

# Overview of 5G Core Network Advanced Technologies in 3GPP Release 16

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Deployment of 5G, which is being advanced rapidly by telecommunications operators in Japan and around the world, was initially focused on a non-standalone configuration providing both NR and LTE access. However, development of a 5G Core network (5GC) is also advancing, which will implement a standalone configuration providing only NR as well as other new technologies such as network slicing. Discussion of future extensions to core network functionality is expected to focus on 5GC.

This article gives an overview of 5GC functionality specified in 3GPP Release 16.

## 1. Introduction

5G Core network (5GC), which is specified in Release 15 (Rel-15) from the 3rd Generation Partnership Project (3GPP), is a core network<sup>\*1</sup> that will provide New Radio (NR)<sup>\*2</sup> in a standalone<sup>\*3</sup> configuration for 5th Generation mobile communication systems (5G), together with new communication

technologies such as network slicing<sup>\*4</sup> [1]. 3GPP Rel-16 introduces new functionality mainly targeting 5GC, and makes other advances such as expanding network slicing and other 5GC platform functions and improving support for various services provided by 4th generation mobile communication systems (LTE). This article gives an overview of the 5GC features specified in Rel-16.

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<sup>\*1</sup> Core network: A network comprising switching equipment, subscriber information management equipment, etc. A mobile terminal communicates with the core network via a radio access network.

## 2. Overview of 3GPP Rel-16 5GC Technology

### 2.1 Newly Introduced Functionality

#### 1) Vertical LAN

Vertical LAN refers to a network that applies various new communication functions specified in Rel-16 to realize particular requirements and services for a “vertical domain”, which is an industry, enterprise or organization that is developing, producing or providing a particular type of product or service of the same type. These Rel-16 functions realize features such as real-time communication between IoT devices in smart factories and other environments. Further detail can be found in another article in this special feature [2].

#### 2) Network Data Analysis Functions

5GC specifies a Network Data Analytic Function (NWDAF) that handles collection and analysis of

various data from the network. Network automation making full use of NWDAF (enablers for Network Automation: eNA) was discussed thoroughly for Rel-16, and functionality was extended to implement various use cases.

As shown in **Figure 1**, NWDAF is equipped with functionality to connect with each Network Function (NF)<sup>\*5</sup> through Service-Based Interfaces (SBI), to collect data from each NF and from Operation, Administration and Management (OAM)<sup>\*6</sup>, and to analyze the data. The results of NWDAF analysis can be used by the communications operator for various operational tasks, by NFs directly to control communication, and by external applications through the Network Exposure Function (NEF)<sup>\*7</sup> and Application Programming Interfaces (API)<sup>\*8</sup>.

The analysis items provided by NWDAF as specified in Rel-16 are shown in **Table 1**. Use cases

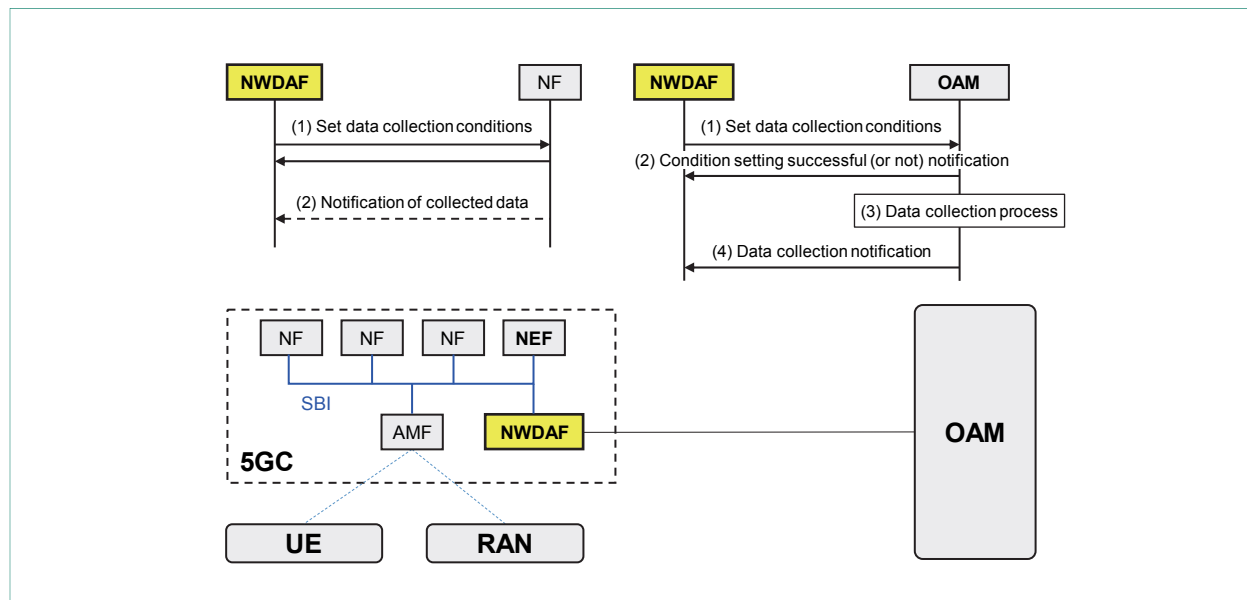


Figure 1 Network configuration using NWDAF

\*2 NR: The radio interface between base stations (gNB (See \*40)) and terminals (UE) specified in 3GPP Release 15.

\*3 Standalone: Standalone systems operate with only NR, in contrast with non-standalone systems that operate NR in cooperation with existing LTE/LTE-Advanced using LTE-NR DC.

\*4 Network slicing: A feature introduced in 5GC that provides communication services by partitioning various network communication resources according to use, to satisfy the varying

requirements of each slice.

\*5 NF: The 5GC architecture has been reorganized to be composed of network function units rather than the conventional network device units, in logical units that identify individual network functions.

\*6 OAM: Functions for maintenance and operational management on a network.

Table 1 NWDAF analysis items

Analytics ID	Analysis description
load level information	Analysis of network slice congestion level
Service Experience	Analysis of service experience
NF load information	NF load information
Network Performance	Network performance information
UE Mobility UE Communication Abnormal behaviour	Analysis of device mobility, communication, and identification of abnormal behavior
User Data Congestion	Information on user data congestion
QoS Sustainability	Quality of Service sustainability

include network optimization operations, such as managing cell occupancy using cell occupancy and traffic data, selecting optimal User data Plane (U-Plane)<sup>\*9</sup> routes, or analyzing to identify devices with particular behaviors and taking further measures as necessary. Application for operation of connected cars is also anticipated, such as using prediction of communication quality in a given area and span of time (Predictive QoS) to achieve low latency, which is important for providing self-driving cars, or for securing sufficient bandwidth to transmit high-quality video or other data.

## 2.2 Enhancement of 5GC Platform Functions

### 1) Enhancement of SBA

5GC has adopted a Service Based Architecture (SBA)<sup>\*10</sup> in which communication between NFs is achieved through APIs. Each NF provides APIs for one or more NF Services, and performs its NF processing. Considering Unified Data Management (UDM)<sup>\*11</sup> as an example, UDM is a NF Producer

providing NF Services, namely that of providing the Subscriber Data Management Service to NF Consumers, such as AMF, which use the NF Service. The UE Context Management Service performs retrieval, registration, deletion and changes to UE state for the Access and Mobility Management Function (AMF)<sup>\*12</sup>. In this way, individual processes are implemented in various services.

SBA was introduced in Rel-15, but the following issues have been identified.

- Only the signaling between NFs were be optimized, and is not optimized for flexible operation within a NF, and not optimized for overall extensibility of NFs.
- Operations of NFs, such as addition, modification, planned removal or reselection due to failure, is not specified for NFs except for AMF, which has its own dedicated specifications.

The Service Framework<sup>\*13</sup> was reviewed to resolve these issues, and a study to implement such

<sup>\*7</sup> NEF: A NF that provides APIs for obtaining internal 5GC information or controlling within the 5GC from applications outside of 5GC.

<sup>\*8</sup> API: Interface specification used for exchange between 5GC equipment.

<sup>\*9</sup> U-Plane: The communication path used for transmission of user data between a device and the network.

<sup>\*10</sup> SBA: A type of network architecture used in 5GC, which de-

fines sets of network functions as NFs and introduces unified service-based interfaces (SBIs) between NFs so they can use each others' services.

<sup>\*11</sup> UDM: An information management facility in 5GC that stores and provides information including subscriber data, UE contexts (area of attach, and session information).

<sup>\*12</sup> AMF: Facility in 5GC that serves the UE in particular area.

advanced processing was done. As part of reconsidering the Service Framework, NF Discovery<sup>\*14</sup>, NF Registration<sup>\*15</sup>, and Authorization<sup>\*16</sup> were originally assumed to use only direct communication, but in the review, a Service Communication Proxy (SCP)<sup>\*17</sup> was introduced, which allows use of indirect communication between the NFs (Figure 2, 3). Specifically, by introducing the SCP, NF Discovery can be performed by SCP as a proxy rather

than by the NF Consumer (Delegated Discovery), and also delegating the routing of signaling to SCP, which allows deployment of NF Consumers to be simplified.

To implement advanced processing, the concept of a NF Set was introduced (Figure 4). Both NF Services and NFs operate with multiple instances, and by introducing a mechanism that enables a NF Service Instance or NF Instance to cover the

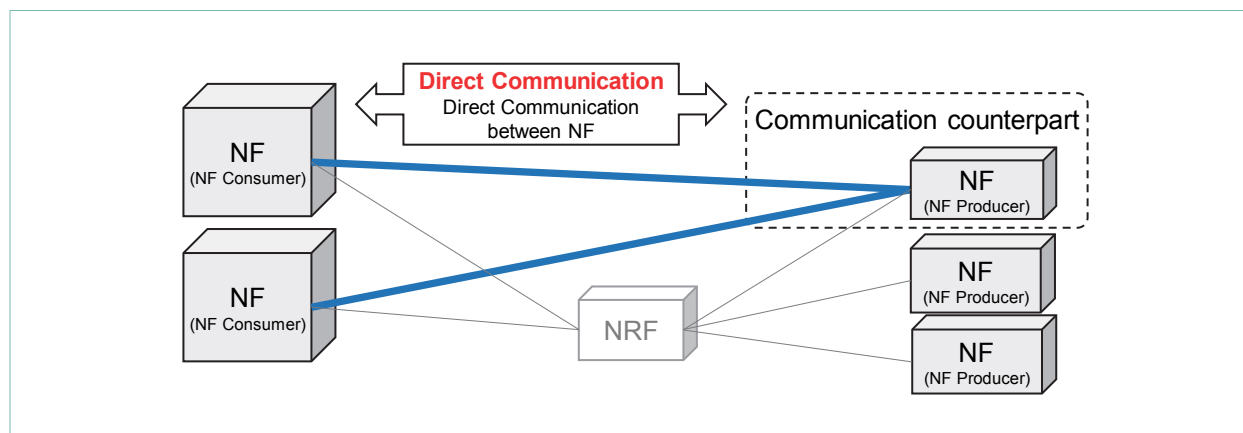


Figure 2 Direct method

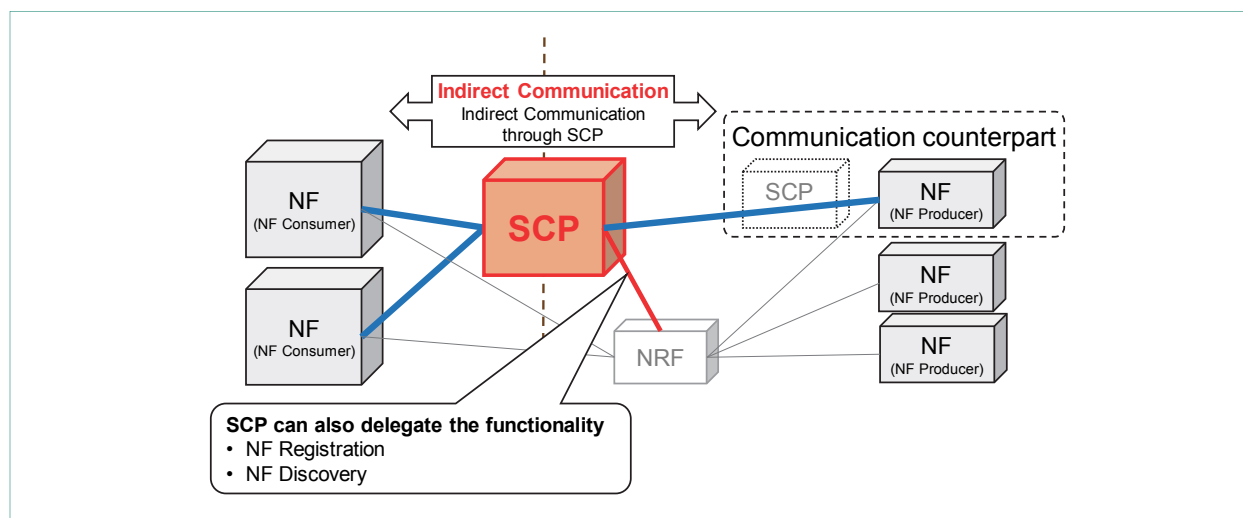


Figure 3 Indirect method (using SCP)

\*13 Service Framework: The framework for providing NF functions as services in 5GC.

\*14 NF Discovery: The mechanism for discovering NFs and Services provided by NFs. Performed before using a NF Service.

\*15 NF Registration: Procedure for registering services provided by a NF.

\*16 Authorization: Controls use of a service provided by a NF.

\*17 SCP: Equipment that relays signals between NFs rather than

having NFs communicate directly. Can perform service discovery in addition to signal routing.

processing of another instance if these instances are in the same “set”, processing can continue without affecting earlier processing.

This enables optimization of signal processing, with multiple Instances providing the same NF Service, continuously distributing processing among themselves and improving efficiency.

## 2) Enhancements to Subscriber Data Management Functions

The architecture implementing user data sharing between 5GC and EPC is shown in **Figure 5**.

In Evolved Packet Core (EPC)<sup>\*18</sup>, subscriber information is held by the Home Subscriber Service (HSS)<sup>\*19</sup>, while in 5GC UDM is defined. Both

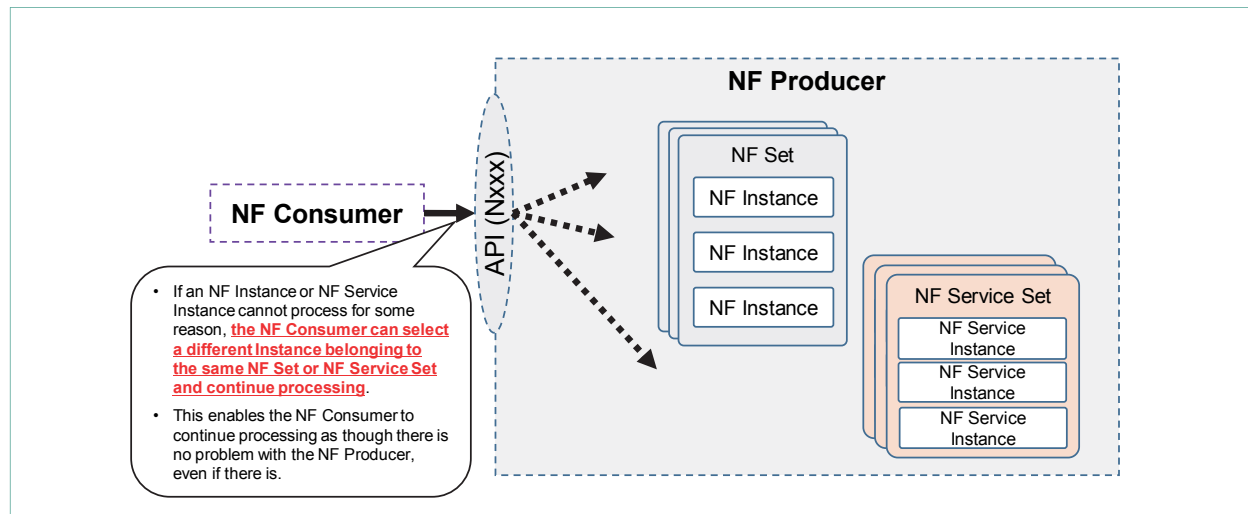


Figure 4 NF Sets

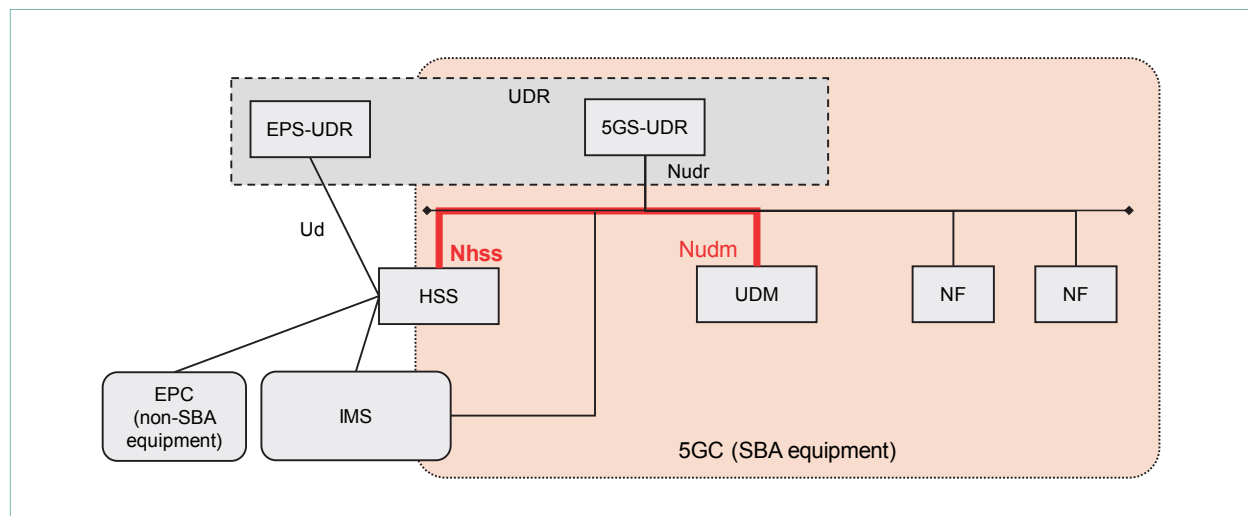


Figure 5 Architecture implementing user data linking between 5GC and EPC

<sup>\*18</sup> EPC: The core network on 3GPP mobile communication networks, mainly accommodating E-UTRA.

<sup>\*19</sup> HSS: The subscriber information database in 3GPP mobile communication networks. Manages authentication and location information.

of these are designed to store the necessary information in a repository<sup>\*20</sup>. In 5GC, User Data Repository (UDR)<sup>\*21</sup> is specified as an NF to serve as the repository, and is designed to interact through the standard APIs specified between UDM and UDR.

HSS and UDM are designed to connect with EPC and 5GC respectively, but the Rel-15 specifications assumed that in practice, UDM and HSS would be integrated in the same device, so the link between them was not clearly specified. As such, when implementing independent HSS and UDM devices, no links are specified for 5GC equipment to access HSS information, or for EPC equipment to access UDM/UDR information.

Thus, to implement links between UDM and HSS, a new SBI was specified for HSS (Nhss), and HSS can access Nudm, which is a UDM API, through the SBI. This enables UDM to access information held by HSS, and HSS can access information held by UDM.

### 3) Expansion of U-Plane Configuration

The Session Management Function (SMF) manages Protocol Data Unit (PDU)<sup>\*22</sup> Sessions, managing the connection through N6<sup>\*23</sup> between Data Network (DN)<sup>\*24</sup> and User Plane Function (UPF)<sup>\*25</sup>, through N4<sup>\*26</sup>.

UPF also has a multi-level structure which can be configured between the Radio Access Network (RAN) and DN. An intervening UPF is called an Intermediary UPF (I-UPF) and the UPF connected with N6 and terminating the PDU Session is called a PDU Session Anchor UPF (PSA-UPF), but issues remain, such as how to allocate the SMF to control the I-UPF, and how to link a PSA-UPF to the managing SMF (Figure 6).

For example, the SMF is designed to manage a UPF for a specific region, and it is not clear how to allocate a new I-SMF or how the AMF and SMF will be linked when a UE moves out of the area managed by the SMF and UPF to which it initially connected, or when the UPF moves to a different

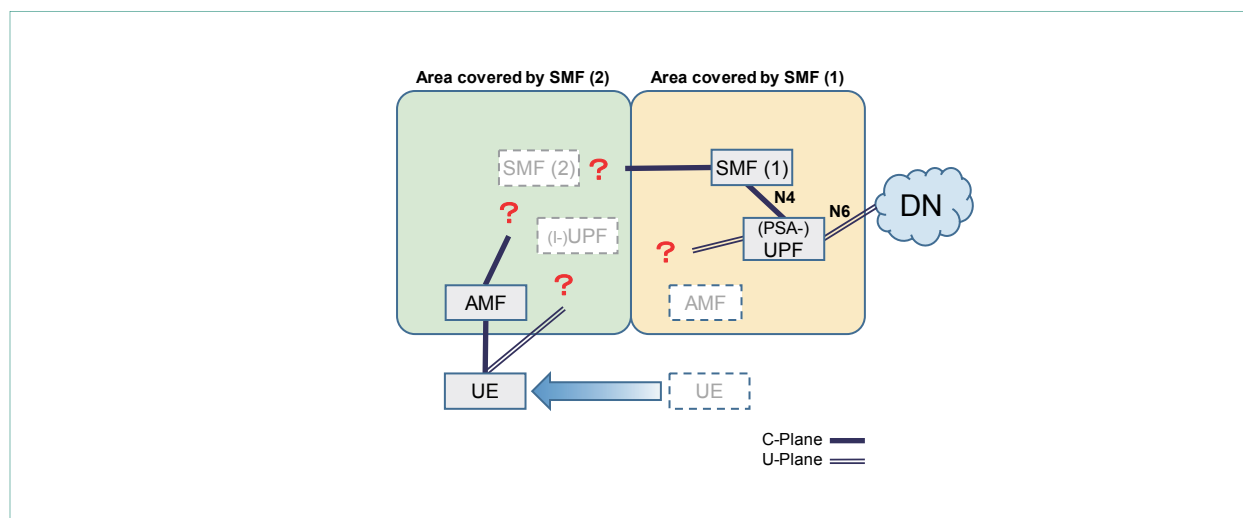


Figure 6 When the areas controlled by AMF and SMF are different, they cannot connect C-Planes directly and control is not possible.

<sup>\*20</sup> Repository: A system that stores application or system configuration data such as subscriber information or current area occupancy information in one place.

<sup>\*21</sup> UDR: A repository in 5GC.

<sup>\*22</sup> PDU: A unit of data processed by a protocol layer/sub-layer.

<sup>\*23</sup> N6: A reference point between a UPF (See <sup>\*25</sup>) and a DN.

<sup>\*24</sup> DN: A user data network that 5GC connects with, such as an ISP or enterprise network.

<sup>\*25</sup> UPF: In 5GC, equipment that relays or terminates a PDU session U-Plane.

<sup>\*26</sup> N4: A reference point between a SMF and a UPF.

Public Land Mobile Network (PLMN)<sup>\*27</sup>.

If the SMF is allocated in an enterprise network<sup>\*28</sup>, the SMF that manages I-UPFs on the macro-network<sup>\*29</sup> was not clear, so in Rel-16, new AMF behavior is specified. When operations such as Mobility change<sup>\*30</sup> or Service Request<sup>\*31</sup> are performed, the AMF determines whether an I-SMF is needed when selecting the SMF. Specifically, the AMF determines the Servicing Area of the SMF through the Network Repository Function (NRF)<sup>\*32</sup>, and then determines whether a new I-SMF must be selected based on the previous I-SMF, the Anchor SMF (A-SMF), and the location of the UE. The PDU Session can continue outside the Service Area managed by the A-SMF by re-establishing the PDU Session through the new I-SMF (**Figure 7**).

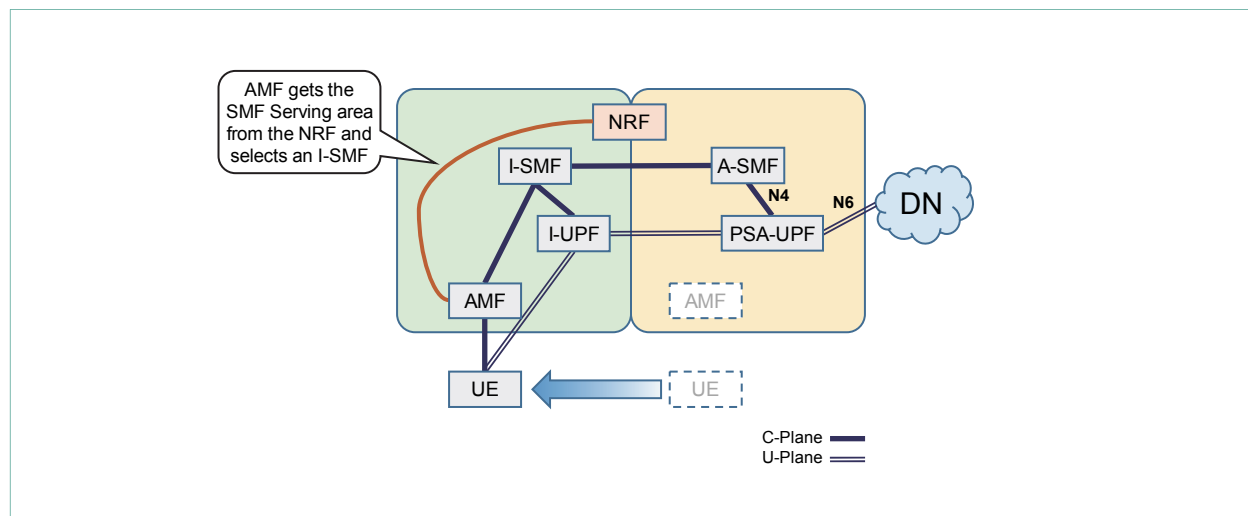
#### 4) Enhancement of Load Balancing Functions between NF

In 5GC, in order to enable telecom operation based on the current load or NF state, notification of load information and the handling of load control

is specified.

In Rel-15, load information was distributed through the NRF, and overload information is provided using standard Response codes adopted by the HyperText Transfer Protocol (HTTP). However, the former suffered delays going through NRF, and the latter only conveyed a single HTTP Response code, which was insufficient for directing congestion<sup>\*33</sup> control adequately. Thus, to enable more accurate and real-time notification of NF Producer<sup>\*34</sup> load information and overload status, a mechanism to notify NF Consumers<sup>\*35</sup> directly was adopted, by including the necessary information in a response signal from the NF Producer, using a custom header that is described below.

For load information, 3GPP used the new SBA and specified a new custom header (the 3gpp-Sbi-Lci header) that enables NF Producers to notify NF Consumers. This enables NF Consumers to obtain data and then make decisions, such as whether to select a different NF Producer to achieve stable



**Figure 7** By selecting an I-SMF/I-UPF in the Serving Area, AMFs in different areas connect through an (A-)SMF

<sup>\*27</sup> PLMN: An operator that provides services using a mobile communications system.

<sup>\*28</sup> Enterprise network: In 5GC, a network that is limited to specific users or a specific use.

<sup>\*29</sup> Macro network: In 5GC, a network for users from the public.

<sup>\*30</sup> Mobility change: Moving across areas handled by the AMF in 5GC.

<sup>\*31</sup> Service Request: A procedure to recover communication when the radio is temporarily interrupted.

<sup>\*32</sup> NRF: Equipment that stores and provides information for NF Producer discovery.

<sup>\*33</sup> Congestion: A state in which demand for communication is concentrated over a short period of time, exceeding the processing capacity of communication and control servers and impairing ability to provide communications services.

<sup>\*34</sup> NF Producer: A NF that provides a NF Service.

<sup>\*35</sup> NF Consumer: A NF that uses a NF Service.

communication (**Figure 8**).

Similarly, another new custom header was added for overload information, enabling information to be sent in addition to the regular HTTP error responses. This enables NF Consumers to obtain more information than just the HTTP response codes, which were not sufficient for making decisions, and provides a mechanism that will promote load distribution over the whole network (**Figure 9**).

#### 5) Enhancement of Network Slicing

One technical feature of 5GC, called network slicing [1], is able to partition network resources and build and optimize flexible networks that can provide various performance requirements such as high speed, high capacity, or connectivity for large numbers of devices, all on a single core network. Use of this network slicing feature is one way to

provide control of network resources for smart factories and other environments that have particular requirements. For such cases, local businesses or individuals would hope to authenticate and gain access to the appropriate network slice through the usual authentication and authorization procedures used by telecommunications operators, so in Rel-16, the new Network Slice-Specific Authentication and Authorization (NSSAA) procedures were specified (**Figure 10**). Within the authentication and authorization process on the public network, the process for the relevant network slice is temporarily suspended, and then performed by the procedure described below. This authentication and authorization is performed by a new NF defined in Rel-16, the Network Slice Specific Authentication and Authorization Function (NSSAAF), which reduces any

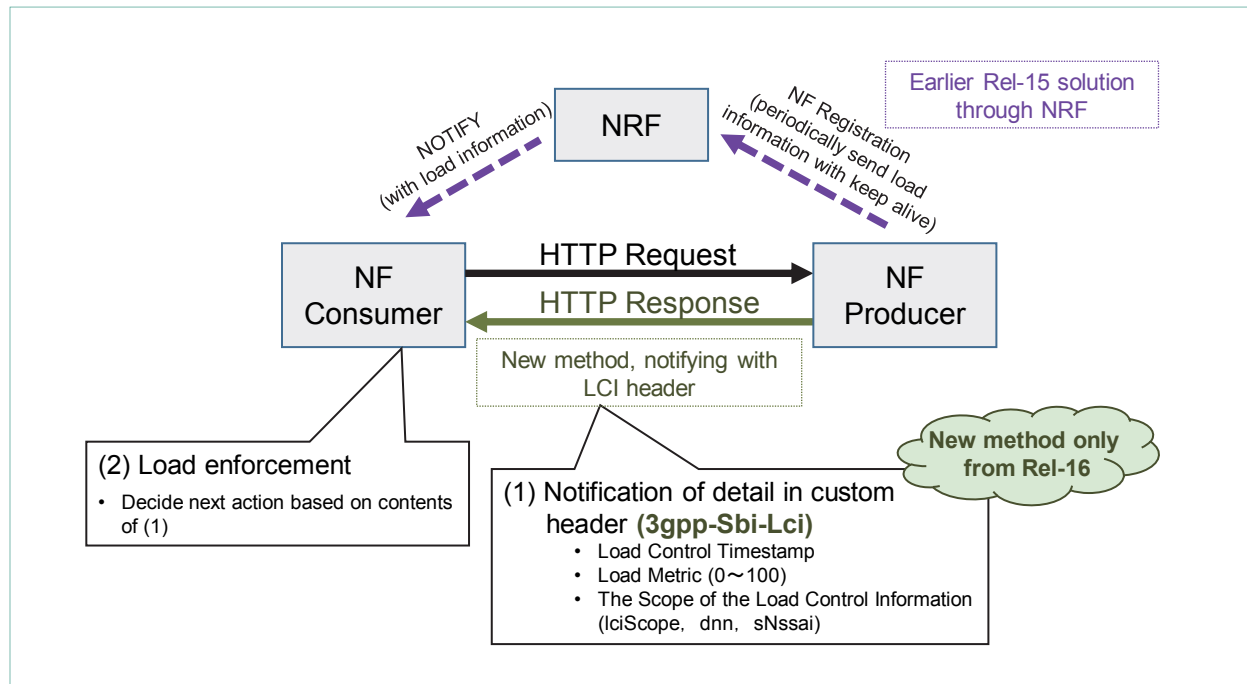


Figure 8 Notification of load information



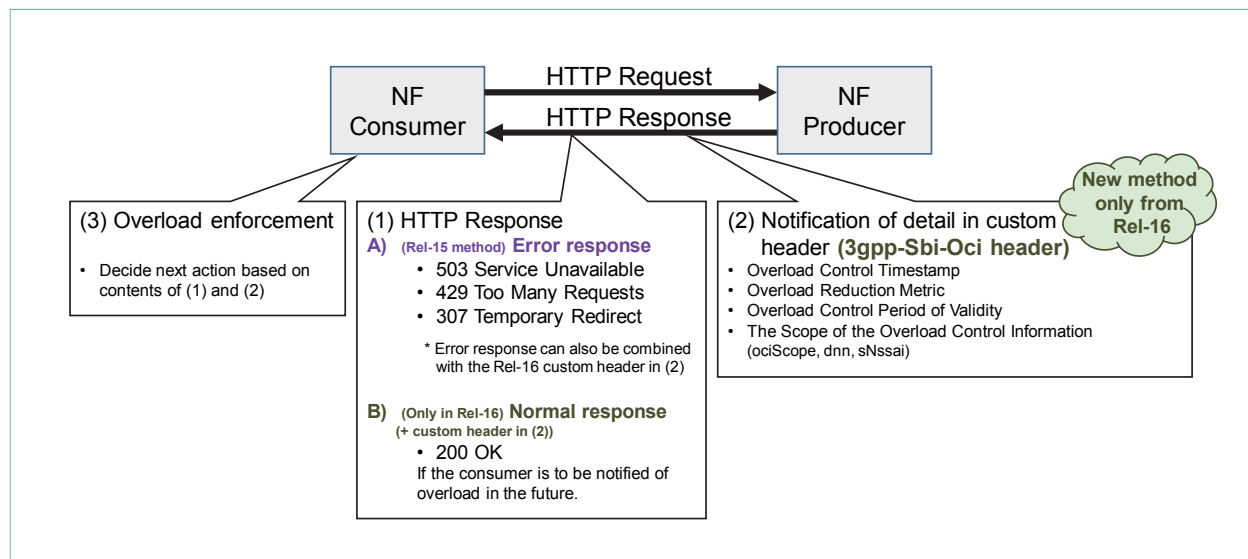


Figure 9 Notification of overload information

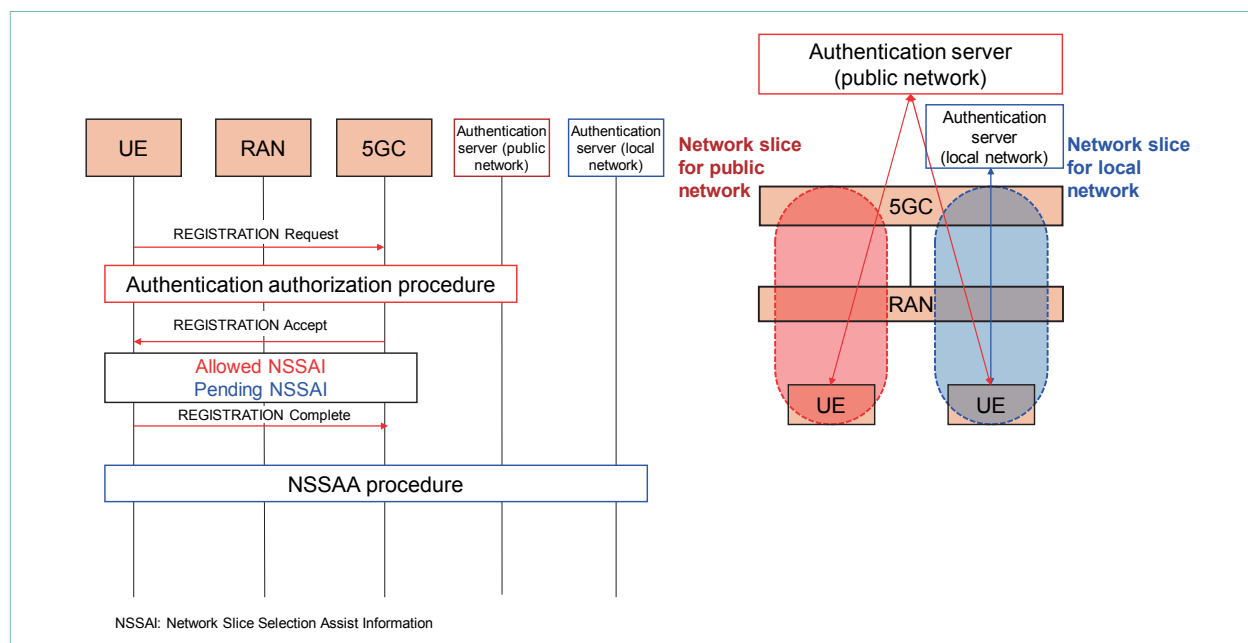


Figure 10 Authentication and approval procedures with NSSAA

effect on public network authentication and authorization servers. Note that the ID (EAP Identity) used in this authentication and authorization

procedure can be obtained securely on a communication channel configured on the public network.

## 2.3 5G Support and Enhancement of Various Services

5GC supports various services that are provided by LTE, such as voice calls, but some of the services were not be supported or were only partially supported in Rel-15, considering issues such as expansion of 5GC areas when 5GC is first introduced, and effects on development of devices and network equipment. In Rel-16, these services will be provided at least to the level provided by LTE, or will have new, extended functionality for 5GC.

### 1) Location Services

Location services for 5GC were limited in Rel-15, only supporting uses such as for emergencies, but Rel-16 supports location services equivalent to those provided by LTE. Functions for interworking<sup>\*36</sup> between 5GC and EPC have also been enhanced,

so that seamless location services can be provided in environments with a combination of 5G and LTE areas. As shown in **Figure 11**, the Location Management Function (LMF)<sup>\*37</sup> handles location services in 5GC, corresponding to the Evolved Serving Mobile Location Centre (E-SMLC)<sup>\*38</sup>, which handles location services in EPC.

Note that for EPC, a non-standalone<sup>\*39</sup> form for providing NR is specified, and for this case Rel-16 defines an extended interface for NR base stations (gNB<sup>\*40</sup>) to notify E-SMLC of location data.

### 2) 5G Voice Provision Method(s)

Since Rel-15, 5GC has followed EPC, supporting voice with an architecture that connects to the Internet protocol Multimedia Subsystem (IMS)<sup>\*41</sup>. In Rel-15 of 5GC, three main forms are specified for provision of voice (**Figure 12**).

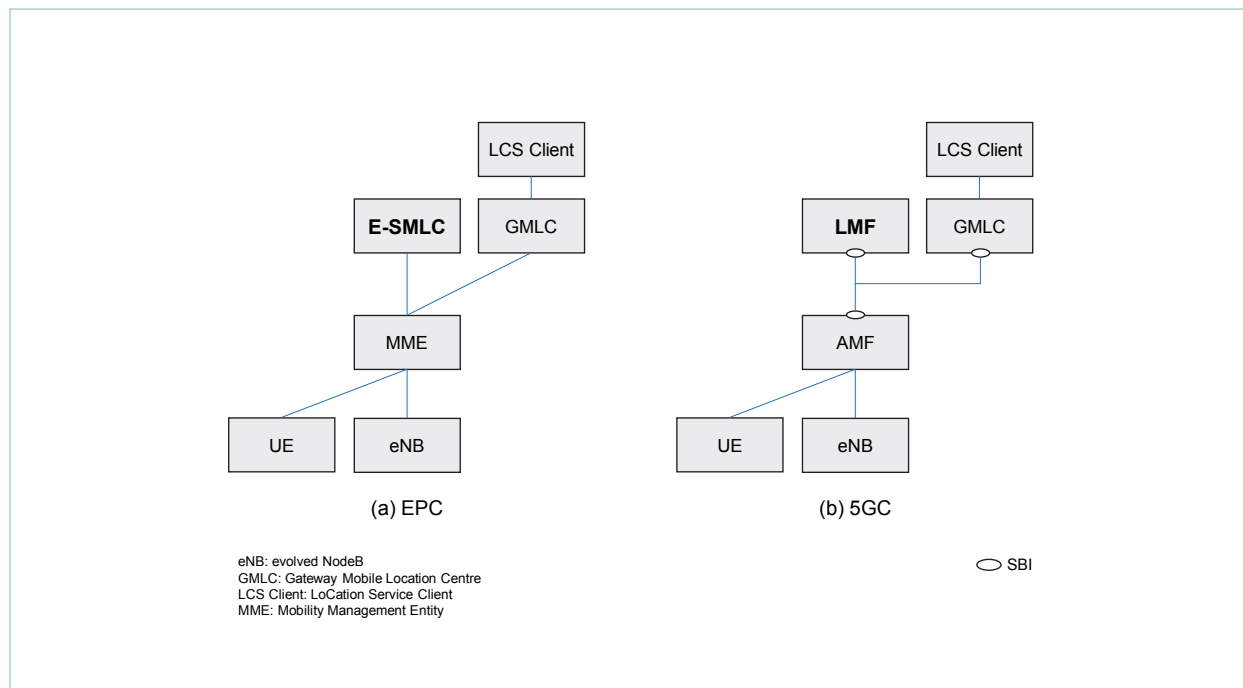


Figure 11 Examples of network configuration for location services in EPC and 5GC

<sup>\*36</sup> Interworking: Interoperation with a different communications system.

<sup>\*37</sup> LMF: A NF specified in 5GC that provides communication and control for location services.

<sup>\*38</sup> E-SMLC: Equipment specified in EPC that provides communication and control for location services.

<sup>\*39</sup> Non-standalone: A form of operation that provides services through a combination of NR and LTE areas, and does not provide a service area with NR alone.

<sup>\*40</sup> gNB: A radio base station that provides NR radio.

<sup>\*41</sup> IMS: A subsystem that provides IP multimedia services (e.g., VoIP, messaging, presence) on a 3GPP mobile communications network. Session Initiation Protocol (SIP) is used for the calling control protocol.

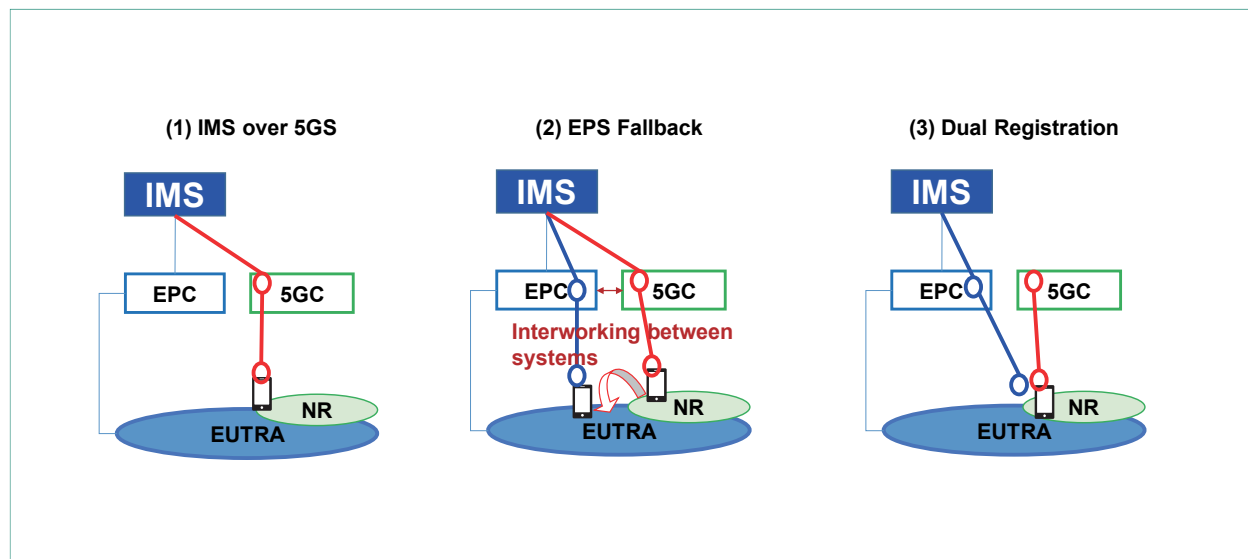


Figure 12 Example of voice provision configuration in Rel-15

- (1) IMS over 5G System (5GS)<sup>\*42</sup>: For devices that are in standby or calling on 5GS, a voice channel is configured directly in 5GS.
- (2) Evolved Packet System (EPS)<sup>\*43</sup> fallback: Devices that are in standby or calling on 5GS are temporarily connected to LTE through handover<sup>\*44</sup> or redirection<sup>\*45</sup>, and voice is provided by LTE.
- (3) Dual Registration: The device is registered in both EPC and 5GC, which handles standby, and voice is provided by LTE.

For provision of voice using methods 1, “IMS over 5GS,” or 2, “EPS fallback,” control between IMS and 5GC is provided by Rx, Cx, and Sh interfaces between IMS and EPC, so each NF on the 5GC side must have these interfaces. SBA is a feature of 5GC, providing SBIs for communication between NF, so Rel-16 also specifies an option to apply these SBIs for the interfaces between IMS and 5GC.

- 3) Enhancement of Functions to Select Roaming Destinations

Steering of Roaming (SoR) is a function that enables the home operator to direct their roaming subscribers to the operator of the home operator’s preference among the operators present at the roaming location. Provision of roaming services equivalent to those of EPC has been specified for 5GC since Rel-15, but SoR functionality has been enhanced in Rel-16.

Operators generally have contracts with several other operators (roaming partners) in a region in order to negotiate roaming user tariffs or to distribute and lower the risk of complete disconnection, including relay channels. Under normal operation, however, the home operator must distribute all roaming users among the roaming partners where they are roaming, making various adjustments for each operator, and SoR is used to control which roaming partner each subscriber should attach to.

<sup>\*42</sup> 5GS: The network system in 5GC, comprised of communication devices (UE) and the radio access network to which they connect.

<sup>\*43</sup> EPS: Generic term for an IP-based packet network specified by 3GPP for LTE or other access technologies.

<sup>\*44</sup> Handover: The communication technology that performs switching between cells and base stations while maintaining communication between the UE and the network.

<sup>\*45</sup> Redirection: A communication technology that temporarily stops communication between UE and network, places the UE in standby, and then reconnects to a cell or base station using a reconnect request signal from the UE.

There have been various non-standard methods for achieving this from 2G through EPC, but there were issues with degraded user experience and reliable control (Figure 13). In 5GC, a new Non-Access

Stratum (NAS)<sup>\*46</sup> signal is used to notify UE with an operator priority list, and functionality has been added for the UE to select the priority operator at any time (Figure 14).

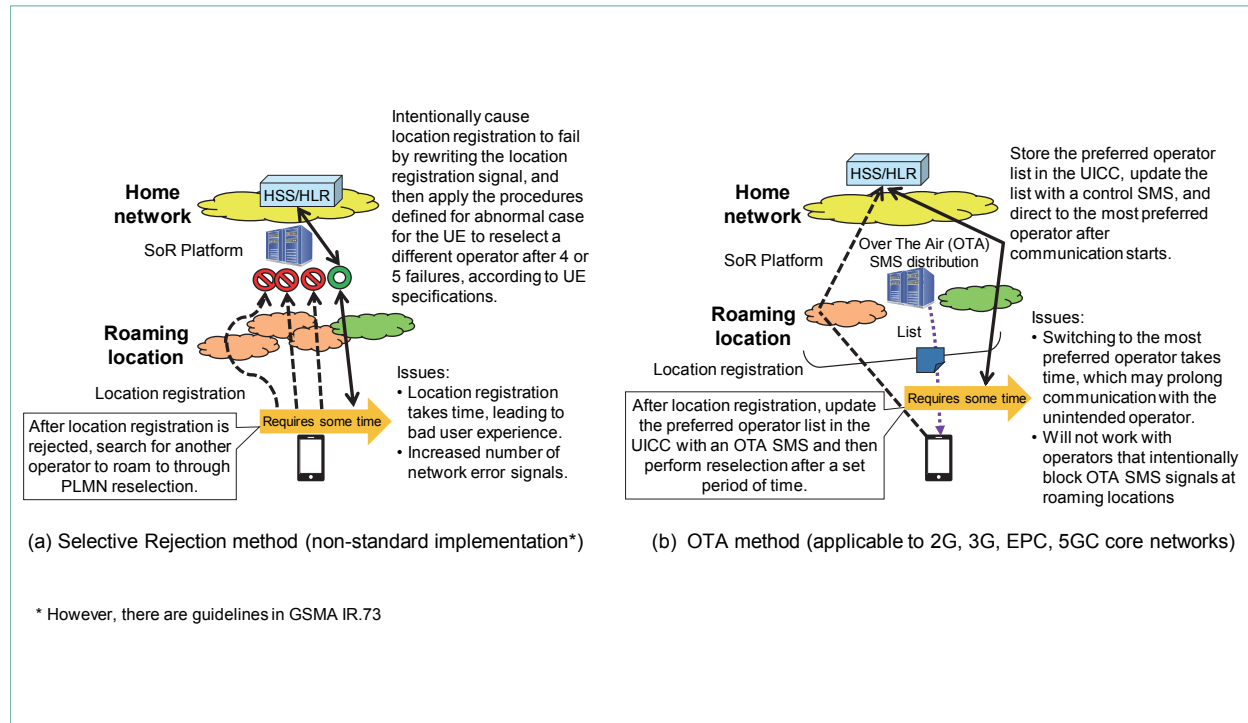


Figure 13 Existing SoR

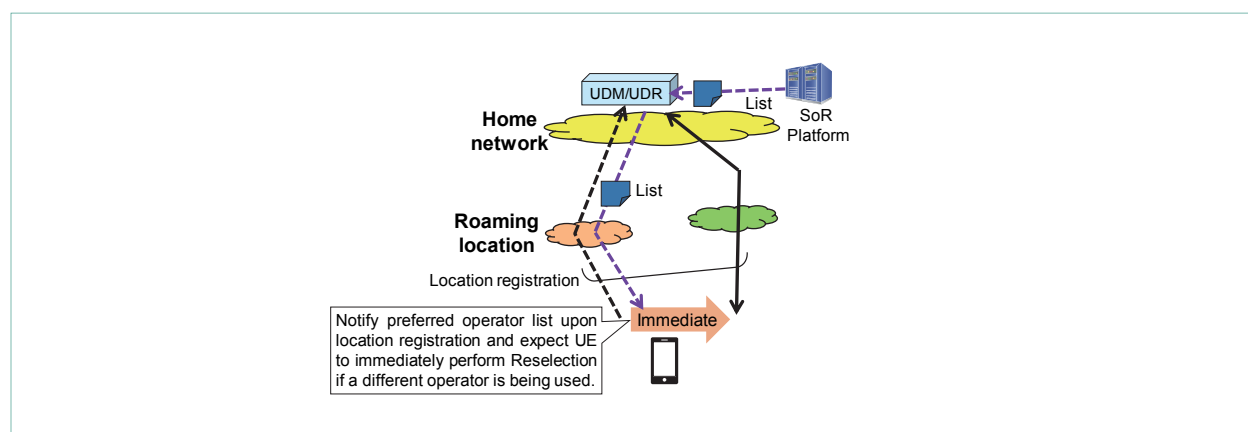


Figure 14 SoR using the NAS signal

<sup>\*46</sup> NAS: A functional layer between the UE and core network.

### 3. Conclusion

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This article has described enhancements to 5GC specified in Rel-16, in terms of newly introduced functions, enhancements to 5GC platform functionality and enhancements to existing services. Discussion is underway at 3GPP on further extensions to the 5GC core network and mobile communication services for Rel-17 and beyond, and NTT DOCOMO will continue contributing to 3GPP

standardization work, toward development of core networks for Beyond 5G and 6G.

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