INTELLIGENCE IN ACTION: AI-DRIVEN NETWORKS

M4. Final Presentation;

Projeto em Informática 2024/2025

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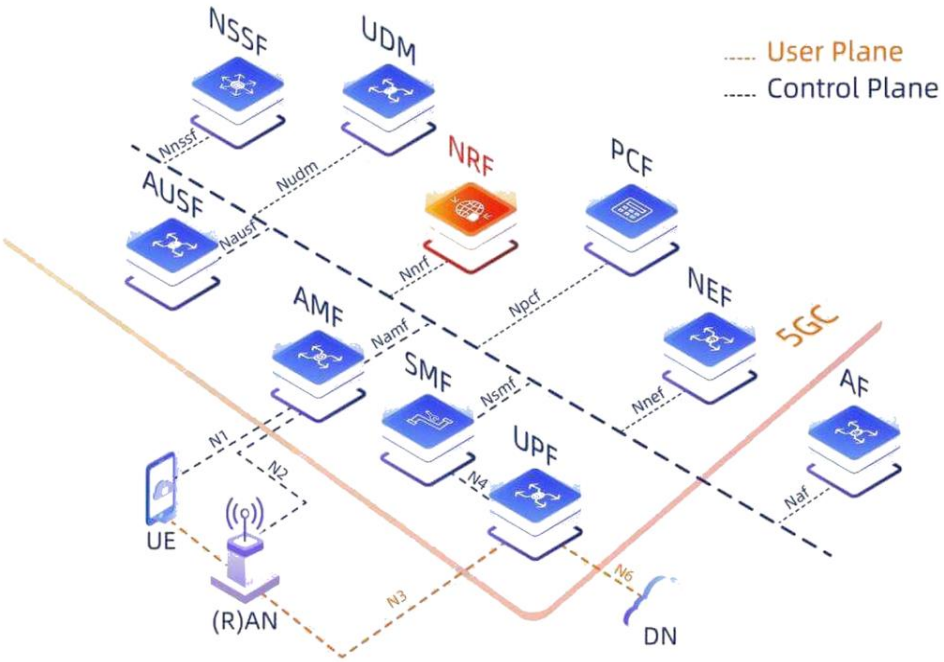
1. Context

- Modern mobile networks are more complex than ever.
- We need smart tools to manage and optimize them.
- For network operators this means faster decisions with lower human intervention.
- NWDAF is a 5G core component that is at the center of this change in paradigm from human-managed to self-managed networks.
- It leverages MLOps to predict network behavior and exposes various data through 3GPP standardized APIs.



2. State of Art

- Papers [1],[2],[3] emphasize ML capabilities but do not address full ML lifecycle management (CI/CD, retraining).

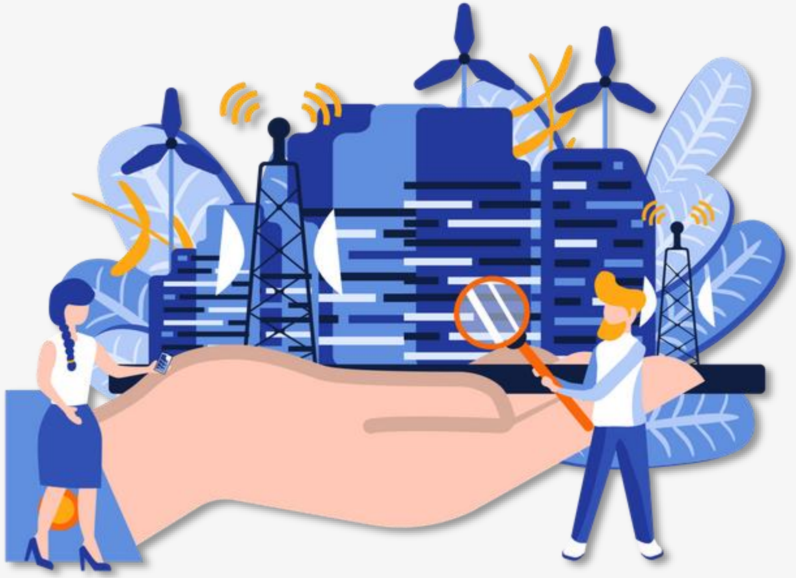
- Papers do not explore how models adapt to changing data (model drift).

- A gap exists between theoretical ML solutions and practical, deployable AI-driven network functions.

- nProbe has emerged as an efficient flow exporter capable of generating suitable features for ML-based network analysis [4].

- There is no proof-of-concept that demonstrates how to operationalize ML pipelines (MLOps) in a NWDAF-like system.

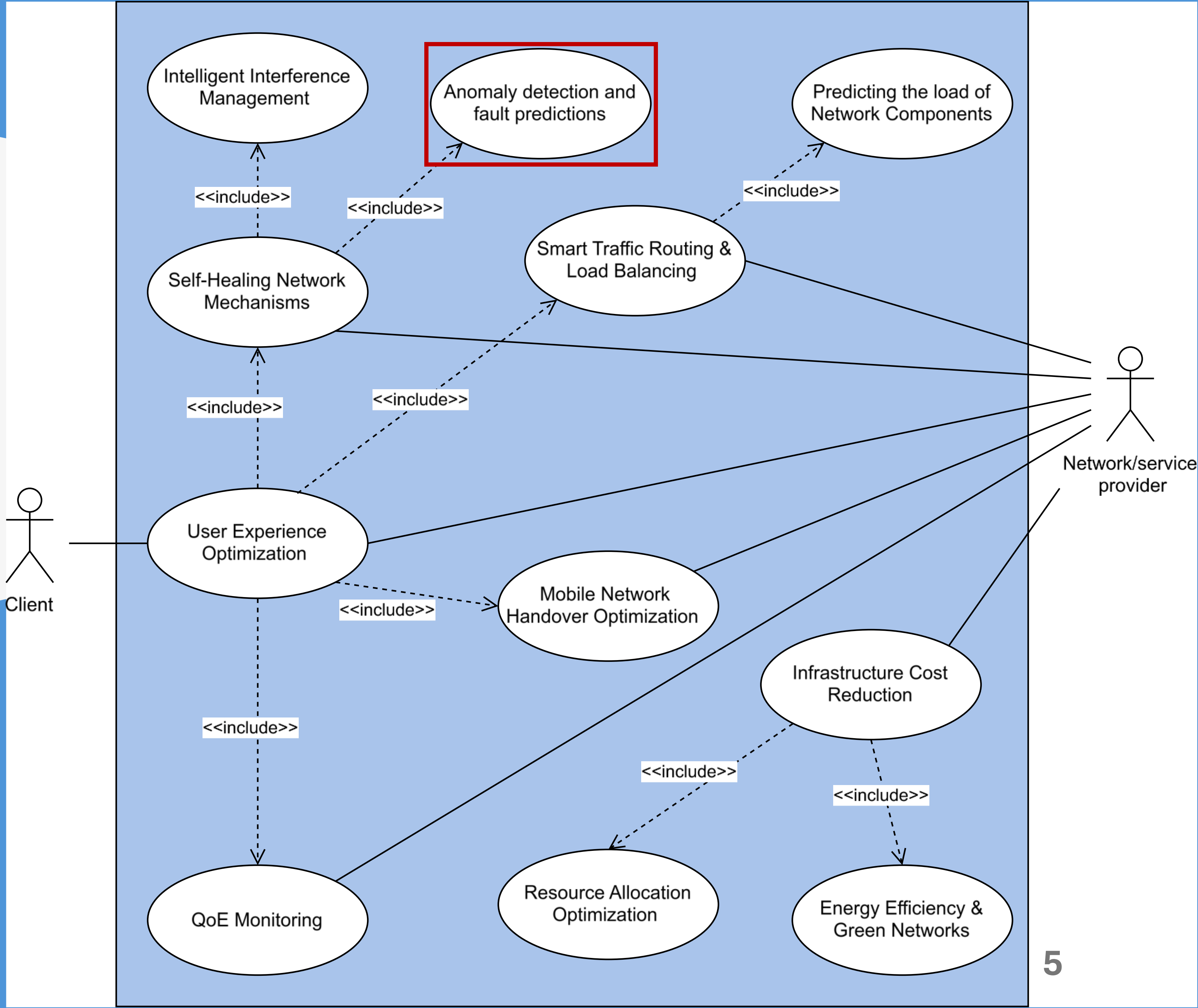
3. Actors



Network/service provider

Service Client

4. Use Cases



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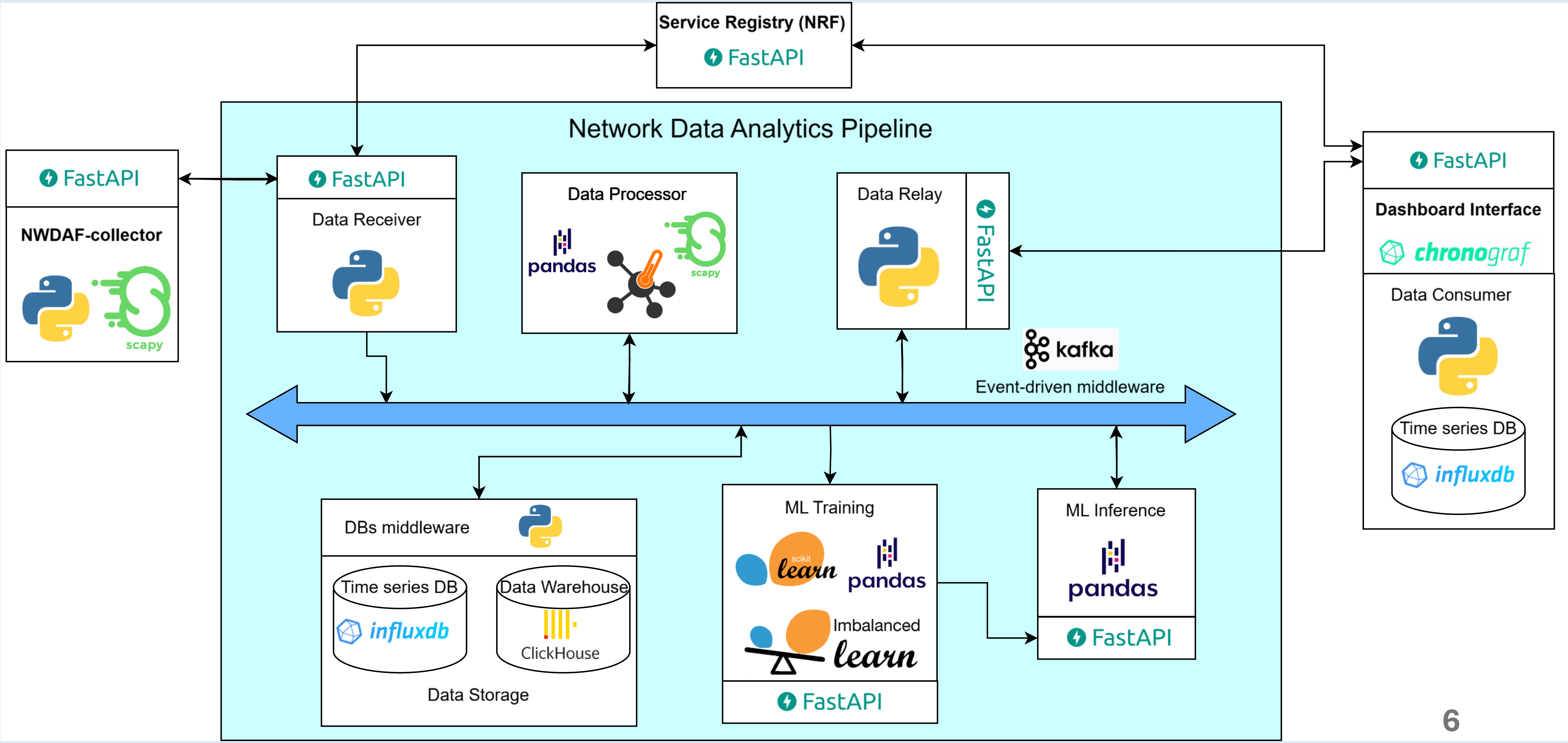
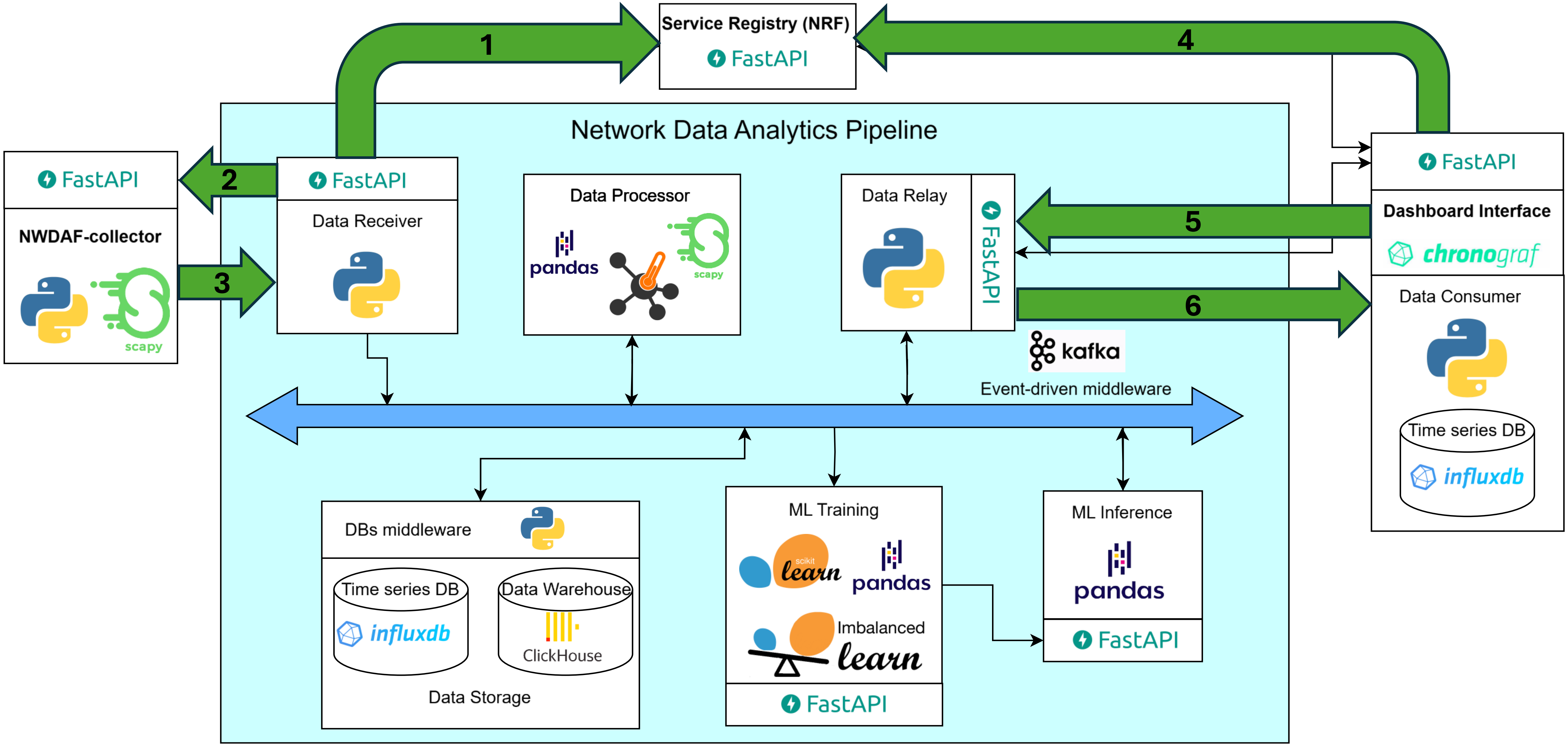
QoE Monitoring
Resource Allocation Optimization
Energy Efficiency & Green Networks

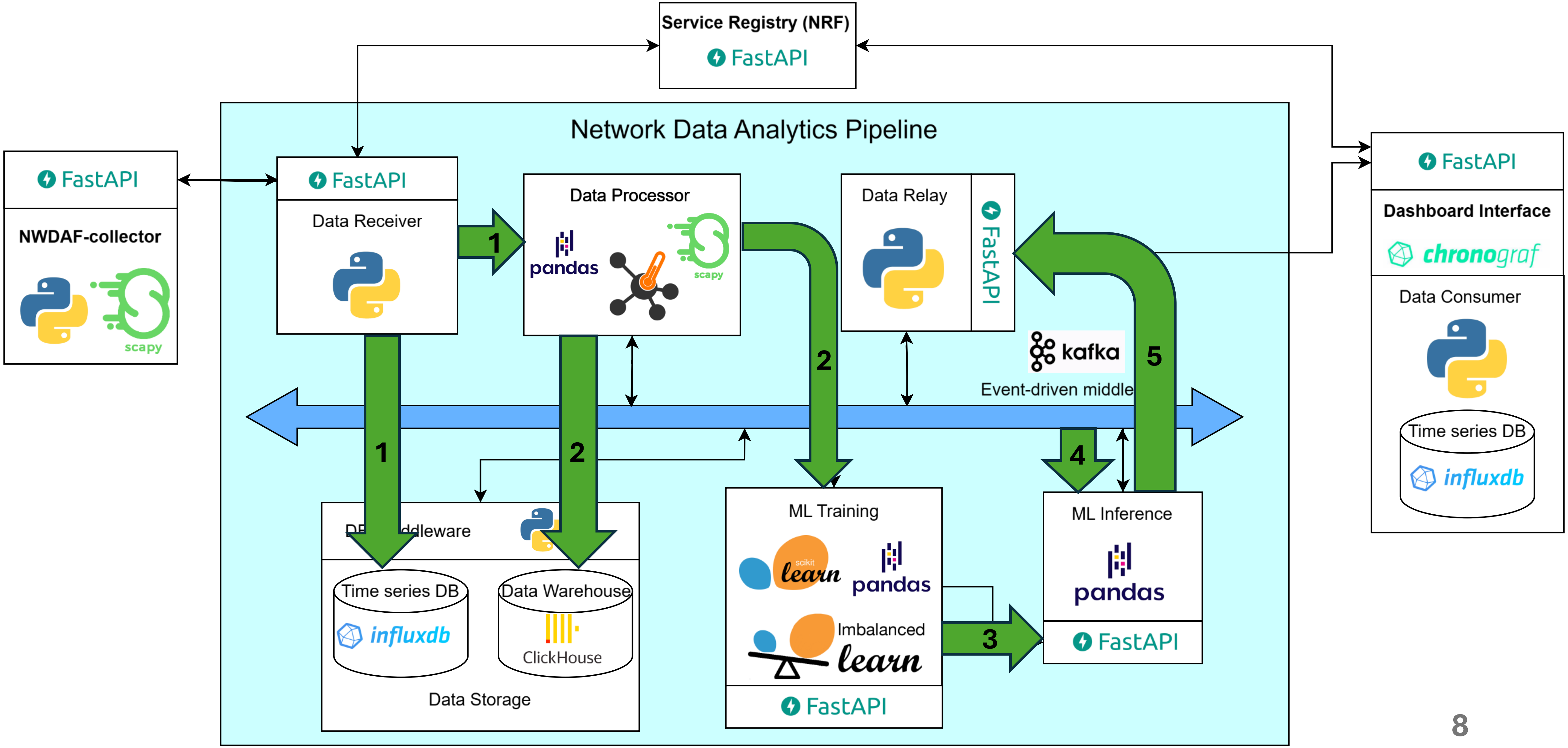
5. System Architecture



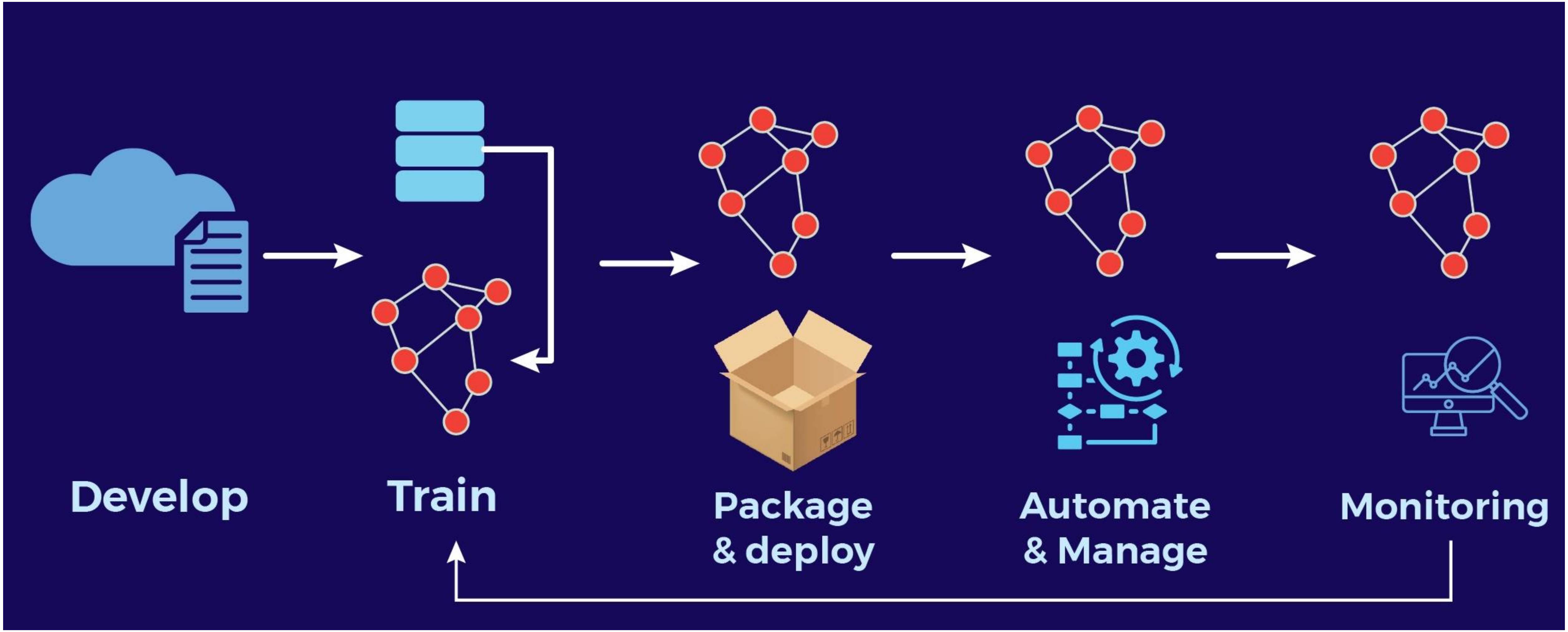
6. 5G Core Flow



6. System Flow



6. System Flow

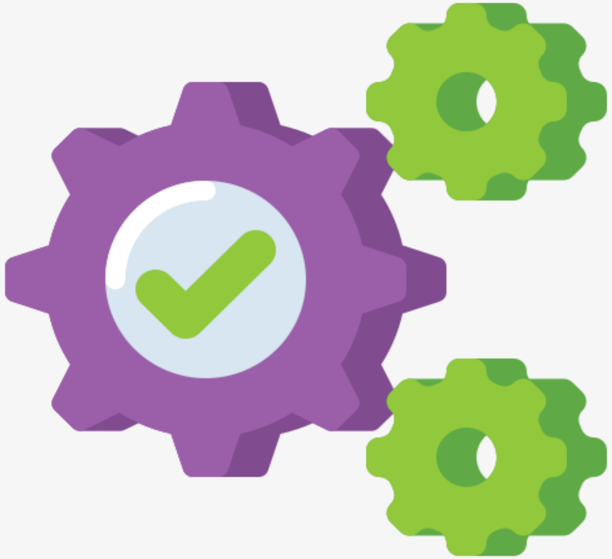


7. Goals Review

- Implement a Data Analytics pipeline for network data. ✅
- Ensure seamless communication between services within the pipeline. ✅
- Develop and Integrate Machine Learning Models. ✅
- Implement an MLOps pipeline. ✅
- Ensure Compliance with 3GPP Standards. ✅
- Provide a user-friendly Deployment and Visualization System. ✅
- Integration with existing 5G Core network components. ❌
- Evaluate system performance under several network conditions. ✅

8. Main Functionalities

- Dynamically train many models and deploy the best one;
- Periodic training to avoid data drift;
- Interact with 5G Core network functions in order to collect and expose data;
- Trigger model training through Nnwdaf_MLModelTraining API call;
- Receive model evaluation results through API callback;
- Extract Netflow features from raw network data.



9. Use Case/Validation

- We implemented one of the many use cases we identified.
- Our use case relies on using live network data to:
  - Detect attacks;
  - Identify the type of detected attack.

- We used the UNSW-NB15 dataset's raw data files.
- Which allowed us to:
  - Extract more than 50 Netflow features.
  - Identify 9 attack types.
  - Analyze network data drift evolution.

Attack	network_processed_data.count
Backdoor	3.00
Benign	124201.00
DoS	44.00
Exploits	476.00
Fuzzers	130.00
Generic	49.00
Reconnaissance	336.00
Shellcode	45.00

10. Main Problems

We did not pick the best approach to receive network data initially;

3GPP 5G API's were extensive and with many nested fields making it complex to map the necessary fields;

Feature extraction methodology wasn't straight forward and required using limited-access and undocumented tools.

11. Lessons Learned

Dividing the raw data for streaming interfered with the effectiveness of the feature extraction process.

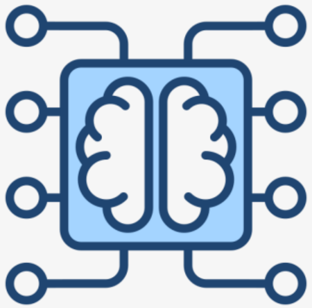
Having more and higher quality data proved more important than the ML methodology

The 3GPP standards for the NWDAF require further refinement, especially the ML APIs standards

There are so many types of network packets that creating a universal converter is extremely complex.

12. Future Work

Deployment in Kubernetes



Implementation of the monitoring API and integration with the trigger for retraining

Integration with real components of 5G-Core

Communicate with other NFs when an attack is detected

Scan the QR code to check our documentation website.

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.

[4]
M. Sarhan, S. Layeghy, and M. Portmann, “Towards a Standard Feature Set for Network Intrusion Detection System Datasets,” *Mobile Networks and Applications*, Nov. 2021, https://doi.org/10.1007/s11036-021-01843-0.