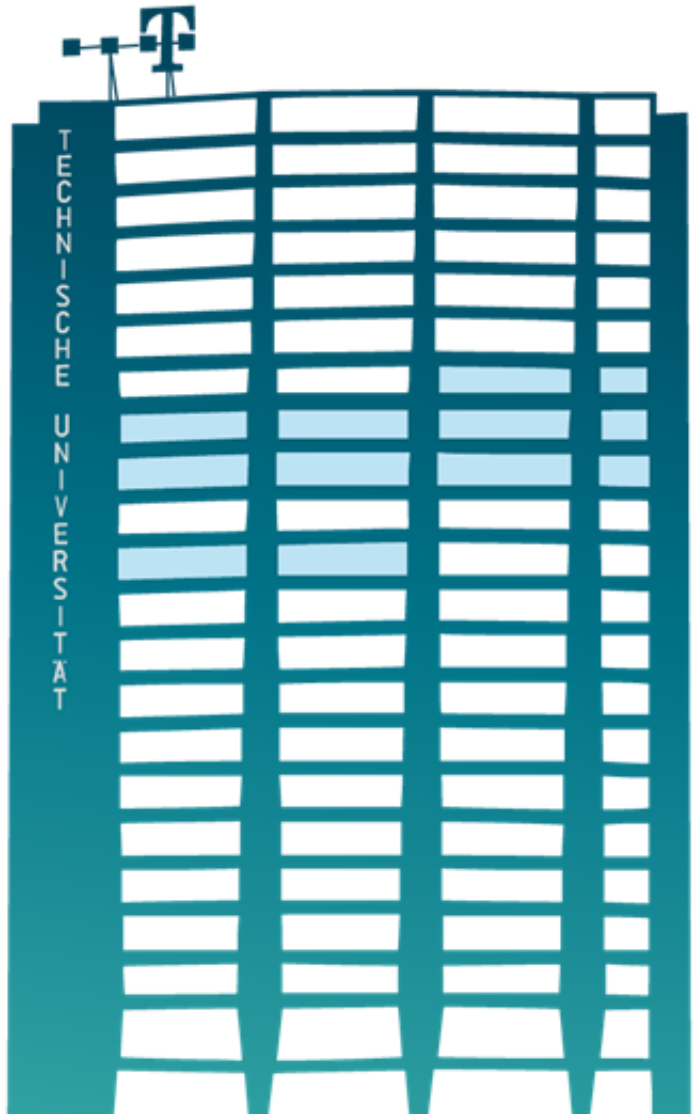
DAI-Labor
TU Berlin



Smart Communication Systems

Project Kickoff

Winter Semester 22/23

Competence Center Future Communication Systems (CC FCS)
Distributed Artificial Intelligence Laboratory, TU Berlin

Outline

- General info, project management, timeline
- Overview of project topics
- Relevant background and starting pointers
- Project groups
- Next Steps

Course Instructor & Project Supervisor

Lectures:

- Dr. Fikret Sivrikaya
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  - fikret.sivrikaya@gt-arc.com

Project Coordination:

- Sebastian Peters
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- Umuralp Kaytaz
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No regular office hours; [online] appointments can be arranged by email at any time

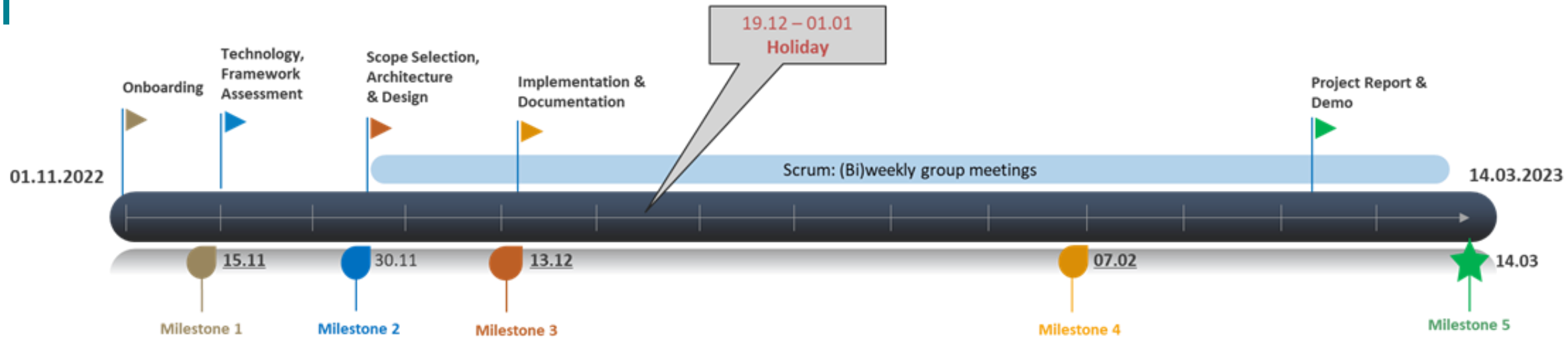
General Info

- **Target outcomes:** (possibly longer term)
  - Producing paper draft(s) that may be submitted for publication in a scientific conference in the future (not necessarily by the end of the semester).
  - Contribution to open source projects (especially to Open5GS)
- In general, it is very important to clearly document everything that you design and develop or the issues that you resolve throughout the semester.
- At the end, you will submit a project report that accompanies your research and implementation work in the project (could also be in the form of a scientific paper draft).

Project Management & Practicalities

- We will follow agile development principles (a lighter form of scrum process)
  - See lecture presentation/video on ISIS course page for the basics
- AOT Edu GitLab - https://gitlab-edu.aot.tu-berlin.de/
  - We will soon create your individual accounts; you should then receive an email from the system
  - All collaboration should take place on this platform
  - Create tickets (“issues”) for all planned activities, assign them to the responsible persons, and keep them maintained (planned/ongoing/closed)
- Slack channels suggested for group-level communications
  - https://join.slack.com/t/gtarc/shared_invite/zt-1js9he5cl-2EfNsw0zRV~Swr9DLEd~SA

Timeline



MS1: Kickoff & Intro

Introduction
- Overview of project topics and relevant technologies
- Starting pointers
- Use cases
- Collaboration, Scrum, CI/CD

Milestone:
- Understanding the application domain and technologies
- Problem definition

MS2: Background & Basics

Getting Started
- Group building, selecting technologies, gaining hands-on experiences

Milestone:
- Understanding basic architecture, development flow, tools

MS3: Architecture Design

Basic Knowledge Sharing
- Select working areas and define problem, scope: open 5G core network architecture, virtual 5G network simulation, 5G core network deployment and applications
- Students provide tutorial style knowledge sharing to the class

Milestone:
- Slides, architecture diagram, design decisions, technology choices

MS4: Early Prototype & Documentation

Interim Demo:
- Basic functionality: 5G network management, network function extensions, implementation details, etc.
- Integration testing
- Students present their state of work and demonstrate working prototypes

Milestone:
- Software artifacts
- Documentation

MS5: Final Demo & Delivery

Writing:
- Final demo with user manual
- Technical report

Milestone
- Software release
- Report / Final documentation

PROJECT TOPICS
& RELEVANT BACKGROUND

Topic 1: Enhancement of 5G Core Network with Network Data Analytics Function

Motivation:

- Future 5G and 6G are expected to be driven by AI approaches
- A key role in this AI-driven intelligent mobile network will be played by NWDAF
- Open Source 5G Core Network projects as of yet miss NWDAF implementations
  - NWDAF function calls and interfaces need to be created and overall NF functionality needs to be designed and composed of suitable data analytics components for an example Use Case

Topic 1: Enhancement of 5G Core Network with Network Data Analytics Function

General Steps:

- Learn and adopt the open-source 5G core network “Open5GS” [1]
- Simulate 5G RAN with User Equipment (UE) and Base Station (BS) instances using the open-source “UERANSIM” solution [2]
- Establish end-to-end data connectivity from a UE to a remote application server
- Implement the interfaces and basic functionalities of NWDAF as a new network function in Open5GS
- Realize the collection and storage of data from certain NFs in NWDAF
- Realize the provision of certain services from NWDAF (Nnwdaf)

[1] https://open5gs.org/

[2] https://github.com/aligungr/UERANSIM

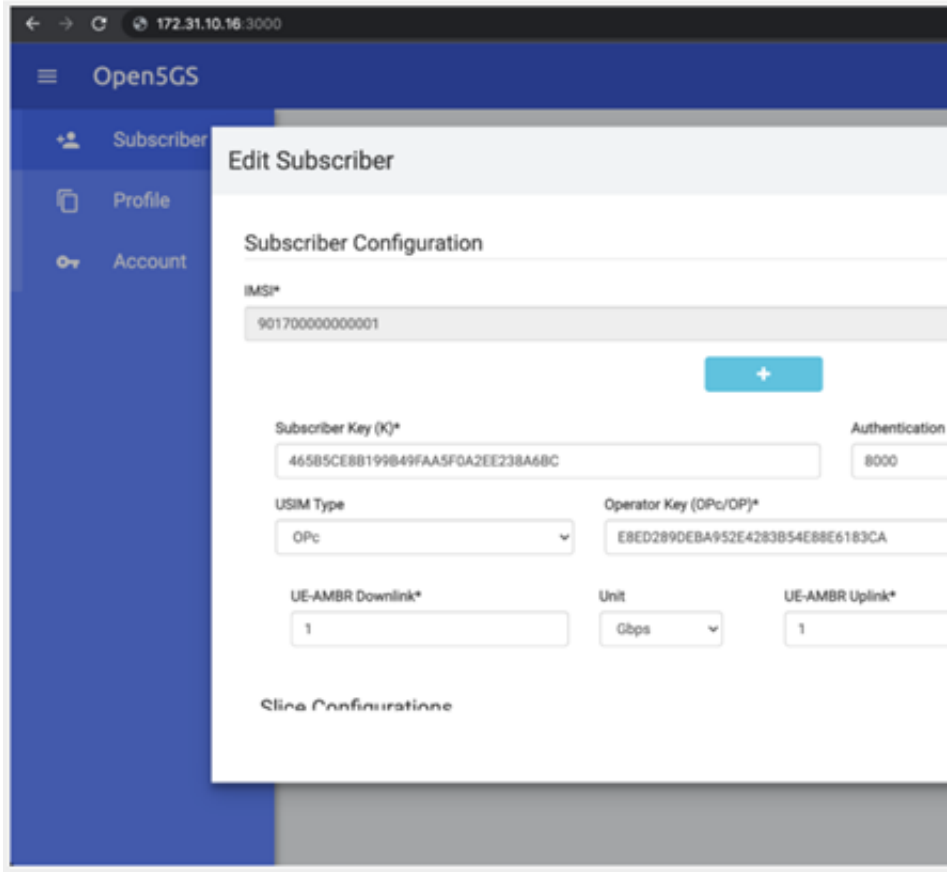
Open5GS: Open-Source 5G Core

A C-language open-source implementation of 5GC and EPC, i.e., the core networks of 4G/5G

- 3GPP Release-16 compliant
- Provides a Web UI for configuration and testing (implemented in Node.JS and React)
- Together with a physical gNB or with UERANSIM, allows us to establish end-to-end (E2E) 5G connectivity.

Documentation: https://open5gs.org/open5gs/docs/

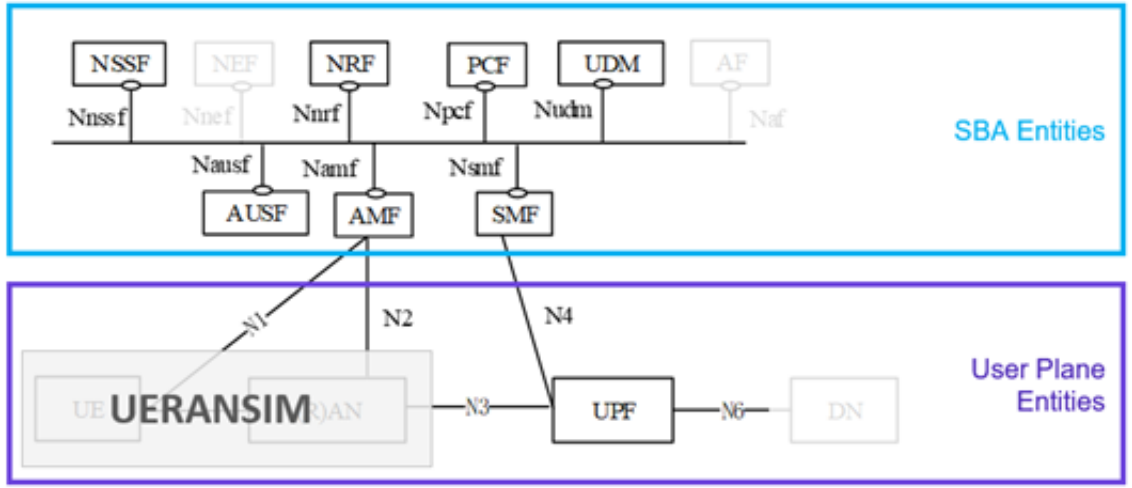
Source code: https://github.com/open5gs/open5gs



Open5GS: Open-Source 5G Core

The Open5GS includes the following 5G SA Core functions:

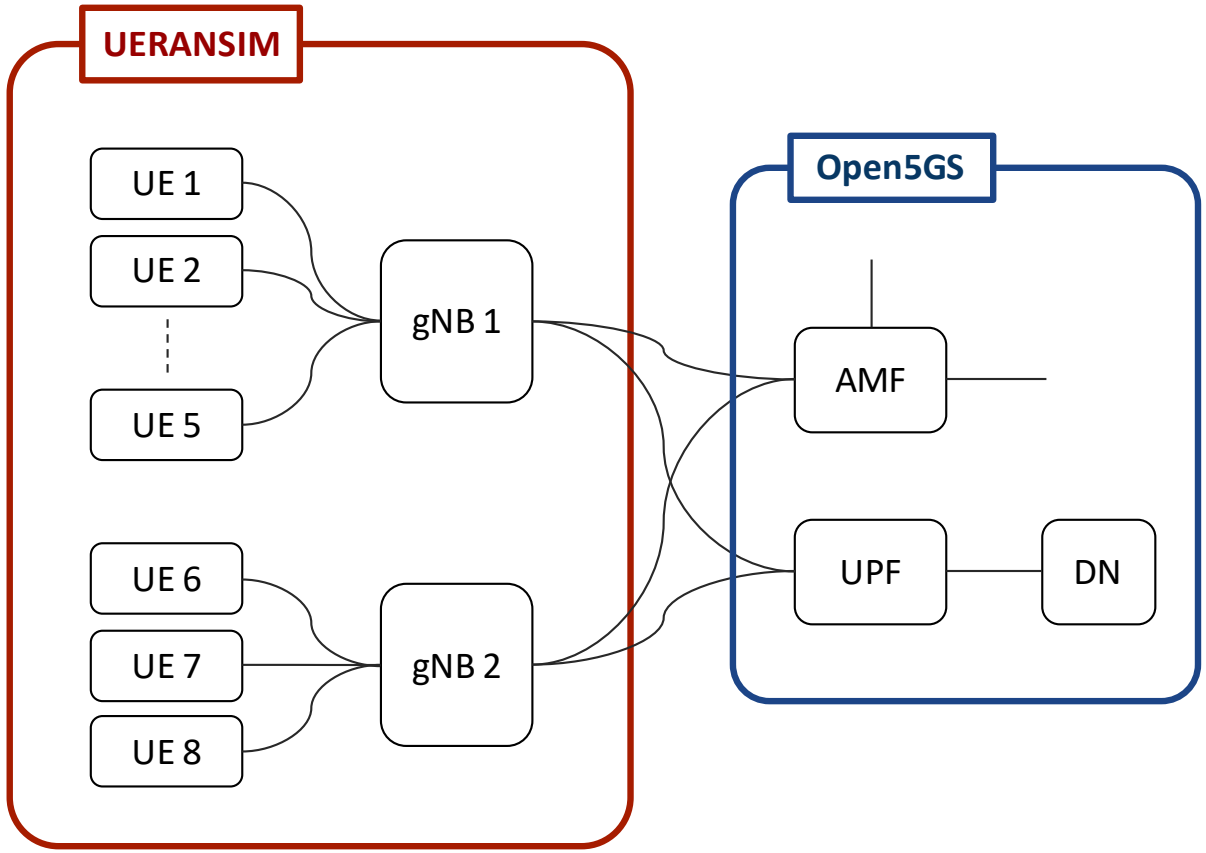
- NSSF - Network Slice Selection Function
- NRF - NF Repository Function
- PCF - Policy and Charging Function
- UDM - Unified Data Management
- AUSF - Authentication Server Function
- AMF - Access and Mobility Management Function
- SMF - Session Management Function
- UPF - User Plane Function
- UDR - Unified Data Repository
- SCP - Service Communication Proxy
- BSF - Binding Support Function



UERANSIM

Open source state-of-the-art 5G UE and RAN (gNodeB) simulator

- Can be used for testing a 5G core network and studying the 5G System
- Allows for easy creation of multiple UEs and base stations, e.g.,
  - `nr-gnb -c myconfig1.yaml`
  - `nr-ue -c myconfig2.yaml -n 10`
- Configurations[2] enable simulated UE & RAN to connect our Open5GS core network
  - `vi ./config/open5gs-gnb.yaml`
  - `vi ./config/open5gs-ue.yaml`



[2] https://github.com/aligungr/UERANSIM/wiki/Configuration

Network Data Analytics Function (NWDAF)

NWDAF: The Key Data Analysis Function for 5G

- Introduced (already starting in Rel-15) towards utilizing AI/ML techniques to realize network automation through unified interfaces
- Mainly specified in 3GPP **TS 23.288** and **TS 29.520**.
- Supports other network functions with data analytics, allowing them to subscribe/unsubscribe to certain info.
- Analytics information are either statistical information of the past events or predictive information.
- A single instance or multiple instances of NWDAF may be deployed in a 5G core.

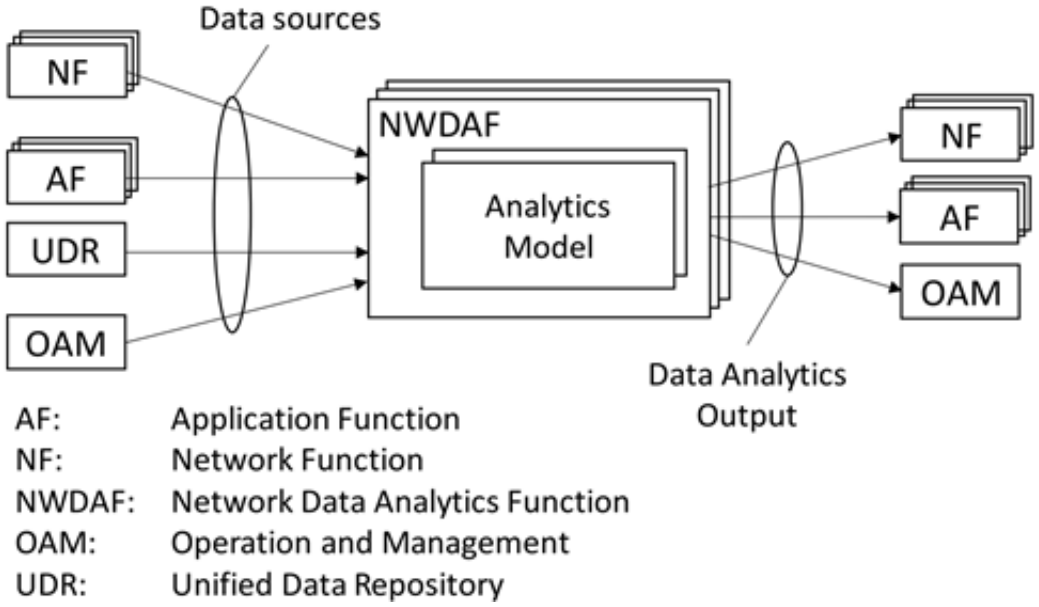


Figure source: A. Ghosh, A. Maeder, M. Baker and D. Chandramouli, "5G Evolution: A View on 5G Cellular Technology Beyond 3GPP Release 15," in IEEE Access, vol. 7, pp. 127639-127651, 2019.
https://doi.org/10.1109/ACCESS.2019.2939938

- ***3GPP TS 23.288:*** *"Architecture Enhancements for 5G System (5GS) to Support Network Data Analytics Services"*
- ***3GPP TS 29.520:*** *"5G System; Network Data Analytics Services"*

Services Provided by NWDAF (Release 16 & 17)

	Service Name	Description	Service Operations	Operation Semantics	Example Consumer(s)
Release 16	**Nnwdaf_Events Subscription** **(NOTE)**	This service enables the NF service consumers to subscribe to/unsubscribe from notifications for different analytics information from the NWDAF. It also enables the transfer of subscriptions between NWDAFs	Subscribe	Subscribe / Notify	PCF, NSSF, AMF, SMF, NEF, AF, OAM, CEF, NWDAF, DCCF
			Unsubscribe		
			Notify		
			Transfer	Request / Response	NWDAF
	Nnwdaf_ AnalyticsInfo	This service enables the NF service consumers to request and get specific analytics or context information related to analytics subscriptions from the NWDAF.	Request	Request / Response	PCF, NSSF, AMF, SMF, NEF, AF, OAM, NWDAF, DCCF
			ContextTransfer	Request / Response	NWDAF
Release 17	**Nnwdaf_ DataManagement**	This service enables the NF service consumers to subscribe to/unsubscribe from notifications when subscribed event(s) are detected or retrieve the subscribed data from the NWDAF.	Subscribe	Subscribe / Notify	NWDAF, DCCF, MFAF
			Unsubscribe		
			Notify		
			Fetch	Request / Response	NWDAF, DCCF, MFAF
	Nnwdaf_MLModel Provision **(NOTE 2)**	This service enables the NF service consumers to subscribe to/unsubscribe from notifications when a ML model matching the subscription parameters becomes available.	Subscribe	Subscribe / Notify	NWDAF
			Unsubscribe		
			Notify		
NOTE: This service corresponds to the Nnwdaf_AnalyticsSubscription service defined in 3GPP TS 23.288.					

Source: 3GPP TS 29.520 V16.12.0 & V17.8.0 "5G System; Network Data Analytics Services" (Table 4.1.1)

NWDAF Components (Release 17)

The NWDAF provides analytics to 5GC NFs and OAM. An NWDAF may contain the following logical functions:

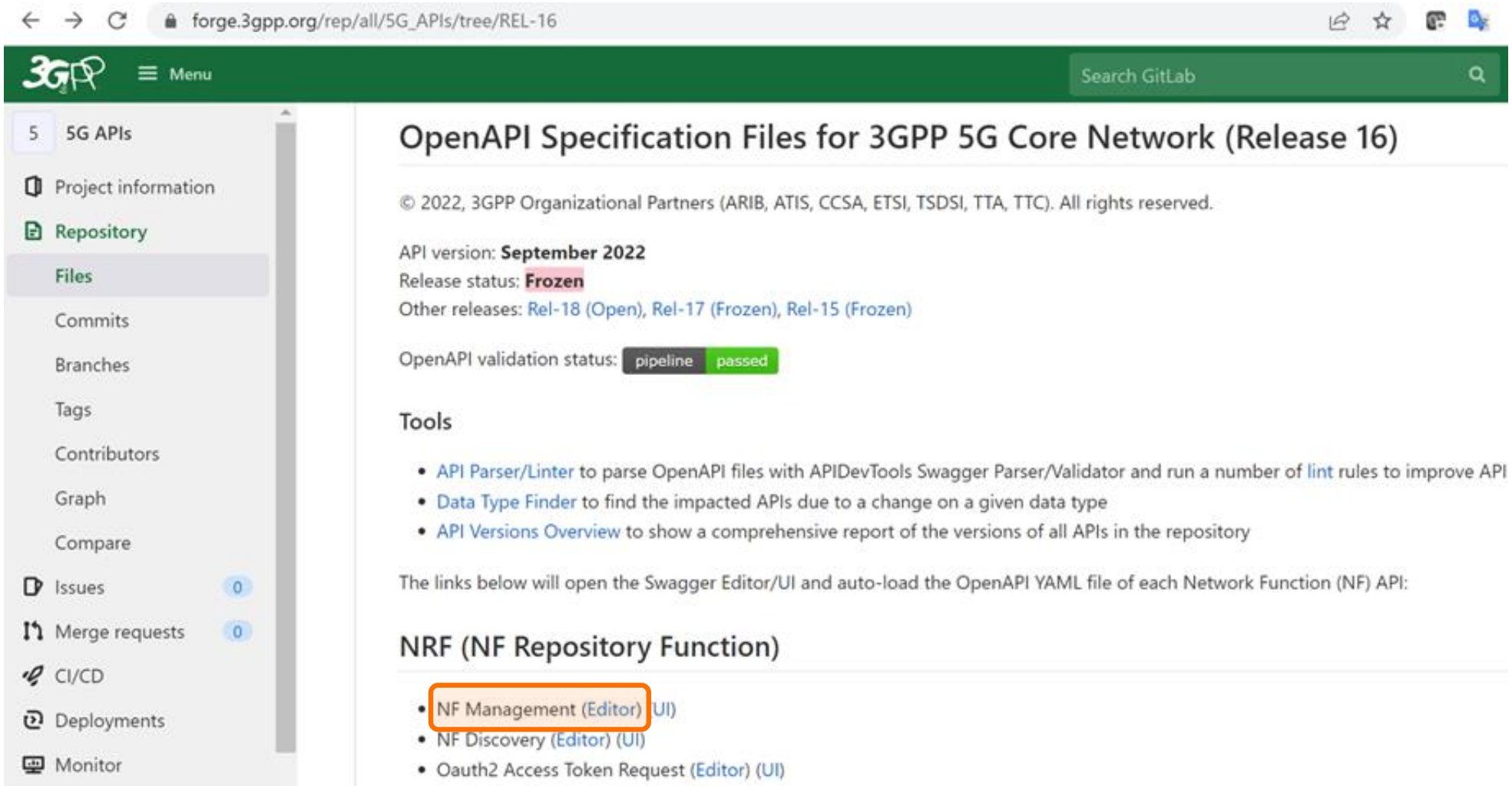
- **Analytics logical function (AnLF)**: A logical function in NWDAF, which performs inference, derives analytics information (i.e. derives statistics and/or predictions based on Analytics Consumer request) and exposes analytics service i.e. Nnwdaf_AnalyticsSubscription or Nnwdaf_AnalyticsInfo.
- **Model Training logical function (MTLF)**: A logical function in NWDAF, which trains Machine Learning (ML) models and exposes new training services (e.g. providing trained ML model) as defined in clause 7.5 and clause 7.6.
- NWDAF can contain an MTLF or an AnLF or both logical functions.
- Pre-trained ML model storage and provisioning to NWDAF is out of the scope of 3GPP.

General Note: *The internal details of the architecture of a Network Function instance is out of the scope of 3GPP and are entirely implementation-specific.*

Source: 3GPP TS 23.288 V17.6.0 *"Architecture enhancements for 5G System (5GS) to support network data analytics services"*

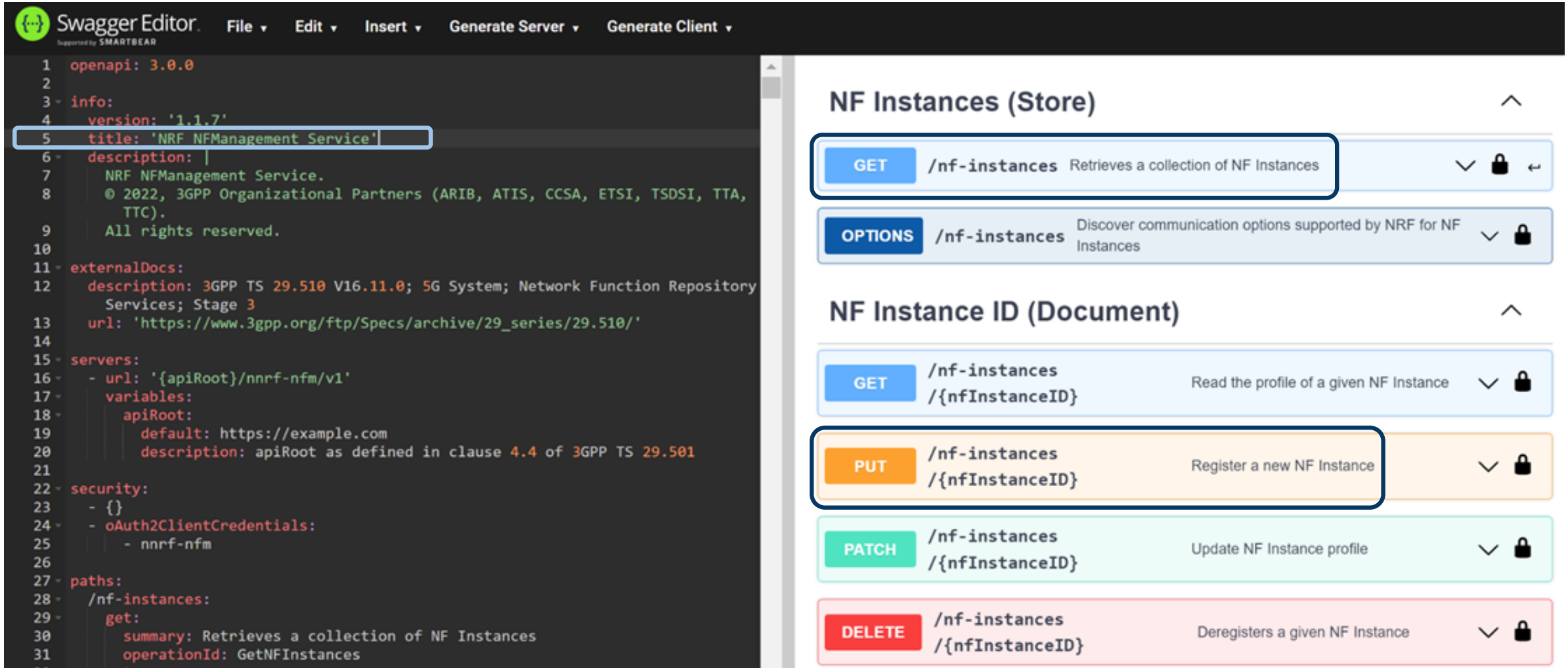
NF Interfaces – Open API Specifications (YAML)

https://forge.3gpp.org/rep/all/5G_APIs/tree/REL-16 (recall: Open5GS is Rel-16 compliant)
https://github.com/jdegre/5GC_APIs/tree/Rel-16#readme (alternative)



NF Interfaces – Open API Specifications (YAML)

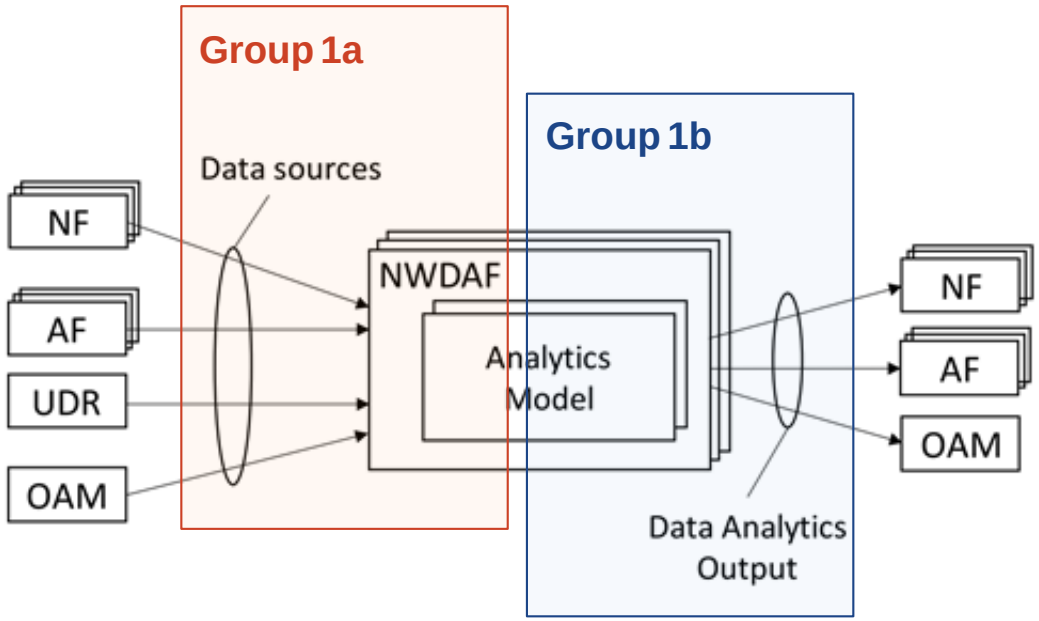
E.g., NRF's NF Management Service API (Swagger Editor/UI Interface)



Topic 1 Organization and Subgroups

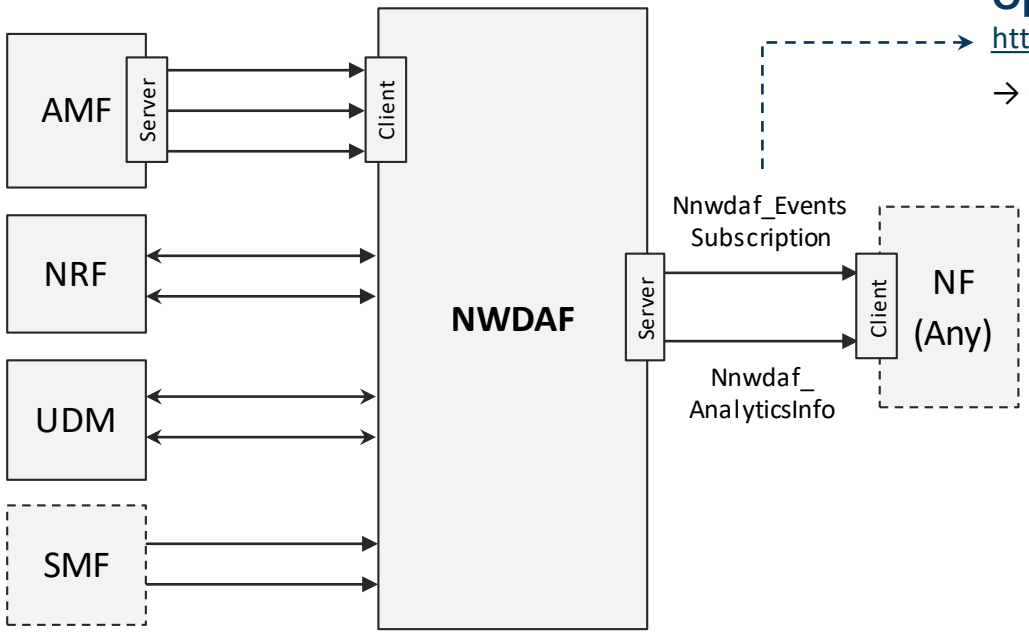
Two complementary focus groups for NWDAF implementation

- **Group 1a**: Focus on data ingestion and data management/storage
- **Group 1b**: Focus on the service provision interface (Nnwdaf)



Topic 1 Organization and Subgroups

- Further info on the implementation of NF interfaces



OpenAPI Generator

https://openapi-generator.tech/

→ Generate client and server code directly from OpenAPI documents

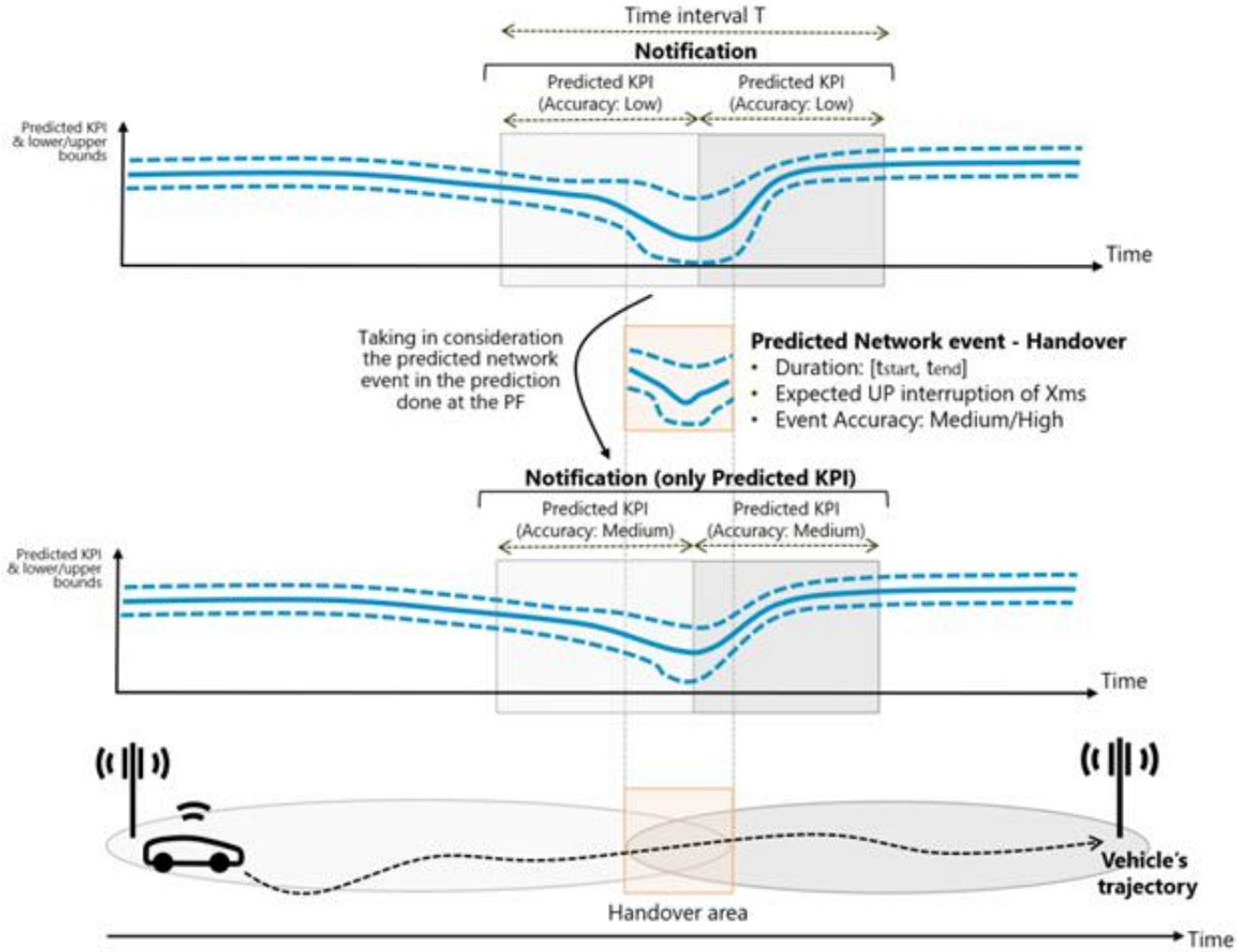
Topic 2: Predictive QoS for Connected Automated Mobility

Motivation:

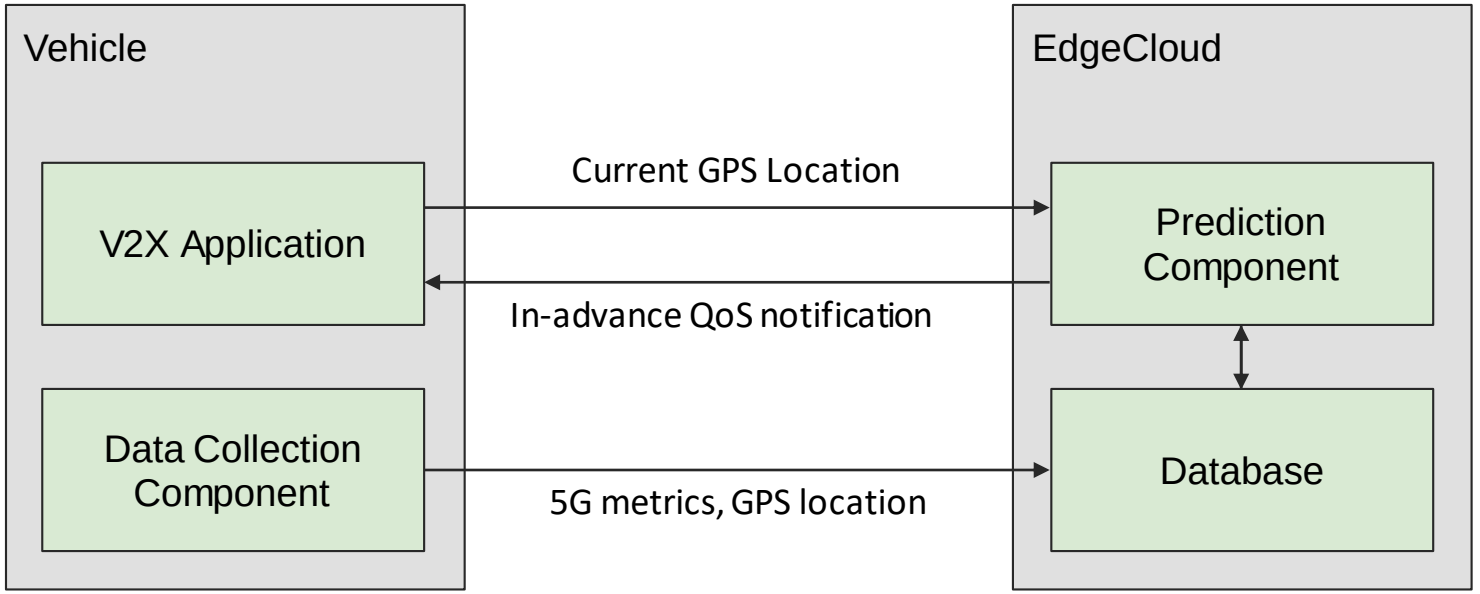
Predictive QoS for CAM is aiming at supporting the advanced driving use cases by optimizing use of 5G networks to attain best connectivity for in-vehicle CAM applications

- The implementation of a predictive QoS solution involves data gathering of relevant CAM application key performance indicators for an example CAM application
- Implement data analytics function to evaluate gathered data
- Implement in-advance QoS notification framework to warn vehicle about QoS degradations on the road ahead

Topic 2: Predictive QoS for Connected Automated Mobility



Topic 2: Predictive QoS for Connected Automated Mobility



Topic 3: 5G-based intelligent RSU monitoring and management solution

Motivation:

Long downtimes of Roadside Unit deployments at specific locations are mostly caused by crashing edge server hardware

- Sometimes this requires on-site reboot by turning local power supply of RSU site off and on again -> time and labor consuming task that needs optimization
- Solution: Create remote 5G-based power cycling solution for remote hard reset of edge server at RSU site, utilize 5G architecture with RSU app (connected via 5G Uu), MEC server app (in Deutsche Telekom Edge), Cloud center control app (hosted @ DAI)

Examples of RSU Deployments

Manual RSU reboot / power cycling can be done by interrupting the power supply directly at Lantern base.

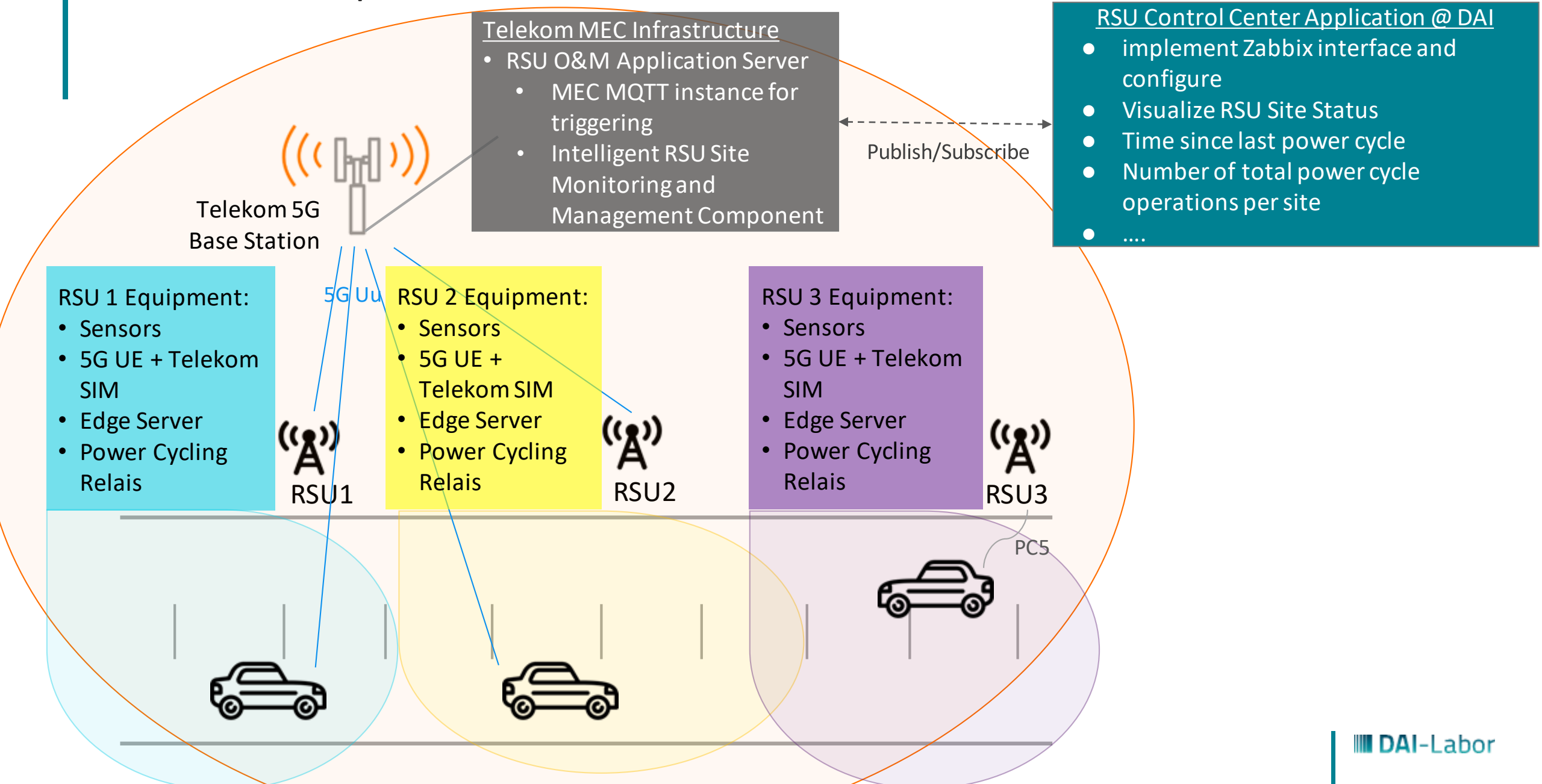
Topic 3: 5G-based intelligent RSU monitoring and management solution

Approach: Create a 5G-based solution for operations and maintenance (O&M) of the RSU site

- Equip Edge Server with power cycling relay, MQTT capable device*
- Implement client “heartbeat” function on RSU
- 5G user device provides connectivity for the RSU platform
- MEC Application Server in 5G Mobile Network creates O&M platform that monitors the availability of the RSU site
- Intelligent monitoring component determines if the edge server has crashed and needs to be power cycled
- Power cycling decision to be sent to RSU location, monitoring component to determine if successful, otherwise escalate issue to global O&M

* https://www.robot-electronics.co.uk/files/eth002b.pdf

RSU O&M Component Communication-Architecture Overview

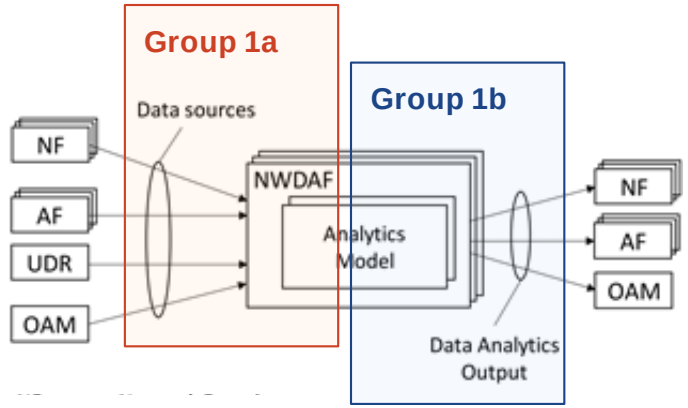


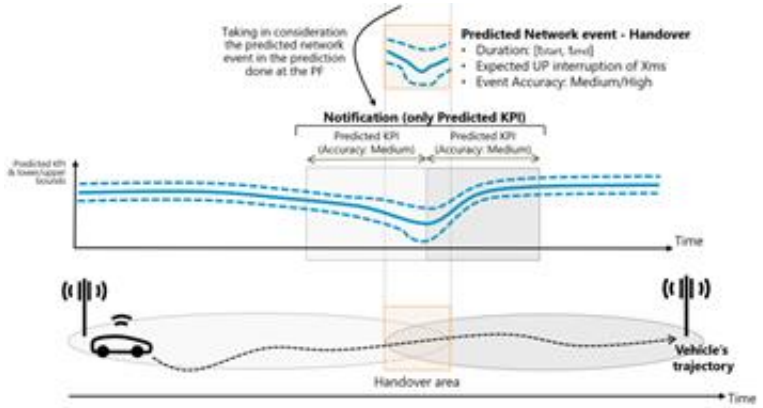
PROJECT GROUPING
& NEXT STEPS

Project Grouping

Planned capacity for project groups:

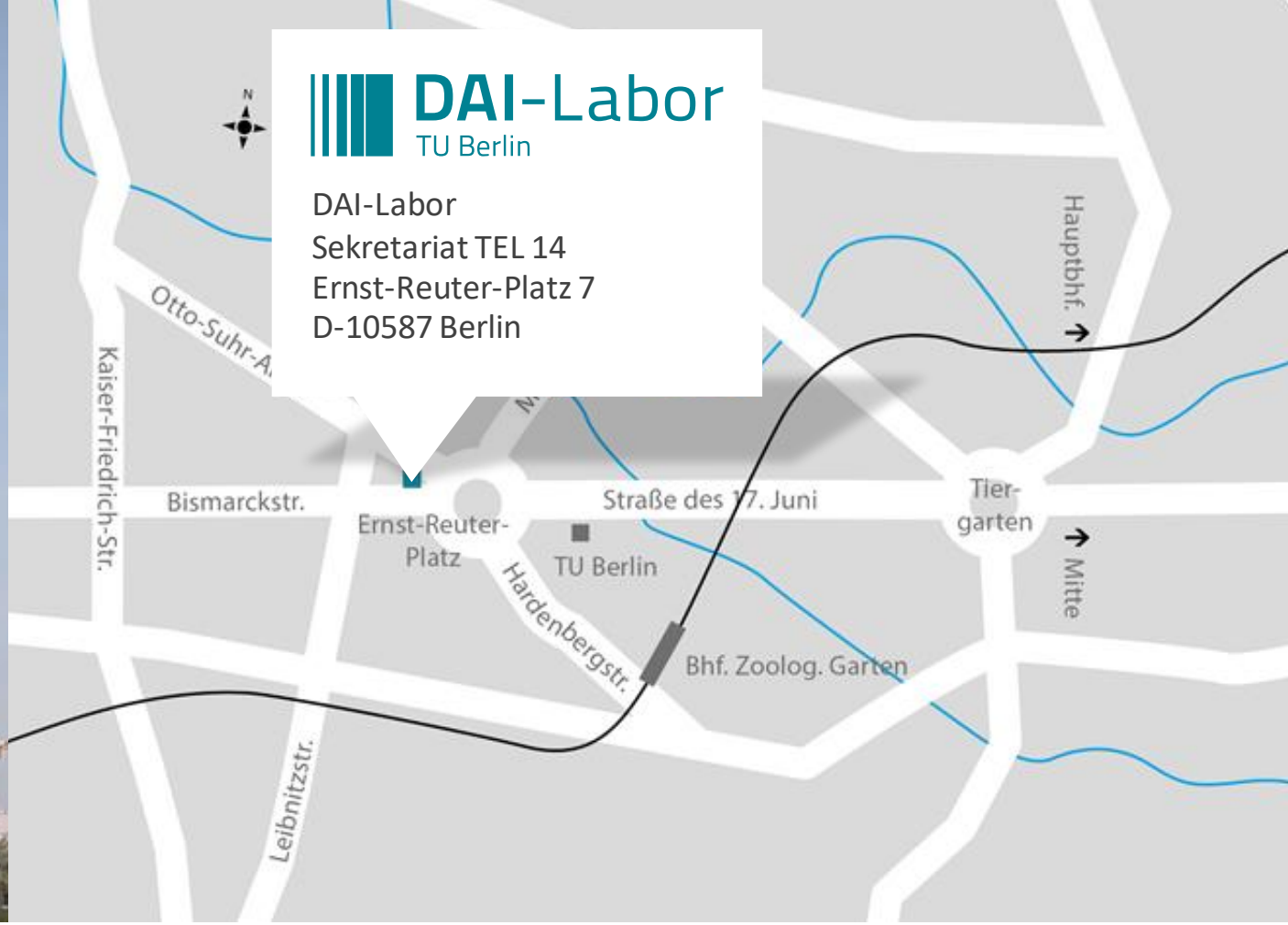
- **Project Topic 1 (NWDAF Implementation)**
  - Group 1a: 3-4 students
  - Group 1b: 3-4 students
- **Project Topic 2 (Predictive QoS for CAM)**
  - 2-3 students
- **Project Topic 3 (5G-RSU Monitoring and Management)**
  - 1-2 student(s)





Next Steps

- **15 Nov.** (Starting today) Student submit topics preferences on ISIS
  - https://isis.tu-berlin.de/mod/ratingallocate/view.php?id=1386617
- **18 Nov.** Finalization and announcement of group members by course organizers
- **13 Dec.** Student group presentations about the initial work plan, task allocation, and progress so far
  - Allows for synchronization before the new year's break
  - Ensures we're all on the same page
- **7 Feb.** Student group presentations for detailed status update and early prototype demonstrations
- **14 Mar.** Final delivery of software and documentation



Get In Touch

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