INTELLIGENCE IN ACTION: AI-DRIVEN NETWORKS

M2. Project inception and lifecycle architecture

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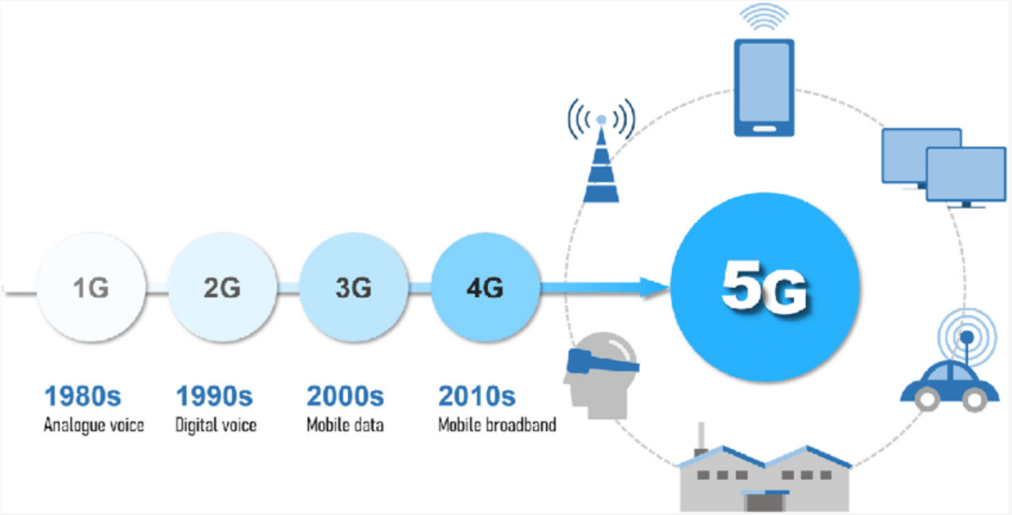
TABLE OF CONTENTS

1. CONTEXT

Networks have evolved significantly from traditional static infrastructures to more dynamic, intelligent, and adaptive systems.

5G and Beyond-5G networks must:
- handle vast amounts of data.
- support a diverse range of applications.
- ensure high reliability and low latency.

Goal: Achieve self-managing networks, where human intervention is minimized.

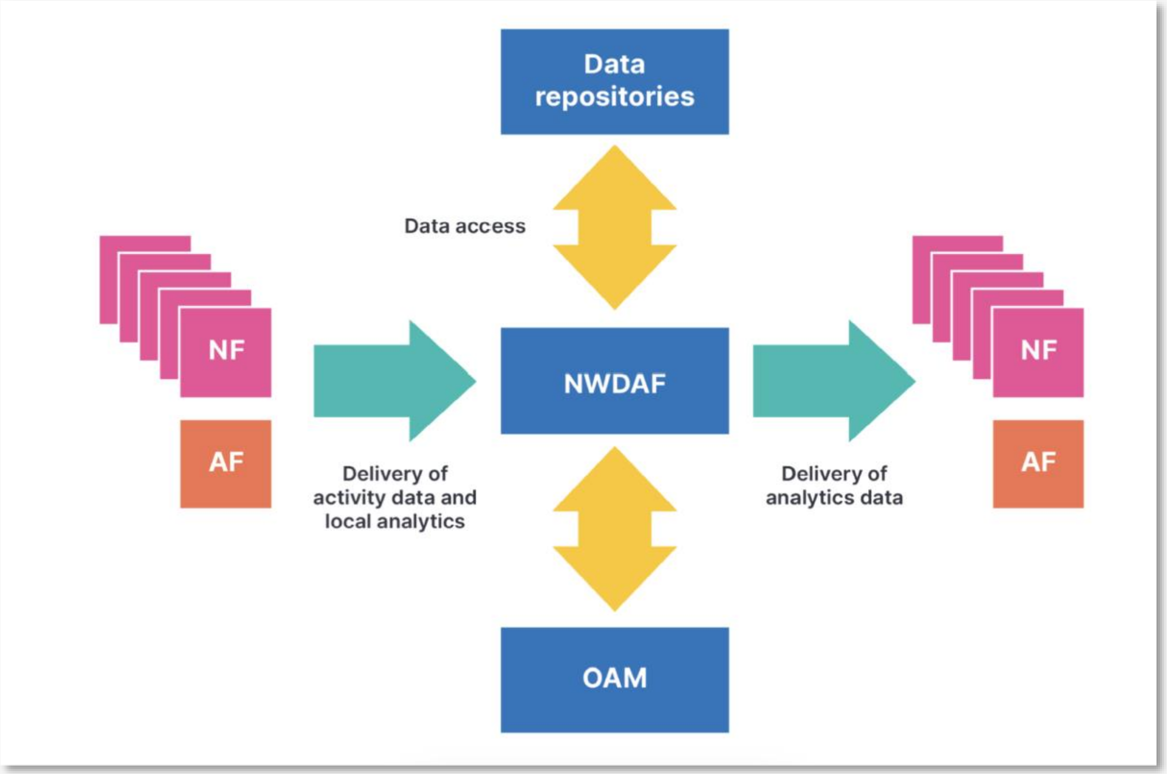


NWDAF

Network Data Analytics Function
- collecting and analyzing network data
- provide predictions for network optimization

Has three main aspects:
- Data Collection
- Analytics Processing
- Analytics Exposure

Goal: Automating the 5G network with machine learning and data analytics



2. State of Art

- Machine learning was employed to detect abnormal traffic patterns and potential DDoS attacks. [1]
- The ability of NWDAF to collect data from a 5G network and detect abnormal traffic. [1]
- Neural networks perform better in network load prediction than linear regression. [2]
- The load data of network components can be used for anomaly detection. [3]

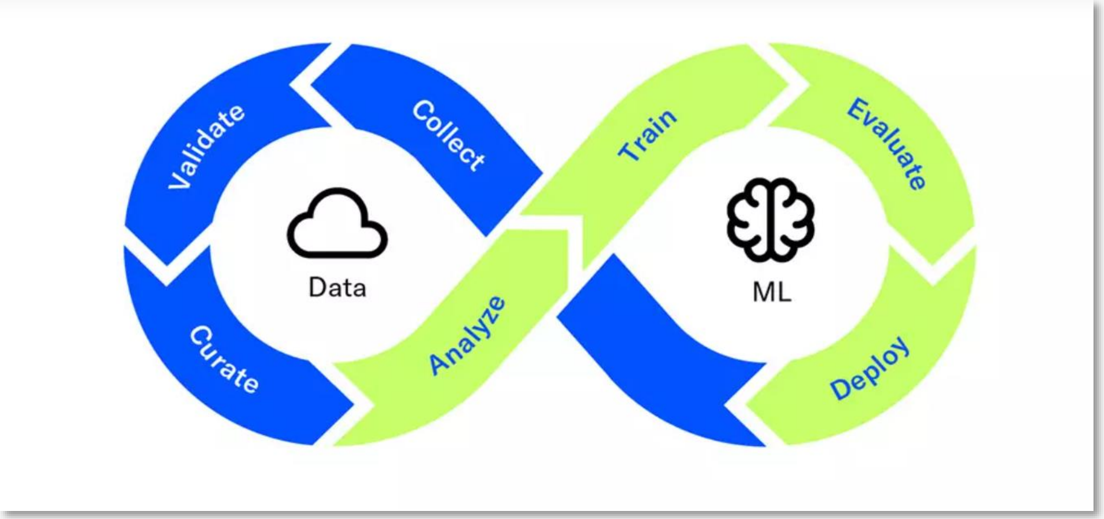
MLOps Pipeline

MLOps is an extension of DevOps, specifically adapted for machine learning workflows.

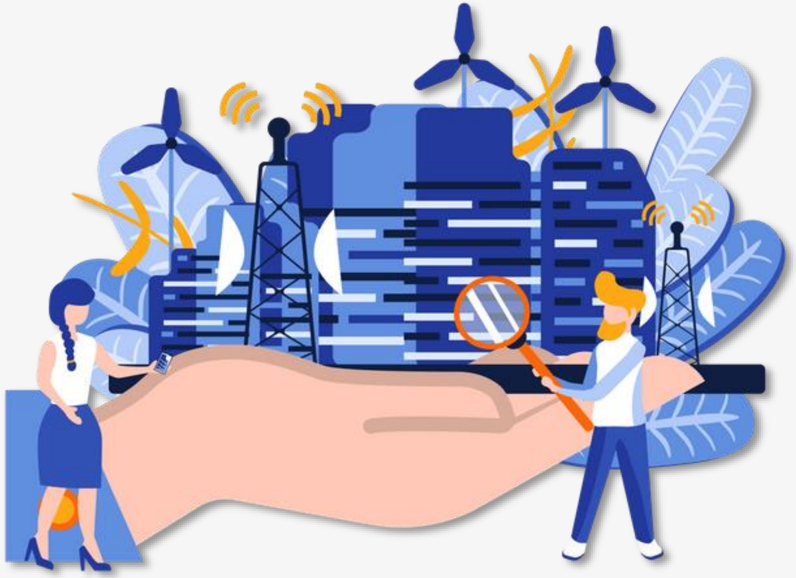
End-to-end machine learning development process.

Aims to unify the release cycle for machine learning.

Enables the application of agile principles to machine learning projects.



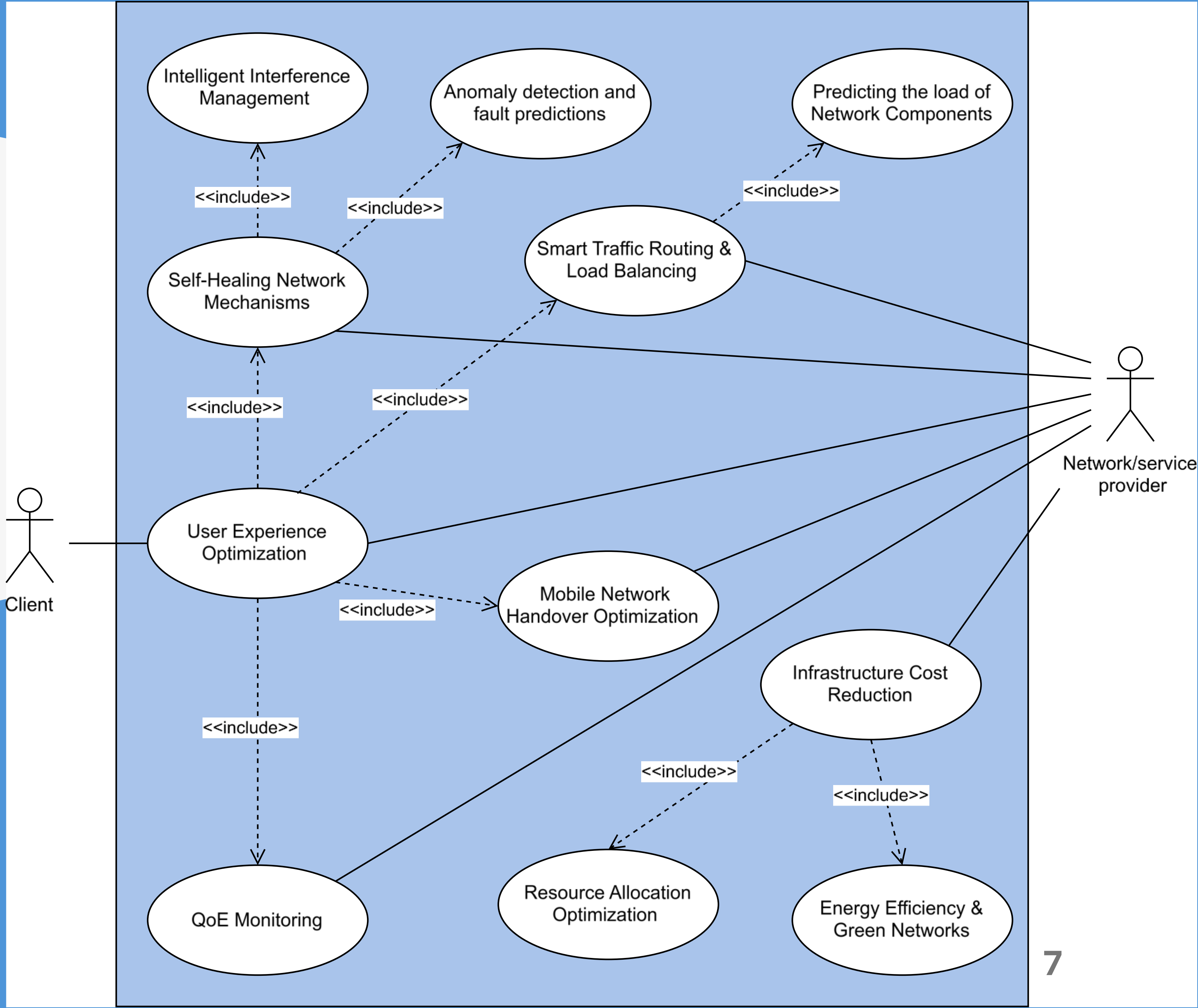
3. Actors



Network/service provider

Service Client

4. Use Cases



Intelligent Interference Management
Anomaly detection and fault predictions
Predicting the load of Network Components
<<include>>
<<include>>
<<include>>
Smart Traffic Routing & Load Balancing
Self-Healing Network Mechanisms
<<include>>
<<include>>
Network/service provider
Client
User Experience Optimization
Mobile Network Handover Optimization
<<include>>
Infrastructure Cost Reduction
<<include>>
<<include>>
<<include>>
QoE Monitoring
Resource Allocation Optimization
Energy Efficiency & Green Networks

UC: Anomaly Detection & Fault Prediction

Detect abnormal patterns in network behavior.

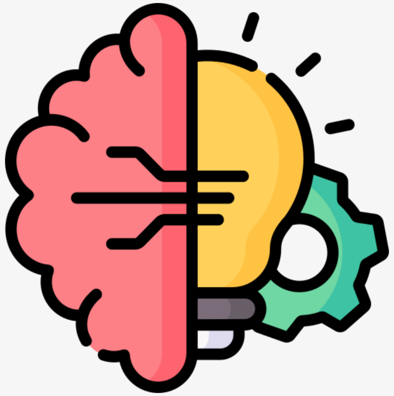
Predict failures before they occur.

Provide actionable recommendations to prevent service disruptions.

Real-life scenario:
A smart manufacturing facility.

5. Requirements Elicitation

Telecommunications and
5G research



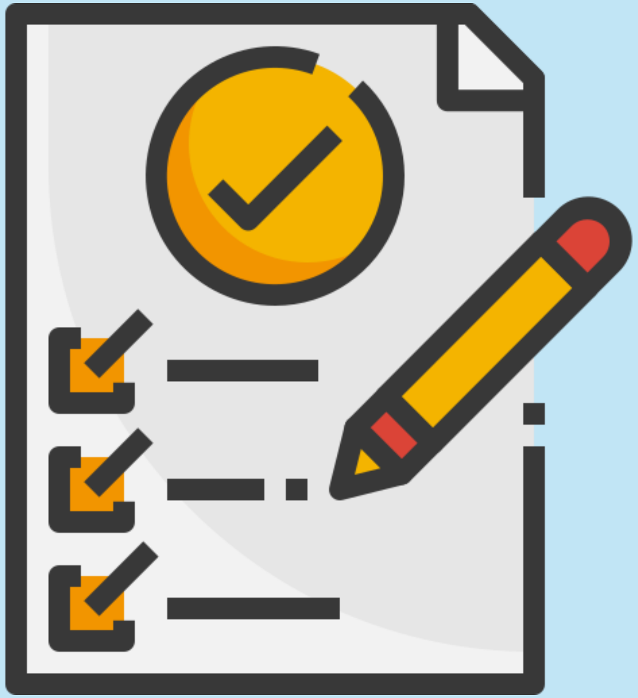
Machine Learning
research

State-of-art

Team brainstorming

Functional Requirements

- Data Collection
- Model
- Monitoring Dashboard
- External Integration



The system must...

Data Collection

- Support JSON and CSV data formats.

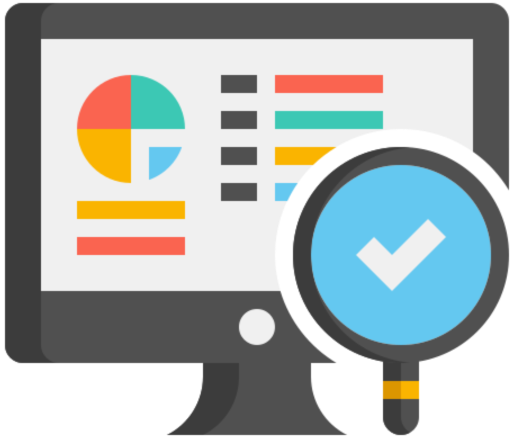
- Collect and store raw data in a time series data base.

- Perform data pre-processing (cleaning, normalization, and aggregation).

Model

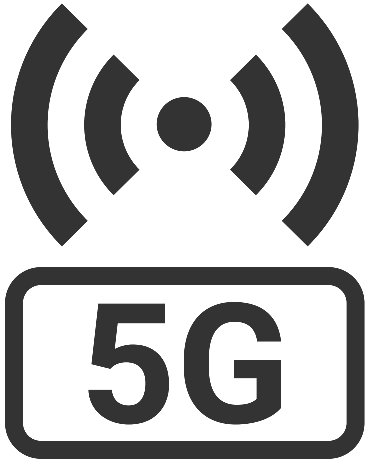
- Allow model training with stored data.
- Implement automation in model training, supporting continuous re-training based on new data or data drift.
- Validate and test the models using the obtained metrics.
- Continuous model deployment mechanisms.

Monitoring Dashboard



- Show anomaly alerts.
- Show relevant metrics,

External Integration



- Provide APIs so that external functions can subscribe to events.
- Enable compliance with 5G architecture standards.

Non-Functional Requirements

- Scalability
- Interoperability
- Performance
- Security
- Maintainability

Non-Functional Requirements

Scalability

- The system must efficiently process large volumes of data with a maximum processing latency of 100 milliseconds.

Interoperability

- The system must be interoperable, making available APIs and adopting machine learning frameworks.

Non-Functional Requirements

Performance

- To support real-time analytics, data processing should have minimal latency and a response time inferior to 1 millisecond.
- ML inference APIs should provide responses within 1 millisecond for fast decision-making.

Security

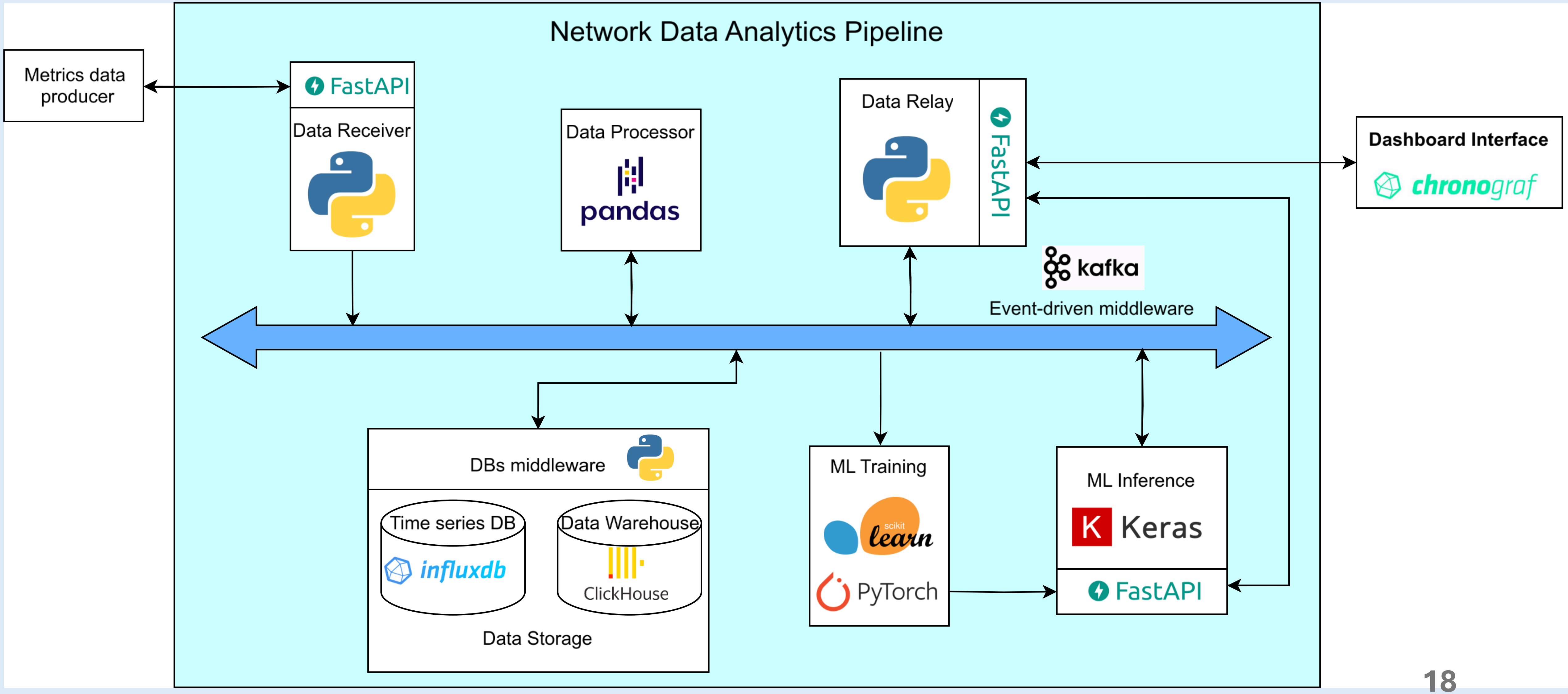
- The system must be GDPR compliant and keep all data on-premise.

Non-Functional Requirements

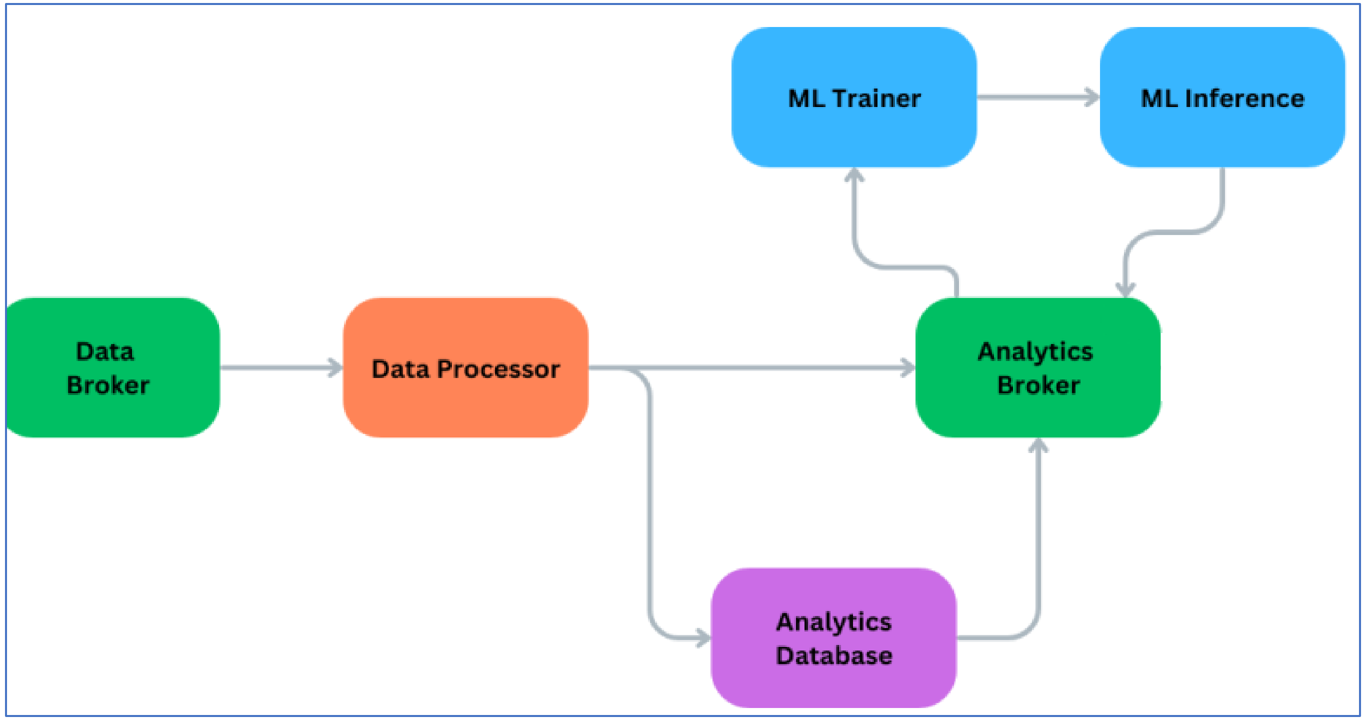
Maintainability

- The system should use modular components to allow easy updates and debugging.
- The system must allow modules to be replaced by others with higher performance, with minimal impact on other modules.
- The system must be easily adaptable for deployment in several network environments.
- The system must follow good MLOps practices, guaranteeing modularity, reproducibility and complete automation of the ML lifecycle.

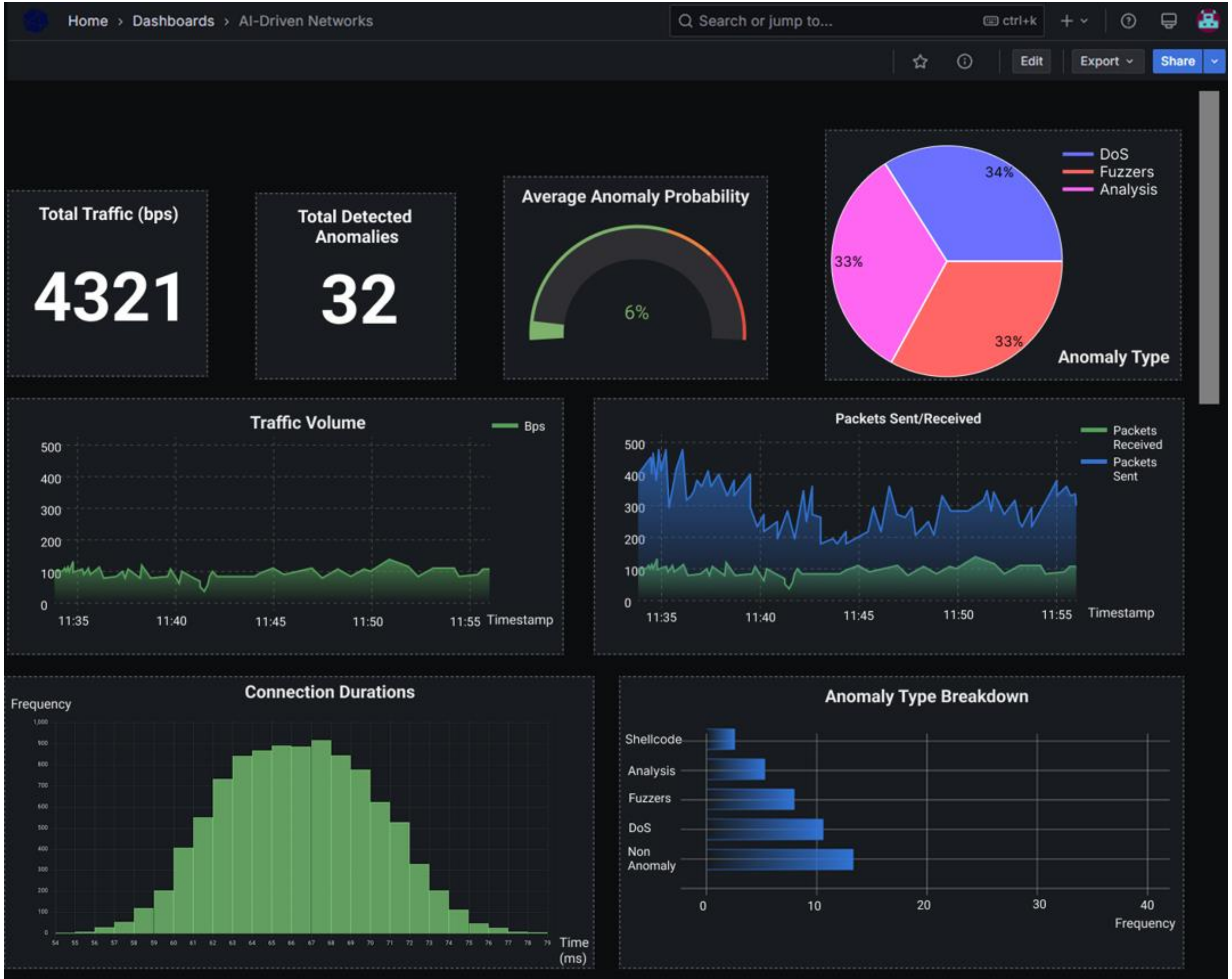
6. System Architecture



Deployment


ML Trainer
ML Inference
Data Broker
Data Processor
Analytics Broker
Analytics Database

7. DASHBOARD MOCKUP - I



7. DASHBOARD MOCKUP - II

chronograf

High-Risk IPs & Services

Rank	IP	Number Anomalies	Risk Level	Rank	IP	Number Anomalies	Risk Level
1°	192.168.1.10	25	Severe	5°	192.168.1.10	7	Low
2°	172.16.1.5	13	High	6°	172.16.1.5	7	Low
3°	192.168.1.10	7	Low	7°	192.168.1.10	7	Low
4°	172.16.1.5	7	Low	8°	172.16.1.5	7	Low

7. DASHBOARD MOCKUP - III

chronograf

Anomaly Events Table

Timestamp	Source IP	Destination IP	Protocol	Anomaly Type	Confidence Score	Action Taken	Severity
2025-03-08 12:30	192.168.1.10	10.0.0.5	TCP	DDoS	79%	Deny Service	🔴 Extreme
2025-03-08 12:33	172.16.1.5	8.8.4.4	TCP	Login Faliure	97%	None	🔵 Low
2025-03-08 12:30	192.168.1.10	10.0.0.5	TCP	DDoS	79%	Deny Service	🔴 Extreme
2025-03-08 12:33	172.16.1.5	8.8.4.4	TCP	Login Faliure	97%	None	🔵 Low

Scan the QR code to check our documentation website.

Let's Start!

Or click here.

THANK YOU

References

[1]
A. Mekrache, K. Boutiba, and A. Ksentini, "Combining Network Data Analytics Function and Machine Learning for Abnormal Traffic Detection in Beyond 5G," *GLOBECOM 2023 - 2023 IEEE Global Communications Conference*, Dec. 2023, https://doi.org/10.1109/globecom54140.2023.10436766.

[2]
N. Nisha, Lakshman K, and R. Kumar, "A Smart Data Analytics System Generating for 5G N/W System Via ML Based Algorithms for the Better Communications," Apr. 2024, https://doi.org/10.1109/istems60181.2024.10560068.

[3]
Rui Cruz Ferreira *et al.*, "Demo: Enhancing Network Performance based on 5G Network Function and Slice Load Analysis," Jun. 2023, https://doi.org/10.1109/wowmom57956.2023.00057.