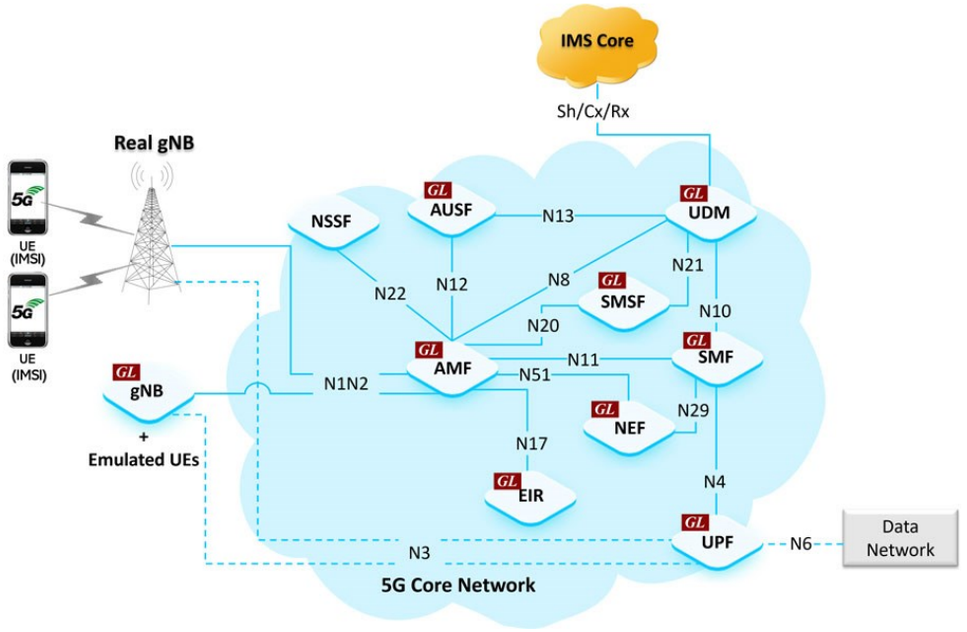
5G Core (5GC) Network Test Solutions

October 2024



- **5G Communications Network Lab**
- **5G Core Network Emulation -**
  - **MAPS™ 5G N1 N2 Interface Emulator**
  - **MAPS™ 5G N4 Interface Emulator**
  - **MAPS™ 5G N8 Interface Emulator**
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  - **MAPS™ 5G N29 Interface Emulator**
  - **MAPS™ 5G N51 Interface Emulator**
- **Monitoring 5G Core Network**

For more information, refer to 5G Core (5GC) Network Test Solution webpage.

GL Communications Inc.
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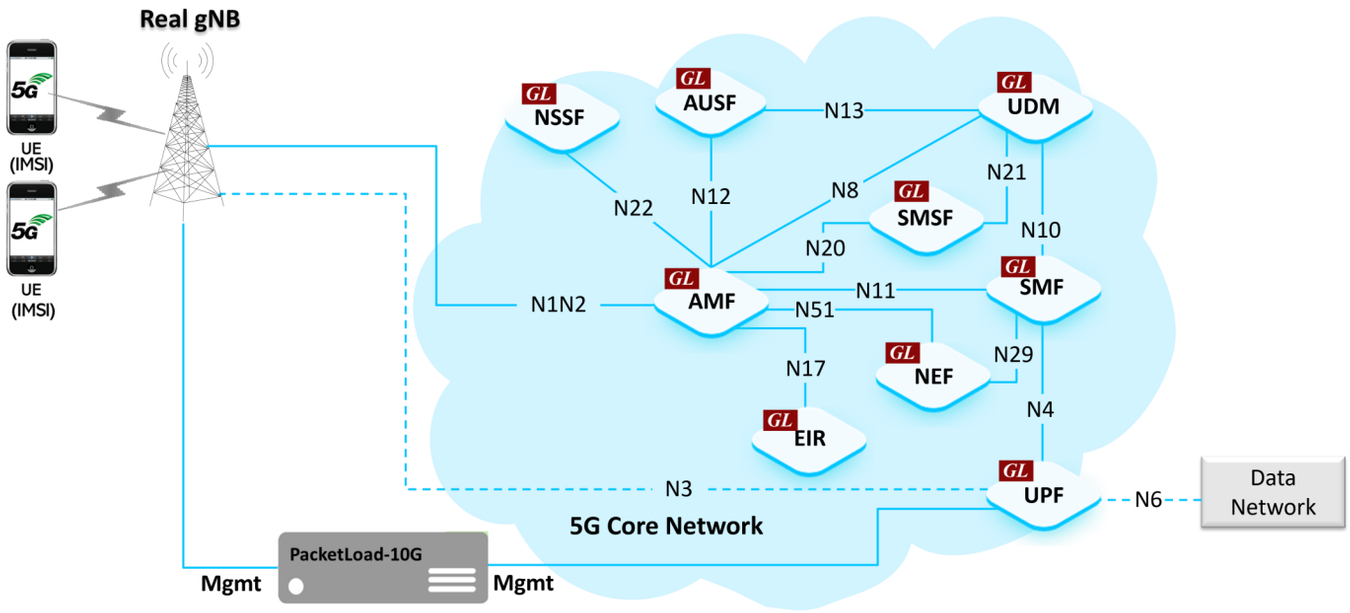
5G Core Network Emulation

5G Communications Network Lab



GL offers an end-to-end 5G Communication Network Lab (CNL) with all components within the wireless infrastructure to emulate 5G Core and it provides an advanced full-fledged "Live Network" at premises in any customized package to suit test requirements. The test suite provides reliable integrated solutions to vendors and service providers for emulation, monitoring, troubleshooting the wireless network, including, 5G, 4G, 3G and 2G. All functionalities conform to industry standards.

MAPS™ 5GC Network emulator can emulate multiple UEs and elements such as UE+gNB, AMF, SMF, UPF, AUSF, UDM, SMSF and EIR which forms the 5GC network. The Emulator is designed to test 5G NR base stations (gNBs) and 5G Core Network Functions (NF) according to 3GPP standards (Release 17). With the help of mobile phones, and other emulated wireless networks, the 5G Lab setup can be operated in real-time for making Voice over New Radio (VoNR) calls and for interworking with PSTN and VoIP networks. It includes ready-to-use scripts, as per IETF specification. Test scripts include general messaging and call flow scenarios for multimedia call session setup and control over IP networks.

GL's MAPS™ supports emulation of 5GC network interfaces - N1N2, N4, N8, N10, N11, N12, N13, N17, N20, N21, N22, N29, N51, and other GTP interfaces.

Supported procedures include both roaming and non-roaming, including interworking between 5G System (5G RAN + 5GC) and Evolved Packet System (4G RAN + EPC), mobility within 5GS, QoS, policy control and charging, authentication and in general 5G System wide features such as SMS, Location Services, Emergency Services.

MAPS™ is enhanced to support Linux® environments, expanding deployment options. Its web interface enables 5G emulation and testing on Linux® servers. The multi-user interface allows easy, remote test configuration from any device.

MAPS™ 5G can be configured as Command Line Interface (CLI) server application, to enable remote controlling of the application through command-line based clients. Supporting clients include Python. Clients can remotely perform all functions such as start testbed setup, load scripts, profiles, apply user events such as originate call, terminate call, start and stop traffic. Users can also generate and receive calls through commands.

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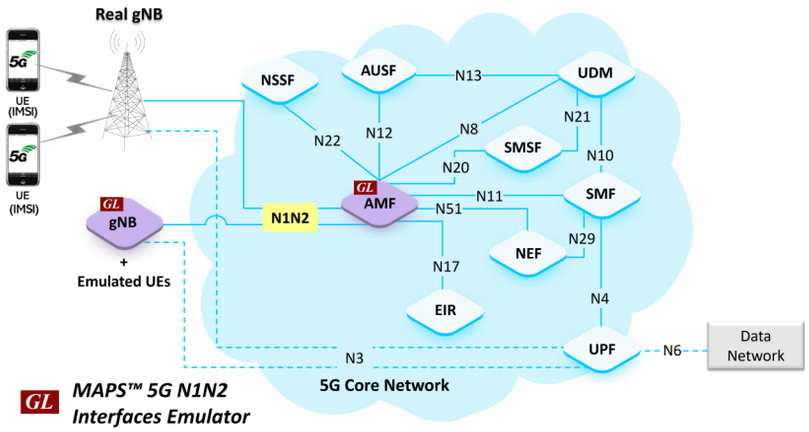
5G Core Network Emulation

MAPS™ 5G N1N2 Interface Emulator

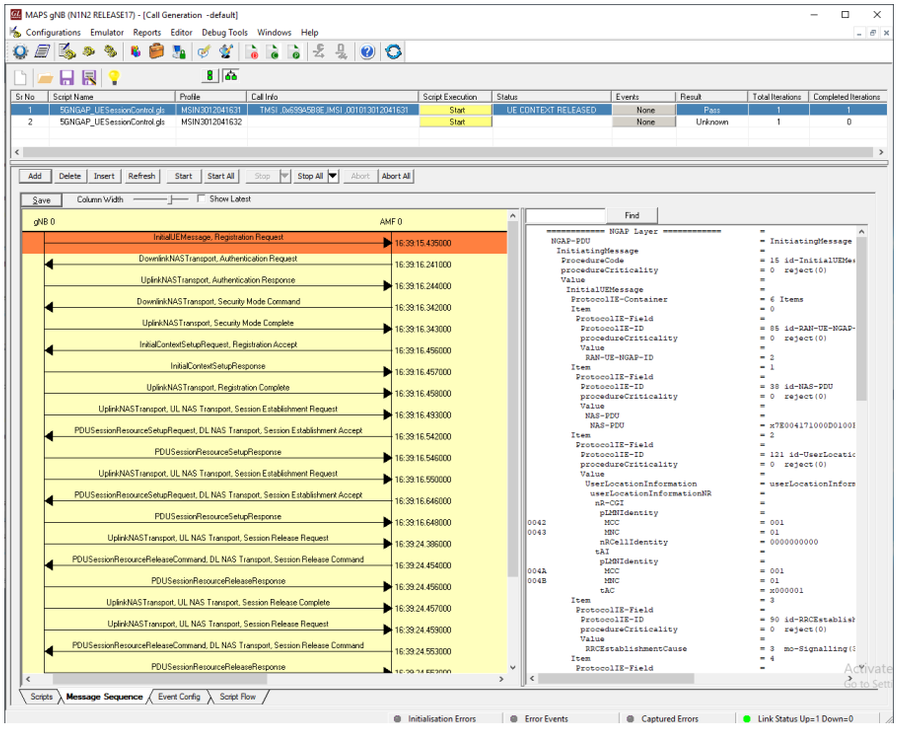
GL's Message Automation and Protocol Simulation (MAPS™) is enhanced to test 5G N1N2 interfaces, it can emulate gNodeB (gNB), and Access and Mobility Management Function (AMF) according to 3GPP standards (Release 17).

It supports Non-Access-Stratum (NAS) signaling on N1 interface between UE and AMF. It supports NGAP to emulate signaling services between NG-RAN and AMF.

In addition to control plane emulation, the application supports generation and verification of traffic, including VoNR (Voice) calls with SIP signaling and RTP Traffic generation. It also emulate mobile traffic such as HTTP, FTP, Video by playing back stateful real capture over established TCP connection with additional licenses - Mobile Traffic Core – GTP (ETH101) and Mobile Traffic Core – Gateway (ETH102).



- Setup a virtual real-time scenario simulating 5G interoperability with 4G-LTE network elements
- Emulates UE+gNodeB and AMF nodes
- Supports Control plane signaling and User plane traffic
- Supported Procedures in N1 and N2 interfaces includes -
  - NG Reset
  - NG Setup
  - Initial Context Setup
  - UE Context Release
  - Registration
  - De-registration
  - Primary authentication
  - key agreement procedure
  - Security mode control
  - Identification
- Includes gateway functionality to forward mobile traffic over GTP to and from external IP network
- Generate and process NGAP/NAS (valid and invalid) messages
- Emulates tens of thousands of 5G subscribers (Load Testing)



5G N1N2 interface Call Control Procedure at gNodeB Node (Call Generation)

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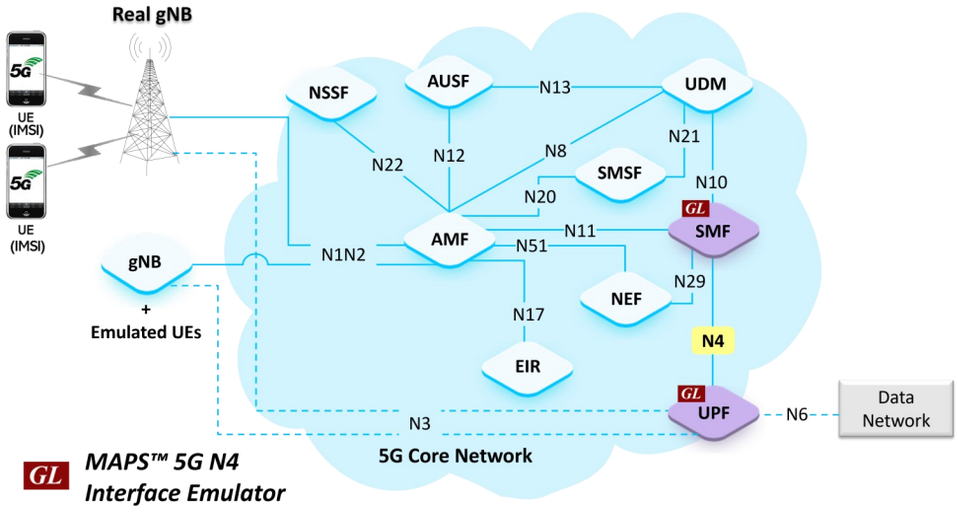
5G Core Network Emulation

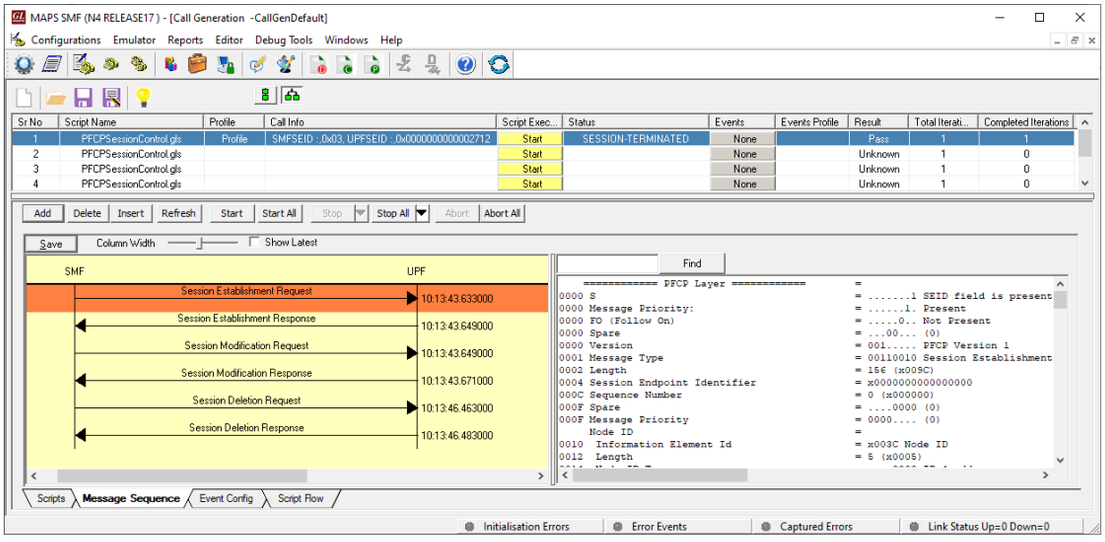
MAPS™ 5G N4 Interface Emulator

GL's MAPS™ 5G-N4 Interface Emulator is an advanced protocol emulator for 5G emulation over N4 interface that can emulate PFCP signaling messages as defined by 3GPP standards (Release 17). Packet Forwarding Control Protocol (PFCP) used on the interface between the control plane and the user plane function. As shown in the network diagram, N4 is the reference point in the control and user plane separation (CUPS) architecture.

MAPS™ 5G-N4 can emulate and test Session Management Function (SMF) and User Plane Function (UPF) elements. SMF in the 5G N4 interface is primarily concerned with managing the UE's PDU sessions. Its responsibilities include the establishment, modification, and release of the PDU sessions. UPF in the CUPS architecture is responsible for handling user data and reporting the traffic usage data to the SMF.



- Emulates Session Management Function (SMF) and User Plane Function (UPF) elements
- Supports 5G Control plane and User plane
- Supported procedures include - establishment, modification, and release of the PDU sessions
- Supported Traffic types include Mobile Traffic, Packet Traffic, and VoNR
- Generates and process PFCP (valid and invalid) messages
- Supports GTP Traffic (GTP User Plane Data), HTTP traffic generation capability
- Supports customization of call flow and message templates using Script and Message Editor
- Provides Call Statistics and Events Status
- Automation, Remote access, and Schedulers to run tests 24/7



5G N4 interface Call Control Procedure at SMF Node (Call Generation)

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5G Core Network Emulation

MAPS™ 5G Service-Based Interface Emulator

GL's MAPS™ 5G System as a service-based architecture, includes a set of network functions providing services as defined in 3GPP standards (Release 17). The service-based interfaces use HTTP/2 protocol with JavaScript Object Notation (JSON) as the application layer serialization protocol.

Main Features

- Services use REST APIs based on HTTP and JSON data format
- Supports CLI through a client-server model, enabling users to control all features via Python APIs
- Supports TLS and TCP transport
- Supports scripted call generation and automated call reception
- Supports customization of call flow and message templates using Script Editor and JSON Messages
- Ready-to-use scripts for quick testing
- Provides Call Statistics and Events Status
- Emulates multiple subscribers using CSV Profiles
- Automation, Remote access, and Schedulers to run tests 24/7

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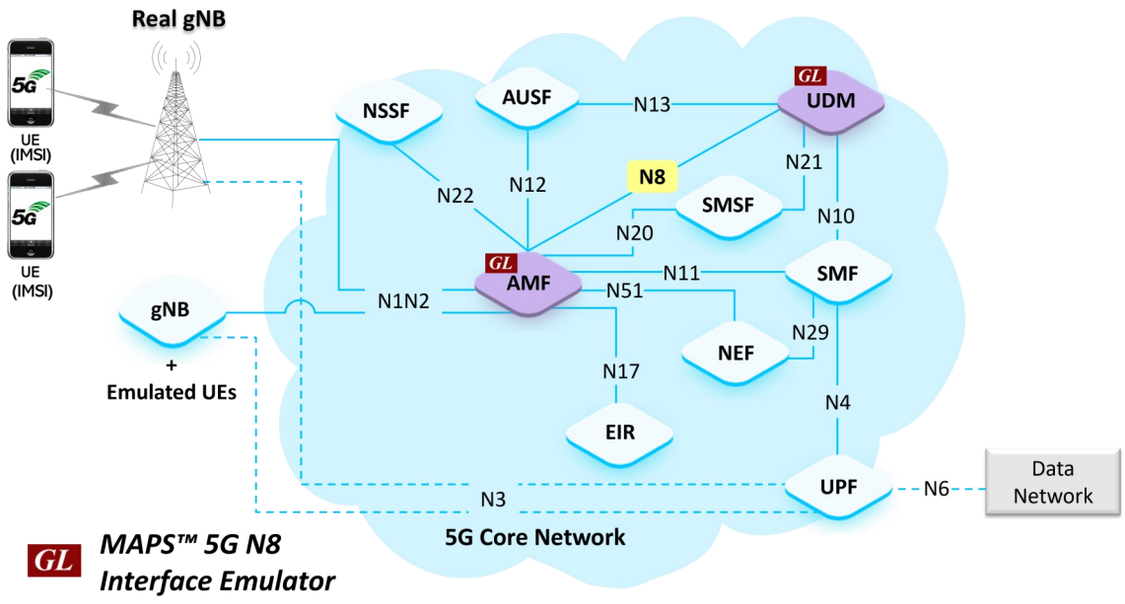
5G Core Network Emulation

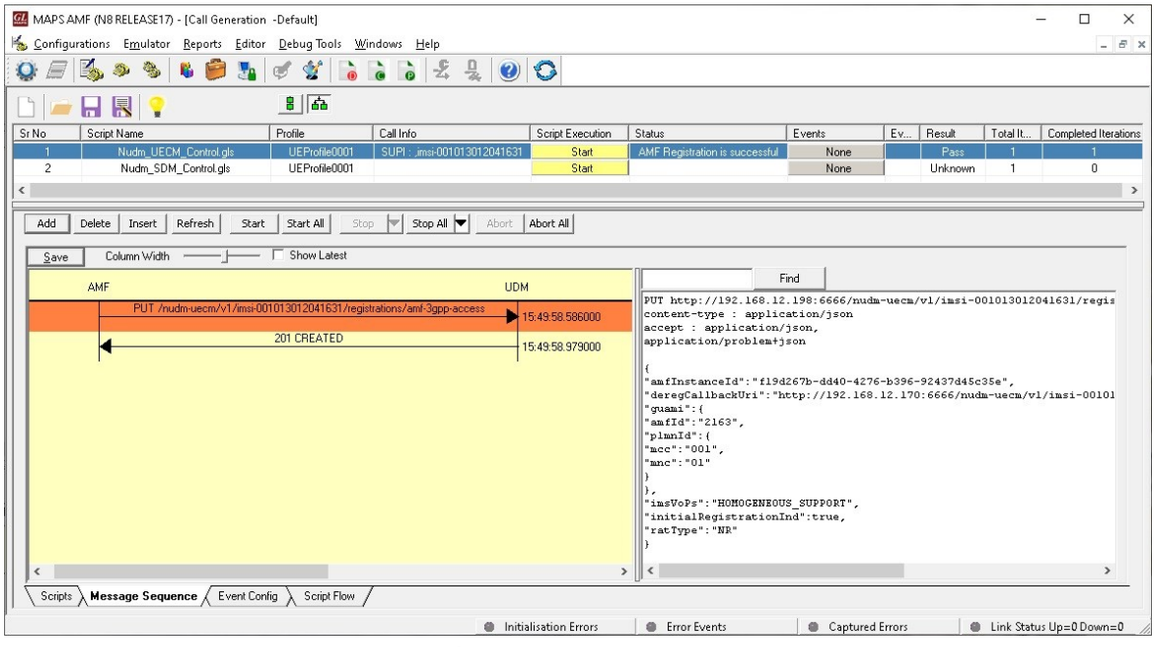
MAPS™ 5G N8 Interface Emulator



MAPS™ 5G N8 can emulate Unified Data Management (UDM) and Access and Mobility Management Function (AMF) within the 5G Core network.

The Network Function UDM is the entity in the 5G Core Network (5GC) supports **Nudm_SubscriberDataManagement** Services, **Nudm_UEContextManagement** Services, **Namf_MT** Service, **Namf_Location Service**, and **Namf_Communication** services via the Nudm and Namf services-based N8 interface.

- Emulate AMF and UDM elements



5G N8 interface Call Generation at AMF Node

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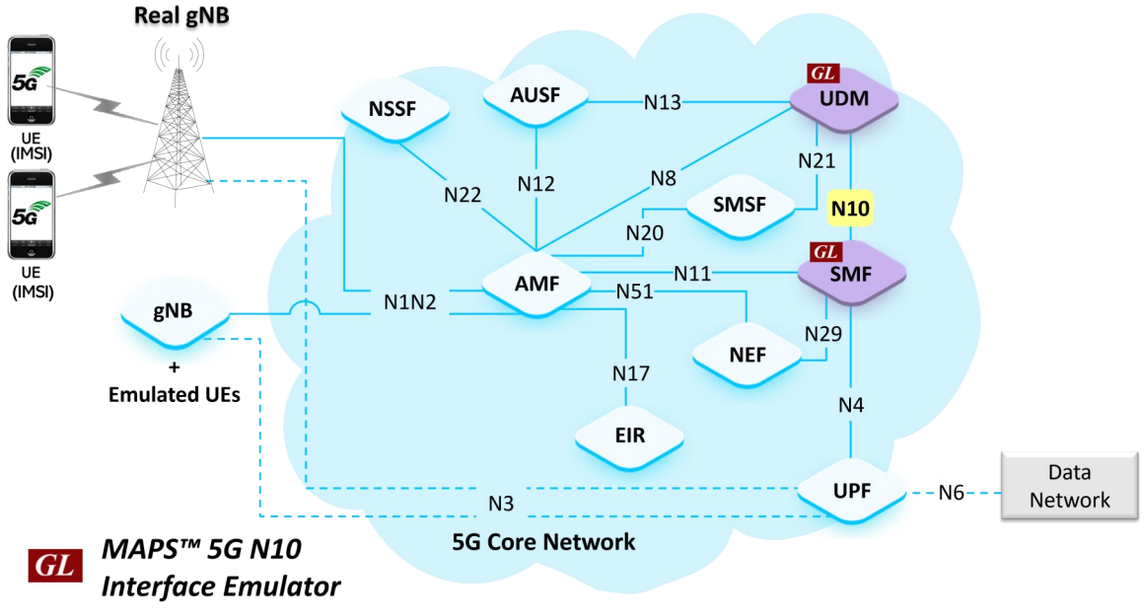
5G Core Network Emulation

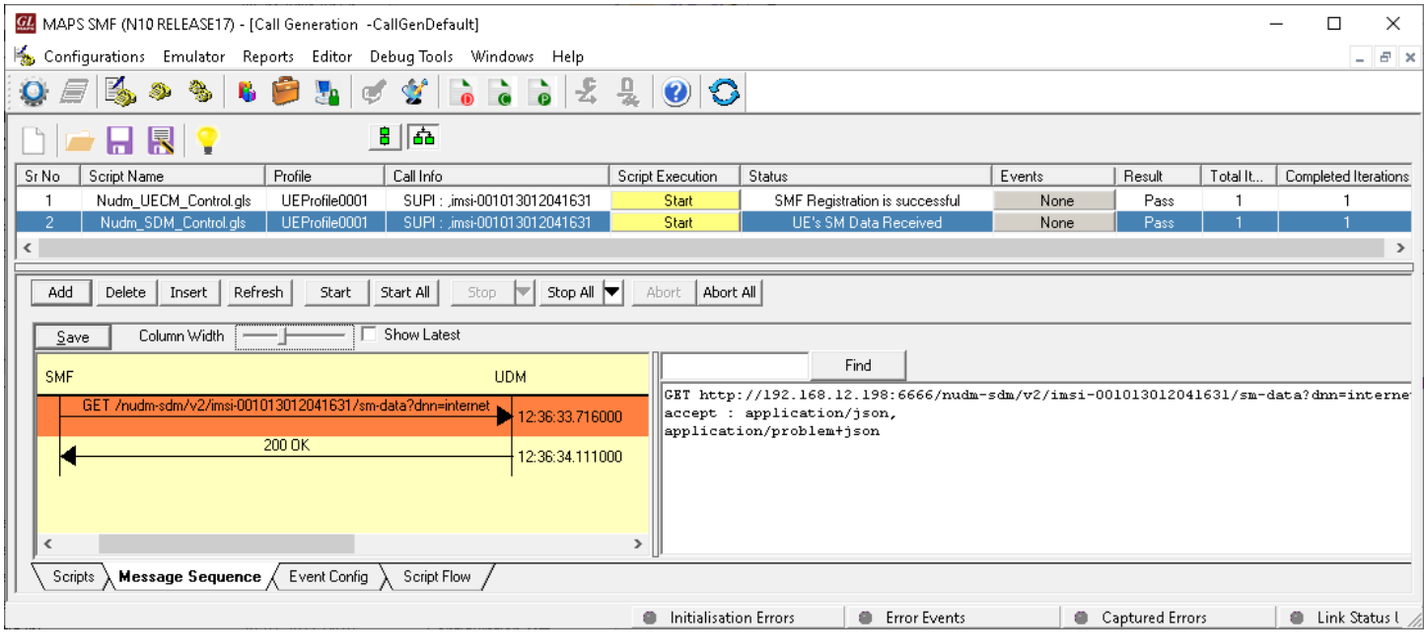
MAPS™ 5G N10 Interface Emulator



MAPS™ 5G N10 can emulate UDM within the 5G Core offering services to the SMF via the Nudm service-based N10 interface respectively. The 5G network represents the service-based interface, with focus on N10 between UDM and SMF.

The network function UDM and SMF are the entities in 5G Core Network, which supports the following services via the Nudm service-based N10 interface respectively.

- **Nudm_SubscriberDataManagement Services**
- **Nudm_UEContextManagement Services**



Emulate UDM and SMF elements 5G N10 interface Call Generation at SMF Node

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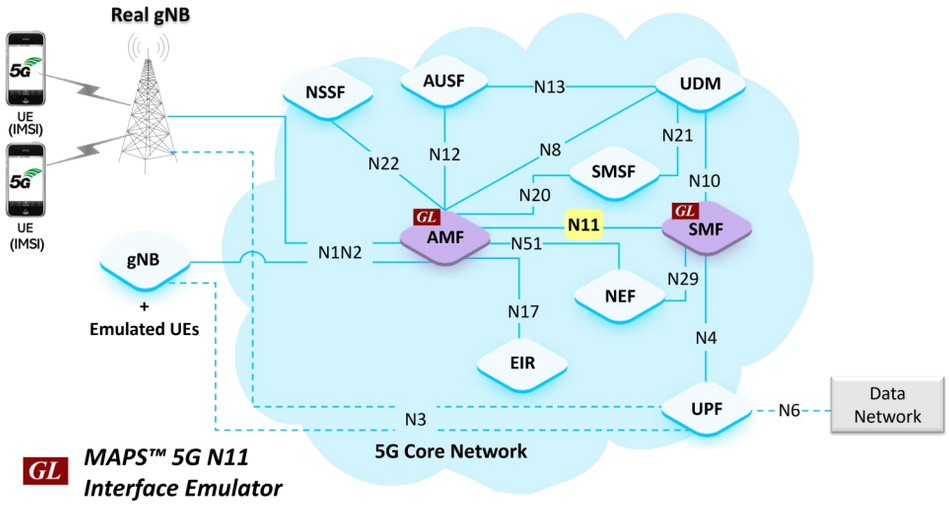
5G Core Network Emulation

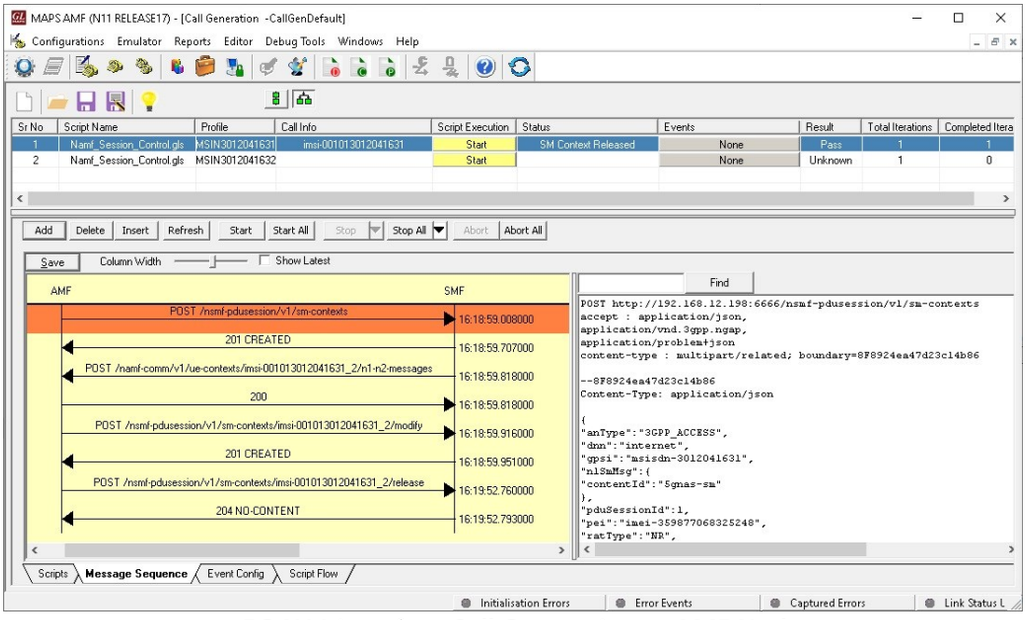
MAPS™ 5G N11 Interface Emulator



MAPS™ 5G N11 can emulate Session Management Function (SMF) within the 5G Core offering services to the Access and Mobility Management Function (AMF) via the Nsmf service-based N11 interface. The network diagram represents the service-based interface, with focus on N11 between AMF and SMF. Here, both AMF and SMF act as "NF Producer".

The Network Function SMF and AMF are the entities in 5GC, which supports the following services via the Nsmf and Namf service-based N11 interface.

- Nsmf_PDUSession: Create SM Context, Update SM Context, Release SM Context, Notify SM Context Status and Retrieve SM Context operations
- Namf_Communication Service: N1N2 Message Transfer (UE Specific) operations based on N11 interface
- Emulate SMF and AMF elements



5G N11 interface Call Generation at AMF Node

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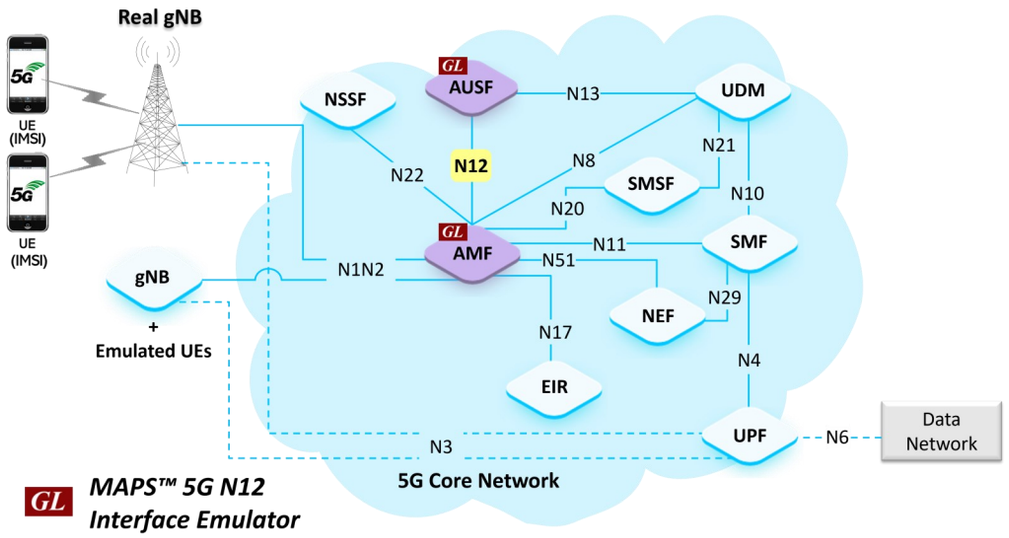
5G Core Network Emulation

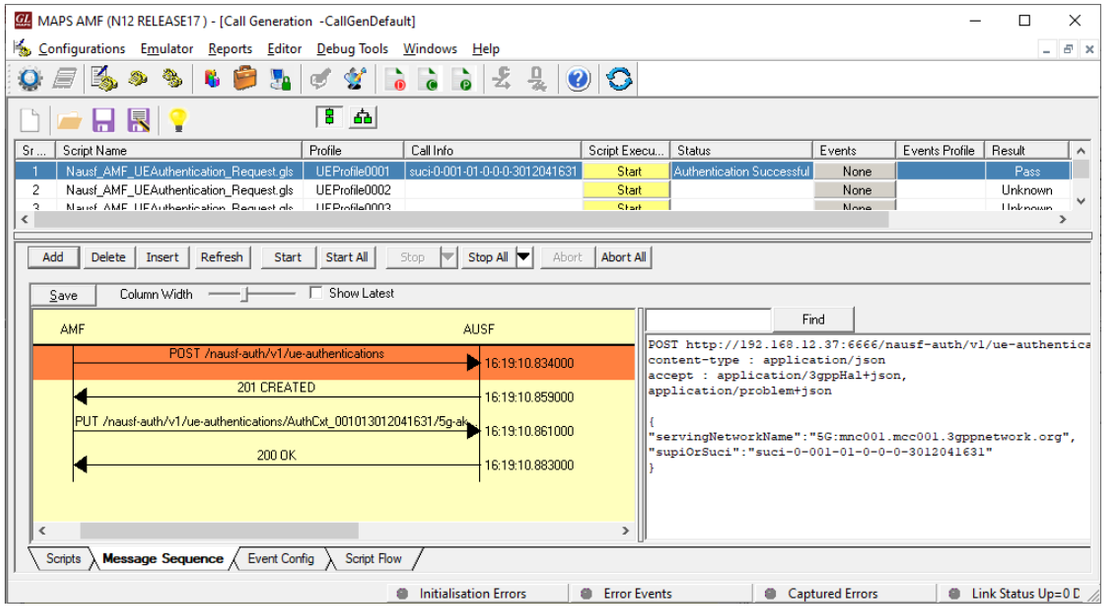
MAPS™ 5G N12 Interface Emulator



MAPS™ N12 emulates Authentication Server Function (AUSF) within the 5G Core offering services to the Access and Mobility Management Function (AMF) via the Nausf service-based N12 interfaces. The 5G network represents the service-based interface, with focus on the AUSF and AMF. Here, AUSF act as producer.

The Network Function AUSF is the entity in the 5GC, which supports the following services via the Nausf service-based N12 interface:

- Nausf_UEAuthentication (Authentication and Key Agreement)
- Nausf_SoRProtection (Steering of Roaming)
- Nausf_UPUProtection (UE Parameters Update)
- Emulate SMF and AMF elements



5G N12 interface Call Generation at AMF Node

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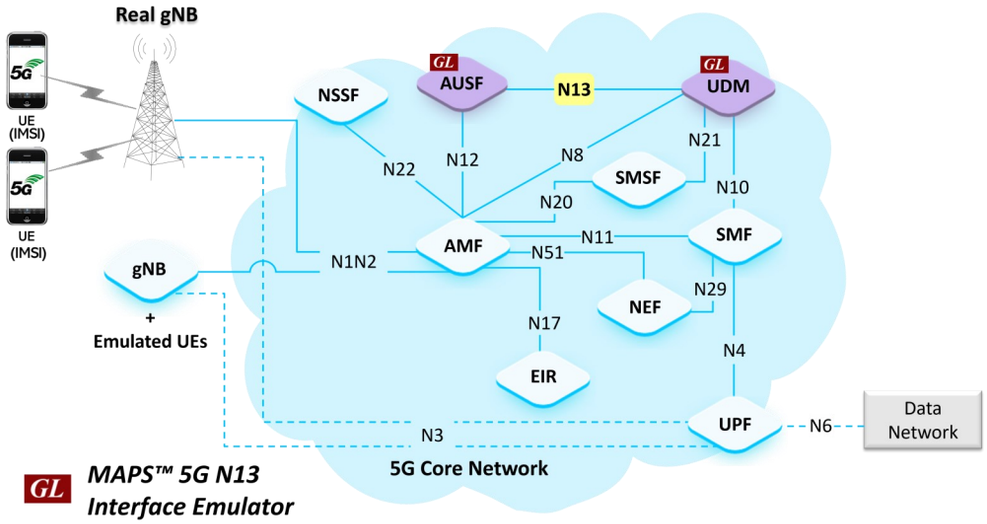
5G Core Network Emulation

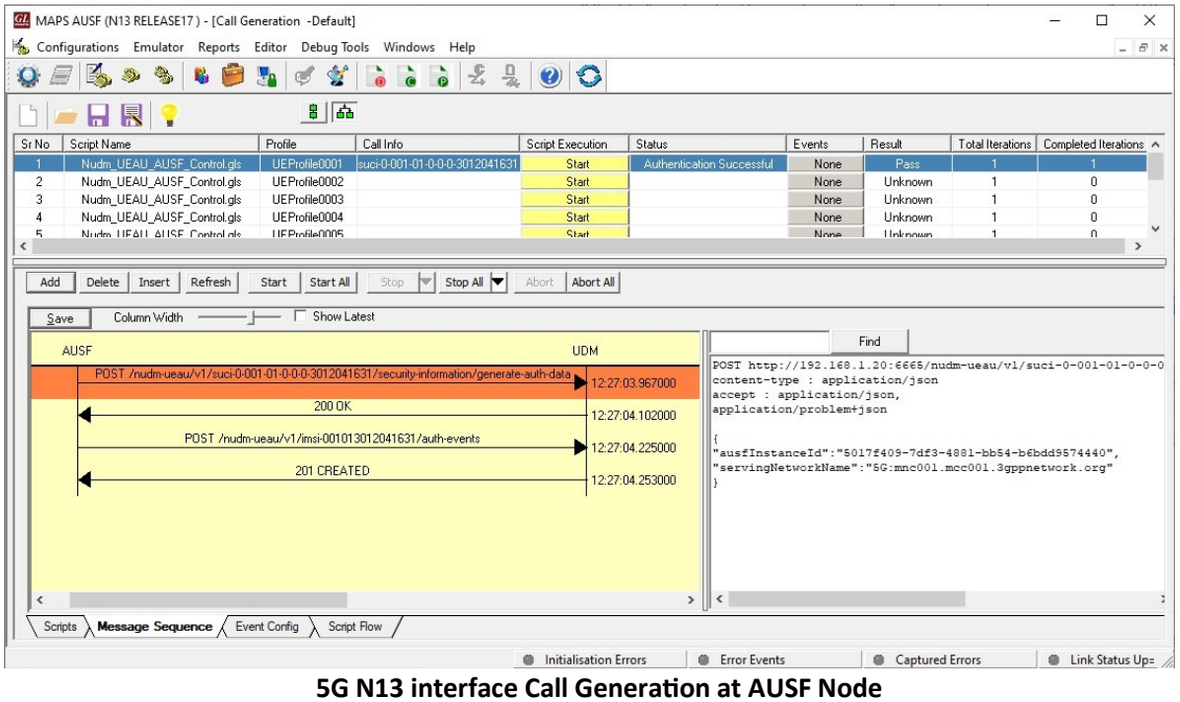
MAPS™ 5G N13 Interface Emulator



MAPS™ 5G N13 Authentication Server Function (AUSF) within the 5G Core offering services to the User Data Management (UDM) via the Nausf and Nudm service-based N13 interface respectively. The 5G network represents the service-based interface, with focus on N13 between AUSF and UDM. Here, UDM acts as producer.

The Network Function AUSF and UDM are the entities in 5GC, which supports the following services via Nudm service-based N13 interface:

- Nudm_UEAuthentication Services : Get and Result Confirmation operations
- Emulate AUSF and UDM elements
- Supports Nudm_UEAuthentication Services Procedure



5G N13 interface Call Generation at AUSF Node

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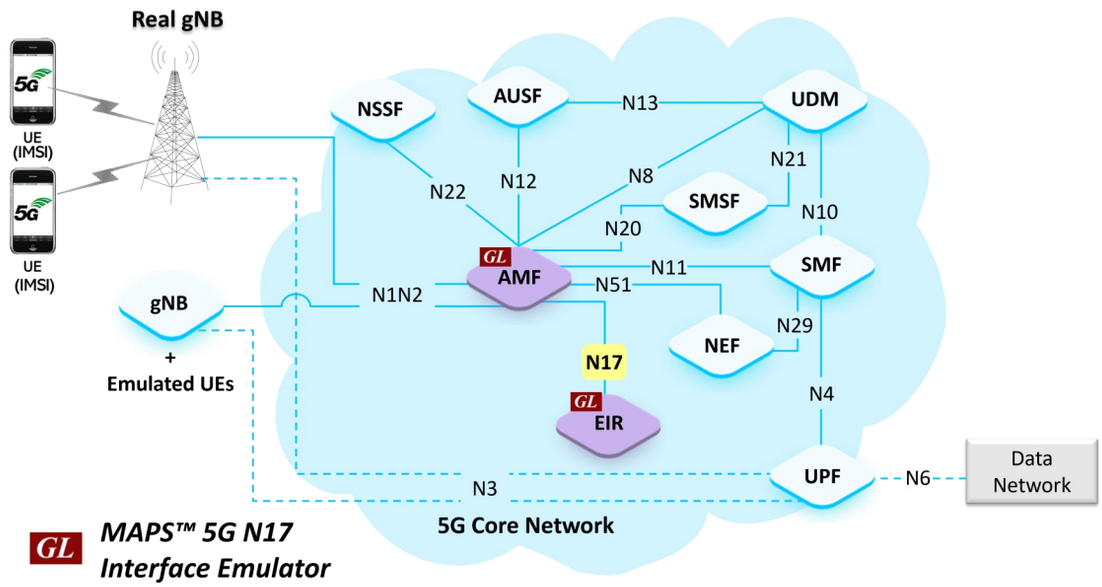
5G Core Network Emulation

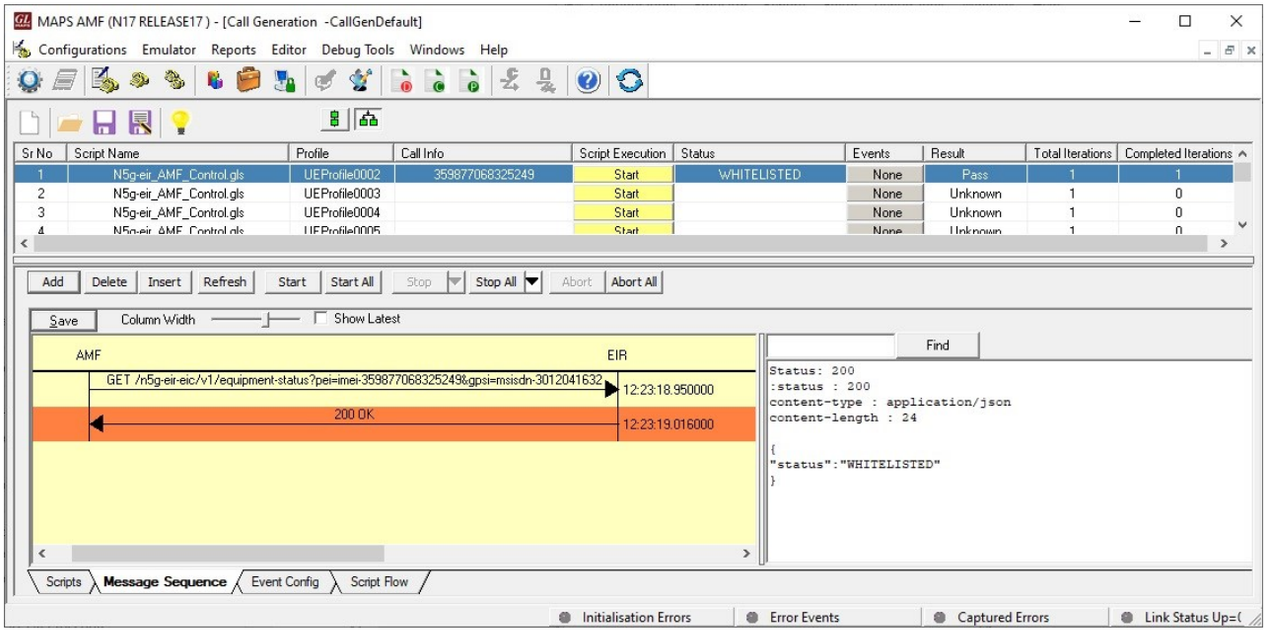
MAPS™ 5G N17 Interface Emulator



MAPS™ 5G N17 emulate Equipment Identity Register (EIR) within the 5G core offering services to the AMF via the N5g-eir service-based interface. The 5G network represents the service-based interfaces, with focus on the EIR and AMF.

The EIR and AMF support N5g-eir_EquipmentIdentityCheck Service. In N17 interface, EIR acts as NF Service Producer and AMF acts as NF Service Consumer.

- Emulate EIR and AMF network functions
- Supports Equipment Identity services via the N5g-eir service-based N17 interface



5G N17 Interface Call Generation at AMF Node

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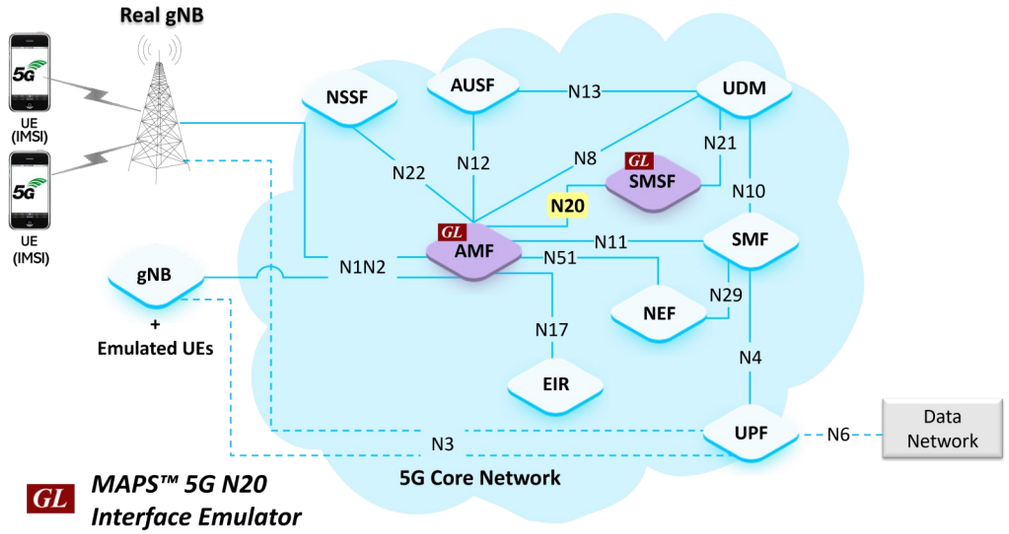
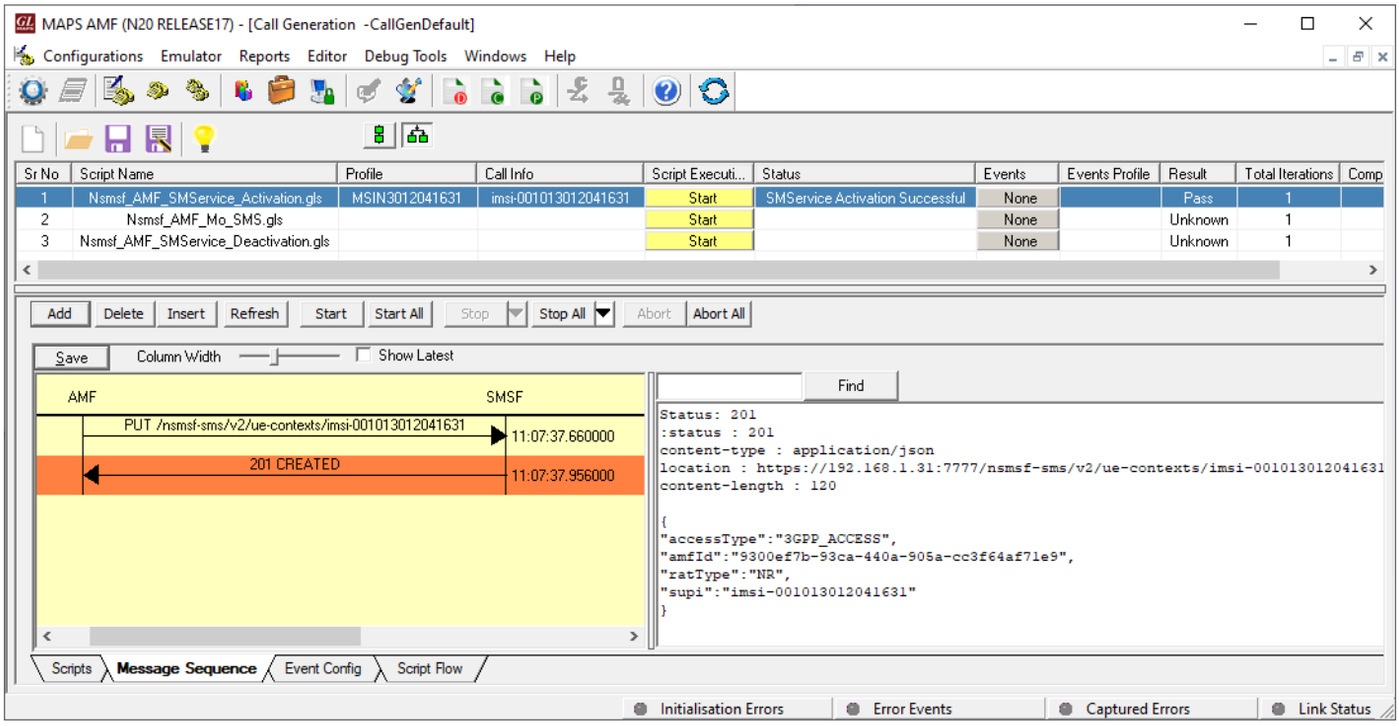
5G Core Network Emulation

MAPS™ 5G N20 Interface Emulator



MAPS™ 5G N20 emulates Short Message Service Function (SMSF) within the 5G core offering services to the AMF via the Nsmsf service-based N20 interface. The 5G network represents the service-based interfaces, with focus on the SMSF and AMF.

- Emulate SMSF and AMF network function.
- Supported procedures are -
  - Nsmsf_SMService : Activate, Deactivate and UplinkSMS (MOSMS)
  - Namf_Communication Service : N1N2MessageTransfer(UE Specific) operations based on N20 interface



5G N20 interface Call Generation at AMF Node

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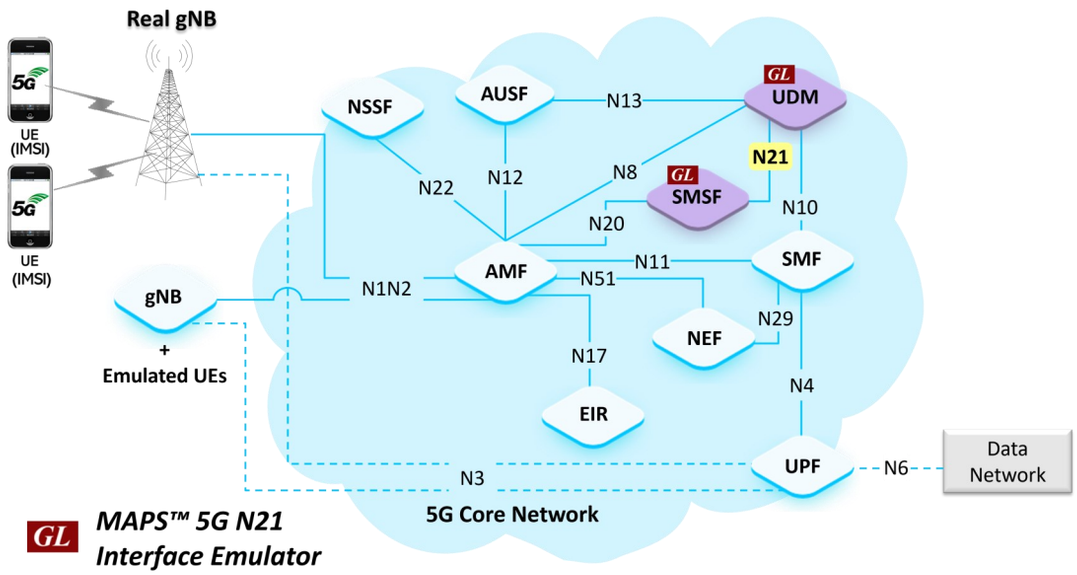
5G Core Network Emulation

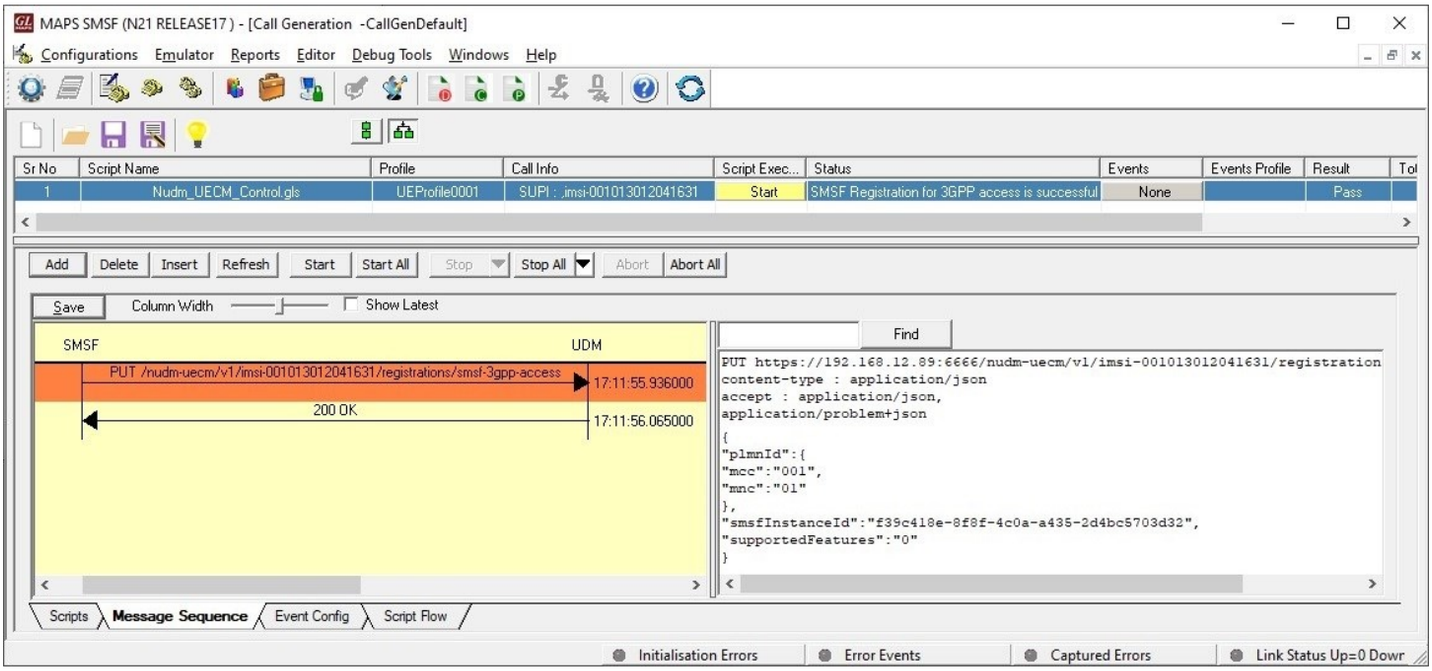
MAPS™ 5G N21 Interface Emulator



MAPS™ 5G N21 emulates Unified Data Management (UDM) within the 5G Core offering services to the Short Message Service Function (SMSF) via the Nudm service-based N21 interface respectively. The 5G network represents the service-based interface, with focus on N21 between UDM and SMSF. Here UDM node can act as "NF Producer".

The SMSF and UDM are the entities in 5G Core Network, which supports the following services .

- Nudm_UEContextManagement Service
- Nudm_SubscriberDataManagement Service
- Emulates Short Message Service Function and Unified Data Management (UDM) elements



5G N21 interface Call Generation at SMSF Node

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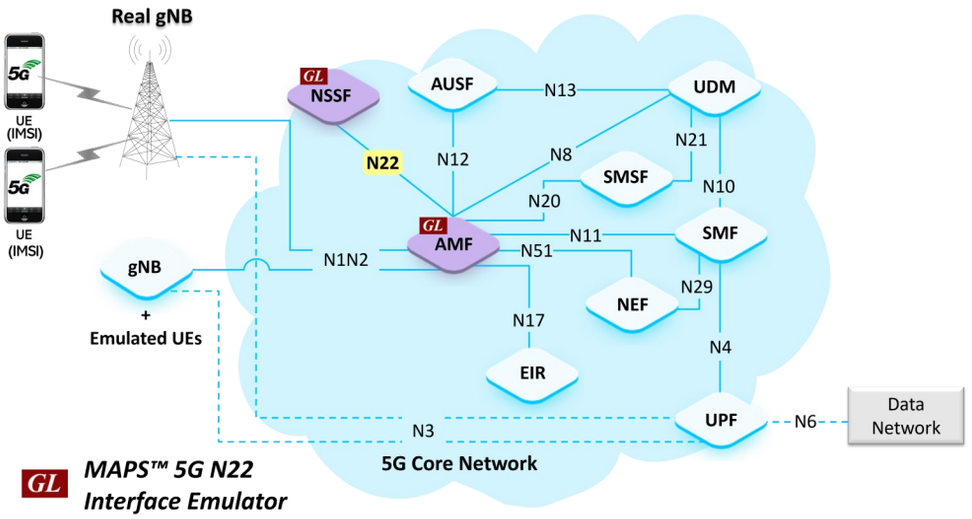
5G Core Network Emulation

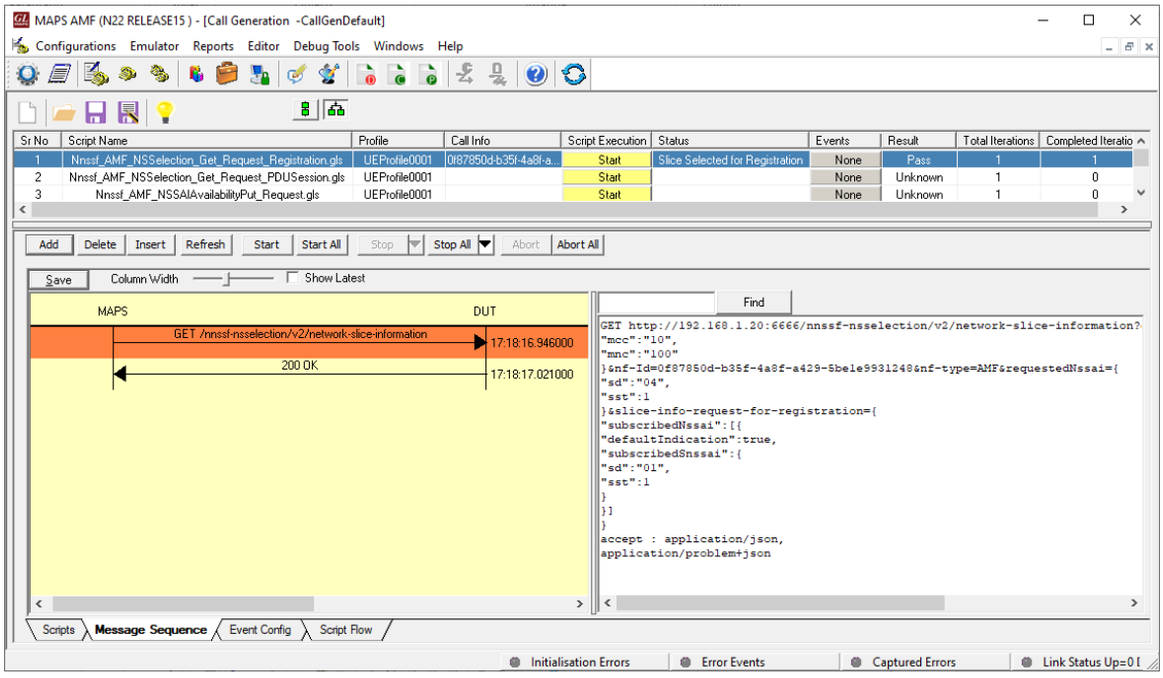
MAPS™ 5G N22 Interface Emulator



MAPS™ N22 emulate Network Slice Selection Function (NSSF) within the 5G Core offering services to the Access and Mobility Management Function (AMF) via the Nnssf service-based N22 interface. The above network architecture represents the service-based architecture, with focus on N22 between NSSF and AMF. Here, node NSSF can act as "NF Producer".

The AMF and NSSF are the entities in 5G Core Network (5GC), which supports the following services .

- Nnssf_NSSelection
- Nnssf_NSSAIAvailability
- Emulates Short Message Service Function and Unified Data Management (UDM) elements



5G N22 interface Call Generation at SMSF Node

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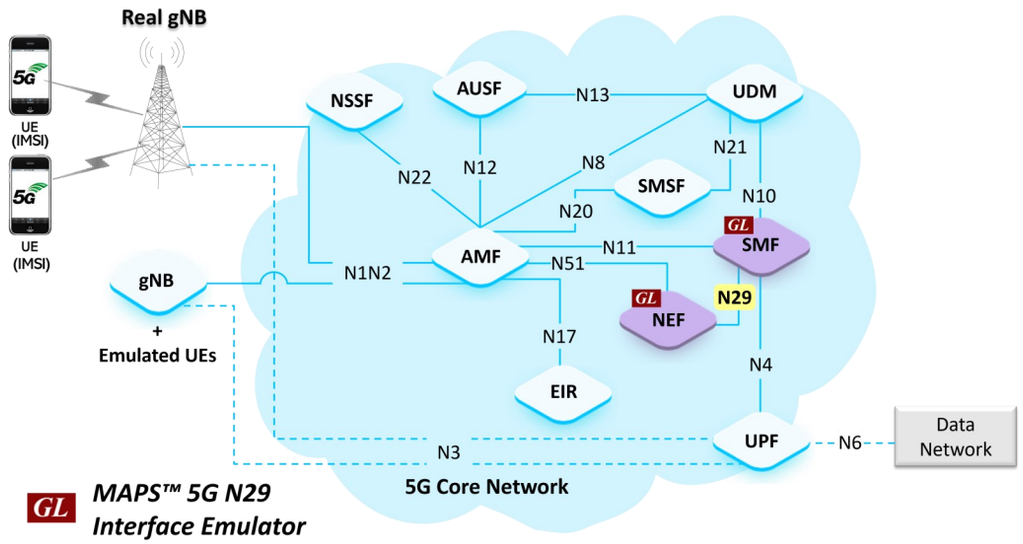
5G Core Network Emulation

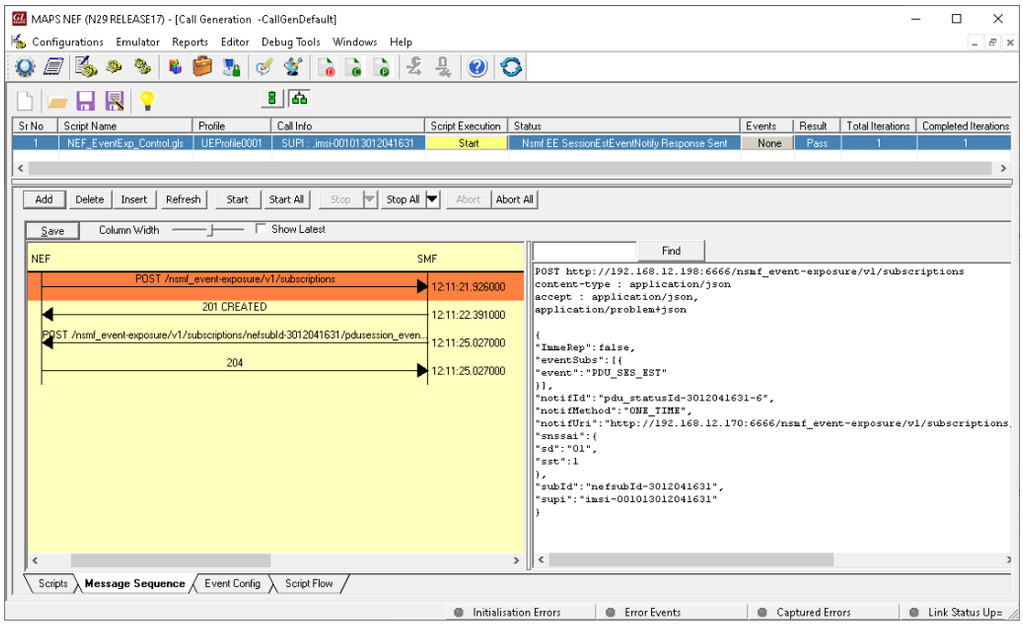
MAPS™ 5G N29 Interface Emulator



MAPS™ 5G N29 Interface emulate Network Exposure Function (NEF) within the 5G Core offering services to the Session Management Function (SMF) via the Nsmf service-based N29 interface. The above network architecture represents the service-based architecture, with focus on N29 between NEF and SMF. Here, node NEF can act as "NF Producer".

The NEF and SMF are the entities in 5G Core Network (5GC), which supports the following services

- UE Subscription for notification for one time event detection
  - PDU session release Event
  - QFI allocation Event
  - UE IP address/prefix change Event



5G N29 interface Call Generation at NEF Node

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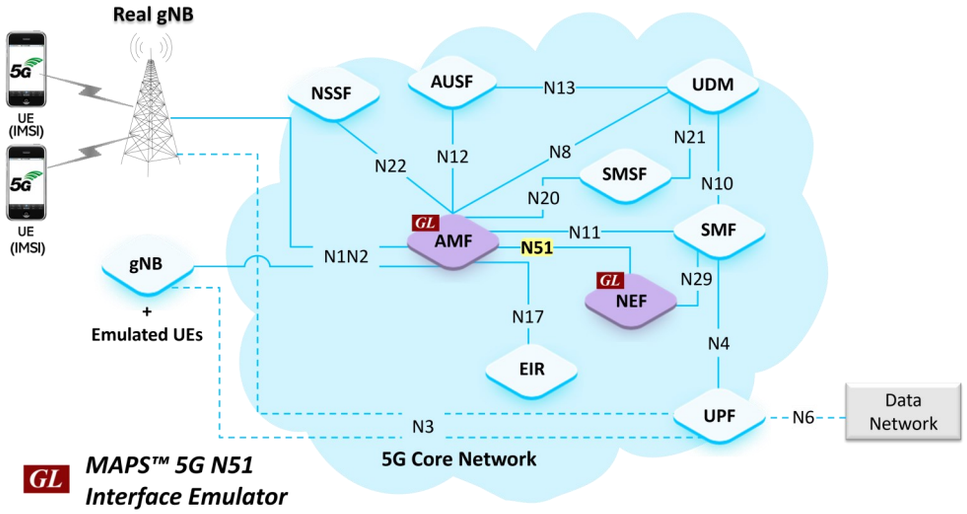
5G Core Network Emulation

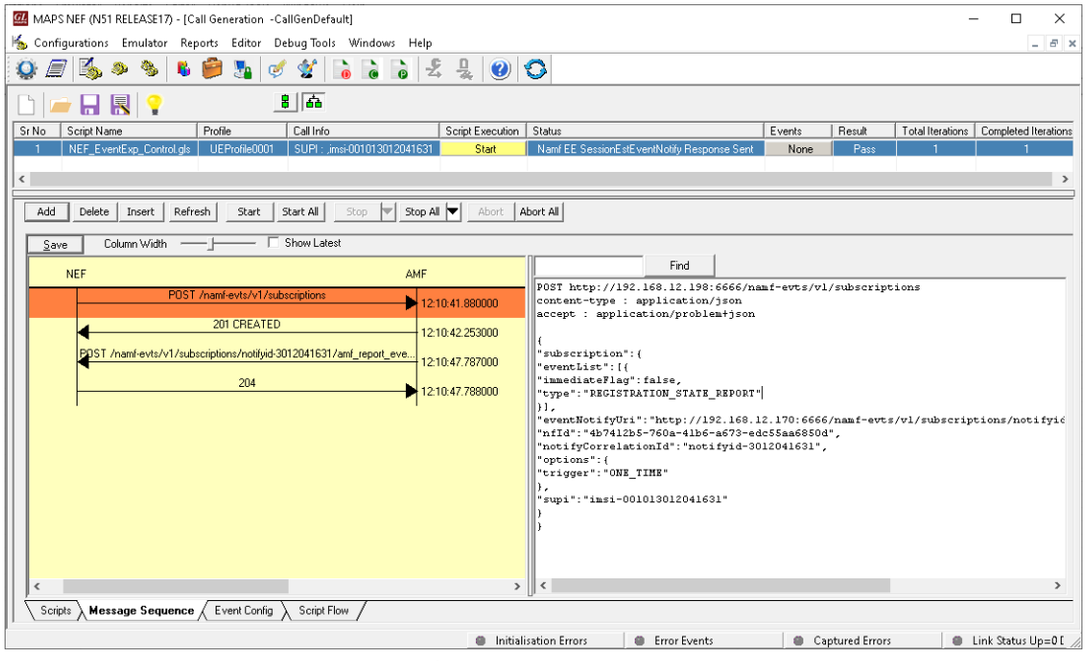
MAPS™ 5G N51 Interface Emulator



MAPS™ 5G N51 emulate Network Exposure Function (NEF) within the 5G Core offering services to the Access and Mobility Management Function (AMF) via the Namf service-based N51 interface. The above network architecture represents the service-based architecture, with focus on N51 between NEF and AMF. Here, node NEF can act as "NF Producer".

The NEF and AMF are the entities in 5G Core Network (5GC), which supports the following services

- UE Subscription for notification for one time event detection
  - Registration State Change Event
  - Connection State Change Event
  - Location Report Event
  - Presence In Area of Interest Event



5G N51 interface Call Generation at NEF Node

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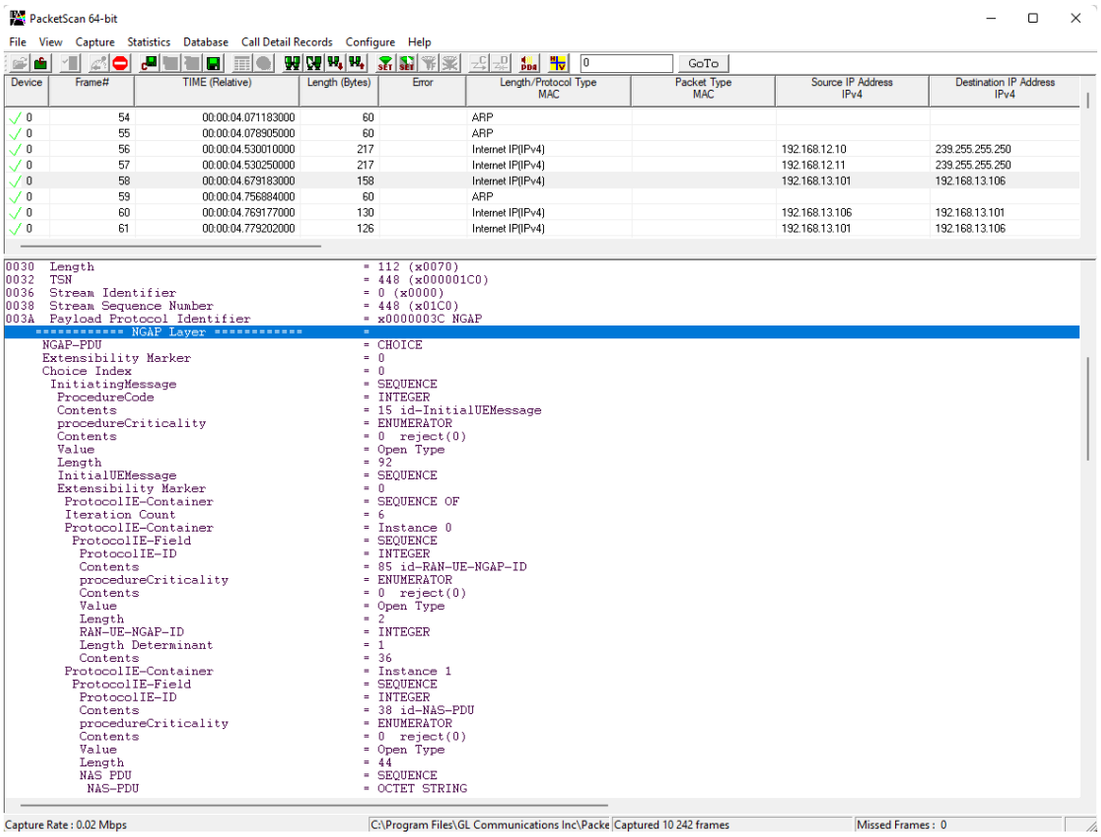
5G Core Network Monitoring & Diagnosis



5G Network Call Capture

GL's PacketScan™ - an All-IP Network Monitoring software offers powerful features to capture and monitor live signaling and traffic over IP. PacketScan™ with Voice, Data, and Video QoS capability addresses customers long felt need of call quality analysis in IP networks.

- Capable of capture, decode and perform various test measurements between any two nodes across various interfaces of the 5G network
- Support for wide-range of codecs, including AMR and AMR WB – visit Voice Codec webpage for more details.
- Supports QoS parameters such as E-model (G.107) based MOS/R-Factor scores, Media Delivery Index (Delay Factor: Media Loss Rate) for video calls, Jitter, Delay, and Gap for Audio and Video traffic
- Segregates, captures, and collects statistics on VoIP and Wireless calls
- Live monitoring of traffic statistics - digits, tones, voice, video, and T.38 fax over IPv4 and IPv6 (version 4 and version 6) networks
- Monitors QoS (quality of service) on voice and video calls
- Supports both real-time and offline analysis
- Trace files for analysis can be loaded through simple command-line arguments
- Decode and analyze 5G N1N2, N4, N8, N12, and N13 interfaces
- The protocols supported for decoding across all these interfaces are NAS, NGAP, GTP-U, SCTP, UDP, TCP, and IP

High-Density Packet Monitoring Tool (**PacketScan™ HD**): PacketScan™ HD is an high density multi-protocol VoIP monitoring, reporting and diagnostic network monitoring appliance. It can capture and process high volumes of communication protocols over IP and Wireless at 1GigE (PKV120) and 10GigE (PKV122) data rates.

For more details, refer to PacketScan™ for Wireless Networks webpage.

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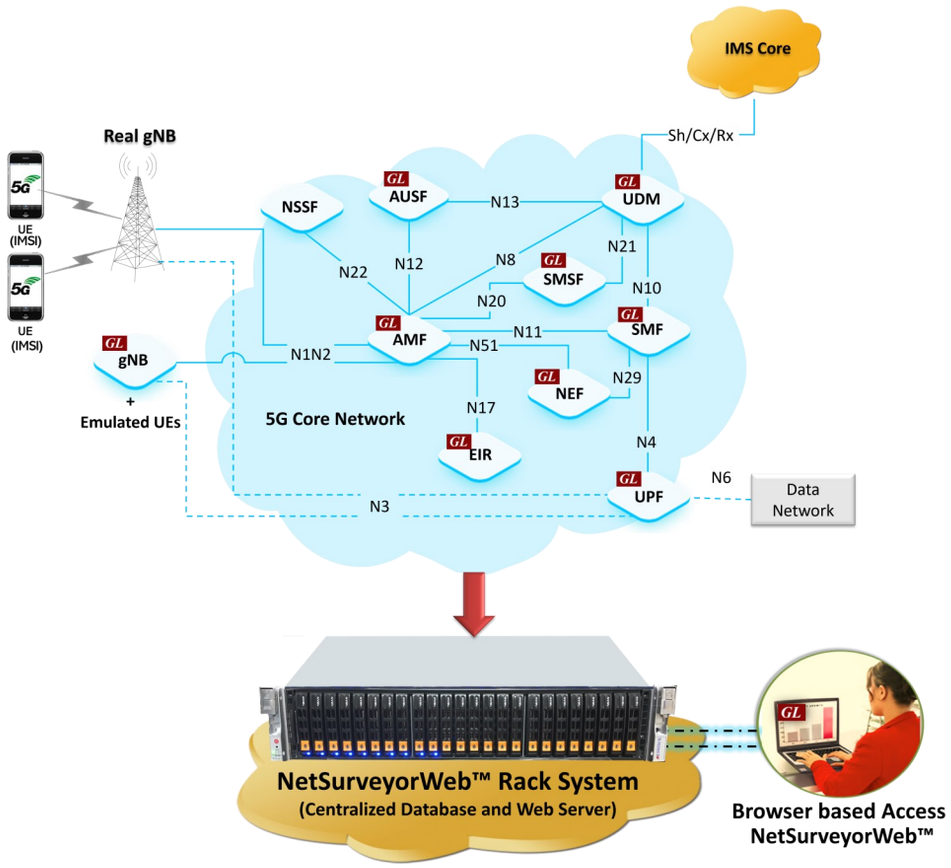
5G Core Network Monitoring & Diagnosis

NetSurveyorWeb™ - Centralized System



GL's NetSurveyorWeb™ (PKV170) is a centralized web-based client that facilitates display of call data records and call summary using a web interface based on a scalable and flexible architecture. It is used in conjunction with GL's LTE Protocol Analyzer and IMS Protocol Analyzer probes to non-intrusively monitor the entire network from a central remote testing location.

GL's 5G Protocol Analyzers have unlimited ability to capture, decode, and measure KPIs. The analyzers support decoding of all 5G protocols. GL's 5G protocol analysis probes feed data to centralized database (Oracle) in real-time for further analysis. The probes provide instant visibility into the performance with extensive KPIs, and also the operation of nodes in 5G networks.

For more information, refer to NetSurveyorWeb™ - Centralized System webpage.

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