ENEA

TECHNICAL WHITE PAPER

Data Management Interworking between 4G HSS and 5G UDM

A summary of the options and related factors operators must consider when interworking data management architectures between 4G and 5G

Abstract

Deploying 5G involves difficult decisions regarding interworking with 4G, particularly in the area of subscriber data management. This white paper summarizes the different options available for interworking between a 4G Home Subscriber Server (HSS) and a 5G Unified Data Management (UDM) system and provides an overview of the Enea data management portfolio. It is suitable for personnel within mobile operators responsible for planning and executing on core-network 4G-5G migration/interworking architectures and with a focus on subscriber data management systems.

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Executive Summary

The race to 5G is by now well underway with 5G expected to radically transform networks, operations, and revenue streams in the near future. This is a competitive race with the winners expected to gain future proofing and competitive edge perhaps for the next 3 to 5 years. However, as always there is a legacy issue of how to maintain seamless interworking with previous (4G and earlier) generations of architectures since 5G adoption will occur only gradually with years of co-existence with previous technologies.

This interworking must be achieved seamlessly from the customer's perspective, yet efficiently from the operator's perspective. Operators need to ensure that 4G and even older generations continue to function while at the same time being able to introduce new services with specific 5G benefits based on the new 5G Packet Core architecture (5G standalone or 5G SA).

Moreover, any interworking strategy should take advantage of the opportunity afforded by 5G to break the dependence of operators on a specific vendor, so called "vendor lock-in". 5G, correctly deployed, offers the possibility for operators to pick and choose best-in-breed technologies, to take back control of their network, and simultaneously to simplify the 5G Core. Breaking the cycle of vendor lock-in applies not only to the HSS/UDM but for large parts of the core network, due to dependencies on front-end modules and the UDR.

Nowhere are the problems of interworking more evident than in the difficult area of subscriber data management. During the build out of the 5G Core, intelligent interworking with existing systems with context to subscriber data is crucial to allow operators to offer seamless service delivery both within their own networks and roaming, and all of this needs to be achieved within the parameters defined by 3rd Generation Partnership Project (3GPP). To this end, 3GPP Release 16 introduces new standards, including Unified Data Management (UDM) as the 5G successor to Home Subscriber Server (HSS), thereby clarifying the core subscriber data management systems to be reconciled for successful network transformation.

This whitepaper discusses the options available to operators for successful interworking between 4G and 5G SA from a data management perspective. The focus is on technical interworking for subscriber management aspects, including authentication and mobility for packet switched networks such as 4G and IMS domains. The paper describes the 3 key 3GPP standard options for interworking between the 4G Home Subscriber Server (HSS) and the 5G Unified Data Management (UDM) and discusses how operators can identify an optimal strategy. For the scope of this paper, the use of 4G/LTE core for 5G Radio) is subsumed under 4G as there are no direct interworking aspects from 5G NSA (non stand-alone).

To achieve efficient interworking of subscriber data management between 4G and 5G Standalone (5G SA), there are essentially three options:

1. **UDM-HSS Interworking via SBA**
   This uses a service-based architecture (SBA) to achieve interworking. It requires changes to the legacy HSS, but it enables seamless interworking between 3G/4G/5G environments. This option is the best for operators who wish to deploy a new 5G Core with a UDM function since this provides the possibility to add SBA support to legacy 5G core and HSS products.

2. **UDM-HSS Diameter Interaction**
   This avoids changes to the legacy HSS. Instead, it uses diameter interfaces already available in the HSS, with the UDM acting as a gateway and sole access point to 5GC and EPC/IMS. This option is a pragmatic way for operators who want the benefits of a new 5G Core and UDM but without changing the interfaces of the legacy 4G Core and HSS.

3. **UDM with Basic EPC HSS Functionality**
   In this option, the UDM supports Nudm interfaces for 5GC procedures, but also introduces a basic EPC HSS support with S6a interface for EPS procedures. The S6a interface is introduced to support EPS procedures between MME and HSS.
   This, final option is suitable for operators introducing 5G subscriber data without impacting or migrating legacy subscriber data already provisioned on a legacy HSS.

These interworking options are flexible depending on how the network operator is planning to deploy their 5G SA networks. As well as summarizing the options with their advantages and disadvantages, this paper provides a decision tree for deciding between the three. Finally, it provides details of Enea's complete data management portfolio, including key functions such as the Unified Data Manager (UDM), the Unified Data Repository (UDR) and Unstructured Data Storage Function (UDSF), and discusses how this portfolio can facilitate network transformation whichever of the three options is selected.

Introduction

Operators worldwide face the challenge of upgrading their existing network to offer 5G services in the most effective way. However, since the start of 5G deployments in 2020 it's clear that legacy 4G networks will run alongside 5G for the foreseeable future. Operators therefore need to ensure seamless interworking with 4G while at the same time introducing new services leveraging specific 5G benefits enabled by the new 5G Core architecture (5G standalone or 5G SA).

This seamless interworking is especially important for subscriber and data management. Specifically, operators migrating from a 4G network to a 5G system will need to integrate the 5G's Unified Data Management (UDM) and its 4G predecessor, the Home Subscriber Server (HSS). Although there are challenges with this process, 3GPP has investigated and proposed a number of options for this integration in TR 23.732 and TR 23.973 in order to ensure that 5G core networks can coexist with legacy systems.

Interworking Options for Subscriber Data Management

When weighing-up interworking options, the following need to be considered first:

- Basic UDM and HSS interface: Nhss vs Diameter/MME replication
- SIM card vector generation for 5G and legacy subs in old and new security elements
- Centralized vs separated subscriber database
- And the fact that 4G interworking can be either based on the 4G diameter interfaces or on the new service-based architecture (SBA)

Taking these into account, there are 3 options for successful interworking between 4G and 5G SA:

Option	Principle
1. UDM-HSS Interworking via SBA	This option, standardized in 3GPP's proposed interworking approach, is based on service-based architecture (SBA). It requires an HSS upgrade to add SBA support. The UDM UDICOM option supports Nudm and Nhss for 4G interworking with 3rd party HSS.
2. UDM-HSS Diameter Interaction	This option, also discussed in 3GPP's proposed interworking approach, avoids changes to legacy HSS by utilizing interfaces already available in HSS. The 5G vendor provides 4G interfaces to the HSS, and the UDM acts as a gateway.
3. UDM with Basic EPC HSS Functionality	Here the UDM supports Nudm interfaces for 5GC procedures, but also introduces a basic EPC HSS support with S6a interface for EPS procedures. The S6a interface is introduced to support EPS procedures between MME and HSS.

The 3 options are now considered in turn.

Option 1 - UDM-HSS Interworking via SBA

This co-existence option specifies a new Service Based Interface (SBI) between the UDM and HSS that allows a smooth evolution to 5G Core SA. This approach is based on TS 23.632, which specifies the SBA interfaces (ie a new Nhss and extended Nudm).

Architecture

The Nhss/Nudm is used as an enhancement in which the existing 4G HSS is upgraded to communicate directly with the 5G UDM. This new interface for interworking between HSS and the UDM is based on SBI principles. These allow operators vendor independence, as the UDM and the HSS can be deployed in a standalone manner, with the HSS provided by a third party.

This option requires standardization of the interface between the HSS and the UDM. The standardization is part of 3GPP R16 and allows for well-defined interworking scenarios when an existing HSS is upgraded with the new SBA interface (3GPP TS23.632 in release 16, "UDICOM").

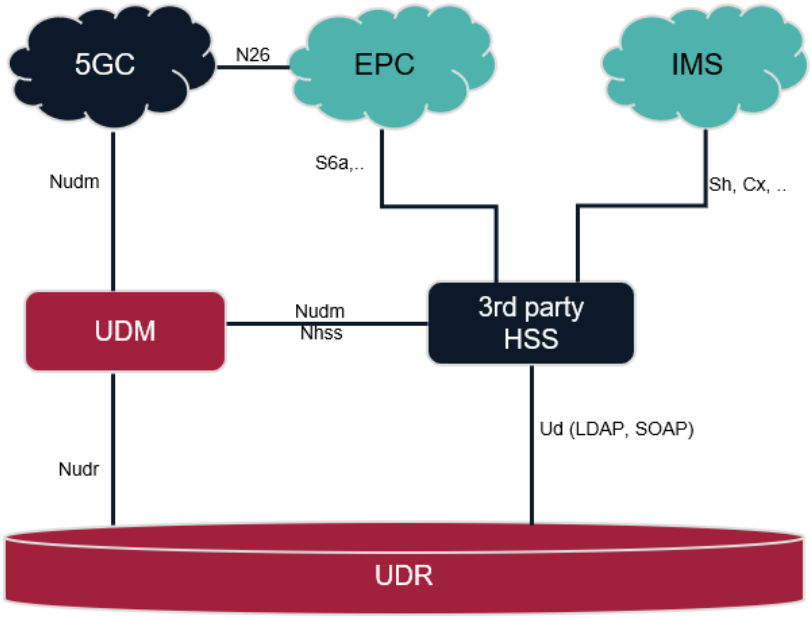

Figure 1. Interworking with SBA, the UDM supports Nudm and Nhss for 4G interworking with 3rd party HSS

Adding this SBI for interworking between the UDM and the HSS parallels the interworking between the MME and AMF. When using this option there is no impact on existing interfaces or procedures.

The solution can work for both layered and non-layered architectures of HSS (i.e. with and without database separation). In addition, it supports all the procedures that have been defined on EPC and 5GC without any impact on any interface other than the one between the HSS and the UDM.

This interworking option enables smooth functioning of UDM-HSS services. Figure 1 shows how HSS uses Nudm and Ud and offers Nhss. The UDM uses Nudr and Nhss and offers Nudm in an extendable fashion. This process is enabled through new service operations under a new service set offered by the HSS: the Nhss service set. The UDM uses Nhss when it is triggered by a particular 5GC procedure, and HSS uses Nudm when it is triggered by a specific EPC procedure.
Overall, in this option, the SBA HSS and the UDM provide services to support authentication and data exchange – discussed further below.

Authentication

Authentication data needs to be stored in a single repository so that a single sequence number can be maintained for the subscriber. The authentication vectors for 5G and 4G should be calculated in a single place which is either the UDM or the HSS.

Data Exchange

This use of UDICOM interworking between the UDM and the HSS parallels the interworking between the MME and AMF (N26). Use cases of this interworking include:

- Mobility between 5G and 4G (both directions)
- Authentication and vector generation in the UDM (ARPF) or HSS (AuC) for 5G and 4G subscribers
- Various procedures for IMS support (T-ADS and others)
- Joint management and retrieval of user states, locations, and other characteristics
- Short Message Services from 2G to 5G

Benefits

The UDICOM option performs all defined procedures without any impact on any interface other than the one between the HSS and the UDM. It allows operators to leverage the full potential of agile 5G architecture by managing various access technology networks with their own level of operations or administration. In other words, it helps them build a solution that evolves at its own pace while introducing disruptive edge services with shorter deployment time.

The SBA service strictly follows the registration/discovery/selection procedures as specified in Release 16, ensuring seamless interworking between 3G/4G/5G environments, and hence smooth migration as needed.

Option 2 - UDM/HSS Diameter Interaction

The other interworking option specified by the 3GPP is to avoid changes to legacy HSS by utilizing existing HSS interfaces, with the UDM acting as a gateway. Specifically, the UDM in its gateway role reproduces 4G EPC elements (MME), enabling a smooth integration by supporting essential 4G diameter interfaces and procedures to serve 5G subscribers in 4G, and 4G subscribers in 5G SA.

Architecture

To avoid any impact on legacy HSS, retrieval or update of user data is initiated through the UDM by reusing existing HSS supported protocol and procedures.

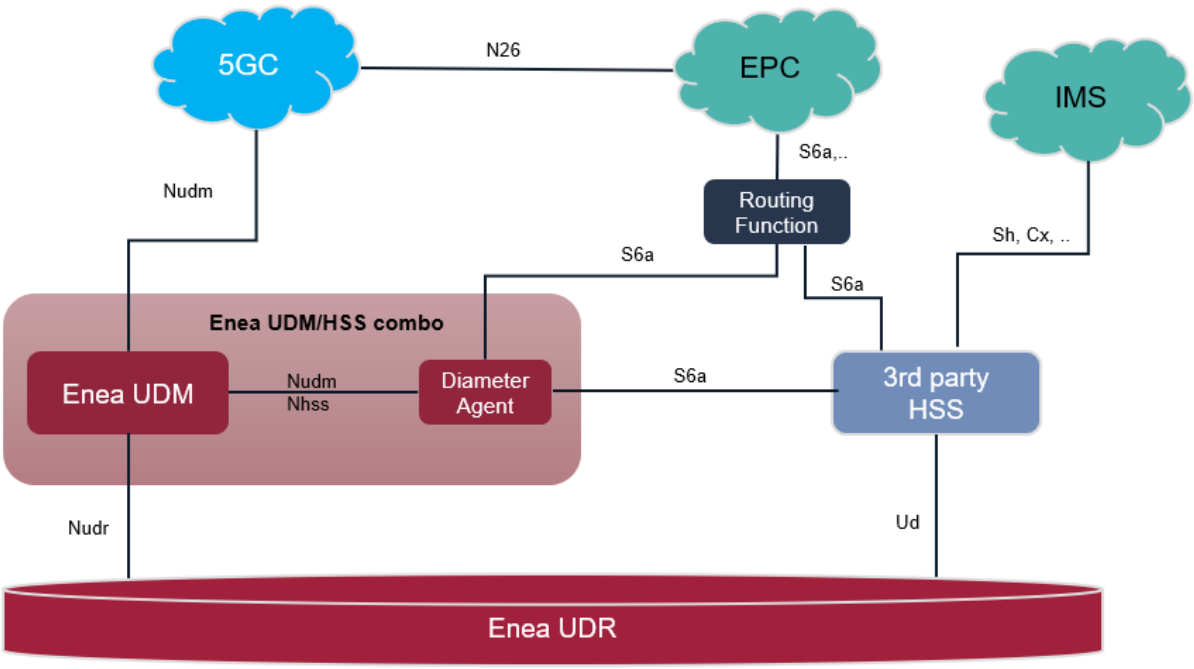

Figure 2. Interworking as UDM/HSS Diameter interact

The UDM serves as the access point for 5G subscribers roaming in 5G and 4G.
For a 5G subscriber roaming in 5G, messages go directly to the UDM, and 5G profiles are stored in the UDR. This enables the retrieval of subscriber profiles via the Nudr interface and also subscription to notifications and storage of UE context.

When a 5G subscriber needs to connect to 4G, messages go to a routing function. Based, for example, on IMSI range, this function directs S6a messages for 5G subscribers to the UDM/HSS diameter agent, and messages for 4G subscribers are routed directly to the foreign HSS. When a S6a message arrives at the UDM/HSS diameter agent from the routing function, interworking is achieved by the internal Nudm and Nhss interface and it is proxied to the foreign HSS.

IMS service data is always stored in the HSS and retrieved via the related diamter interfaces (Cx, Sh). This is the case for 4G and also 5G subscribers, it is not affected by introducing the UDM.

Authentication

A subscriber's authentication data, including the subscriber's long-term key(s) and sequence number, are stored in a single repository so that a single sequence number can be maintained for the subscriber (based on TS 23.632):

- If subscriber authentication data is stored in the UDR associated with the UDM, the UDM performs the authentication procedure independently if the subscriber is roaming in 5G or 4G (vector generation in the UDM).
- If subscriber authentication data is stored in the HSS, the UDM reproduces MME towards the HSS to retrieve the authentication vector for subscriber roaming in 5G and also for subscriber roaming in 4G, with requests being routed by the Routing Function to the UDM (vector generation in HSS).

5G Interworking with EPS

In the case of single registration in 5G, in order to cancel the registration in 4G, the UDM supports a synthetic 4G registration in the legacy HSS – reproducing MME. This triggers the HSS to cancel the 4G

registration. When the UE moves back to 4G, the HSS sends a cancel location to the UDM: legacy HSS considers the UDM is MME based on previous synthetic registration. This triggers the UDM to de-register the UE in 5G.

5G Interworking with IMS

To support IMS procedures such as T-ADS, P-CSCF Restoration or Network Provided Location Information, the legacy HSS is responsible for IMS handling and is based on synthetic registration performed during 4G to 5G mobility. The UDM reproduces MME for legacy HSS to retrieve requested information from 5GC.

Storage of Subscriber Data

The storage of subscriber data is made possible through a provisioning system. All data is provisioned to the system in a secure way, validated and synchronized between the application front ends and the database – see below

4G Subscribers

- For existing 4G subscribers there is already a 4G profile in the EPS UDR
- For 5G-enabled 4G subscribers, the 4G profile will persist in the EPS UDR alongside the subscriber's 5G profile as provisioned into 5G UDR

5G Subscribers

- For existing 4G subscribers a 4G profile is provisioned into EPS UDR
- For new 5G subscribers a 5G profile is provisioned in the 5G UDR

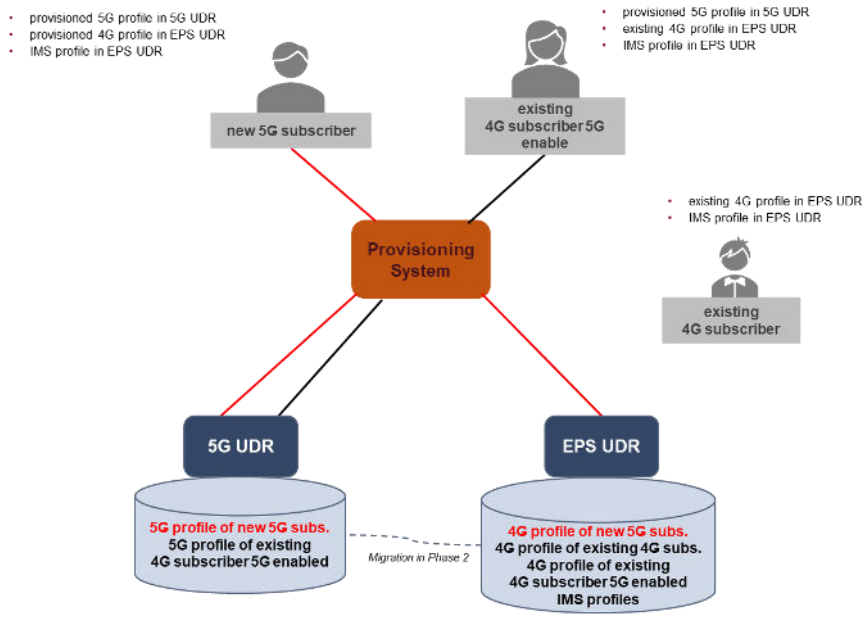

Figure 3. Storage of subscriber data through provisioning system

Option 3 – UDM with Basic EPC HSS Functionality

In the recommended architecture the UDM supports Nudm interfaces for 5GC procedures, but also introduces a basic EPC HSS with S6a interface for 4G procedures. The S6a interface is introduced to support 4G procedures between MME and HSS. Nudm/Nhss as defined in TS 23.632 is internal between the UDM and basic EPC HSS. The UDM manages subscription data in the UDR through the Nudr service for 5G procedures and the Ud interface for 4G procedures, as shown in Figure 4.

The UDM network function provides authentication and subscription information to the 5G Core (5GC) network functions that are generally concerned with controlling network access and establishing a subscriber's session.

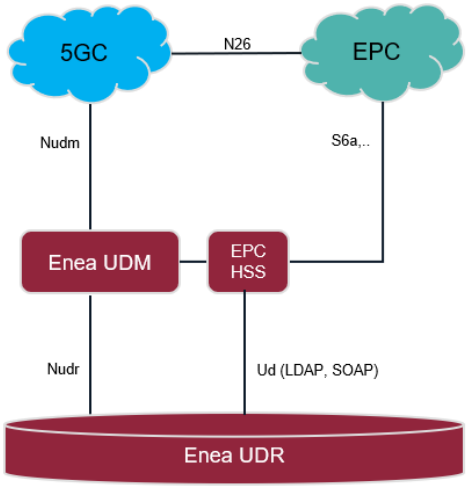

Figure 4. UDM with basic EPC HSS functionality

The UDM is the only access point both to 5GC and EPC, i.e. the UDM supports S6a and other Diameter interfaces along with Nudm. The approach assumes the UDM incorporates essential HSS FE interfaces (ie S6a) as this option assumes no interaction with legacy HSS. The S6a, which is an LTE 4G mobile-related interface between the MME and HSS, is used for authentication, location & service information about the subscriber. These are 4 messages initiated by the MME and 4 messages initiated by the mini-HSS.

In relation to subscriber data, the UDR holds 4G and 5G data. It is suitable for introducing 5G subscription data without impacting or migrating legacy subscription data already provisioned on legacy HSS. For operators aiming to build new 5G "greenfield" networks, this interworking option, supported by the UDM with the basic EPC HSS features, reduces operational costs and overhead caused by upgrading the existing working nodes for supporting new 5G networks.

To summarize, the UDM also accesses subscriber's 4G profiles in the UDR. Therefore, it is able to perform full S6a functionality (authentication, mobility) and interworking between the UDM and an HSS with basic functionality without any major impact on the legacy core.

Migration Considerations

When choosing which of the 3 options may be right for you, several factors need to be borne in mind.

Successful migration to 5G SA requires a comprehensive strategy that considers all network domains, network coverage, spectrum assets and a decision as to which services to offer where. In particular, the change from 4G to 5G is important in terms of protocols and interfaces and also because 5G explicitly specifies independence between the network data layer and the network functions in the control plane.

This change offers service providers significant new flexibility. They can source domain-level services, or even single network functions, from multiple vendors to optimize costs and functionality. And they have flexible 3GPP-specified interworking options for ensuring a smooth transition towards 5G, and 4G interworking based on either 4G diameter interfaces or the new service-based architecture.

Special Considerations

Key aspects to consider during 4G to 5G data management migration are potential use cases and how subscriber data is managed in the control plane. This includes data for new 5G users on 4G radio as well as transitioning 4G users onto 5G radio.

It is also important to keep in mind the fact that the majority of initial 5G radio deployments re-use the functionality of 4G core networks. The roll-out of 5G SA will be gradual and requires interworking with 4G to provide coverage for the various types of subscribers listed below and shown in the Figure 5 architecture:

***New* subscribers with 5G SIM and entry in the 5G UDR**

- Connecting to 5G New Radio (NR) served by standard 5G Network Functions
- Connecting to 4G Radio (LTE) served by diameter interfaces for legacy EPC

***Existing* subscribers with 4G SIM and entry in HSS**

- Connecting to 5G NR, with the UDM getting profiles and vectors from HSS via UDICOM or diameter interfaces and reproducing an MME
- Connecting to 4G Radio (LTE) served by 3rd party EPC and HSS

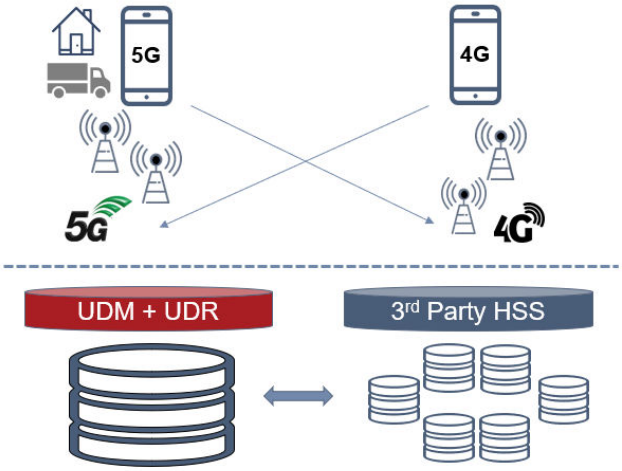

Figure 5. Separate repositories for 4G and 5G interacted with use of a Data Access Layer for between HSS FE and the UDM.

Below is a summary view of the decision tree for choosing the correct approach/architecture based on these factors and the three options presented in this white paper.

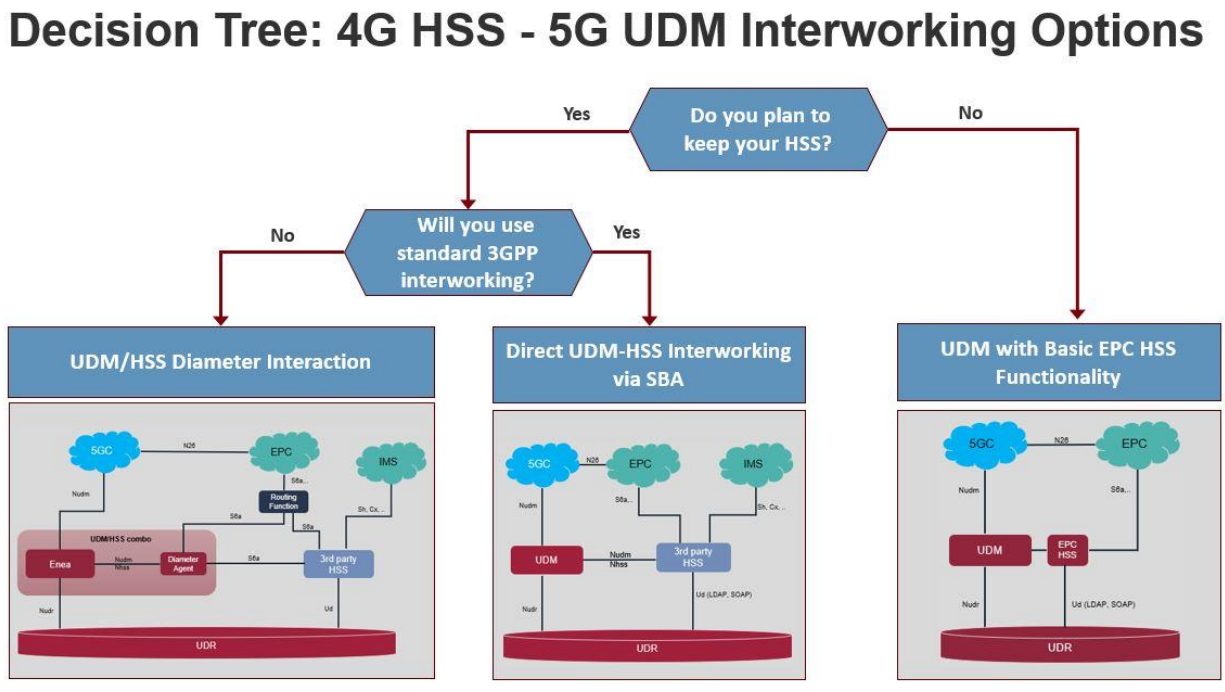

Figure 6. Data management architectures resulting from decisions made between the interworking options

The Enea Data Management Portfolio

Clearly, given their service-oriented, cloud-native nature, 5G core networks require a new approach to data management. Enea's 5G Data Management portfolio stores and manages data across all 5G core and edge functions, supporting multi-vendor 4G/5G interworking and proven in multiple commercial deployments worldwide. Enea's cloud-native suite spans the common network data layer (NDL) and scales the control plane with critical 3GPP functions including the UDM, UDR, UDSF, AUSF, PCF and EIR.

Tier 1 operators in North America and Europe have selected Enea's 5G Data Management based on features such as:

- Clear separation between the network data layer and applications, avoiding vendor lock-in
- Open orchestration and automation, enabling independence from the 5G core vendor
- Platform agnostic architecture, with support for any PaaS, private cloud, and public cloud
- A software architecture purpose-built and optimized for 5G

Enea Unified Data Management (UDM)

Cloud-native Unified Data Management (UDM) from Enea provides authentication credentials, user identification, access authorization, registration, and subscription management. In the case of 4G/5G interworking the UDM supports all relevant scenarios and manages all subscriber and device data. It can be used in all network environments and it enables many options beyond the standard Nudr interface to the backend system, including the UDR and UDSF, legacy LDAP, and custom integration that guarantees full service and mobility between 4G and 5G.

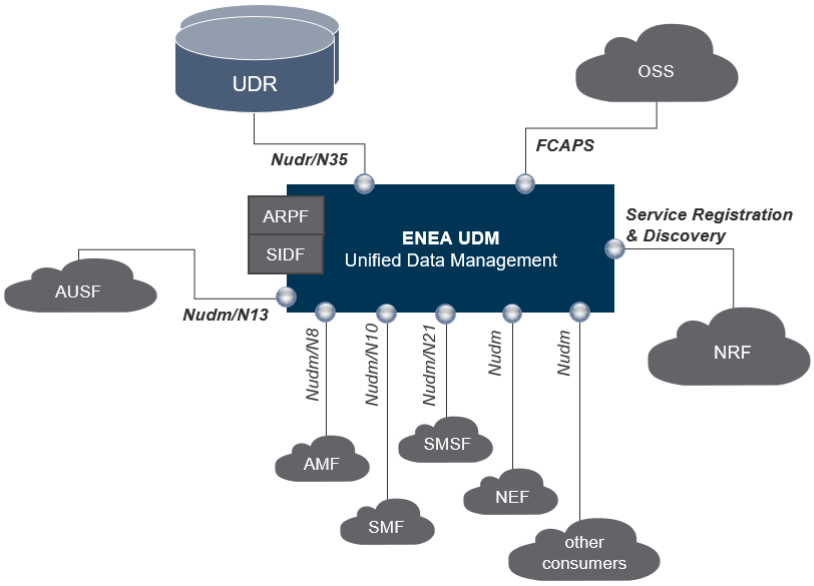

Figure 8. UDM architecture

Key benefits of Enea's UDM beyond the full 3GPP compliance and rigorous implementation of the latest standards are:

- Provides subscriber keys for authentication and encryption of all user equipment
- Can support between 1 and 10 billion data entries at a rate of 1 to 500,000 transactions per second

- Scales efficiently and handles demanding network sizes and use cases
- Supports different Interworking options as detailed in this white paper
- Zero-touch operations using self-management features and standard management tools
- Has a Powerful Rules Engine for use of customized rules and interfaces so with proprietary business logic it is possible to differentiate 5G offerings. This allows DevOps for fast integration on the field with 3rd party network elements
- Based on an established platform and framework that allows interworking from day zero
- Developed based on more than 15 years' experience delivering subscriber data management components to Tier 1 network operators
- Includes integrated security functions with main element ARPF module (Authentication Credential Repository and Processing Function) as protected authentication center for key derivation, etc. as well as supporting 5G AKA, EAP-AKA', MILENAGE and TUAK

Enea Stratum Network Data Layer

In a 5G cloud-native solution, applications must be allowed to be stateless and separated from the processing of the data. Separating application logic from data avoids vendor lock-in, and situations where large vendors maintain control over applications (and the network) by embedding data within their solution, often in a proprietary format. However, thanks to a cloud-native environment combined with REST API-based interfaces, it is now possible to separate data from applications by using an independent Network Data Layer (NDL) including both the Unified Data Repository (UDR) and Unstructured Data Storage Function (UDSF) functionality.

In 5G, a network data layer enables a clear separation between the Data Layer, Control Plane and User Plane, which creates unique flexibility. This common network data layer is a single point of storage for all fast-changing session/state data, subscriptions, policy, and configuration data in a 5G network.

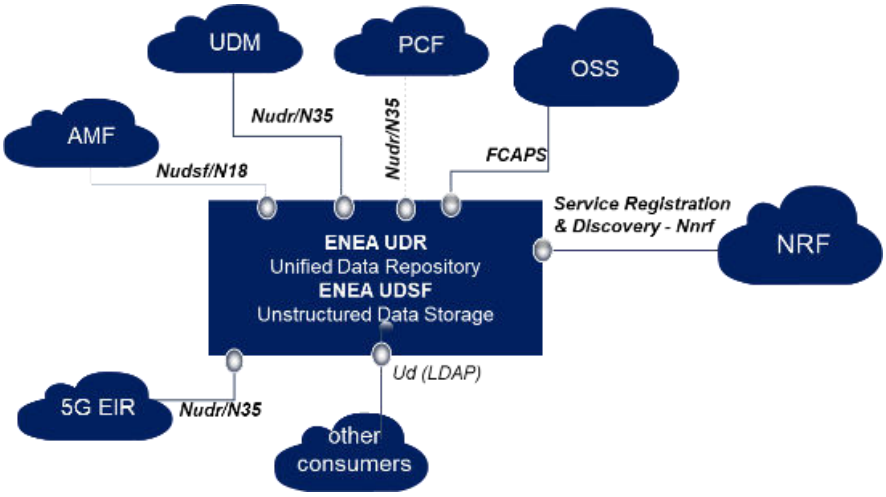

Figure 9. UDR and UDSF architecture

The key benefits of Enea Stratum are:

- Solves the problem of vendor lock-in by collapsing all vendor data silos into one common Network Data Layer
- Hybrid Storage – disk based as well as in-memory, configurable at attribute level
- Flexible consistency models (strong vs eventual) which are configurable
- Integrated Application Load Distribution
- 100% operator owned schema and virtual schemas for application specific data views

- Supports 4G and 5G interfaces and built-in protocol translation
- Data Federation capabilities to integrate with external repositories
- Enables sharing of data across network slices as well as responsible sharing of data
- Simplifies networks by streamlining IT systems and eliminating data duplication
- Flexible replication options (synchronous or asynchronous) for real-time data availability across data centers
- Intelligent Edge Replication to provide subscriber awareness for MEC (roadmap)
- 99.9999% availability in the Cloud – Configurable Redundancy, Dynamic Scaling and Self-Healing

Conclusion

4G and 5G will co-exist for the foreseeable future, so a crucial step in the migration to 5G is the deployment of a data management system capable of operating in a mixed 4G-5G architecture. This white paper describes interworking options available to operators for long term success.

Using the 3GPP standardized interworking options, and given that 3GPP Release 16 stipulates the separation of 5G functions and 5G data, service providers are thus able to consider the best choice based on their direction and vision. Choosing well allows operator 5G Core systems to enable new services leading to revenue growth and often based on new 5G devices i.e. a true 5G service where devices can access the 5G system any-time, any-place.

Direct UDM-HSS interworking via a service-based architecture allows operators to create a flexible new architecture by disaggregating legacy network elements. The various entities involved in this option can be adapted depending on operator plans to evolve to 5G SA Core, meaning that operators can leverage 5G benefits without needless complexity and cost.

The second option is diameter-based interworking between the UDM and the legacy 3rd party HSS. This allows the UDM to act as a gateway, reproducing 4G EPC by translating 5G procedures into their 4G equivalents, supporting essential 4G diameter interfaces and procedures to serve 5G subscribers in 4G, and 4G subscribers in 5G SA. This enables a smooth integration which does not require any change in the existing HSS.

In the last option - UDM with basic EPC HSS functionality - the UDM supports Nudm interfaces for 5GC procedures, but also introduces a basic EPC HSS support with S6a interface for 4G procedures. The S6a interface is introduced to support 4G procedures between MME and HSS with hardly any impact to legacy core. This option is particularly suitable for operators introducing 5G subscriber data without impacting or migrating legacy subscriber data already provisioned on a legacy HSS.

It is important that operators unlock the benefits of 5G through identifying the critical use cases that require 4G interworking and engage as early as possible to achieve their vision. Ultimately, the success of 4G and 5G interworking rests on vendors being cloud-native and having continuous integration and delivery (CI/CD) processes for improvement.

The Enea Data Management solution supports all options, combined where needed, to serve customer needs and ensure standards compliance. This is in line with best practices in 5G SA rollout: open architecture of the 5G core, and the use of a best-of-breed, multi-vendor environment, with zero vendor lock-in to optimize flexibility, costs and functionality.

For more information:

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Abbreviations

5G NR	5G New-Radio
5GC	5G Core
5G SA	5G Stand Alone
5G NSA	5G Non-Stand Alone
3GPP	3rd Generation Partnership Project
AAA	Authentication, Authorization and Accounting
AMF	Access and Mobility Management Function
CS	Circuit Switched
EPC	Evolved Packet Core
EPS	Evolved Packet System
HSS	Home Subscriber Server
HSS FE	Home Subscriber Server Front-End
IMS IP	Multimedia Subsystem
LTE	Long-Term Evolution
LDAP	Lightweight Directory Access Protocol
MME	Mobility Management Entity
P-CSCF	Proxy Call Session Control Function
R16	3GPP Release 16
SBI	Service Based Interfaces
SBA	Service Based Architecture
SMS	Short Message Service
SUR	Subscriber User Repository
T-ADS	Terminating Access Domain Selection
UDM	Unified Data Manager
UDR	United Data Repository

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