
KubeCon
CloudNativeCon
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E2E Observability for Connected Vehicle Service via Distributed Tracing

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Summary

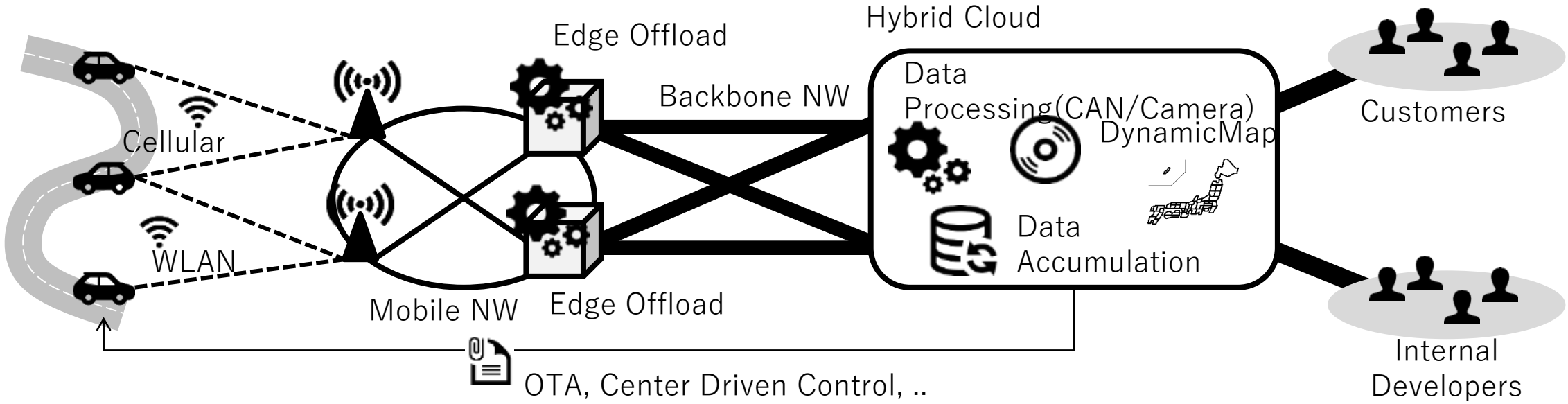
Instrumenting 5G System used by Connected Vehicle Service with OpenTelemetry:

- Prompt RCA from correlation of Traces, Metrics and Logs
- Calculation of the number of affected subscribers of 5G used by SUPI
- Reduction in the amount of computation required to create a transaction log

Example of 5G System Procedure: Registration Procedure

Overview of E2E Communication of Connected Vehicles

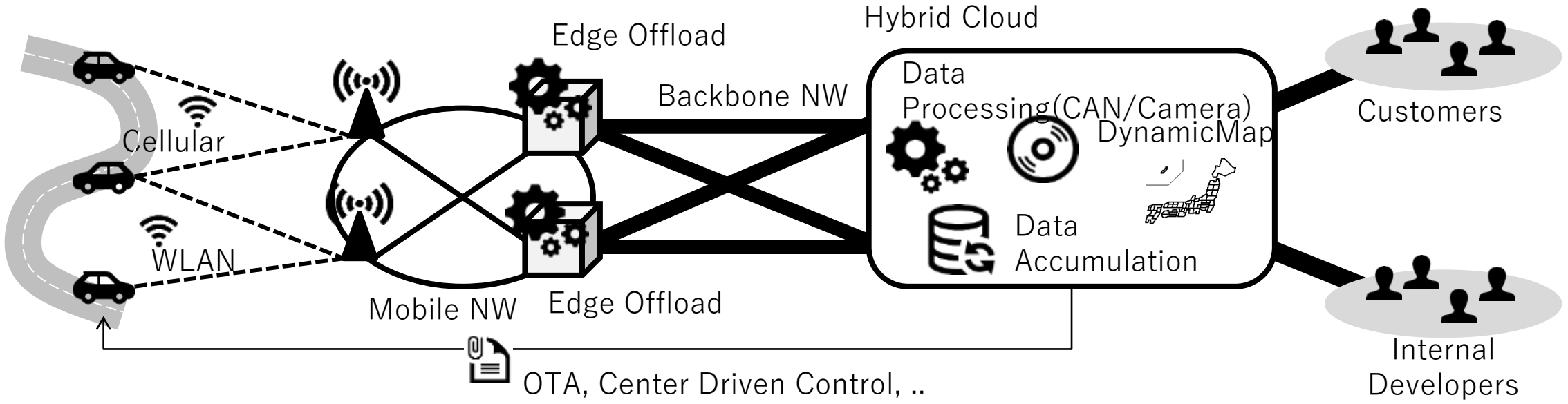
- Trend : CASE - Connected, Autonomous, Shared, Electric
- Data Type : CAN(Sensor data) , Camera, Geo Location, …
- Data Handling : Real-time/Batch processing, Data accumulation
- System Architecture : Hybrid Cloud (Public Cloud, On-premise, Edge Offload…)
- Connectivity : Cellular, WLAN, V2X, …



Requirements for Mobile Network Operator

Requirements from Mobile Network Operator side:

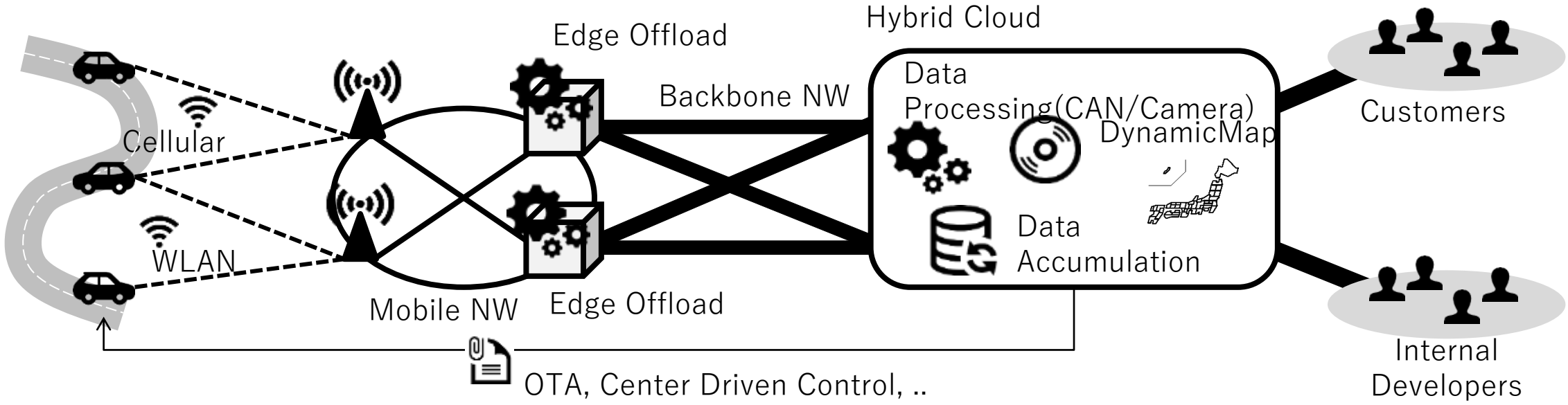
- Systems with large numbers of users constantly connected
- Provided for IoT devices such as connected cars
- Accountability for the failure impact



Requirements for Mobile Network Operator

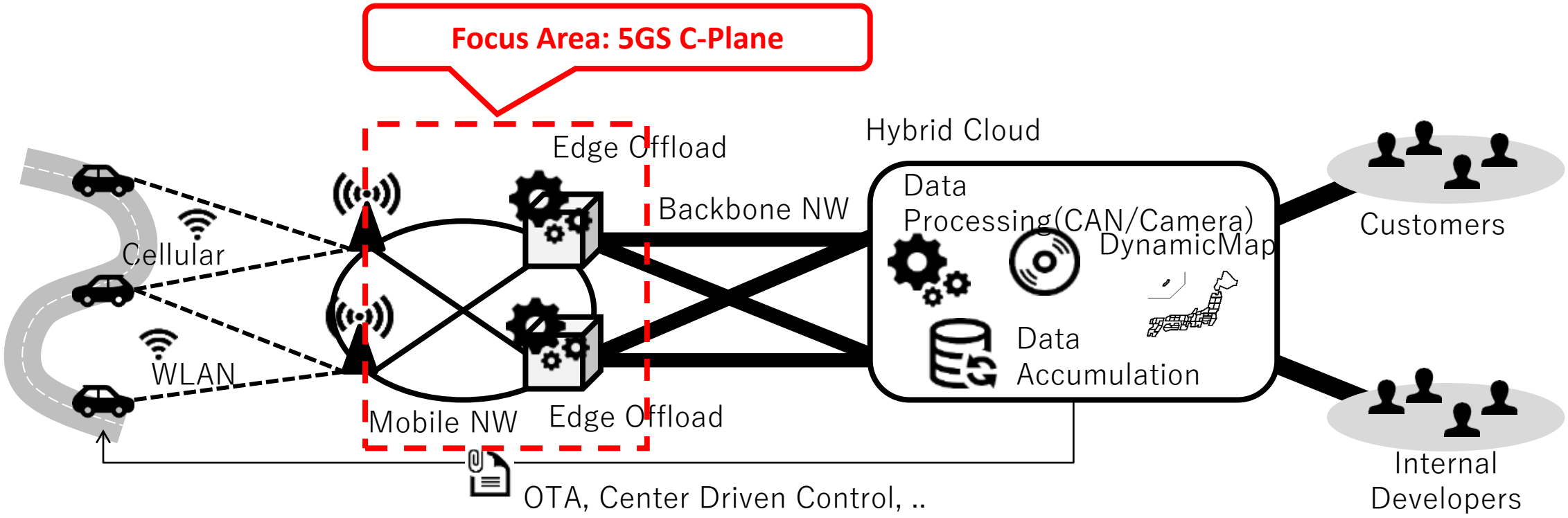
Requirements from Connected Vehicles Service side:

- Areas where vehicle communication is affected
- Vehicles that get affected from the trouble
- What kind of communication trouble? (e.g., Intermittent or Persistent)
- When the trouble are expected to be resolved



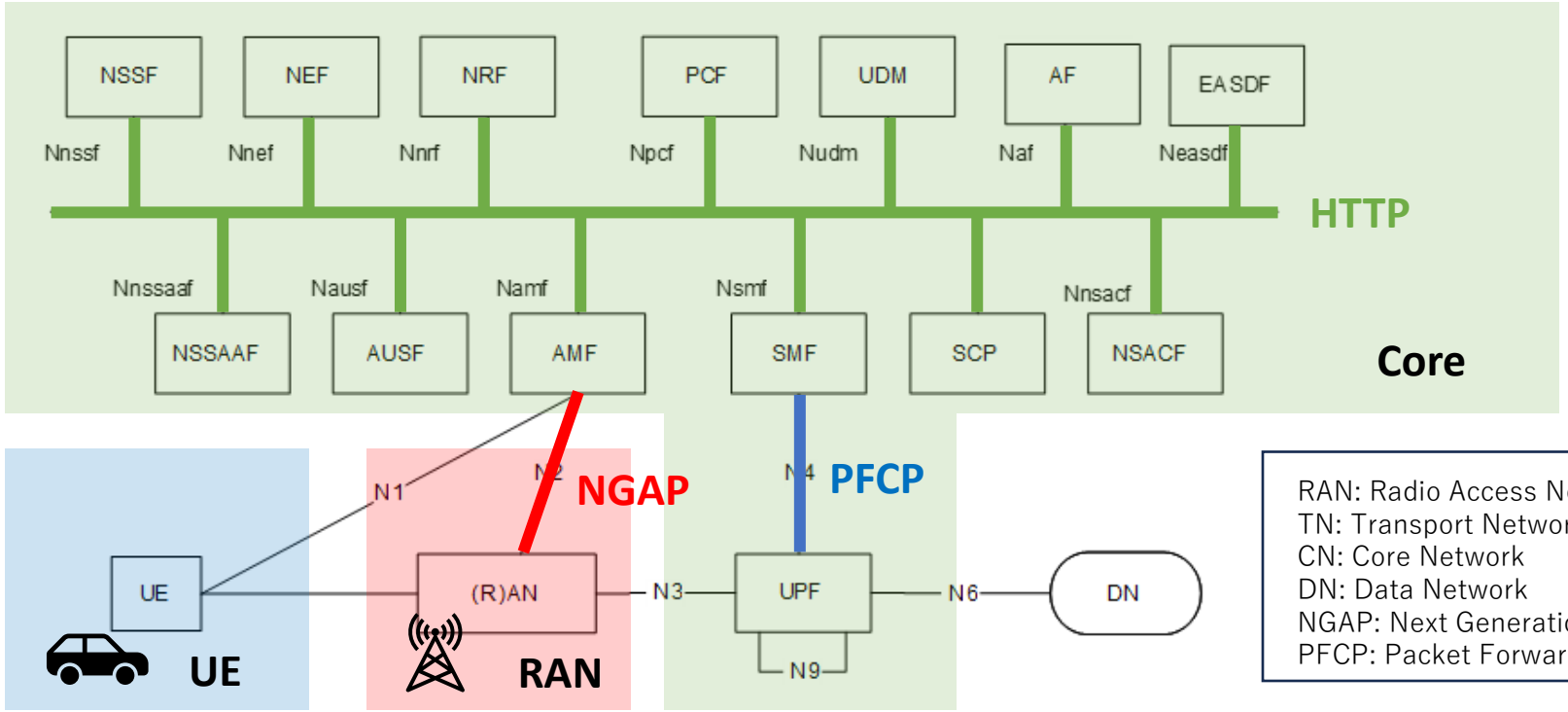
Current Challenges

- It is difficult to identify network or application domain issue
- Quick recovery from failures and understanding the impact of failure
- It takes time to create session logs at each NF and to combine them with other NFs



3GPP 5GS Architecture

- Mobile Network are composed of RAN, TN, and CN
- 5GS adopt Control and User Plane Separation (CUPS)
- The C-plane protocols used in 5GC include **HTTP** and 3GPP-defined such as **NGAP** and **PFCP**

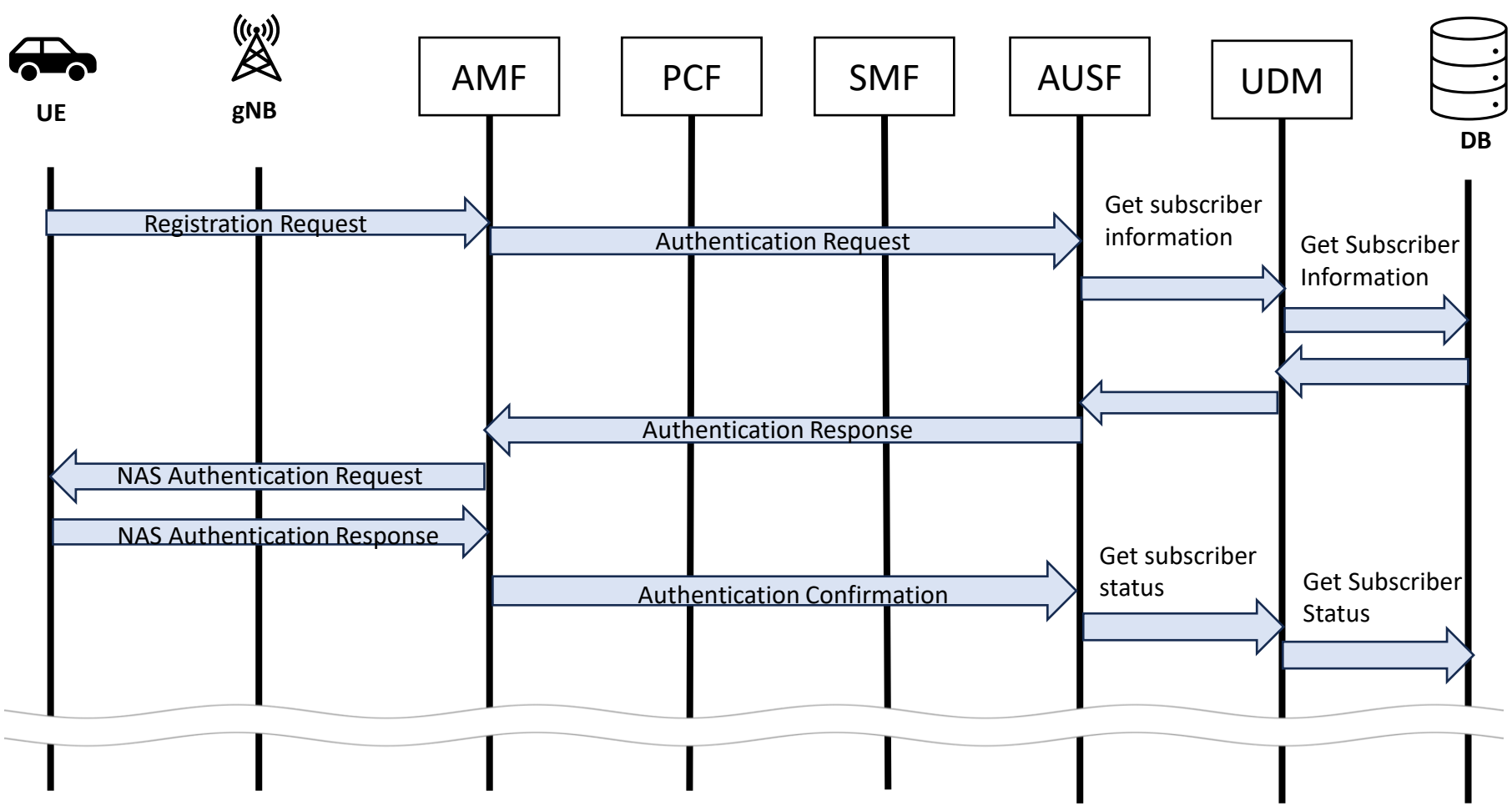


RAN: Radio Access Network
TN: Transport Network
CN: Core Network
DN: Data Network
NGAP: Next Generation Application Protocol
PFCP: Packet Forwarding Control Protocol

Fig. 3GPP TS 23.502, "System Architecture for the 5G System (5GS); Stage 2," Version 18.3.0 Release 18 , September 2023, Figure 4.2.3-1: Non-Roaming 5G System Architecture.

5GS Procedure – Registration Outline

- Messages are exchanged by several 5G components, making it difficult to trace procedures



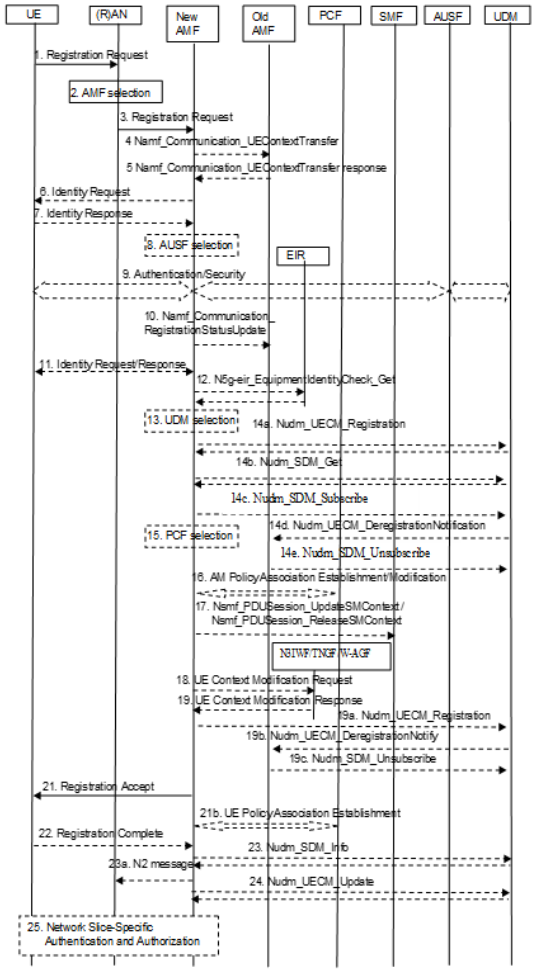


Fig. 3GPP TS 23.502, “System Architecture for the 5G System (5GS); Stage 2,“ Version 18.3.0 Release 18 , September 2023, Figure 4.2.3-1: Non-Roaming 5G System Architecture.

Introduction to free5GC and UERANSIM

https://github.com/free5gc

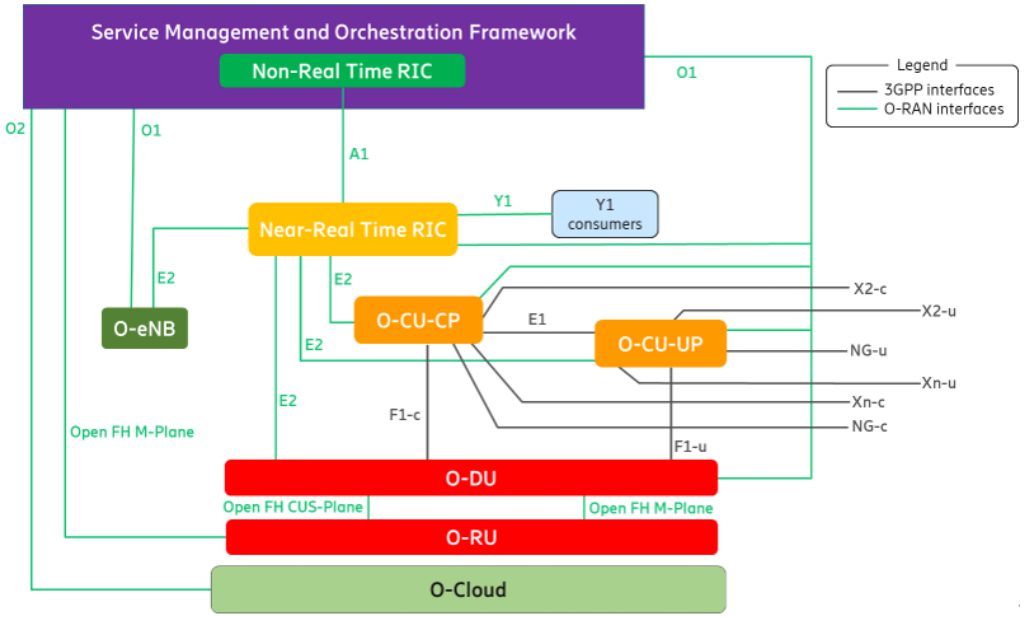
- Open source 5G core network software
- Implements 3GPP Release 15 specifications for 5G core network
- Supports network slicing, QoS, and security features

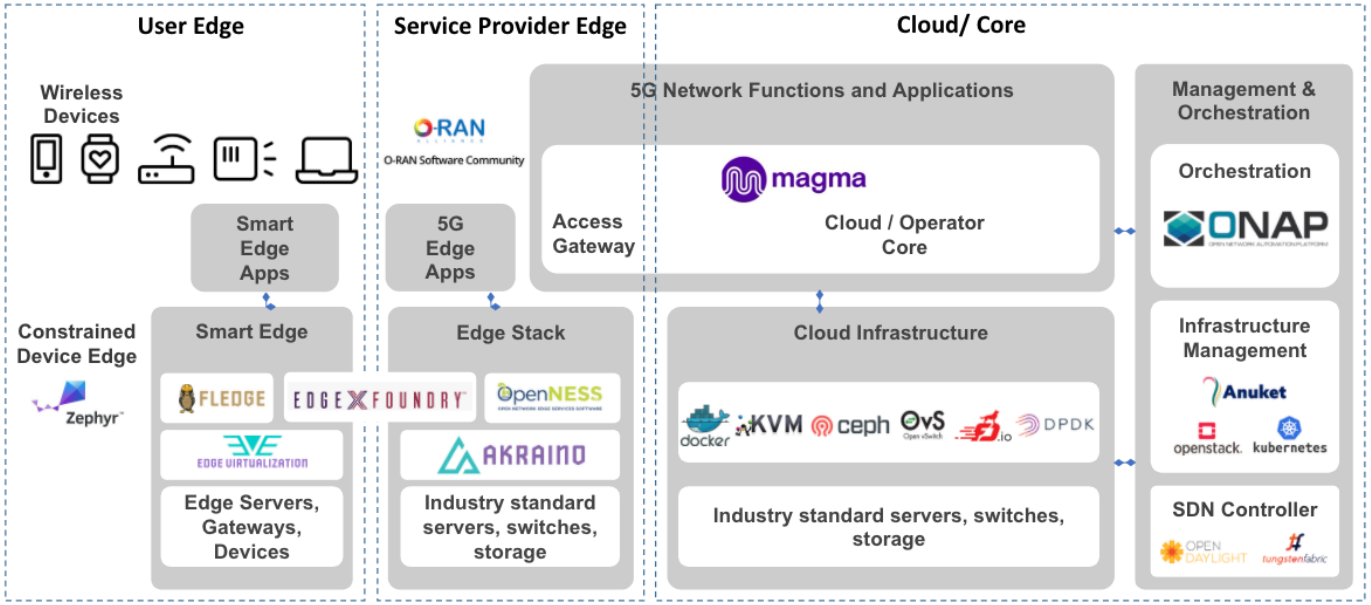
https://github.com/aligungr/UERANSIM

- Open source 5G RAN simulator
- Supports 3GPP Release 15 and 16 specifications
- Allow users to simulate various RAN scenarios

Cloud-native Network Function (CNF)

- Using Cloud-Native Network Function enables the implementation of Slice and MEC
  - Providing a flexible and efficient network infrastructure
- Linux Foundation 5G Super Blueprint
  - It means to collaborate and create end-to-end 5G solutions
  - CNFs are essential for automation and Closed-Loop



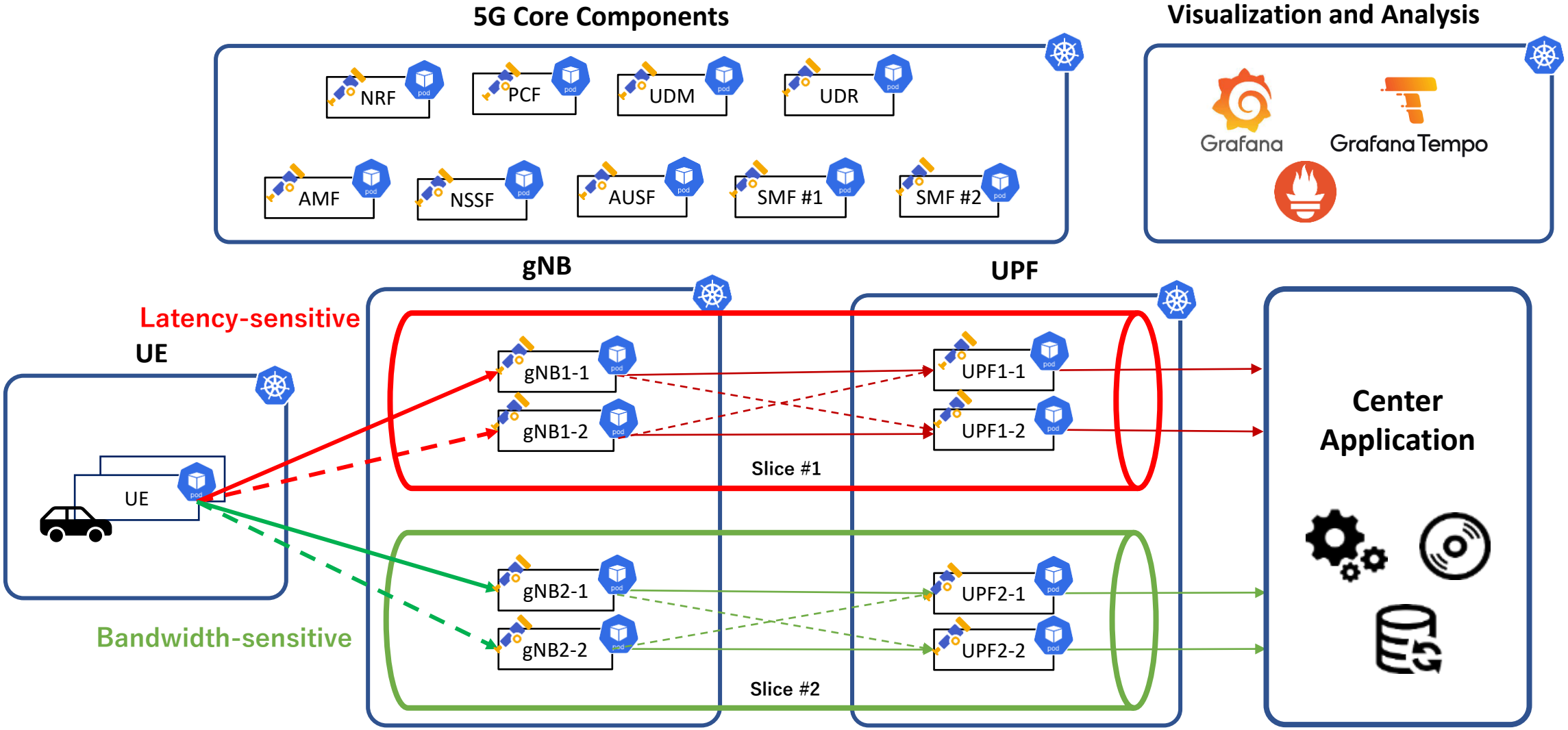


https://docs.o-ran-sc.org/en/latest/architecture/architecture.html

https://wiki.lfnetworking.org/pages/viewpage.action?pageId=53609061

5GS Used in the Demonstration

- Using OpenTelemetry, we instrumented each component of the 5G network



Propagate TraceContext in 5G System

- NGAP and PFCP are defined as a set of messages composed by Information Elements (IE)
- Add TraceContext IE to Message in NGAP and PFCP so that TraceContext can be propagated
- As for HTTP, it is standardized as W3C TraceContext

NGAP

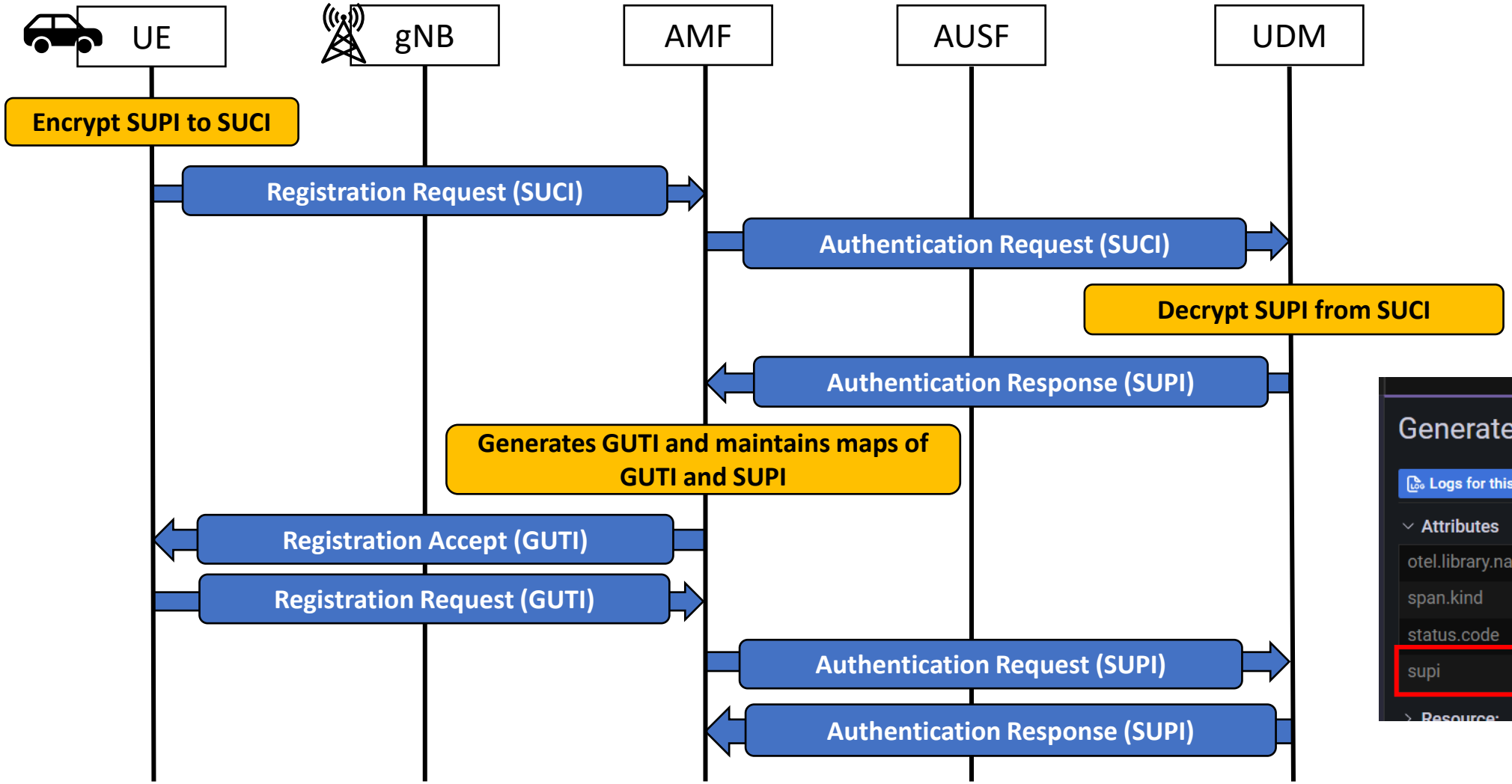
Message
DOWNLINK RAN CONFIGURATION TRANSFER
DOWNLINK RAN STATUS TRANSFER
DOWNLINK NAS TRANSPORT
ERROR INDICATION
Initial UE Message
UPLINK NAS TRANSPORT
AMF STATUS INDICATION
PWS RESTART INDICATION
PWS FAILURE INDICATION
DOWNLINK UE ASSOCIATED NRPPA TRANSPORT
UPLINK UE ASSOCIATED NRPPA TRANSPORT
DOWNLINK NON UE ASSOCIATED NRPPA TRANSPORT
UPLINK NON UE ASSOCIATED NRPPA TRANSPORT
TRACE START
TRACE FAILURE INDICATION
DEACTIVATE TRACE
CELL TRAFFIC TRACE
LOCATION REPORTING CONTROL
LOCATION REPORTING FAILURE INDICATION
LOCATION REPORT
UE TNLA BINDING RELEASE REQUEST
UE RADIO CAPABILITY INFO INDICATION
RRC INACTIVE TRANSITION REPORT
OVERLOAD START
OVERLOAD STOP
SECONDARY RAT DATA USAGE REPORT
UPLINK RIM INFORMATION TRANSFER
DOWNLINK RIM INFORMATION TRANSFER
RETRIEVE UE INFORMATION
UE INFORMATION TRANSFER
RAN CP RELOCATION INDICATION
CONNECTION ESTABLISHMENT INDICATION
AMF CP RELOCATION INDICATION
HANDOVER SUCCESS
UPLINK RAN EARLY STATUS TRANSFER
DOWNLINK RAN EARLY STATUS TRANSFER

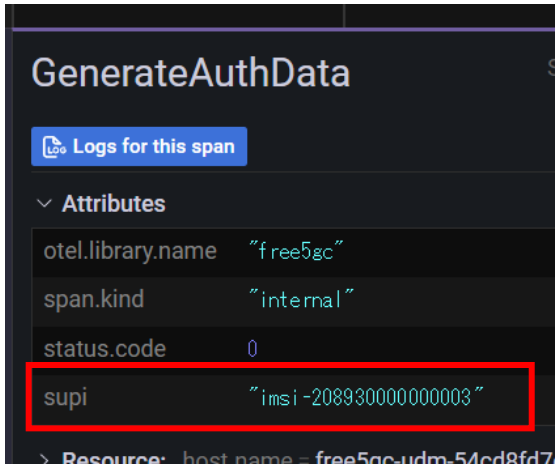
```
InitialUEMessage ::= SEQUENCE {
    protocolIEs     ProtocolIE-Container        { {InitialUEMessage-IEs} },
    ...
}

InitialUEMessage-IEs NGAP-PROTOCOL-IES ::= {
    { ID id-RAN-UE-NGAP-ID                      CRITICALITY reject  TYPE RAN-UE-NGAP-ID                      PRESENCE mandatory   }|
    { ID id-NAS-PDU                             CRITICALITY reject  TYPE NAS-PDU                             PRESENCE mandatory   }|
    { ID id-UserLocationInformation             CRITICALITY reject  TYPE UserLocationInformation             PRESENCE mandatory   }|
    { ID id-RRCEstablishmentCause               CRITICALITY ignore  TYPE RRCEstablishmentCause               PRESENCE mandatory   }|
    { ID id-FiveG-S-TMSI                        CRITICALITY reject  TYPE FiveG-S-TMSI                        PRESENCE optional    }|
    { ID id-AMFSetID                            CRITICALITY ignore  TYPE AMFSetID                            PRESENCE optional    }|
    { ID id-UEContextRequest                    CRITICALITY ignore  TYPE UEContextRequest                    PRESENCE optional    }|
    { ID id-AllowedNSSAI                        CRITICALITY reject  TYPE AllowedNSSAI                        PRESENCE optional    }|
    { ID id-SourceToTarget-AMFInformationReroute CRITICALITY ignore TYPE SourceToTarget-AMFInformationReroute PRESENCE optional    }|
    { ID id-SelectedPLMNIdentity                CRITICALITY ignore  TYPE PLMNIdentity                        PRESENCE optional    }|
    { ID id-IABNodeIndication                   CRITICALITY reject  TYPE IABNodeIndication                   PRESENCE optional    }|
    { ID id-CEmodeBSupport-Indicator            CRITICALITY reject  TYPE CEmodeBSupport-Indicator            PRESENCE optional    }|
    { ID id-LTEM-Indication                     CRITICALITY ignore  TYPE LTEM-Indication                     PRESENCE optional    }|
    { ID id-EDT-Session                         CRITICALITY ignore  TYPE EDT-Session                         PRESENCE optional    }|
    { ID id-AuthenticatedIndication             CRITICALITY ignore  TYPE AuthenticatedIndication             PRESENCE optional    }|
    { ID id-NPN-AccessInformation               CRITICALITY reject  TYPE NPN-AccessInformation               PRESENCE optional    },
    ...
}
```

Insert TraceContext IE

Embed SUPI in Span Attribute

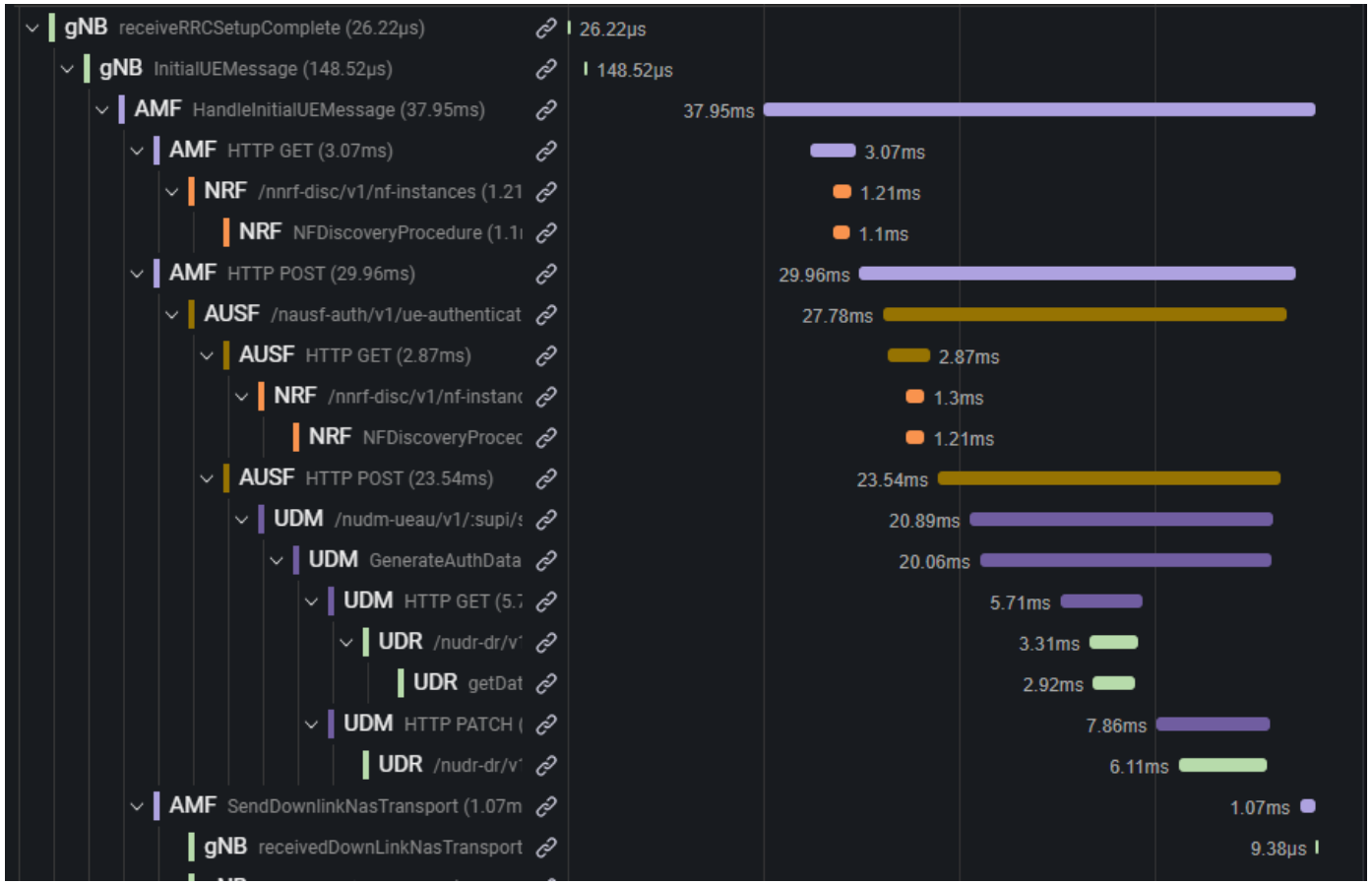
- Assign SUPI to Span Attribute in AMF and UDM to enable tracing per UE





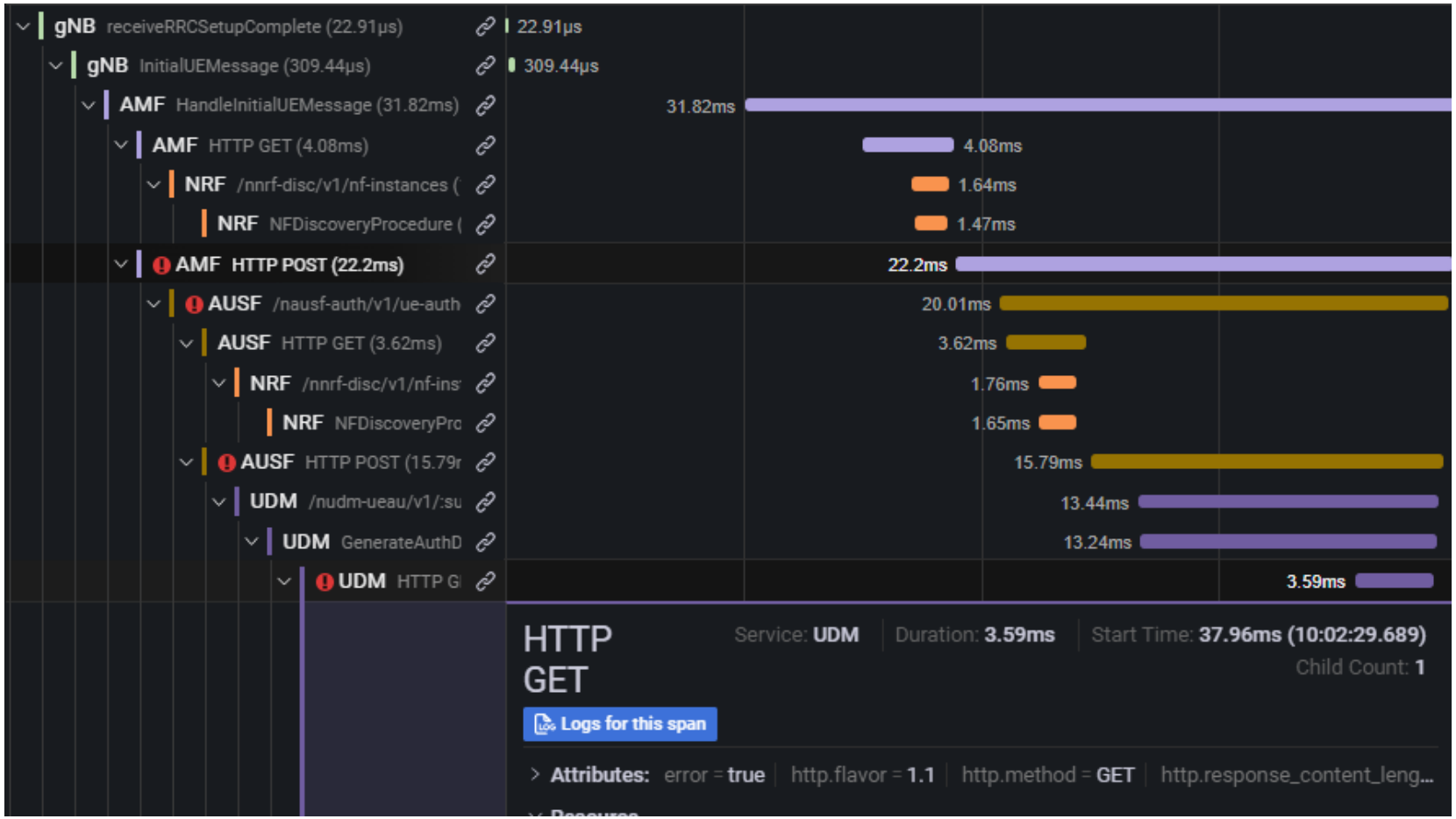
Tracing the Registration Procedure in 5G Network

- Easily understand the Registration Procedure process based on the actual process



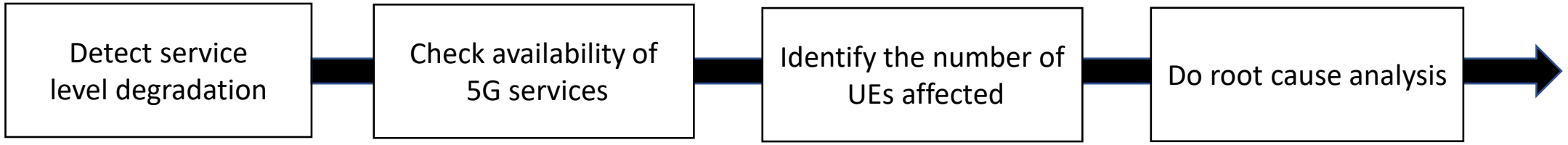
Tracing the Registration Procedure in 5G Network

- Easily identify which component is causing the error



Correlate to Traces, Metrics, and Logs for RCA

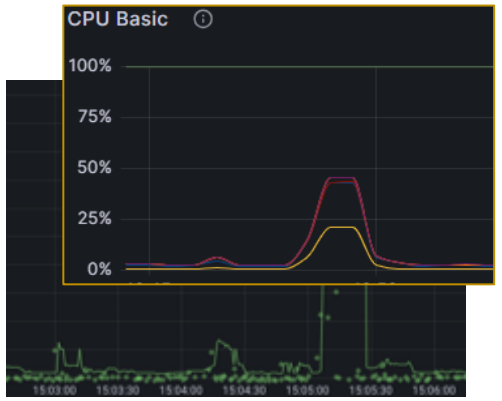
Troubleshooting Step



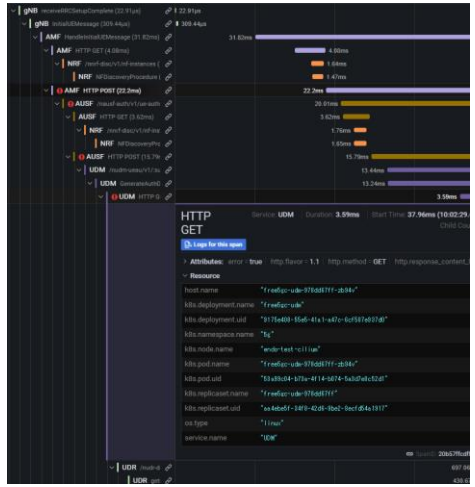
Requirements for correlation

- Instrumentation of 5GS for traces
- Logging TraceID
- Configured Loki datasource
- Implemented Prometheus exemplar

Metrics



Traces

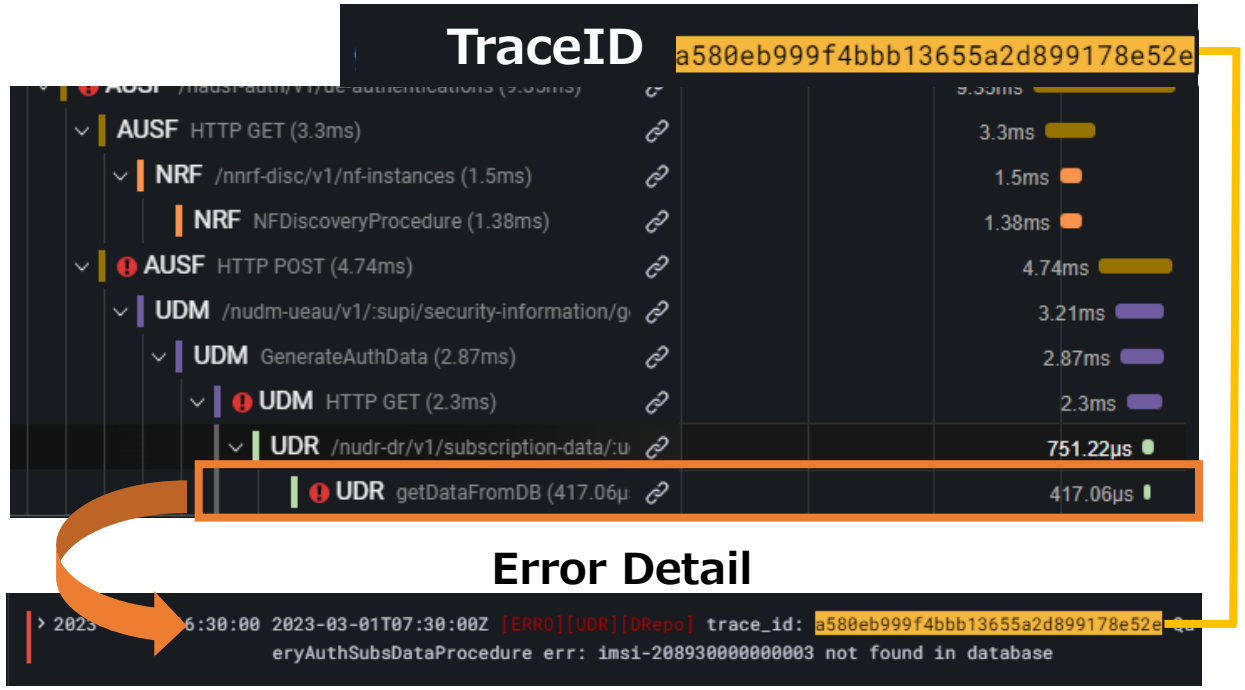


Logs

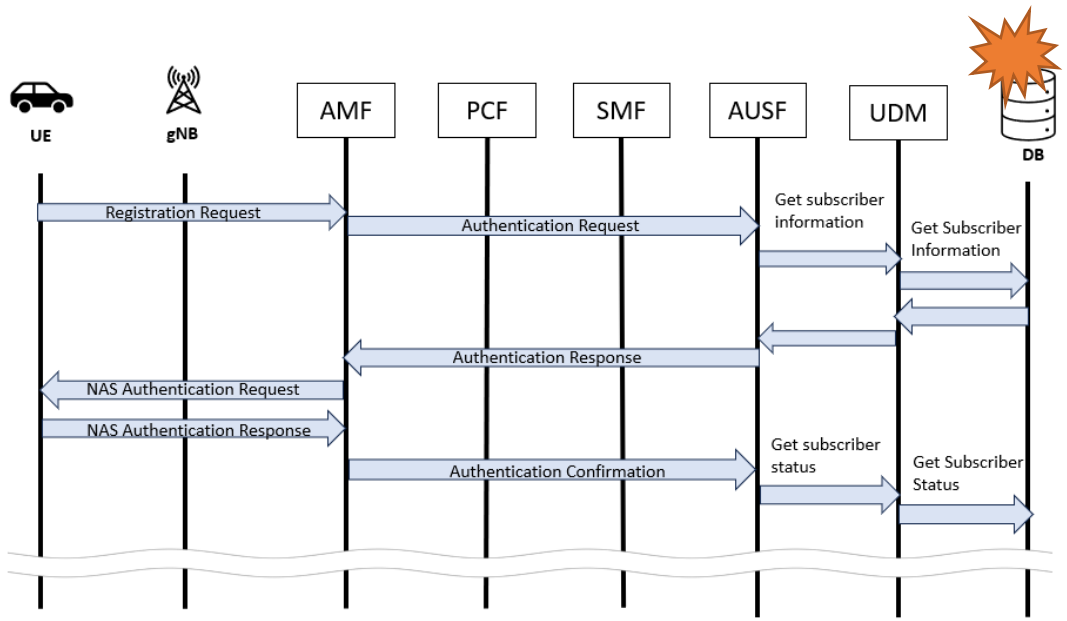
```
> 2023-03-01 16:30:00 2023-03-01T07:30:00Z [ERRO][UDR][DRepo] trace_id: a580eb999f4bbb13655a2d899178e52e QueryAuthSubsDataProcedure err: imsi-208930000000003 not found in database
```

Correlate to Traces, Metrics, and Logs for RCA

- It is possible to identify where the failure has occurred and the root cause



DB failure occurred



Detailed analysis with Log from Trace

Calculation of the Number of Affected Terminals Using Tracing

Embedding SUPI in Span Attribute allows linking UE and Trace

- Enables understanding of the impact of failures and performance measurement per UE
- **SUPI ⇔ IMEI ⇔ Vehicle ID**

Search Target

✓ error=true

✓ procedure=registration

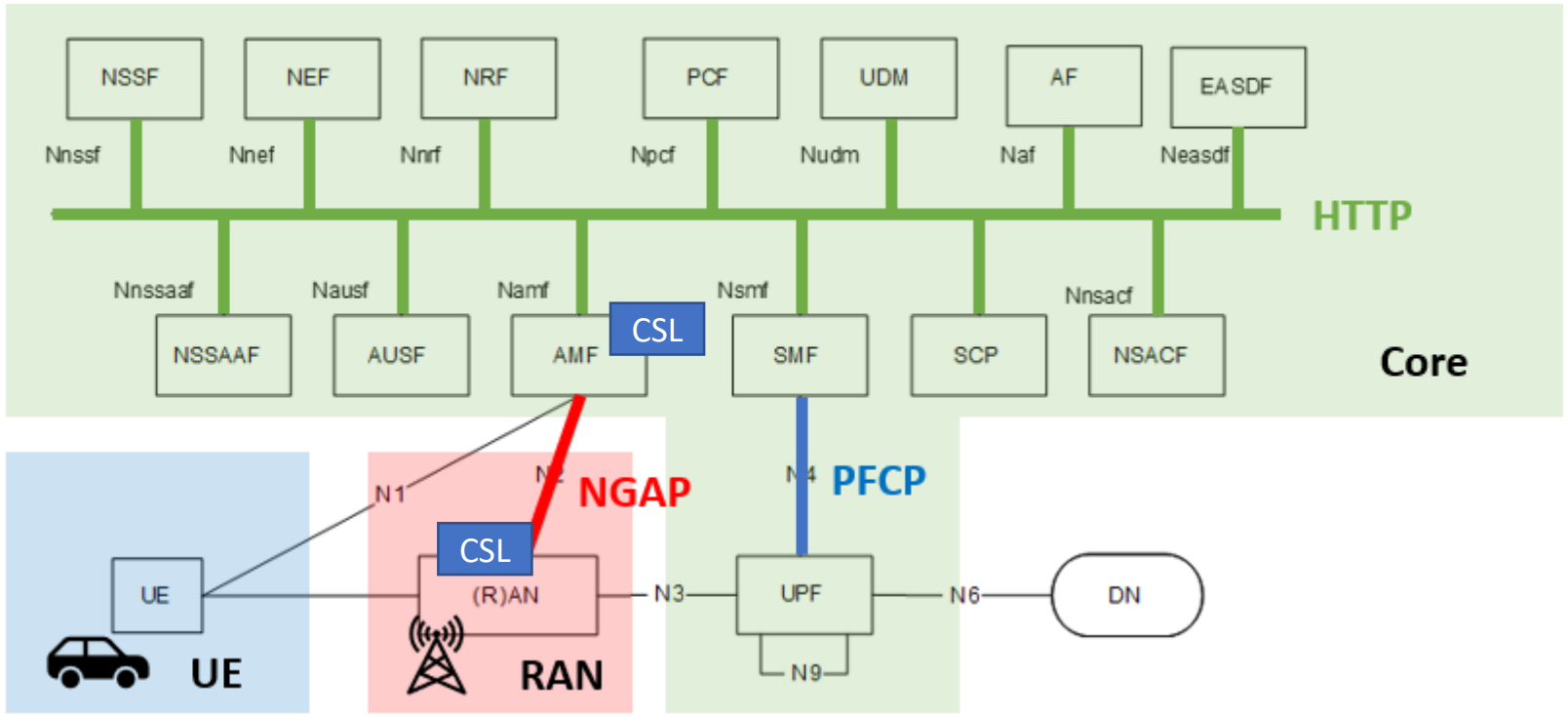
Data Utilization Efficiency Compared to Conventional Methods

- Call Summary Log (CSL) is not integrated in E2E
- Creating CSL and creating transaction logs by merging CSLs is computationally expensive

⇒Using Trace eliminates the need for later CSL integration

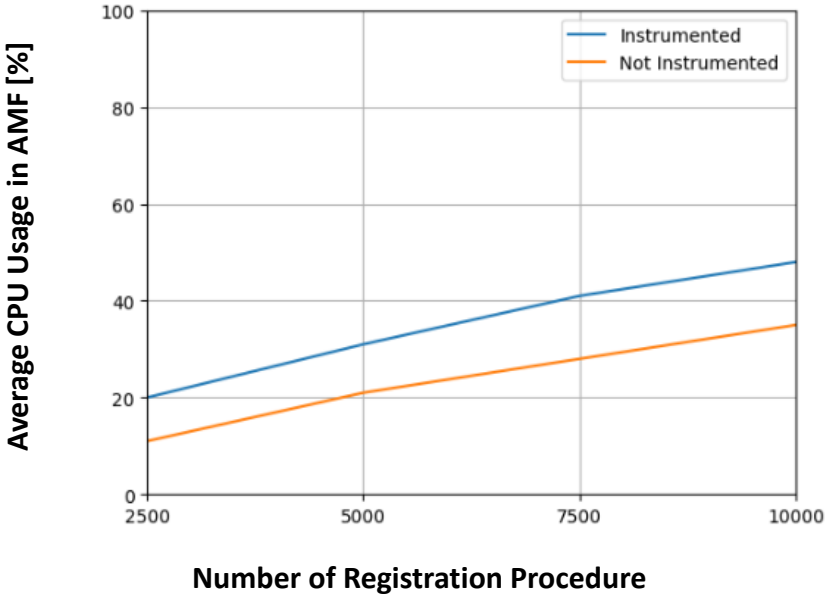
CSL example

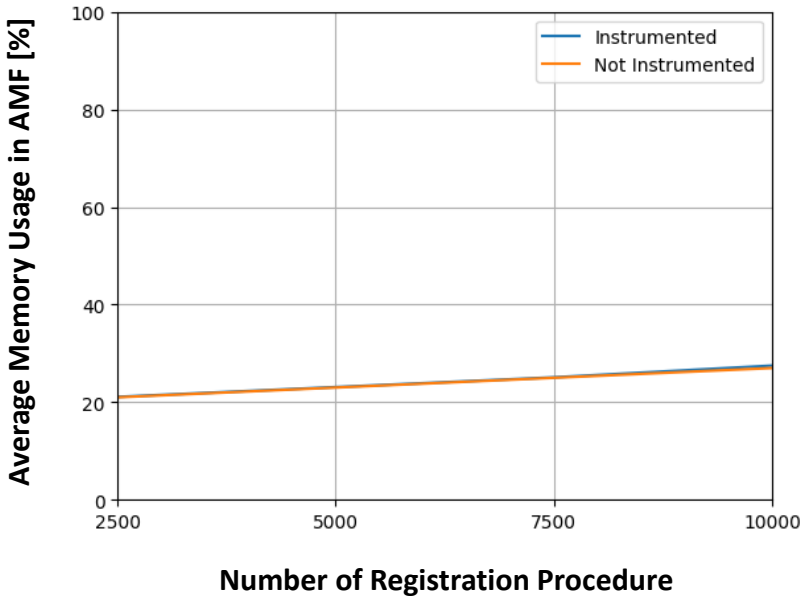
1	CSLVersion
2	IMSI
3	IMEISV
4	MSISDN
5	N_TMSI
6	PLMN
7	N_TAC
8	NCI
9	Access time
10	Disconnection time
11	CRR(Call Release Reason)
12	AMF_REGION_ID
13	AMF_SET_ID
14	AMF_POINTER
15	COR(Call ORIGINATING Reason)
16	SERVICE_QUERIED
17	GNODEB_UE_NGAP_ID
18	AMF_UE_NGAP_ID
19	TARGET_GLOBAL_ENB_ID
20	TARGET_EPS_TAI
21	TARGET_MME
22	PDU_SESSIONS
23	OLD_GNODEB_UE_NGAP_ID
24	OLD_AMF_UE_NGAP_ID
25	OLD_AMF_REGION_ID
26	OLD_AMF_SET_ID
27	OLD_AMF_POINTER
28	SMF_INSTANCE
29	SMF_INSTANCE_IP
30	S_NSSAI
31	ASSIGNED_EBIS
32	N_OLD_TAI
33	OLD_NCI
34	EMERGENCY_REGISTRATION
35	MICO_MODE
36	PERIODIC_REGISTRATION_UPDATE_TIMER
37	SLICE_SELECTION_INFO
38	PDU_SESSION_ID
39	UE_REQUESTED_DNN
40	SERVICE_REQUEST
41	PDU_SESSIONS_REACTIVATE
42	PDU_SESSIONS_NOT_REACTIVATE
43	PDU_SESSIONS_MISMATCH
44	[illegible]
45	PDU_SESSIONS_REMOVAL_ON_SMF_FAILURE
46	N_PAGING
47	PAGING_DETAILS
48	EVENT_ID
49	EVENT_RESULT
50	N_CAUSE_PROT_TYPE_AND_N_CAUSE_CODE
51	N_SUB_CAUSE_CODE
52	TAC
53	Serial
54	SV



CPU and Memory Usage

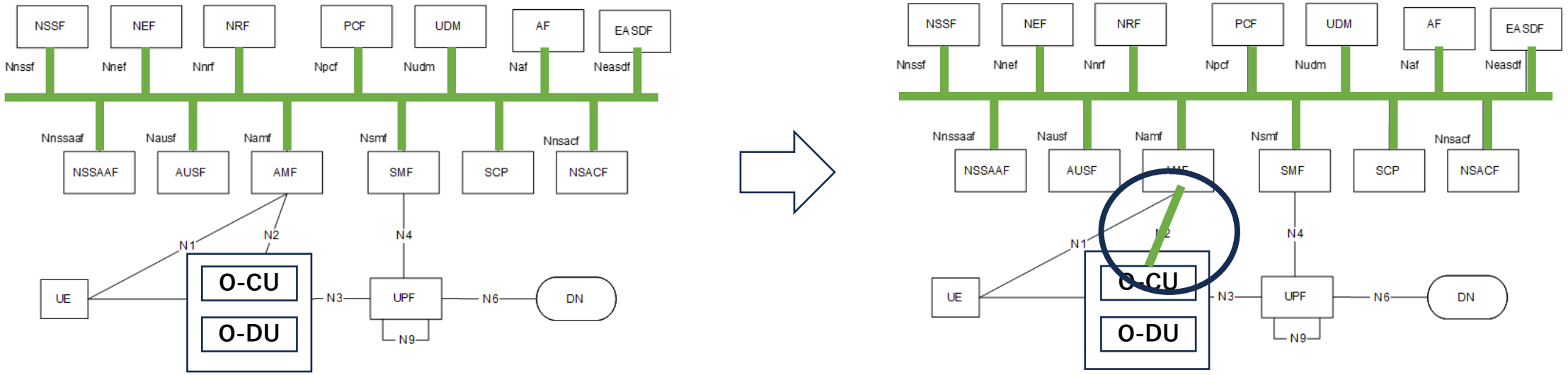
- Benchmark Scenario
  - The Network Function (NF) benchmarked is the AMF with the highest C-Plane processing load
  - In the AMF Pod, vCPUx4 (Intel Xeon E5-2650L v3 @ 1.80GHz) and Memory 8 GB are allocated
  - Deploy OTel Collector as a sidecar
  - Generate Registration error caused by user not being registered in the subscriber DB
  - The Registration procedure occurred 2500~10000 times within 30 seconds





Next Step

- Harmonization with 3GPP
  - There was a proposal in 3GPP to adopt HTTP over N2
  - This use case using OpenTelemetry will contribute to the standardization of RAN and Core convergence, serving as an example for future developments



- Toyota is presenting their 5G U-Plane activity related to this presentation at Open Source Summit Japan on 6 December 2023.
  - https://ossjapan2023.sched.com/event/1Tyrm

Summary

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  - Prompt RCA from correlation of Traces, Metrics and Logs
  - Calculation of the number of affected subscribers of 5G used by SUPI
  - Reduction in the amount of computation required to create a transaction log
- Next Step: Harmonization with 3GPP, U-Plane observability and SMO observability

Example of 5G System Procedure: Registration Procedure

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