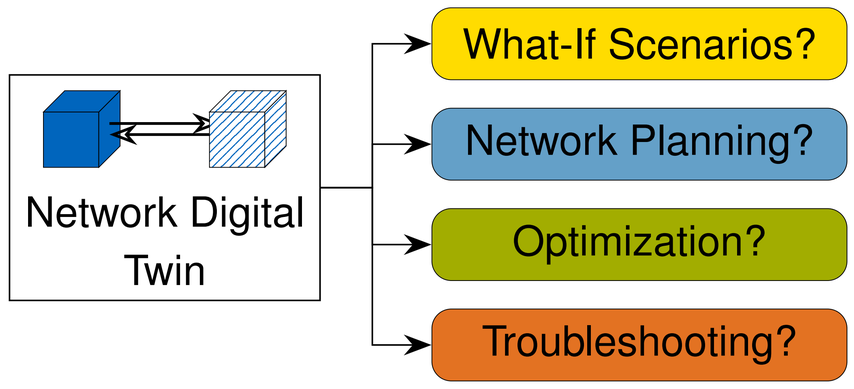
**RAN Intelligent Controller**

*Microservice Architecture*




*Optimized Configuration?*

## Network Digital Twin




Network Digital Twins (NDTs) are a valuable tool for optimizing the configuration of the system. Data-driven NDTs can empower *Autonomous Networks*, which are able to self-configure and self-optimize.

## KAPETÁNIOS: Automated Kubernetes Adaptation through a Digital Twin

KAPETÁNIOS uses a digital twin to gather performance statistics and learn a model for the workload. With the model, the cluster autonomously adjusts HPA parameters.

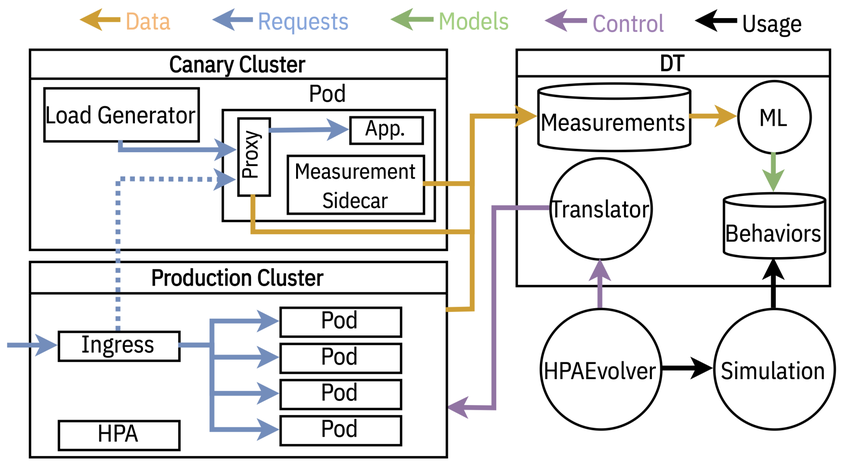



**Figure 1** Major components of KAPETÁNIOS. It consists of five building blocks: Production Cluster, Canary Cluster, Digital Twin, Simulation, and `HPAEvolver`.

**Using KAPETÁNIOS leads to a decrease in the Total Pod Seconds by 37 %, while the request latency stays mostly unaffected.**

## HyPA: Hybrid Horizontal Pod Autoscaling with Automated Model Updates

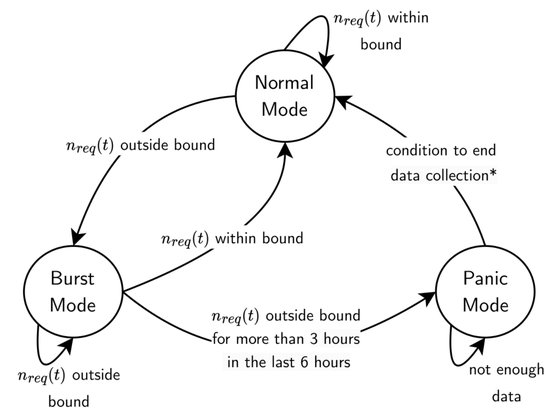



**Figure 2** Hybrid HPA State Machine. HyPA consists of 3 states. Depending on the different conditions specified in the figure, the states, and hence the operation mode of the HPA changes.

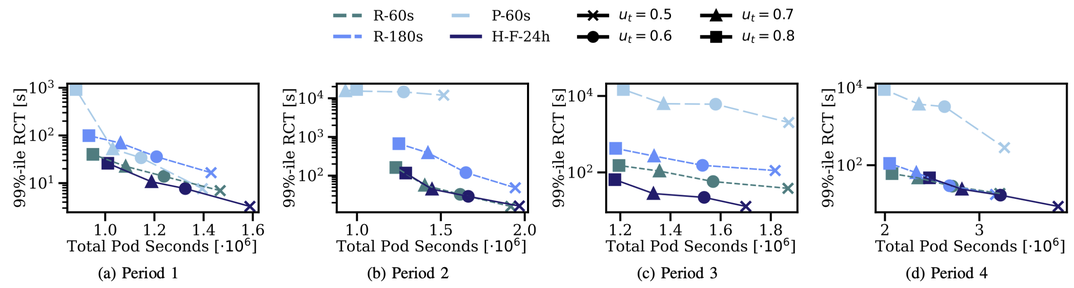
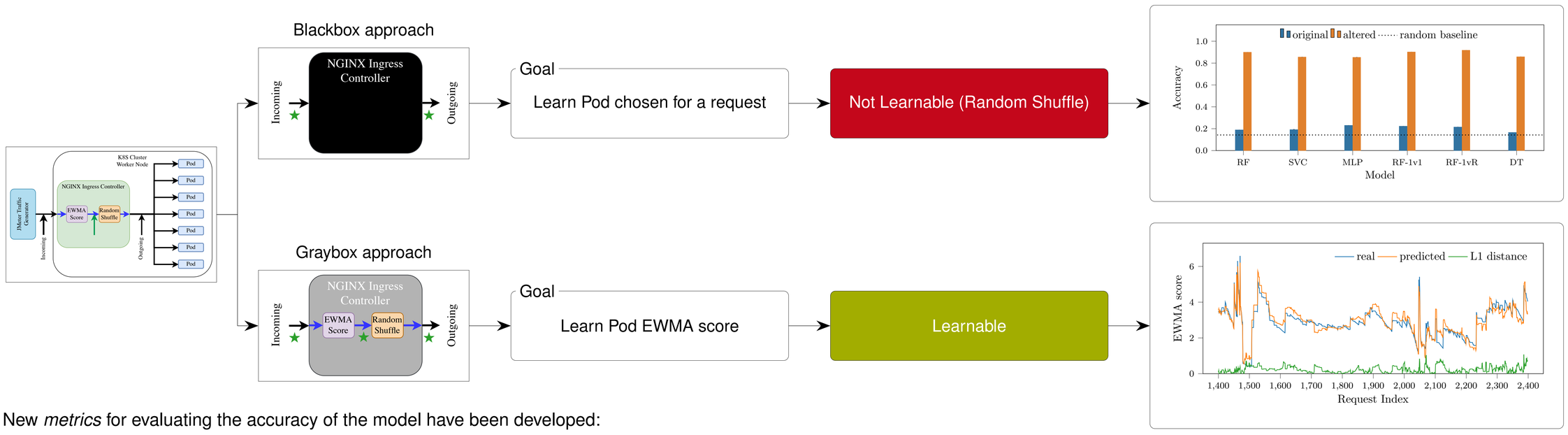



**Figure 3** Pareto-plot of the 99 %-ile RCT vs Total Pod Seconds as performance metrics.

## Towards Digital Network Twins: Can we Machine Learn Network Function Behaviors?




New *metrics* for evaluating the accuracy of the model have been developed:

- The accuracy of having a correct rank. This accuracy measures the percentage of requests for which the inferred ranking position of a pod is identical to the real one. A random ranking leads to an accuracy of ≈ 14.28 %. The accuracy of our DNN model reaches 44.3 % on the Test Dataset.
- The expected error probability in choosing the Pod where to forward the requests. For the Test dataset, the DNN reaches an expected error probability of 17 %, below the random baseline of 50 %.

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[2] Aykurt, K., Ursu, R.M., Zerwas, J., Krämer, P., Asadi, N., Wong, L., Kellerer, W. (2023). HyPA: Hybrid Horizontal Pod Autoscaling with Automated Model Updates. In 2023 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN) (pp. 8-14).
[3] Ursu, R.M., Zerwas, J., Krämer, P., Asadi, N., Rodgers, P., Wong, L., Kellerer, W. (2023). Towards Digital Network Twins: Can we Machine Learn Network Function Behaviors?. In 2023 IEEE 9th International Conference on Network Softwarization (NetSoft) (pp. 438-443).
[4] Hui, L., et al, "Digital Twin for Networking: A Data-driven Performance Modeling Perspective," 2022.

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