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INTELLIGENCE IN ACTION: AI-DRIVEN NETWORKS

M3. Prototype

Projeto em Informática 2024/2025

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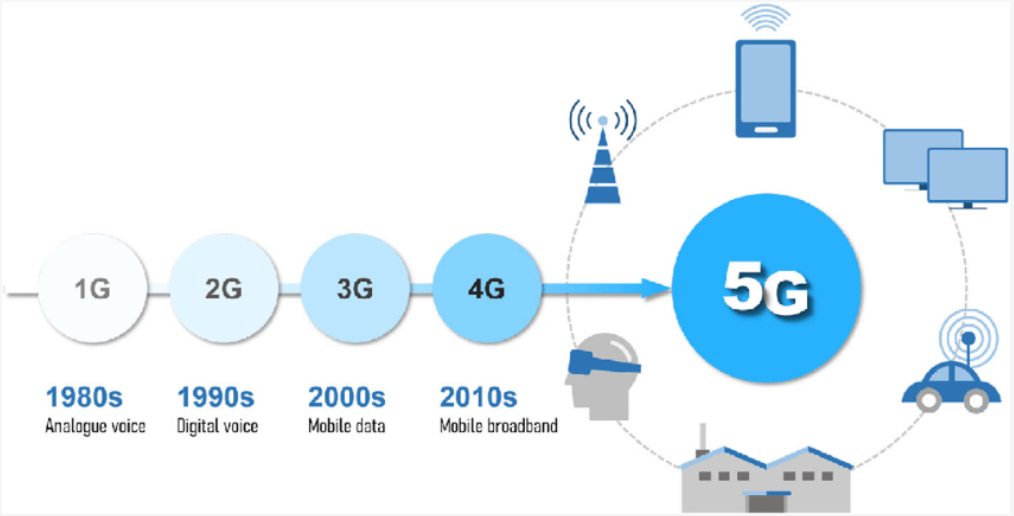
1. CONTEXT

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



5G and Beyond-5G networks must:

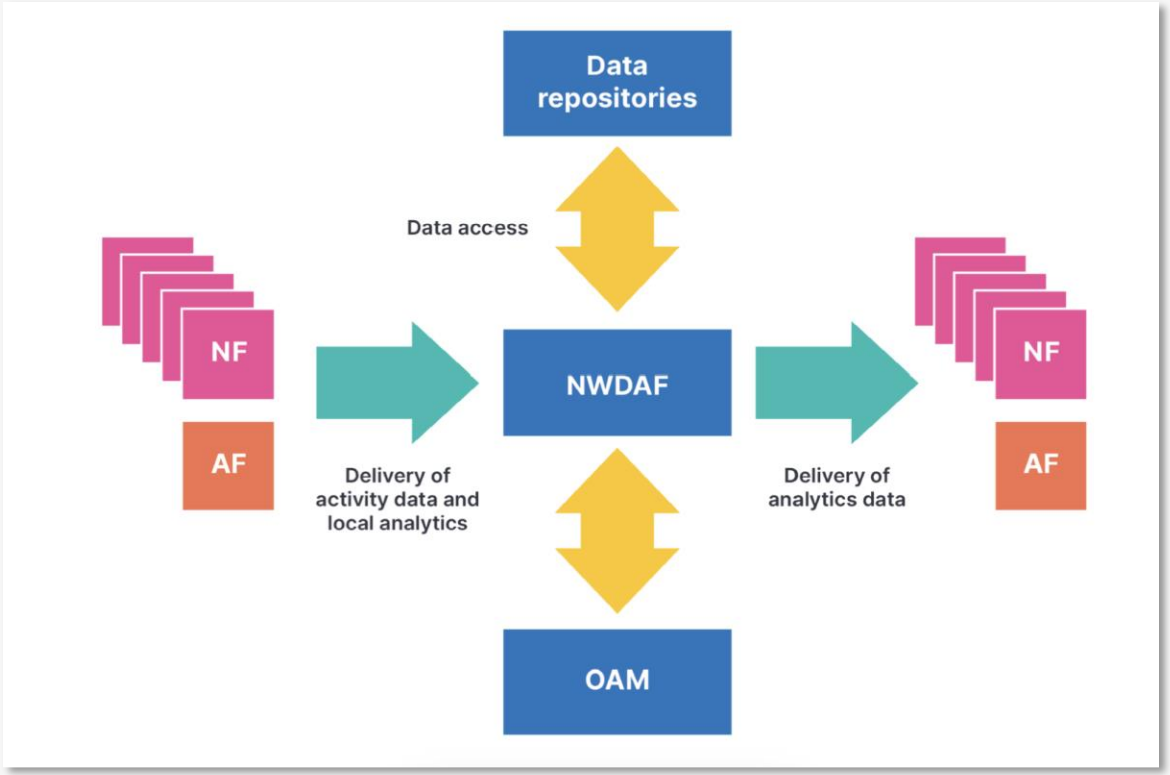
- handle vast amounts of data.
- support a diverse range of applications.
- ensure high reliability and low latency.

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

- 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 not a proof-of-concept that demonstrates how to operationalize ML pipelines (MLOps) in a NWDAF-like system.

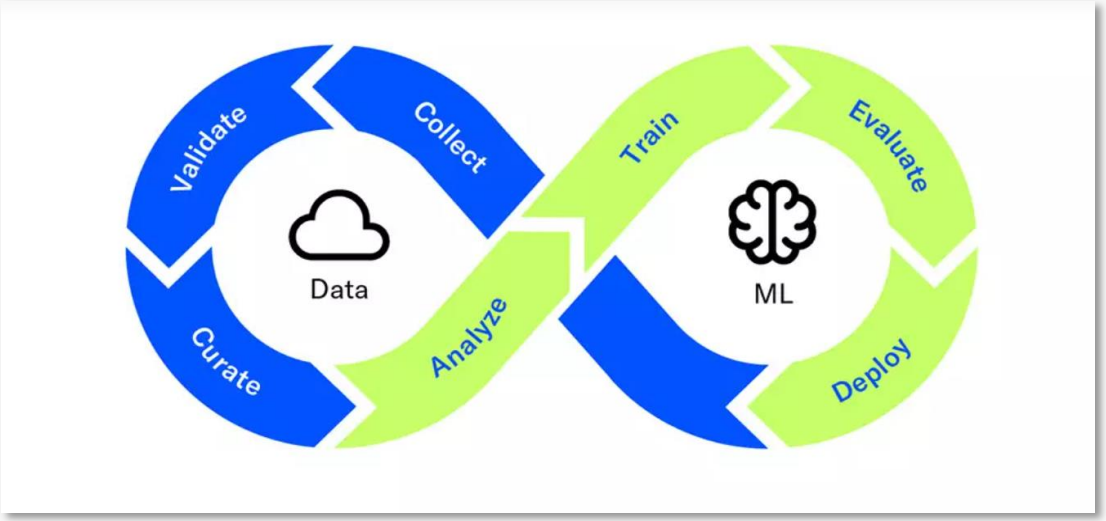
MLOps Pipeline

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

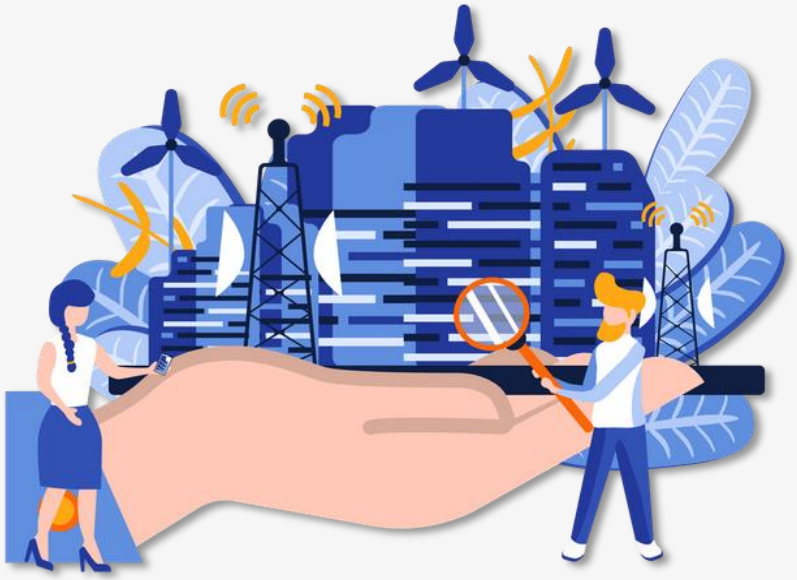
End-to-end machine learning development process.

Aims to unify the release cycle for machine learning.

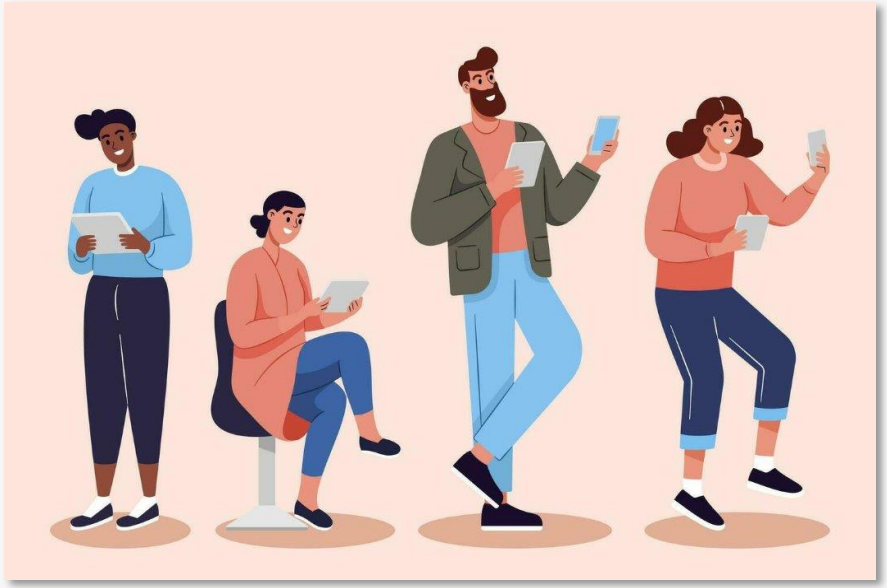
Enables the application of agile principles to machine learning projects.



3. Actors

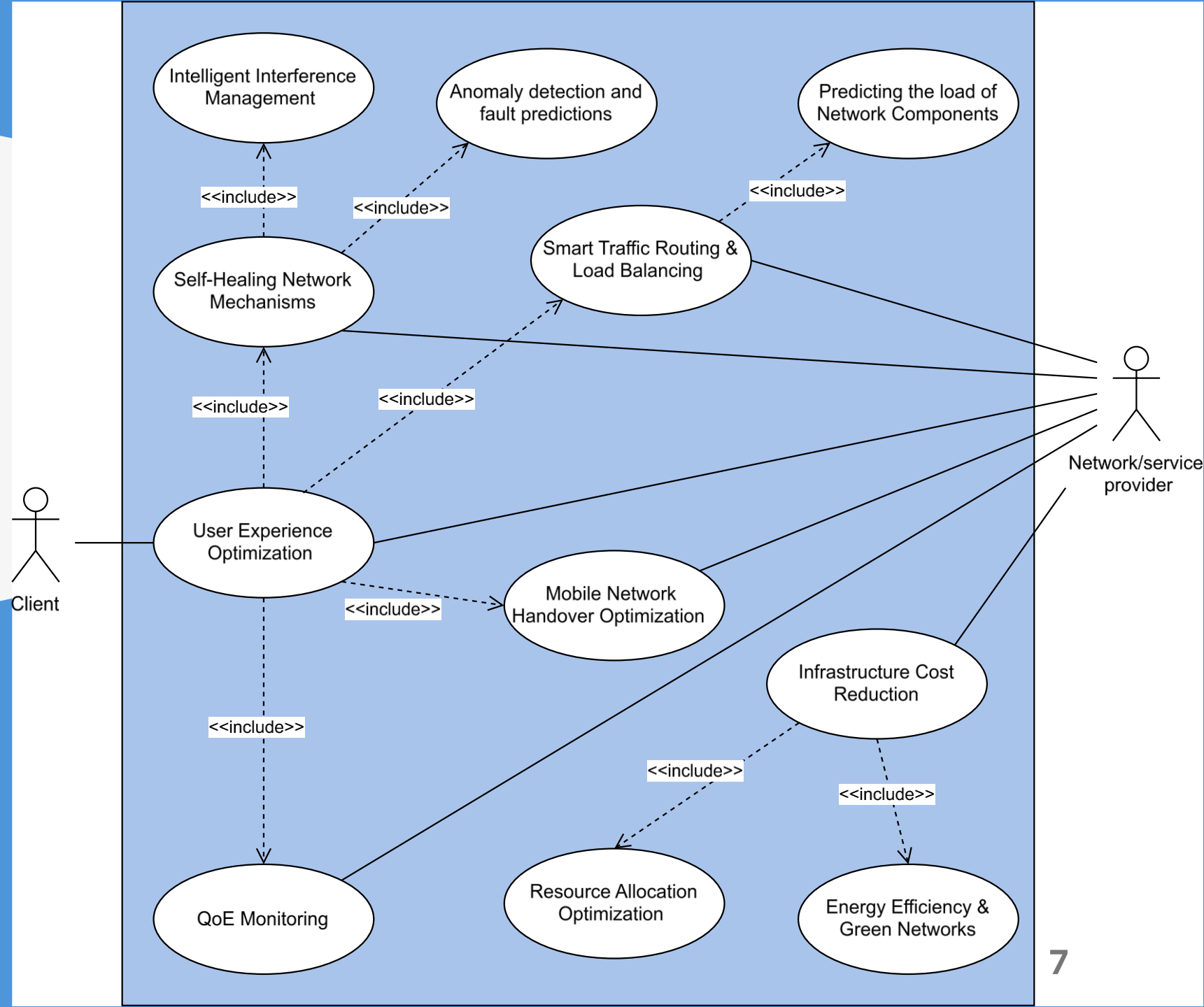


Network/service provider



Service Client

4. Use Cases


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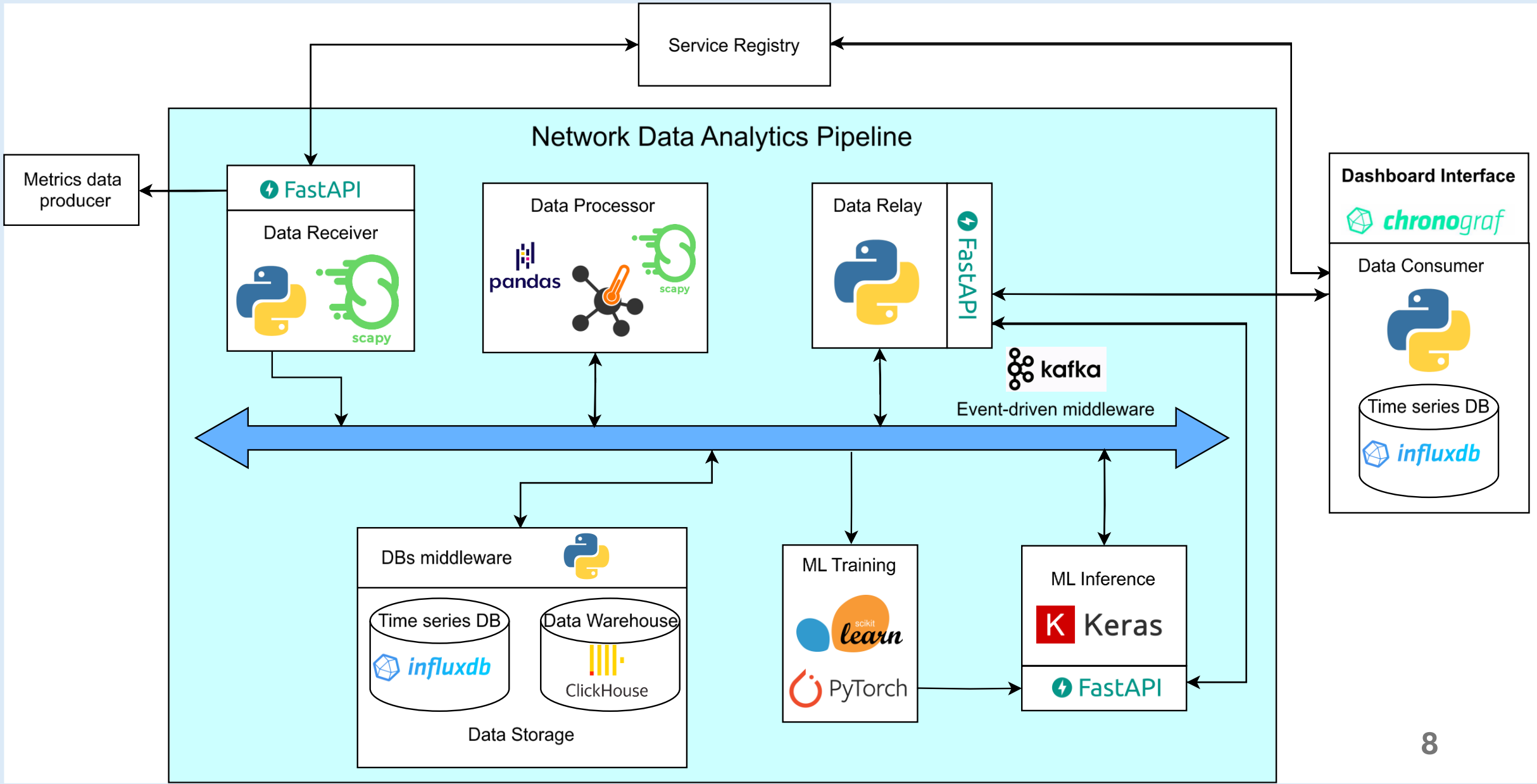
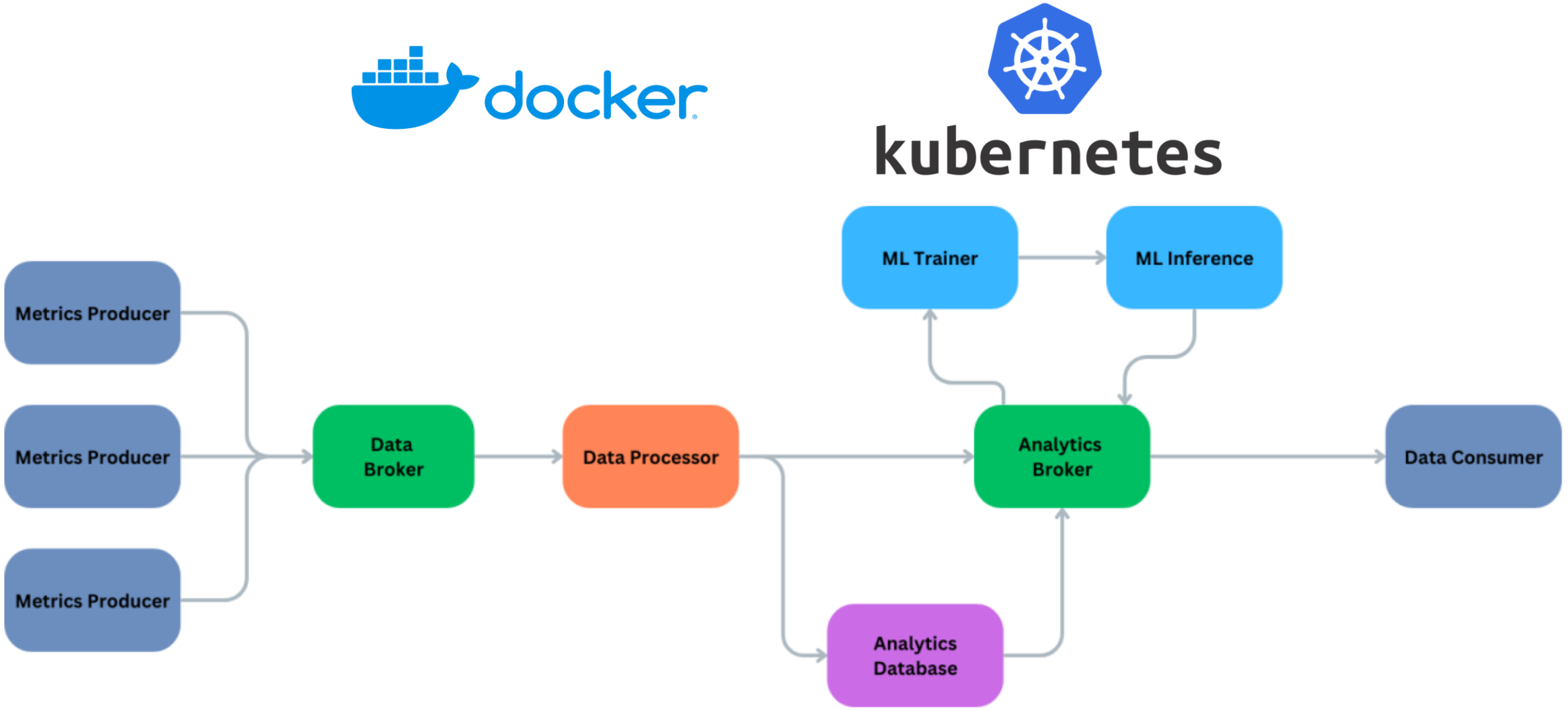
<<include>>
QoE Monitoring
Resource Allocation Optimization
Energy Efficiency & Green Networks

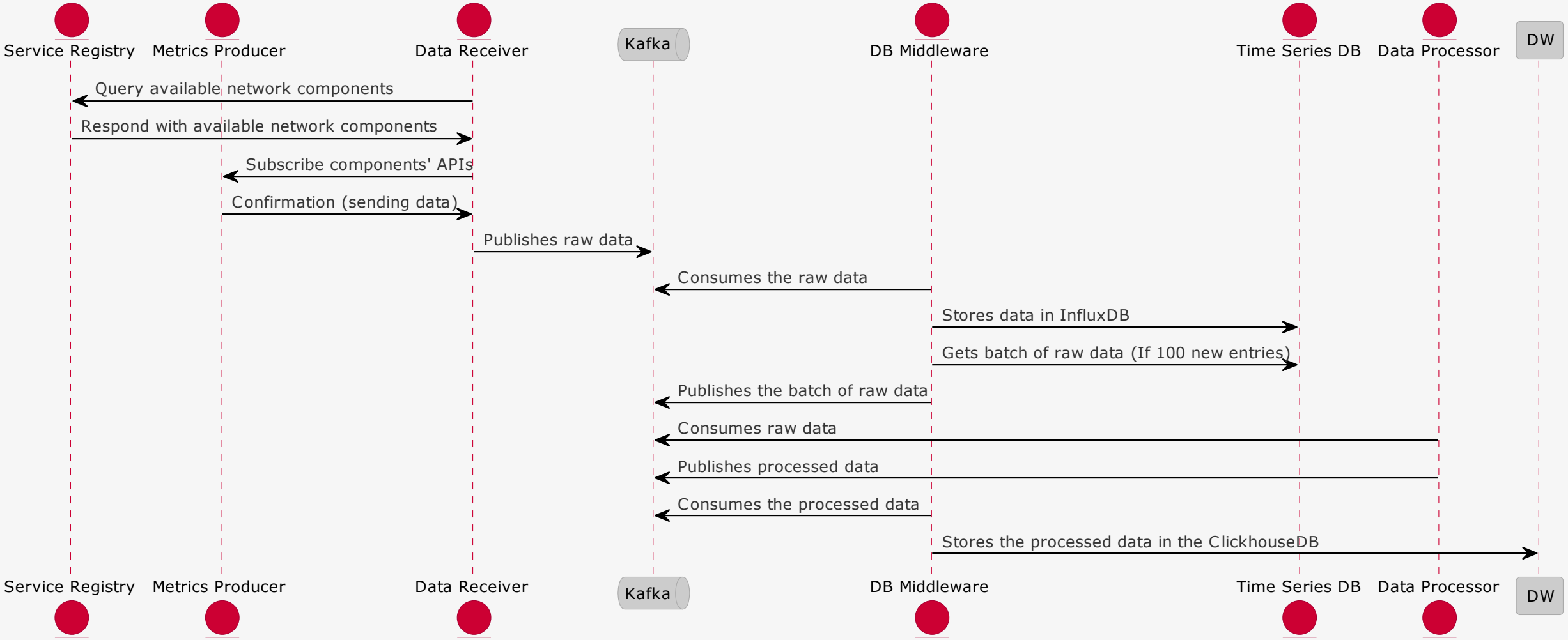
5. System Architecture



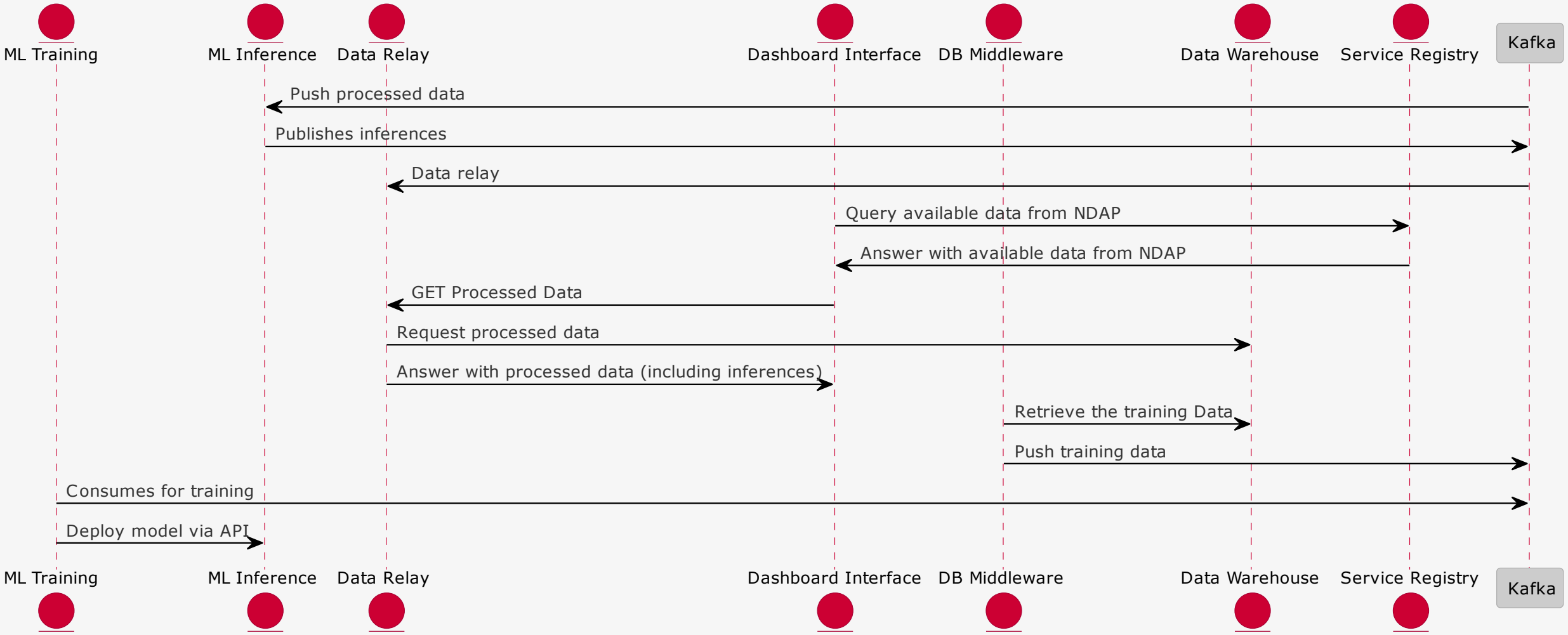
Deployment


docker
kubernetes
ML Trainer
ML Inference
Metrics Producer
Metrics Producer
Metrics Producer
Data Broker
Data Processor
Analytics Broker
Data Consumer
Analytics Database

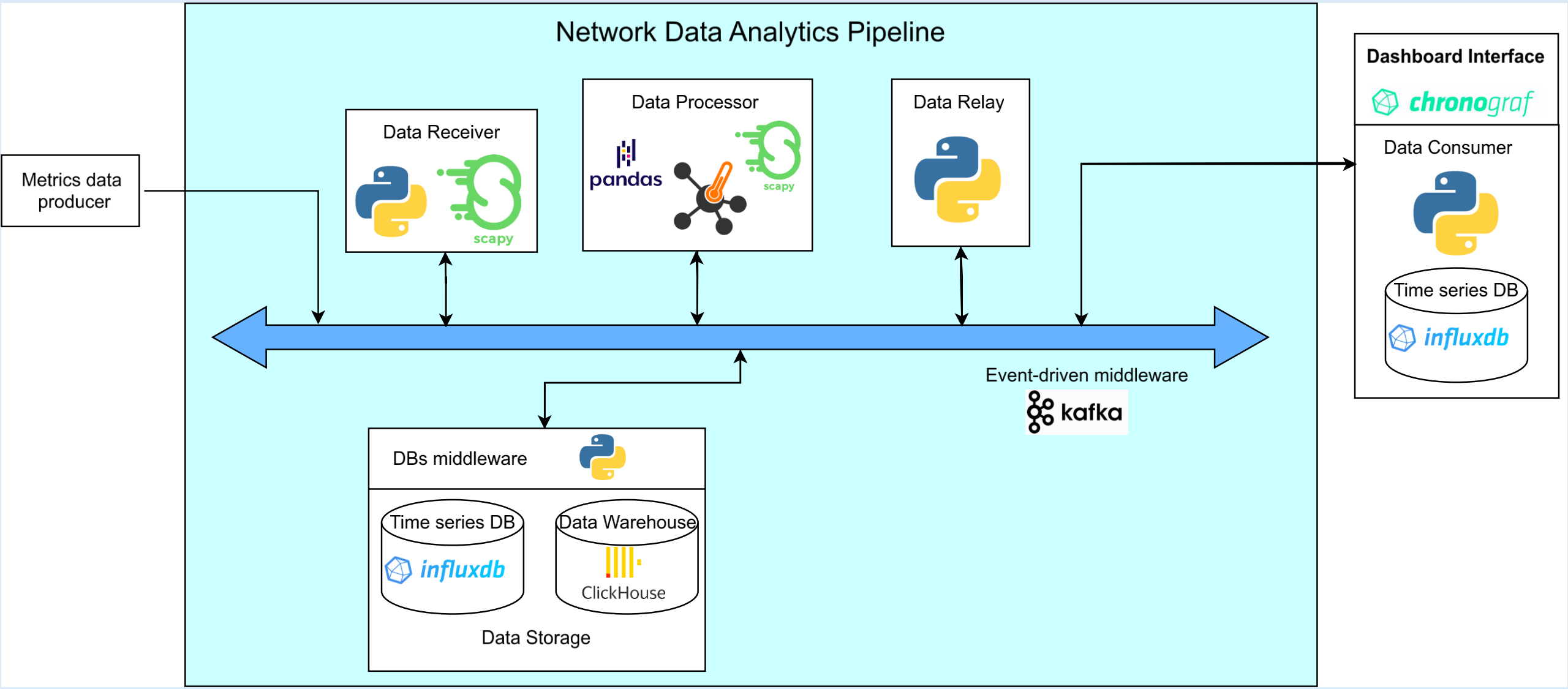
Data Flow Diagram in Detail



Data Flow Diagram in Detail

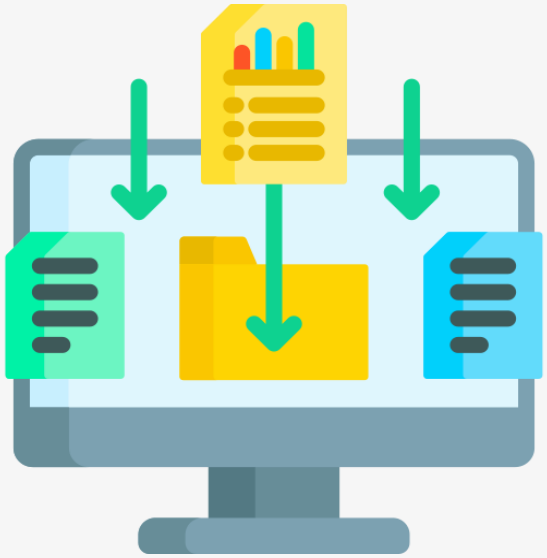


6. MVP System Architecture



7. Work Done

- Simulated network flow using PCAP files to recreate realistic traffic scenarios.
- Use of nProbe to extract 43 NetFlow version 9 features.
- Implemented a data relay to forward processed network information to the visualization system.
- Created a Chronograf dashboard based on the received data.



8. Challenges

Data conversions:

- PCAP -> JSON
- JSON -> InfluxDB
- InfluxDB -> JSON
- JSON -> PCAP

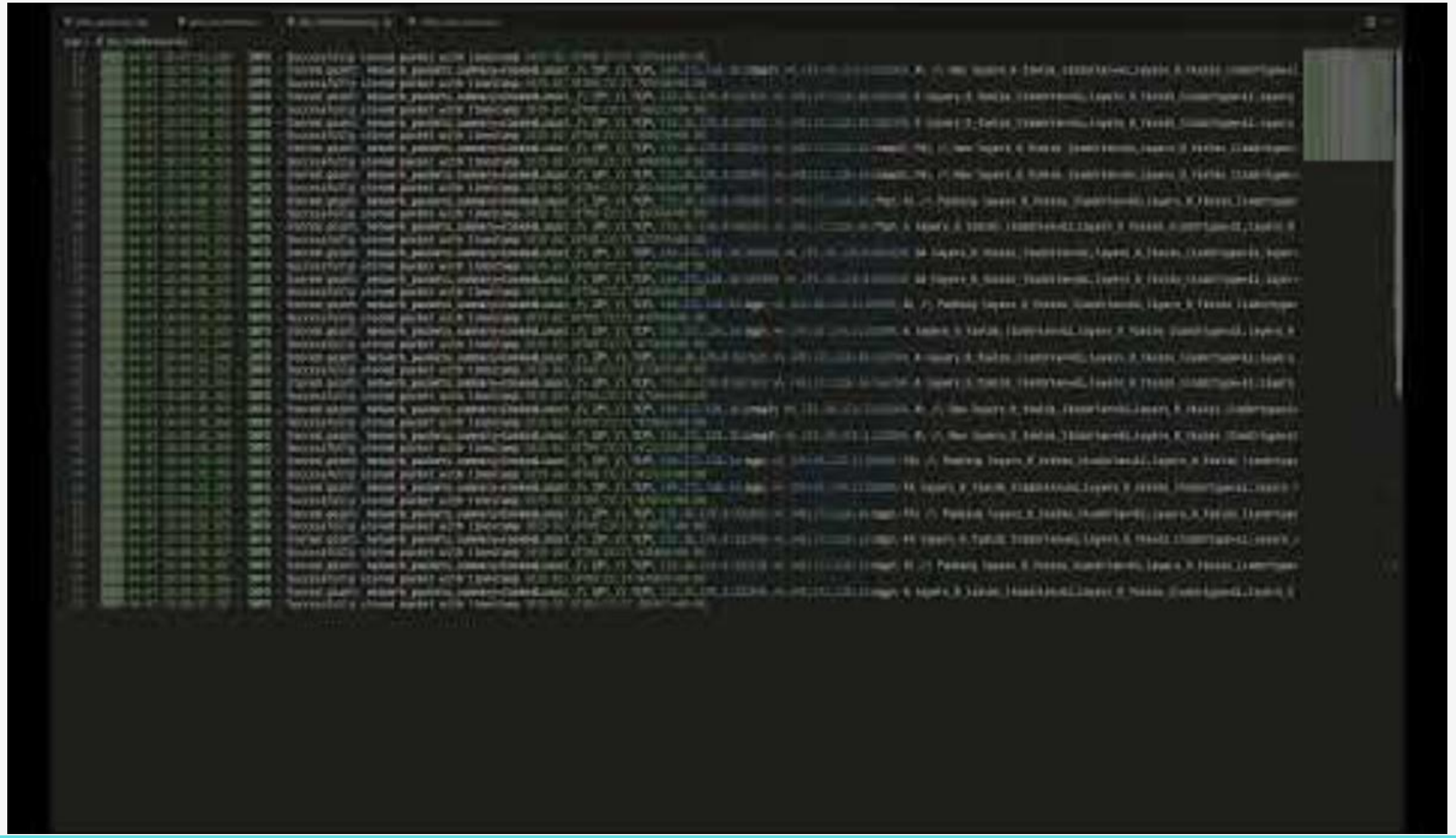
- Exhaustive logging analysis.
- Ensure no packet data is lost/changed during conversions.

- Work with time series DBs.
- InfluxDB integration on chronograph.

JSON NETWORK PACKET EXAMPLE

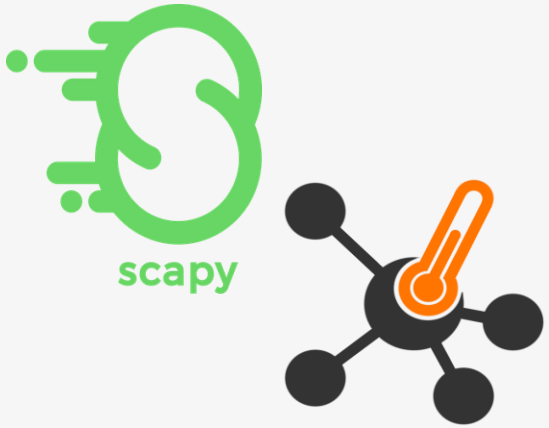

```
{
  "timestamp": 1424219007.801358,
  "timestamp_iso": "2015-02-18 00:23:27",
  "summary": "CookedLinux / IP / TCP 175.45.176.0:45235 > 149.171.126.16:ftp A",
  "length": 56,
  "layers": [
    {
      "name": "cooked linux",
      "fields": {
        "pkttype": 4,
        "lladdrtype": 1,
        "lladdrlen": 6,
        "src": "005056a524c20000",
        "proto": 2048
      }
    },
    {
      "name": "IP",
      "fields": {
        "version": 4,
        "ihl": 5,
        "tos": 0,
        "len": 40,
        "id": 14155,
        "flags": "",
        "frag": 0,
        "ttl": 62,
        "proto": 6,
        "chksum": 53915,
        "src": "175.45.176.0",
        "dst": "149.171.126.16",
        "options": []
      }
    },
    {
      "name": "TCP",
      "fields": {
        "sport": 45235,
        "dport": 21,
        "seq": 1107119178,
        "ack": 1047442890,
        "dataofs": 5,
        "reserved": 0,
        "flags": "A",
        "window": 16383,
        "chksum": 51618,
        "urgptr": 0,
        "options": []
      }
    }
  ]
}
```

9. DEMO



https://youtu.be/pbfqgiKx1DU

10. Future Work

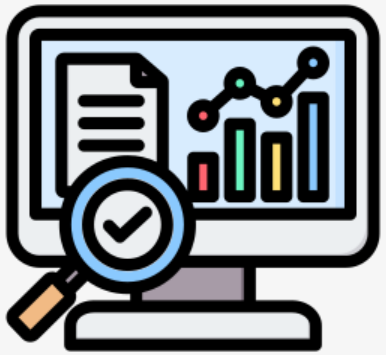


- Fix the issues related with the new technologies we picked up

- Finish pre-processing data

- Change the communication of some components to use API calls instead of Kafka

10. Future Work



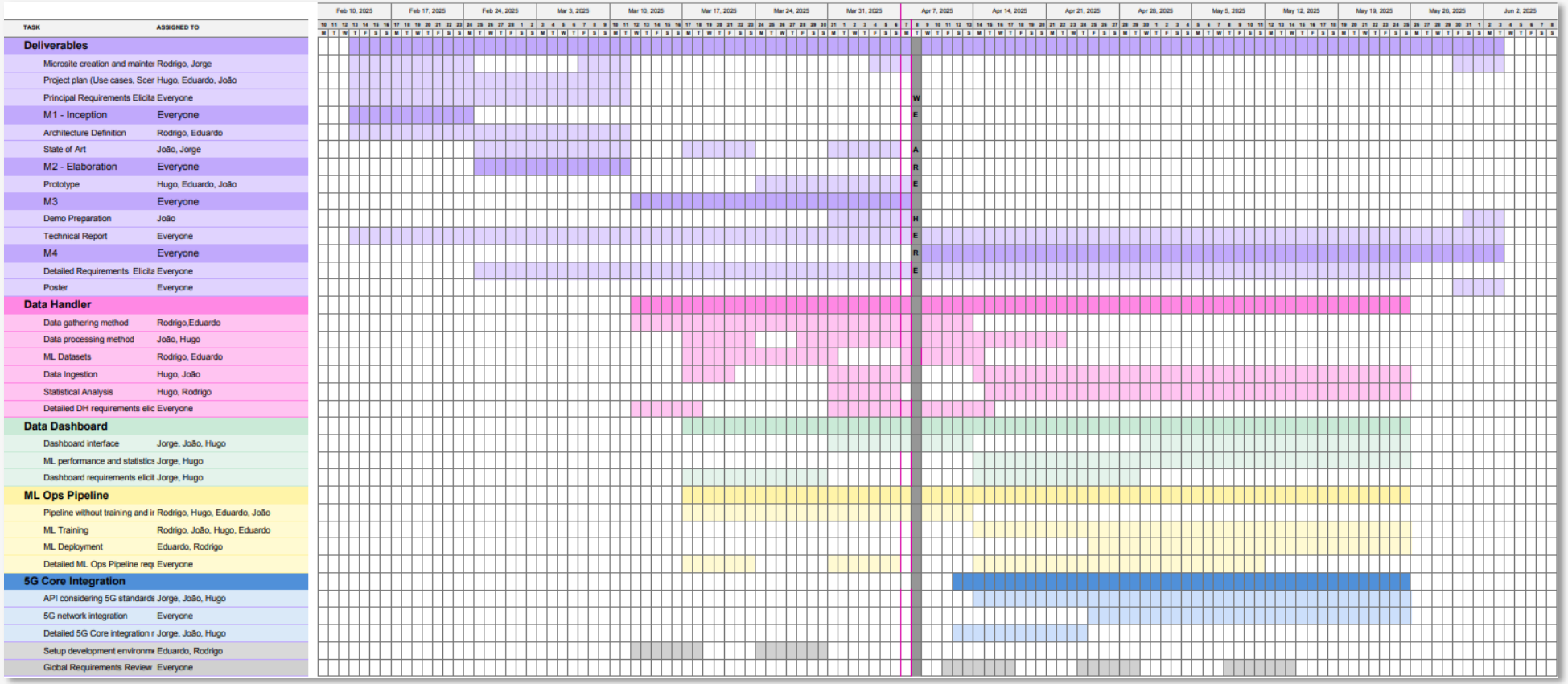
- Add new graphics to our Dashboard Interface.

- Start the ML implementation (ML training and ML inference)

- Evaluate how fast data should flow in our pipeline.

11. Calendar

Check calendar updates here



TASK	ASSIGNED TO
Deliverables	
Microsite creation and mainter	Rodrigo, Jorge
Project plan (Use cases, Scer	Hugo, Eduardo, João
Principal Requirements Elicita	Everyone
M1 - Inception	Everyone
Architecture Definition	Rodrigo, Eduardo
State of Art	João, Jorge
M2 - Elaboration	Everyone
Prototype	Hugo, Eduardo, João
M3	Everyone
Demo Preparation	João
Technical Report	Everyone
M4	Everyone
Detailed Requirements Elicita	Everyone
Poster	Everyone
Data Handler	
Data gathering method	Rodrigo,Eduardo
Data processing method	João, Hugo
ML Datasets	Rodrigo, Eduardo
Data Ingestion	Hugo, João
Statistical Analysis	Hugo, Rodrigo
Detailed DH requirements elic	Everyone
Data Dashboard	
Dashboard interface	Jorge, João, Hugo
ML performance and statistics	Jorge, Hugo
Dashboard requirements elicit	Jorge, Hugo
ML Ops Pipeline	
Pipeline without training and ir	Rodrigo, Hugo, Eduardo, João
ML Training	Rodrigo, João, Hugo, Eduardo
ML Deployment	Eduardo, Rodrigo
Detailed ML Ops Pipeline req	Everyone
5G Core Integration	
API considering 5G standards	Jorge, João, Hugo
5G network integration	Everyone
Detailed 5G Core integration r	Jorge, João, Hugo
Setup development environm	Eduardo, Rodrigo
Global Requirements Review	Everyone

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.