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An Efficient Distributed Storage Solution for Edge Computing Environments

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Outline

- CHARITY Project
- Edge Computing
- Challenges
- Requirements
- Objective
- System Architecture
- Dynamic Lifecycle Framework
- Conclusions

CHARITY - Challenges

From a network standpoint, XR services define a new class of services where best-effort and simple traffic differentiation approaches are insufficient to meet their strict requirements:

- ultra low latency
- extremely large bandwidth
- huge data processing power

To enable a satisfactory user experience, the requirements for the computing platform and its underlying network can be considered extreme and far from what can be attainable today.

CHARITY - Vision and main goal

https://www.charity-project.eu/en

CHARITY aspires to leverage the benefits of intelligent, autonomous orchestration of cloud, edge, and network resources

- to create a symbiotic relationship between low and high latency infrastructures that will facilitate the needs of emerging applications

Edge Computing

Due to the continuous development of Internet of Things (IoT), the volume of the data these devices generate are expected to grow dramatically in the future.

- As a result, managing and processing such massive data amounts at the edge becomes a vital issue

Edge computing moves data and computation closer to the client enabling latency- and bandwidth-sensitive applications, that would not be feasible using cloud and remote processing alone.

Challenges

One of the main challenges in the development of applications at the edge is the efficient data sharing between the edge nodes

- it can be accomplished within individual application frameworks or through an external storage service

Implementing an efficient edge-enabled storage system is challenging due to the distributed and heterogeneous nature of the edge and its limited resource capabilities.

Challenges at the Edge

Edge nodes generally have limited computation, storage, network, or power resources. The edge storage component needs to overcome some inherent edge challenges like:

- coordination of unreliable devices and network in the edge
- hardware and software incompatibilities that arise due to the plethora of different devices
- mobility of the devices and the users
- integration of different data storage formats and data types
- limited resources of the edge devices
- security and privacy concerns
- QoE insurance

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Objective

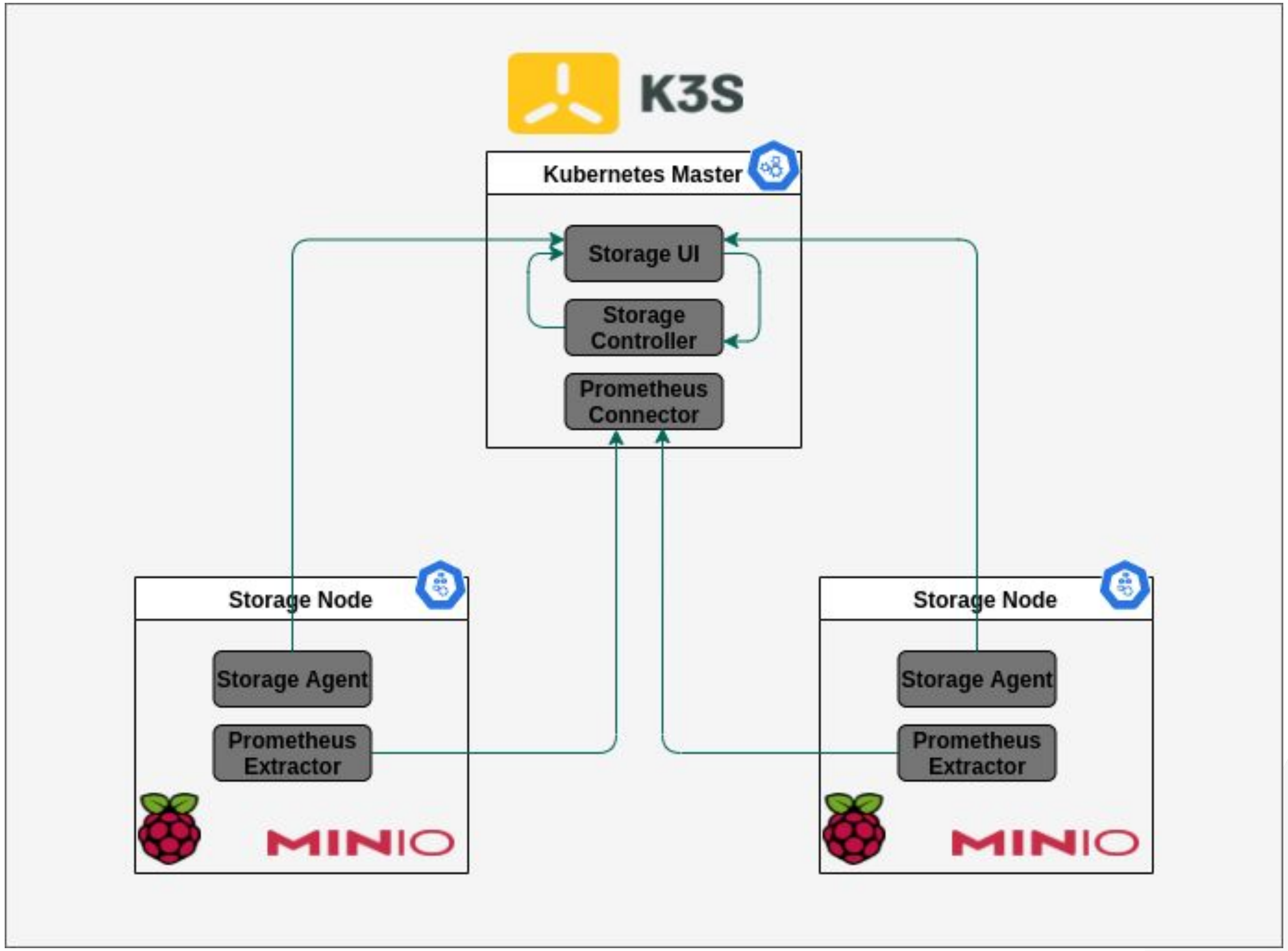
To implement a hybrid distributed edge storage framework spread across heterogeneous edge and cloud nodes, with **intelligent decisions** on **data placement, data caching** and considerations on **performance** and **security**, emphasizing on the resolution of the problem of data distribution and offloading based on application's requirements.

Research Directions

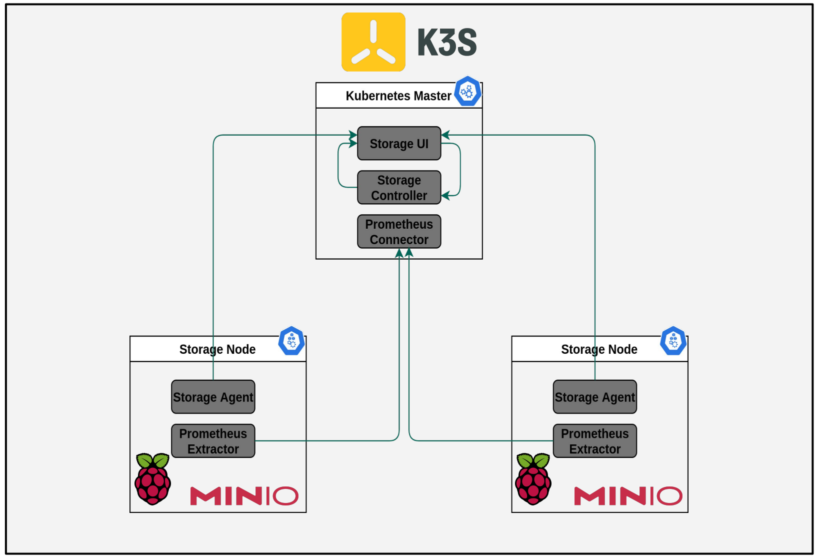
Our research revolves around some decisions we need to take in order to design an edge storage system:

- storage type
- storage system
- system architecture i.e. both the physical and the software architecture

System Architecture



“edge clouds”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Kubernetes Master
Storage UI
Storage Controller
Prometheus Connector
Storage Node
Storage Agent
Prometheus Extractor
MINIO
Storage Node
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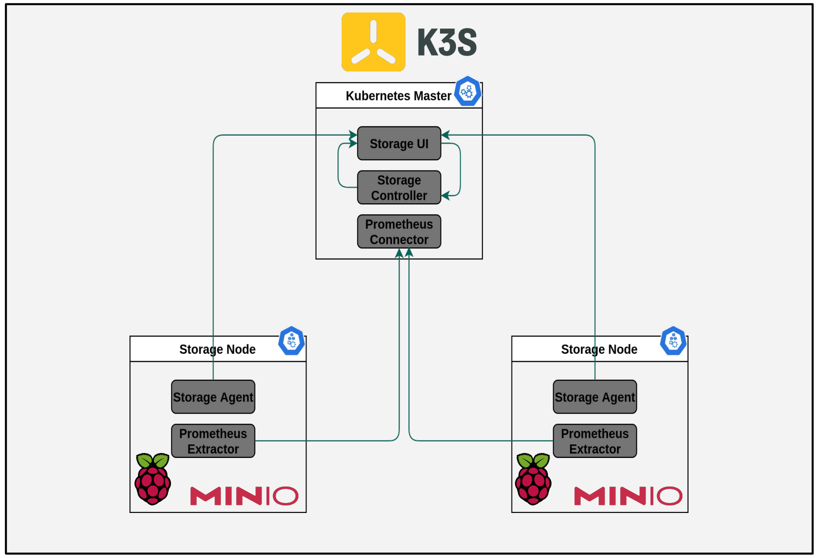
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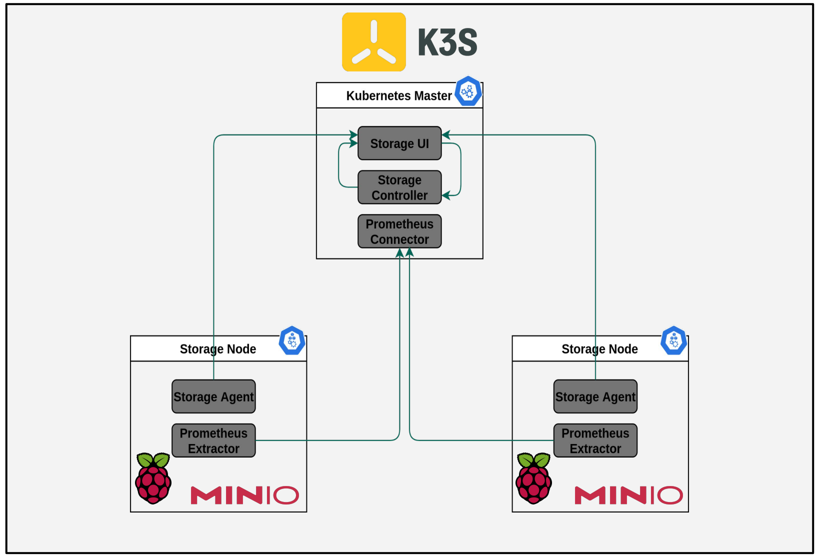
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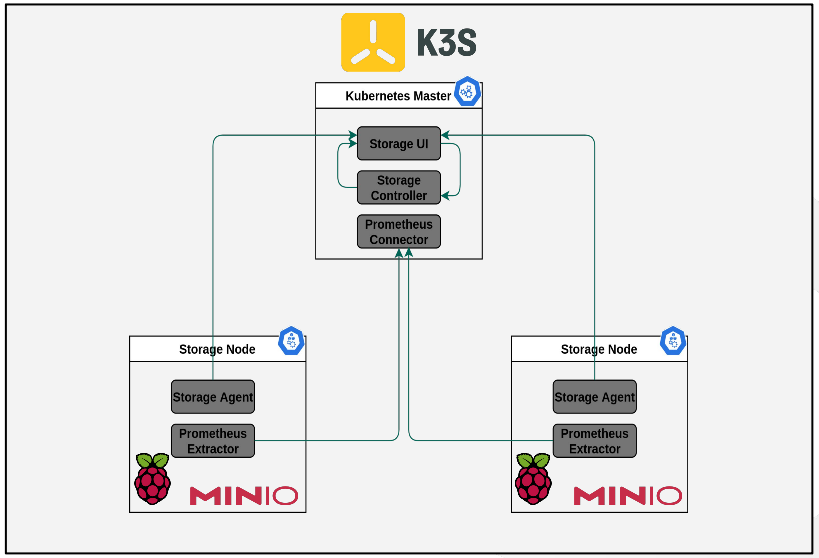
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Hybrid Edge/Cloud environment

Hybrid Edge/Cloud environment is rapidly becoming the new trend for organizations seeking the perfect mix of scalability, performance and security

- it is now common for an organization to rely on a mix of on-premises data-centers (private Cloud), and Cloud/Edge solutions from different providers to store and manage their data

Obstacles

- Developers need to know the exact location of the data and manage the correct credentials to access the specified data-sources holding their data
- Containerization makes it more difficult for the workloads to access the shared file systems
- Access to Cloud/Edge storage is often completely transparent from the cloud management standpoint and it is difficult for infrastructure administrators to monitor which containers are accessing which cloud storage solution

Dataset Lifecycle Framework (DLF)

A Kubernetes framework which enables transparent and automated access to remote data sources via a mount-point within their containerized workloads.

It is aimed to improve usability, security and performance with a higher level construct:

- **Dataset**, implemented as a CRD*. Each Dataset is a pointer to an existing remote data source and is materialized as a PVC object.

On the infrastructure side enables cluster administrators to easily monitor, control, and audit data access.

* Kubernetes enables service providers to define their own Custom Resource Definitions (CRD) to bring the domain-specific logic they desire to their Kubernetes managed infrastructure.

Dataset CRD - Dataset Operator

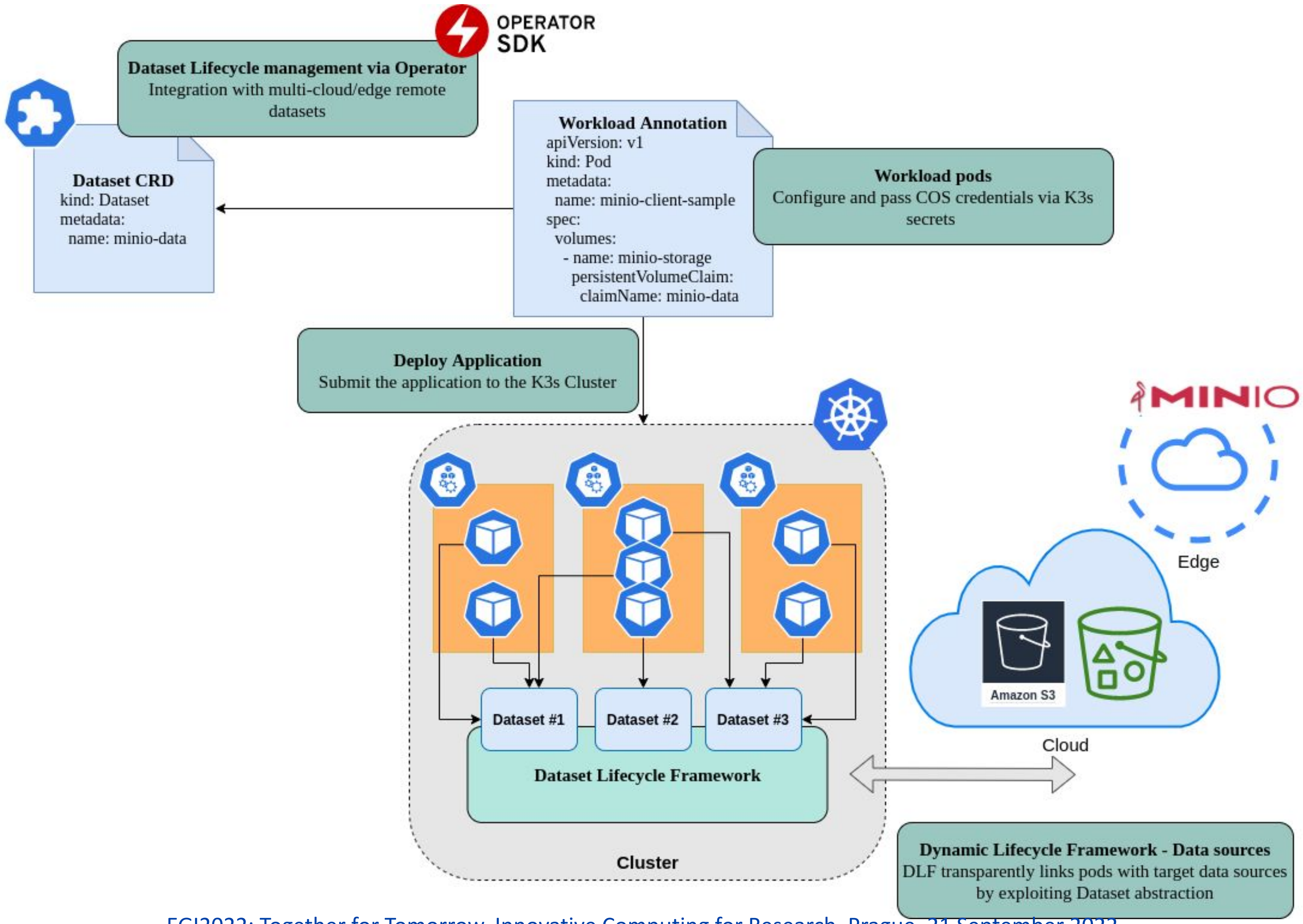
Dataset object is a reference to a storage provided by a cloud-based storage solution, potentially populated with pre-existing data.

```
k3s kubectl apply -f -
apiVersion: com.ie.ibm.hpsys/v1alpha1
kind: Dataset
metadata:
  name: minio-data
spec:
  local:
    type: "COS"
    accessKeyID: "$acesKeyDecoded"
    secretAccessKey: "$acesSecretDecoded"
    endpoint: "$minio_endpoint"
    bucket: "$bucketName"
    readonly: "false"
```

Open source operator-sdk provides the necessary tooling and automation to assist in the development of these components.

Its main functionality is to react to the creation of a new Dataset and materialize the specific object.

DLF - Overall Approach



Conclusions

The distributed and heterogeneous nature of the edge and its limited resource capabilities pose challenges in implementing an efficient edge storage system.

A hybrid distributed edge storage component which aims at improving the QoE of end users by migrating data “close” to them and ultimately reducing data transfer time and network utilization.

The Dynamic Lifecycle Framework is utilized in order to enable transparent and automated access for containerized applications via mount-points to remote workloads.

- File Sharing and Live Syncing
- Real time connection of S3 storage and Kubernetes PVCs
- Filesystem support with shared mounting

The effectiveness of the proposed edge storage component is evaluated by employing a number of QoS and resource utilization metrics:

- the lightweight nature of the storage component, making it a perfect fit for edge device deployments
- the great reduction in data request response times, which on some edge use cases is a necessity for their basic functionality

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Thank you for your attention!

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