Kubernetes for IoT: Seamless Management, Scaling and Application Deployment in IoT-based Environments

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Managing the vast amount of devices and data involved with IoT is one of the main challenges in various domains, such as smart city sensors, intelligent transportation systems, industrial robots, autonomous vehicles[1][2][3]. Scalability along with portability becomes a major obstacle when millions of devices are potentially connected and interacting. With its capacity to autonomously scale systems and down in response to demand, Kubernetes is revolutionizing the Internet of Things by enabling resource management and ensuring optimal performance even as the number of devices increases.

IoT apps may be deployed on any system—edge, local, private, or public—and moved to a different environment as needed with Kubernetes. KubeEdge is an extension of Kubernetes that integrates the container orchestration of Kubernetes with the particular needs of edge computing. It supports many edge protocols and makes it possible to manage edge nodes and devices as part of a Kubernetes cluster, and offers a flexible option for a variety of edge computing applications.

Our innovative work realizes an open-source[i] integrated framework, as shown in Figure 1, involves edge and micro-edge devices seamlessly integrated via extended KubEdge-managed nodes offering:

- Cloud to Edge and Edge to Cloud traffic routing with software multicast support
- Uniformity to manage the heterogeneity of the Leaf-Edge-Devices (LEDs)

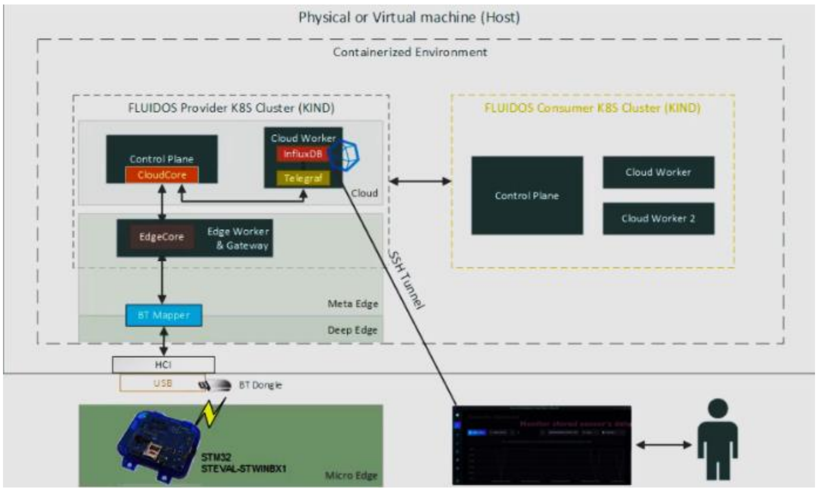

Figure 1. Arcitecture of Kubernetes clusters integrated platform for sensor-data flow management

In particular, this involves a fully automated process tailored for Edge-IoT scenarios. This is achieved using a customized version of KIND, which has been extended to support the deployment of Edge worker nodes as the foundational platform. Following the deployment of the testbed, the novel component *EdgeResourceManager* automatically generates Sensor-type Flavors, derived from the registered devices and the metadata detailing their available sensors. All the required information is acquired by leveraging the Edge API. Once a consumer purchases one or more sensors, the extended *RouterManager*, part of the CloudCore component, is responsible for configuring the KubeEdge Router component to establish data links between the sensor outputs and the consumer's specified target endpoint(s). These endpoints may reside on the provider's or consumer's premises, or on a third-party cloud platform, provided they are accessible to the Router.

The Figure 2 next illustrates such a scenario, in which the consumer has allocated sensor data from two Micro Edge devices. The data is forwarded to two distinct target endpoints, corresponding to the consumer's requirements as defined in the established contract by the two clusters.

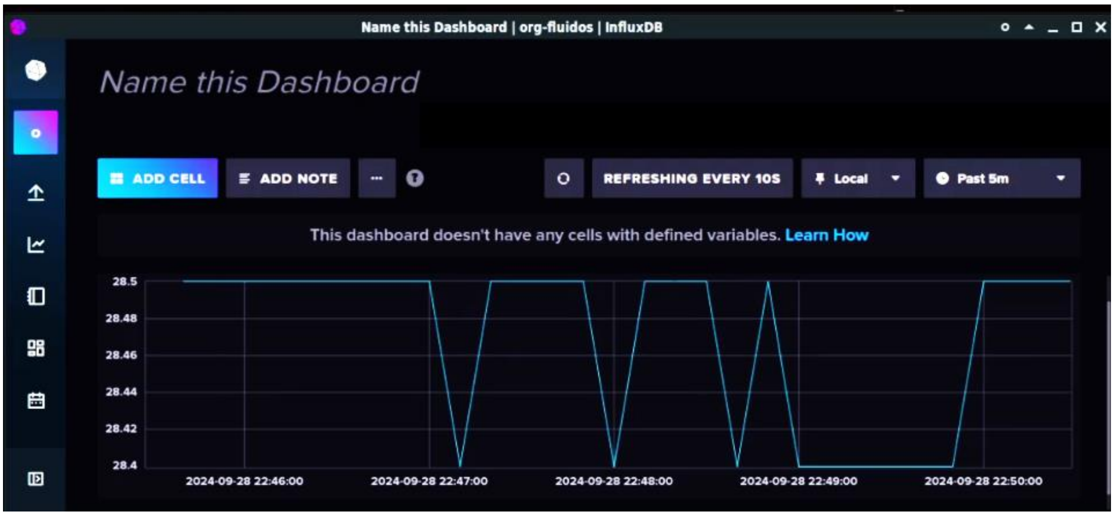

Figure 2. Sensor data captured by deployed application over the integrated KubeEdge/KIND platform

Overall, this novel approach facilitates dynamic collaboration and the best possible use of existing capabilities by connecting users who want to run code on these third parties' resources. By providing access to a range of edge resources and guaranteeing security and adaptability, we revolutionize the deployment and management of applications while satisfying the unique requirements of users in an environment that is becoming more interconnected. This strategy may not only increase operational effectiveness but also spur innovation across other industries, increasing the accessibility and applicability of edge computing technology.

Acknowledgment

This work was supported in part by the European Union (EU) Horizon 2020 Project FLUIDOS (Flexible, scaLable, secUre, and decentralIseD Operating System) under GA No. 101070473

References

[1] S. Dustdar, V. C. Pujol, and P. K. Donta, "On distributed computing continuum systems," IEEE Transactions on Knowledge and Data Engineering, vol. 35, no. 4, pp. 4092–4105, 2023

[2] C. Figueroa, T. Knowles, V. Kukreja and C. -H. Lung, "IoT Management with Container Orchestration," 2023 IEEE 3rd International Conference on Electronic Communications, Internet of Things and Big Data (ICEIB), 2023, pp. 49-54

[3] M. AlSelek, J. M. Alcaraz-Calero and Q. Wang, "Agile AI and Firmware Management in IoT: DevOps for Low-Power Microcontroller-Based Platforms," 2024 9th International Conference on Smart and Sustainable Technologies (SpliTech), Bol and Split, Croatia, 2024, pp. 1-6, doi: 10.23919/SpliTech61897.2024.10612585.

[i] https://github.com/fluidos-project/fluidos-edge