ATIS-1000090

National Security Emergency Preparedness Next Generation Network Priority Service (NS/EP NGN-PS): Transport Level Packet Marking and Packet Scheduling in 5GS

TECHNICAL REPORT

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ATIS Technical Report on

National Security Emergency Preparedness Next Generation Network Priority Service (NS/EP NGN-PS): Transport Level Packet Marking and Packet Scheduling in 5GS

Alliance for Telecommunications Industry Solutions

Approved July 27, 2020

Abstract

This Technical Report provides guidance on how the 5G parameters (e.g., 5QI) are used for transport level packet marking and packet scheduling in support of National Security Emergency Preparedness Next Generation Priority Service (NS/EP NGN-PS).

Foreword

The Alliance for Telecommunications Industry Solutions (ATIS) serves the public through improved understanding between carriers, customers, and manufacturers. The Packet Technologies and Systems Committee (PTSC) develops and recommends standards and technical reports related to services, architectures, and signaling, in addition to related subjects under consideration in other North American and international standards bodies. PTSC coordinates and develops standards and technical reports relevant to telecommunications networks in the U.S., reviews and prepares contributions on such matters for submission to U.S. International Telecommunication Union Telecommunication Sector (ITU-T) and U.S. ITU Radiocommunication Sector (ITU-R) Study Groups or other standards organizations, and reviews for acceptability or per contra the positions of other countries in related standards development and takes or recommends appropriate actions.

The mandatory requirements are designated by the word *shall* and recommendations by the word *should*. Where both a mandatory requirement and a recommendation are specified for the same criterion, the recommendation represents a goal currently identifiable as having distinct compatibility or performance advantages. The word *may* denotes an optional capability that could augment the standard. The standard is fully functional without the incorporation of this optional capability.

Suggestions for improvement of this document are welcome. They should be sent to the Alliance for Telecommunications Industry Solutions, PTSC, 1200 G Street NW, Suite 500, Washington, DC 20005.

At the time of consensus on this document, PTSC, which was responsible for its development, had the following leadership:

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1 Scope, Purpose, & Application

This Technical Report (TR) describes support of National Security/Emergency Preparedness Next Generation Network Priority Services (NS/EP NGN-PS) based on the 3GPP Release 15 5GS QoS model and associated parameters for 5GS standalone architecture option 2, and includes:

1. Transport Level Packet Marking (e.g., to set a DiffServ Code Point value for priority traffic), and

2. Packet Scheduling (e.g., to determine the relative priority of QoS Flows and which packet(s) to serve when the 5QI Packet Delay Budget (PDB) can no longer be met for one or more QoS aggregates across all UEs).

While parts of this report may be applicable to architecture options other than architecture option 2, all aspects of the other architecture options are outside the scope of this document.

2 Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

3GPP

[Ref 1] 3GPP TS 23.501	System Architecture for the 5G System; Stage 2 (Release 15)
[Ref 2] 3GPP TS 23.502	Procedures for the 5G System; Stage 2 (Release 15)
[Ref 3] 3GPP TS 23.503	Policy and charging Control Framework for the 5G System; Stage 2 (Release 15)
[Ref 4] 3GPP TS 24.501	Non-Access Stratum (NAS) protocol for 5G System (5GS); Stage 3 (Release 15)
[Ref 5] 3GPP TS 29.244	Interface between the Control Plane and the User Plane Nodes; Stage 3 (Release 15)
[Ref 6] 3GPP TS 29.514	Policy Authorization Service; Stage 3 (Release 15)
[Ref 7] 3GPP TS 38.300	NR; NR and NG-RAN Overall Description; Stage 2 (Release 15)
[Ref 8] 3GPP TS 38.413	NG-RAN; NG Application Protocol (NGAP) (Release 15)

ATIS

[Ref 9] ATIS-1000057	Service Requirements for Emergency Telecommunications Service (ETS) in Next Generation Network
[Ref 10] ATIS-1000065	Emergency Telecommunications Service (ETS) Evolved Packet Core (EPC) Network Element Requirements
[Ref 11] ATIS-1000066	Emergency Telecommunications Service (ETS) Network Element Requirements for IMS-based Next Generation Network (NGN) Phase 2

[Ref 12] ATIS-1000079 National Security Emergency Preparedness Next Generation Network Priority Service (NS/EP NGN-PS): Transport Level Packet Marking and Packet Scheduling

IETF

[Ref 13] RFC 5865 A Differentiated Services Code Point (DSCP) for Capacity-Admitted Traffic

FCC

[Ref 14] FCC 47 CFR § 64 Appendix B FCC Title 47 Telecommunication Appendix B to Part 64; Priority Access Service (PAS) for National Security and Emergency Preparedness (NSEP)

3 Definitions, Acronyms, & Abbreviations

For a list of common communications terms and definitions, please visit the *ATIS Telecom Glossary*, which is located at < http://www.atis.org/glossary >.

3.1 Definitions

NS/EP NGN Priority Services (NS/EP NGN-PS) ATIS-1000057 [Ref 9]: are the evolution of legacy GETS and WPS to achieve continuity in the packet-switched NGN, and to leverage the NGN to offer new features and priority multimedia services.

3.2 Acronyms & Abbreviations

5QI	5G QoS Identifier
AMF	Access and Mobility management Function
AF	Application Function
AN	Access Network
ARP	Allocation and Retention Priority
ATIS	Alliance for Telecommunications Industry Solutions
AUSF	Authentication Server Function
DL	Downlink
DN	Data Network
DNN	Data Network Name
DRMP	Diameter Routing Message Priority
DSCP	DiffServ Code Point
EPS	Evolved Packet System
FE	Functional Entity
GBR	Guaranteed Bit Rate

GFBR	Guaranteed Flow Bit Rate
HARQ	Hybrid Automatic Repeat reQuest
HPLMN	Home Public Land Mobile Network
IP	Internet Protocol
MDBV	Maximum Data Burst Volume
MPS	Multimedia Priority Service
NGN	Next Generation Network
NR	New Radio
NS/EP	National Security and Emergency Preparedness
NSSF	Network Slice Selection Function
PCF	Policy Control Function
PDB	Packet Delay Budget
PDR	Packet Detection Rule
PER	Packet Error Rate
PDU	Protocol Data Unit
PLMN	Public Land Mobile Network
RPLMN	Registered Public Land Mobile Network
PS	Priority Services
QCI	QoS Class Identifier
QFI	QoS Flow Identifier
QoS	Quality of Service
RAN	Radio Access Network
RPH	Resource-Priority Header
RQA	Reflective QoS Attribute
SBA	Service Based Architecture
SDF	Service Data Flow
SIP	Session Initiation Protocol
SMF	Session Management Function
TS	Technical Specification
UDM	Unified Data Management
UE	User Equipment

UL	Uplink
UPF	User Plane Function
USIM	Universal Subscriber Identity Module

4 Overview

The 3GPP Release 15 specifications for 5G Quality of Service (QoS) allow transport level packet markings, e.g., Differentiated Services (DiffServ) Code Point (DSCP), on a per-QoS Flow basis, to be determined based on the 5QI, the 5QI Priority Level (if explicitly signaled), and the Allocation Retention Priority (ARP) Priority Level of the associated QoS Flow. Other IEs can influence the DSCP setting as discussed elsewhere in this document.

The 3GPP Release 15 specifications also support use of the 5QI Priority Level to differentiate scheduling treatment among QoS Flows when Packet Delay Budget (PDB) targets can no longer be met for one or more QoS Flows across all UEs that have sufficient radio channel quality.

4.1 5G Reference Architectures

The following 5G reference architecture information is based on or excerpted from TS 23.501 [Ref 1] §4.2.3.

Figure 4-1 shows the non-roaming 5GS architecture in reference point representation. In this representation, services are described by interactions between network functions that are interconnected via reference points, also called point-to-point interfaces. Ni, where "i" is an integer, is the naming convention for each point-to-point interface.

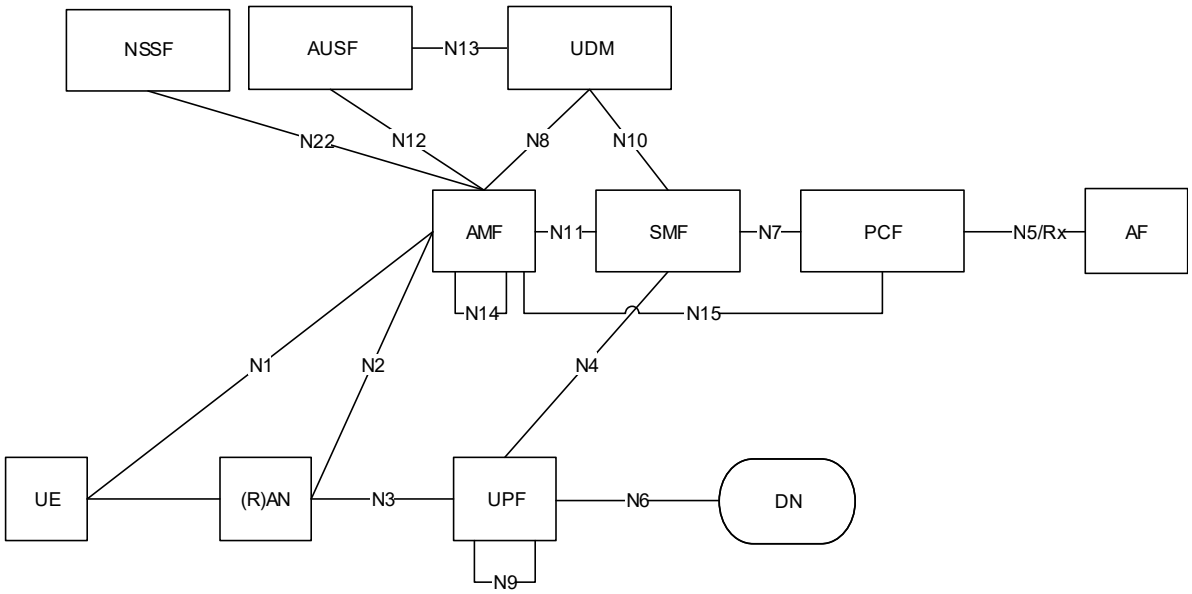

Figure 4-1: Non-Roaming 5G System Architecture in Reference Point Representation

As per TS 23.503 [Ref 3] § 5.2.3, to support 5G interoperability with existing IMS services, the Diameter Rx interface is supported between the AF (e.g., P-CSCF) and the PCF, as an alternative to the N5 interface between the AF and the PCF. Therefore, this document identifies instances where Diameter Routing Message Priority (DRMP) priority markings may be used over Rx to support NS/EP NGN-PS.

Figure 4-2 shows the non-roaming 5G Service Based Architecture (SBA) with service-based interfaces. In this architecture, a Network Function (NF) within the core 5G network may expose its capabilities as services via its service-based interfaces, which can be re-used by other NFs. In general, all interfaces involving the user plane (i.e., N3, N6, and N9) are point-to-point based; all interfaces between user plane entities and control plane entities

(i.e., N1, N2, and N4) are point-to-point based; and all other interfaces involving only control plane entities are service-based.

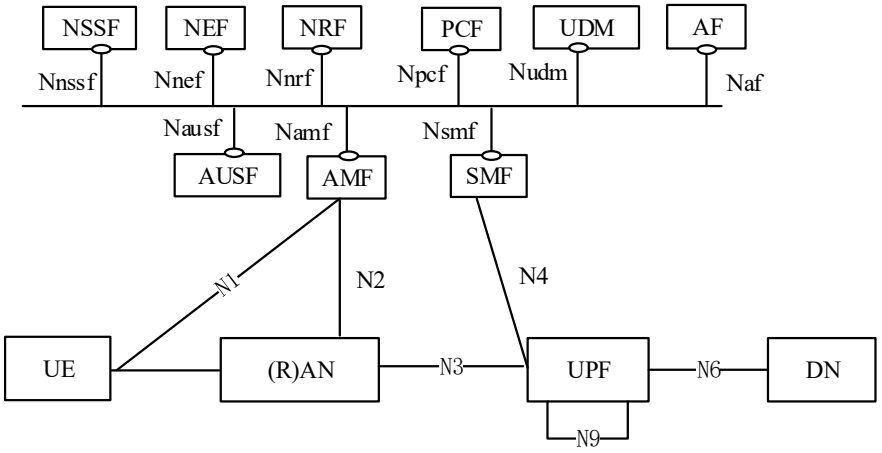

Figure 4-2: Non-Roaming 5G Service-Based Architecture

5 5GS QoS Model and Parameters

This clause describes the 5GS QoS model and parameters that are relevant to transport level packet marking and the packet scheduling behavior (e.g., scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.). 5GS supports a decoupling of Priority Level from other QoS characteristics such as Packet Delay Budget (PDB) and Packet Error Rate (PER). This is a key ingredient to differentiate NS/EP NGN-PS traffic in terms of packet scheduling and packet forwarding treatment.

5.1 5G QoS Model

The 5G QoS model introduces two new QoS concepts which benefit NS/EP NGN-PS.

The 5G QoS Identifier (5QI) is an enhancement to QCI that conveys the 5G QoS characteristics. Though the 5GS can specify a standardized 5QI analogous to the QCI in EPS, dynamically-assigned 5QIs can specify customized values for QoS characteristics (such as Packet Delay Budget, Packet Error Rate and Priority Level). NS/EP NGN-PS can take advantage of dynamically-assigned 5QIs to specify the required priority level for NS/EP NGN-PS.

A significant QoS capability introduced in 5GS is the decoupling of priority from other QoS characteristics. Additionally, the 5G QoS model supports the ability to override the default “Priority Level” QoS characteristic value associated with standardized 5QIs.

The ability to support dynamically-assigned 5QIs and 5QI priority level override allows flexible assignment of QoS characteristics (including the 5QI Priority Level) for NS/EP NGN-PS-related QoS flows.

5.1.1 QoS Flow

The 5G QoS model is based on QoS Flows. The QoS Flow is the finest granularity of QoS differentiation within a PDU Session providing connectivity between a UE and a Data Network. A QoS Flow is identified by a QoS Flow Identifier (QFI) within the context of a particular PDU session. User Plane traffic with the same QFI within a PDU Session receives the same traffic forwarding treatment (e.g., scheduling, admission threshold). The QFI may be dynamically assigned or in specific limited cases may be equal to the numerical value of a standard 5QI (see Clause 5.2.1).

A QoS Flow associated with the default QoS rule is established for each PDU Session and remains established throughout the lifetime of the PDU Session. For the NS/EP NGN-PS Data Transport Service, the priority of the default QoS rule will be elevated to provide higher priority treatment for all data on the QoS flow associated with the default QoS rule.

Additional QoS Flows may be established within a PDU Session to support the media needs of IMS. The P-CSCF will trigger the PCF to create a Service Data Flow (SDF) and an associated PCC rule. The PCC rule from the PCF includes the authorized QoS of the SDF which in turn is bound by the Session Management Function (SMF) to a QoS Flow appropriate to meet the QoS needs of the SDF. For NS/EP NGN-PS Voice and NS/EP NGN-PS Video, a priority QoS flow is created to support the priority needs of the IMS media.

The SMF is responsible for signaling the needed parameters to support the QoS flow. This includes signaling interactions with the UE, RAN, and UPF.

5.1.2 QoS Profile

The SMF provides the RAN (transparently via the AMF) the needed parameters to support a QoS flow. This set of parameters is named generically a "QoS Profile" in 3GPP Stage 2 specifications TS 23.501 [Ref 1] and TS 23.502 [Ref 2], but is formally denoted "QoS Flow Level QoS Parameters" in the Stage 3 specification for signaling between the 5GC and the RAN, TS 38.413 [Ref 8].

The following parameters are included in a QoS profile (details of QoS parameters are described in Clause 5.2):

- All QoS profiles include:
  - QoS Flow identifier (QFI);
  - 5G QoS Identifier (5QI); and
  - Allocation and Retention Priority (ARP).
- A QoS Profile may describe a QoS Flow that is either 'GBR' (Guaranteed Bit Rate) or 'Non-GBR' type.
- GBR QoS profiles must also include:
  - Guaranteed Flow Bit Rate (GFBR) – Uplink (UL) and Downlink (DL); and
  - Maximum Flow Bit Rate (MFBR) – UL and DL; and
- GBR QoS profiles may also include:
  - Notification control; and
  - Maximum Packet Loss Rate – UL and DL.

When a standardized or pre-configured 5QI is used for a QoS Flow, the 5QI is the only piece of QoS information that must be signaled; however, in special cases, some of the 5G QoS characteristics may be signaled as part of the QoS profile (as described in Clause 5.2.1.1). NS/EP NGN-PS is one of these special cases, where the elevated priority level for NS/EP NGN-PS can be signaled along with the standard 5QI to enable priority service.

When a dynamically assigned 5QI is used for a QoS Flow, the complete set of 5G QoS characteristics (described in Clause 5.2.1.1) for the QoS profile must be signaled. Using a dynamically assigned 5QI with all of the explicit QoS profile parameters for NS/EP NGN-PS is an alternative method to obtain priority for NS/EP NGN-PS.

5.1.3 QoS Rules

The SMF provides the UE (transparently via the AMF and the RAN) the needed parameters to support a QoS flow. This set of parameters is named "QoS Rules" in Stage 2 specifications TS 23.501 [Ref 1], TS 23.502 [Ref 2], and TS 23.503 [Ref 3]. Stage 3 specification TS 24.501 [Ref 4] for signaling between the 5GC and the UE includes the concept of "QoS Rules" and adds the concept of "QoS flow descriptions" to add some of the parameters defined for QoS profile in Clause 5.1.2.

The UE performs the classification and marking of UL User plane traffic, i.e., the association of UL traffic to QoS Flows, based on the set of packet filters included within QoS rules. QoS rules may be explicitly provided to the UE (e.g., using the PDU Session Establishment/Modification procedure) or pre-configured in the UE.

A QoS rule contains the QFI of the associated QoS Flow, a Packet Filter Set, a precedence value, and an indication of whether the QoS rule is the default rule or not. An explicitly signaled QoS rule contains a dynamically-assigned QoS rule identifier which is unique within the PDU Session and is generated by the SMF.

A default QoS rule is sent to the UE for every PDU Session establishment for a QoS Flow that lasts for the duration of the PDU session.

The NS/EP NGN-PS Data Transport Service will use an explicitly signaled default QoS rule to modify the priority of the default QoS Flow.

NS/EP NGN-PS Voice and NS/EP NGN-PS Video make use of a QoS rule other than the default QoS rule.

5.2 5G QoS Parameters

5.2.1 5QI

5QI defines a QoS profile that controls QoS forwarding treatment for the QoS Flow (e.g., scheduling weights, admission thresholds, queue management thresholds, link layer protocol configuration, etc.).

- Standardized 5QI values map to a standardized combination of 5G QoS characteristics.
- 5G QoS characteristics for pre-configured 5QI values are pre-configured in the RAN.
- 5G QoS characteristics for dynamically-assigned 5QI values are signaled as part of the QoS profile.

Standardized or pre-configured 5G QoS characteristics are indicated through the 5QI value, and are not signaled on any interface, unless certain 5G QoS characteristics are modified. For NS/EP NGN-PS, the priority level of a standardized 5QI may be overridden in this manner.

5.2.1.1 5QI Characteristics

As per 3GPP TS 23.501 [Ref 1]:

5G QoS characteristics associated with 5QI describe the packet forwarding treatment that a QoS Flow receives between the UE and the User Plane Function (UPF) in terms of the following performance characteristics:

- Resource Type (GBR, Delay critical GBR or Non-GBR);
- Priority Level;
- Packet Delay Budget;
- Packet Error Rate;
- Averaging window (for GBR and Delay-critical GBR resource type only);
- Maximum Data Burst Volume (for Delay-critical GBR resource type only).

The Resource Type determines whether dedicated network resources related to a QoS Flow-level Guaranteed Flow Bit Rate (GFBR) value are permanently allocated (e.g., by an admission control function in a radio base station). GBR QoS Flows are therefore typically authorized "on demand" which requires dynamic policy and charging control. A GBR QoS Flow uses either the GBR resource type or the Delay-critical GBR resource type. A Non-GBR QoS Flow may be pre-authorized through static policy and charging control.

The Priority Level indicates a priority for scheduling resources among QoS Flows. Every 5QI is associated with a Priority Level value, either a default value, or an explicitly signaled value. The lowest Priority Level value corresponds to the highest priority. The Priority Level can be used to differentiate between QoS Flows of the same UE, and differentiate between QoS Flows from different UEs. In cases of congestion, when all QoS requirements cannot be fulfilled, the Priority Level is used to prioritize QoS Flows.

The Packet Delay Budget (PDB) defines an upper bound for the time that a packet may be delayed between the UE and the UPF that terminates the N6 interface. For some 5QIs, the value of the PDB is the same in the UL and DL directions. The PDB is used to support the configuration of scheduling and link layer functions (e.g., the setting of scheduling priority weights and Hybrid Automatic Repeat Request (HARQ) target operating points). Scheduling

between different QoS Flows is primarily based on the PDB. For GBR QoS Flows with GBR resource type not exceeding GFBR, the PDB is interpreted as a maximum delay with a confidence level of 98 percent (i.e., 98 percent of the packets do not experience a delay exceeding the 5QI's PDB).

The Packet Error Rate (PER) defines an upper bound for the rate of packets (e.g., IP packets) that have been processed by the sender of a link layer protocol but that are not successfully delivered by the corresponding receiver to the upper layer. Thus, the PER defines an upper bound for a rate of non-congestion related packet losses. The purpose of the PER is to allow for appropriate link layer protocol configurations. For every 5QI the value of the PER is the same in UL and DL.

The Averaging window represents the duration over which the GFBR and MFBR are calculated (e.g., in the RAN, UPF, UE). Each GBR QoS Flow is associated with an Averaging window. Every standardized 5QI (of GBR and Delay-critical GBR resource type) is associated with a default value for the Averaging window. The Averaging window may also be signaled together with a standardized or a pre-configured 5QI to the RAN, UPF, or UE. In this case, the signaled value overrides the default/pre-configured value.

The Maximum Data Burst Volume (MDBV) denotes the largest amount of data that the 5G-AN is required to serve within the 5G-AN part of the PDB. Every standardized 5QI (of Delay-critical GBR resource type) is associated with a default value for the MDBV. The MDBV may also be signaled together with a standardized or a pre-configured 5QI.

5.2.2 Allocation and Retention Priority (ARP)

The ARP defines the relative importance of a resource request. ARP can be used to decide whether a service data flow establishment or modification request can be accepted or needs to be rejected in case of resource limitations (typically used for admission control of GBR traffic). ARP can also be used to decide which existing service data flows to pre-empt during resource limitations.

The pre-emption capability information defines whether a service data flow can get resources that were already assigned to another service data flow with a lower priority level. The pre-emption vulnerability information defines whether a service data flow can lose the resources assigned to it in order to admit a service data flow with higher priority level. The pre-emption capability and the pre-emption vulnerability are set either to the 'yes' or 'no' values.

The range of the ARP priority level is 1 to 15, with 1 as the highest level of priority. The ARP priority levels 1-8 are assigned to resources for services that are authorized to receive prioritized treatment within an operator domain (i.e., that are authorized by the serving network). This ensures that future releases could use ARP priority levels 1-8 to indicate particular services (e.g., emergency and other priority services within an operator domain in a backward compatible manner). The ARP priority levels 9-15 can be assigned to resources that are authorized by the home network and thus are applicable when a UE is roaming. This does not prevent the use of ARP priority levels 1-8 in roaming situations in case appropriate roaming agreements exist that ensure a compatible use of these priority levels.

5.2.3 Flow Bit Rates

Flow bit rates only apply to GBR QoS Flows. There are distinct parameters for the Guaranteed Flow Bit Rate (GFBR) for the UL and the DL and for the Maximum Flow Bit Rate (MFBR) for the UL and the DL.

The GFBR is the bit rate that is guaranteed to be provided by the network to the QoS Flow over the Averaging Time Window.

The MFBR is the upper-bound on the bit rate that will be given the treatment specified in the QoS rule. Traffic exceeding the MFBR may be delayed or discarded by rate shaping or policing functions at the UE, RAN, or UPF.

5.2.4 Establishment Cause

The Establishment Cause is a field in the RRC “RRCConnectionRequest” message and NGAP “Initial UE Message” message and has “mps-PriorityAccess” as one of its enumerated values. The presence of “mps-PriorityAccess” may be used to set the DSCP marking by the gNB and AMF before other QoS parameters such as the 5QI, 5QI Priority Level (if specifically signaled), and ARP Priority Level of the QoS Flow are known.

5.2.5 Default Values

For each PDU Session setup, the SMF retrieves the subscribed default values for the 5QI and the ARP Priority Level and optionally, the 5QI Priority Level, from the UDM. The subscribed default 5QI as defined in 3GPP TS 23.501 [Ref 1] is a Non-GBR 5QI from within the range of standardized values.

The 5QI Priority Level can be added to the subscription information to achieve an overwriting of the standardized or preconfigured 5QI Priority Level. This is particularly important in scenarios where dynamic PCC is not deployed or the PCF is unavailable or unreachable. The SMF may change the subscribed values for the default 5QI and the ARP priority level, and if received, the 5QI Priority Level, based on local configuration or via interactions with the PCF.

6 Transport Level Packet Marking

This clause provides guidance as to how the DSCP marking based on 5QI, 5QI Priority Level (if explicitly signaled), and, optionally, ARP is used to support transport level packet forwarding for NS/EP NGN-PS traffic. This clause also describes how to support transport level packet marking for NS/EP NGN-PS traffic in the following procedures: Registration, Service Request, PDU Session Establishment, Mobile Origination, Mobile Termination.

Priority treatment for an FE that has “per hop behavior” queues that support both NS/EP NGN-PS and other public (non-NS/EP NGN-PS) traffic is accomplished using Differentiated Services (DiffServ) Code Point (DSCP). This includes intermediate routers not in scope of the 3GPP specification. In this case, the Service Provider provisions and configures these queues so that NS/EP NGN PS traffic is on average the last traffic shed from these queues (e.g., NS/EP NGN-PS traffic is assigned a low drop probability DSCP, while public traffic is assigned a medium or high drop probability DSCP). Once an FE is made aware of the need to mark the DSCP, packets are marked with appropriate DSCP that gives priority to NS/EP NGN-PS traffic over public traffic.

5QI, 5QI Priority Level (if explicitly signaled) and, optionally, ARP Priority Level are key parameters that are used to determine the DSCP value for NS/EP NGN-PS traffic. Establishment Cause may also be used to determine if a different DSCP value should be used. Other parameters (e.g., Diameter Routing Message Priority (DRMP) and SIP Resource Priority Header (RPH)) may also be used to determine whether a different DSCP value should be used and are generally outside the scope of this document except where specifically mentioned.

> Note: In 5GS while there is no specific 5QI available for NS/EP NGN-PS (unless dynamic 5QI is assigned), Priority Level (PL) override can be used for NS/EP NGN-PS QoS flows. Therefore, the influence of 5QI on DSCP marking is based on the 5QI PL (whether it is signaled or not). Other 5QI parameters (PDB, PER, etc.) do not influence DSCP marking. Therefore, mention of 5QI in the context of influencing DSCP marking in this document includes the use of 5QI PL (either the default PL or an explicitly-signaled PL).

Once the FE is made aware of the need to use an appropriate DSCP value for NS/EP during a procedure (e.g., Registration, Service Request, PDU Session Establishment, etc.), the FE may handle all subsequent messages for this procedure with priority and mark all packets carrying subsequent outgoing messages for this procedure with the DSCP value configured for NS/EP.

It is possible that the Establishment Cause priority-marking is encountered before any QoS parameters and a DSCP value based on that Establishment Cause is chosen. Later in the procedure, 5QI and ARP values are encountered (e.g., from subscription data) that map to a different DSCP value which then overrides the Establishment-Cause-associated DSCP value for the rest of the procedure and all subsequent packets.

6.1 Procedures

This clause describes procedures and message/call flow components associated with NS/EP NGN-PS. While many of the message/call flow descriptions described herein are applicable to all forms of NS/EP NGN-PS, as they are independent of the particular user application, some focus specifically on capabilities in support of NS/EP NGN-PS voice. These descriptions are not intended to be a comprehensive procedure list or message flow description, but rather to highlight selected components of procedures that can affect the priority marking and scheduling of NS/EP NGN-PS packets.

Message/call flow descriptions are provided only at a level of detail sufficient to highlight aspects specific to NS/EP NGN-PS. Comprehensive procedure details and message/call flow descriptions for NS/EP NGN-PS Voice and

Video services can be found in TS 23.501 [Ref 1], TS 23.502 [Ref 2], and TS 24.501 [Ref 4]. Enhanced capabilities for the NS/EP NGN-PS Data Transport Service are in the process of being specified in 3GPP Release 17.

6.1.1 Scope of Procedures

When the UE is powered on, it starts in 5GMM-DEREGISTERED state and, when a 3GPP network supporting 5GS is selected, registers with the 5G core network. Unlike 4G where, prior to Release 13, the Attach procedure automatically establishes one or more PDN connection(s), in 5G a PDU Session is not automatically established as part of Registration. Upon the completion of Registration, a UE supporting IMS may establish a PDU Session to support a Default QoS Flow for IMS Signaling to the IMS Data Network (DN). The UE may establish PDU Sessions to additional DNs. Once a PDU Session and associated User Plane connection is established to a specific DN, the UE can exchange packets with that DN.

When the UE is 5GMM-REGISTERED and is in RRC_IDLE state and 5GMM-IDLE mode and has uplink signaling/data to send, the UE establishes an RRC Connection and sends a Service Request message to move to the 5GMM-CONNECTED mode. If the UE has UL packets to send, the Service Request may optionally indicate, via the PDU session status, the list of PDU session(s) for which the User Plane connection should be established.

When the UE is 5GMM-REGISTERED and is in 5GMM-IDLE mode, if the network has signaling to deliver to the UE, the network pages the UE and the UE performs an RRC Connection establishment and Service Request procedure to enter the RRC_CONNECTED state and 5GMM-CONNECTED mode. When media QoS Flows need to be added to a PDU Session (e.g., when a voice call is originated by the UE or is terminated to the UE by the network), the QoS Flows are added by the network-requested PDU Session Modification procedure.

When the UE with established PDU Sessions re-registers (periodic registration or mobility registration), the PDU Sessions are maintained and updated as needed. When the UE is de-registered (powered off, timer expiry with no re-registration, or network initiated deregistration), all PDU Sessions and User Plane connections are released.

6.1.2 Initial Registration

A UE performs Initial Registration when it is powered on, regardless of whether it was previously registered in the same Public Land Mobile Network (PLMN). Prior to the UE initiating an Initial Registration, it starts in 5GMM-DEREGISTERED and RRC_IDLE states and 5GMM-IDLE mode. Figure 6-1 shows the Registration Procedure message flow components that support NS/EP NGN-PS. The numbered items in the list of steps below correspond to the numbered process steps in the figure.

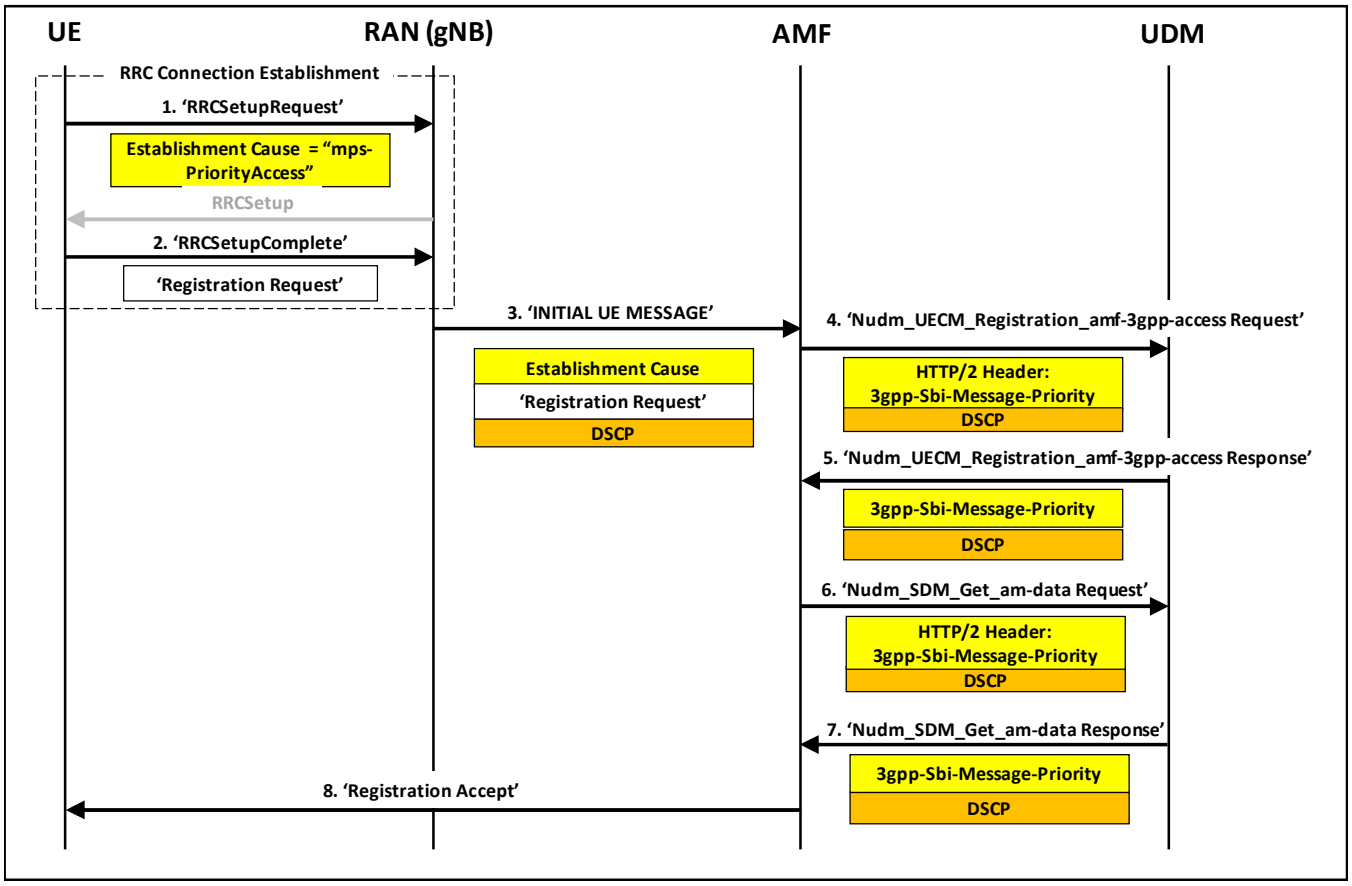

Figure 6-1: Initial Registration Procedure Message Flow Components that Support NS/EP NGN-PS

1. The UE sets up an RRC connection to the Radio Access Network (RAN) (i.e., gNB) via an "RRCSetupRequest" message that includes the "Establishment Cause" IE. For UEs subscribed to NS/EP NGN-PS, the "Establishment Cause" is set to the "mps-PriorityAccess" value which results in priority being given in the allocation of SRB1 radio bearer resources, and the selection of an AMF.

2. Following receipt of an RRCSetup message from the gNB, the UE sends an "RRCSetupComplete" message that includes an encapsulated NAS 5GMM "Registration Request" message.

3. The gNB sends an "INITIAL UE MESSAGE" message to the Access Management Function (AMF) that includes the "Establishment Cause" IE and encapsulated NAS 5GMM "Registration Request" message received from the UE in the "RRCSetupComplete" message. If the gNB is provisioned to set a priority Differentiated Services Code Point (DSCP) value when the "Establishment Cause" is set to the "mps-PriorityAccess" value, it sets the DSCP value for priority handling from this point on for packets exchanged with the AMF.

4. The AMF sends a UEContextManagement (UECM) "Nudm_UECM_Registration_amf-3gpp-access request" to the Unified Data Management (UDM) function to register the UE for 3GPP access at the chosen AMF. The AMF marks the packets with the "3gpp-Sbi-Message-Priority" header value, based on the "mps-PriorityAccess" value of the "Establishment Cause" IE. If the AMF is provisioned to set a priority DSCP value when the "Establishment Cause" is set to the "mps-PriorityAccess" value, it sets the DSCP value to reflect priority treatment appropriate for NS/EP NGN-PS.

5. The UDM responds to the AMF request with a "Nudm_UECM_Registration_amf-3gpp-access response" to confirm successful registration. It is marked with the "3gpp-Sbi-Message-Priority" header value and NS/EP NGN-PS appropriate DSCP value based on the incoming request.

6. The AMF sends a Subscriber Data Management (SDM) "Nudm_SDM_Get_am-data request" to the UDM to retrieve the UE's Access and Mobility Subscription data. The AMF marks the packets with the "3gpp-Sbi-Message-Priority" header value, based on the "mps-PriorityAccess" value of the "Establishment

Cause" IE. If the AMF is provisioned to set a priority DSCP value when the "Establishment Cause" is set to the "mps-PriorityAccess" value, it sets the DSCP value to reflect priority treatment appropriate for NS/EP NGN-PS.

7. The UDM responds to the AMF request with a "Nudm_SDM_Get_am-data response" containing the UE's Access and Mobility Subscription data, which includes the "mpsPriority" attribute to indicate whether the UE has an MPS subscription. It is marked with the "3gpp-Sbi-Message-Priority" header value and NS/EP NGN-PS appropriate DSCP value based on the incoming request.
8. The AMF sends a "Registration Accept" message to the UE. The NGAP and RRC messages which encapsulate the "Registration Accept" are not shown as there are no NS/EP NGN-PS impacts. Based on operator policy, the AMF may include an "MPS Indicator bit" in the "Registration Accept" message, to inform the UE whether configuration of access identity 1 is valid within the registered PLMN.

While the UE remains in 5GMM-CONNECTED state, the AMF retains the "Establishment Cause" value received in the "INITIAL UE Message" message from this UE such that it can be used in a subsequent procedure. For example, if the UE performs a PDU Session Establishment after the Registration procedure, while the UE is still 5GMM-CONNECTED, the AMF can provide priority handling and also include an appropriate priority indication in the first interaction with the SMF for this UE.

Unlike the LTE Attach procedure, the 5GS Registration procedure does not support concurrent initiation of Protocol Data Unit (PDU) session establishment. Therefore, at the end of the 5GS Registration procedure, the UE does not have a PDU Session established to any Data Network (DN). A separate procedure (PDU Session Establishment, described in Clause 6.1.7) is required to establish a PDU Session and a default QoS Flow to a particular DN.

There are no NS/EP NGN-PS-specific policy requirements to be applied during the Registration procedure.

6.1.3 Periodic/Mobility Registration Update

The Periodic/Mobility Registration Update procedure uses the same message flow as the Initial Registration procedure described in Clause 6.1.2. While there are small differences in certain included parameters, from the point of view of NS/EP NGN-PS indicators, the procedures are identical.

6.1.4 Deregistration

There are no NS/EP NGN-PS-related priority packet marking aspects associated with either UE-initiated deregistration or network-initiated deregistration.

6.1.5 Service Request

Per §5.6.1.1 of TS 24.501 [Ref 4], the Service Request procedure triggers a change from 5GMM-IDLE mode to 5GMM-CONNECTED, and may also request the establishment of user-plane resources for existing PDU sessions without user-plane resources. The latter case applies also when the UE is in 5GMM-CONNECTED mode. The Service Request procedure is always initiated by the UE. It can be triggered by a Paging procedure (see Clause 6.1.6) when the UE is in the 5GMM-IDLE mode, or by a Notification procedure when the UE is in the 5GMM-CONNECTED mode.

Figure 6-2 shows the Service Request Procedure message flow components that support NS/EP NGN-PS. The numbered items in the list of steps below correspond to the numbered process steps in the Figure.

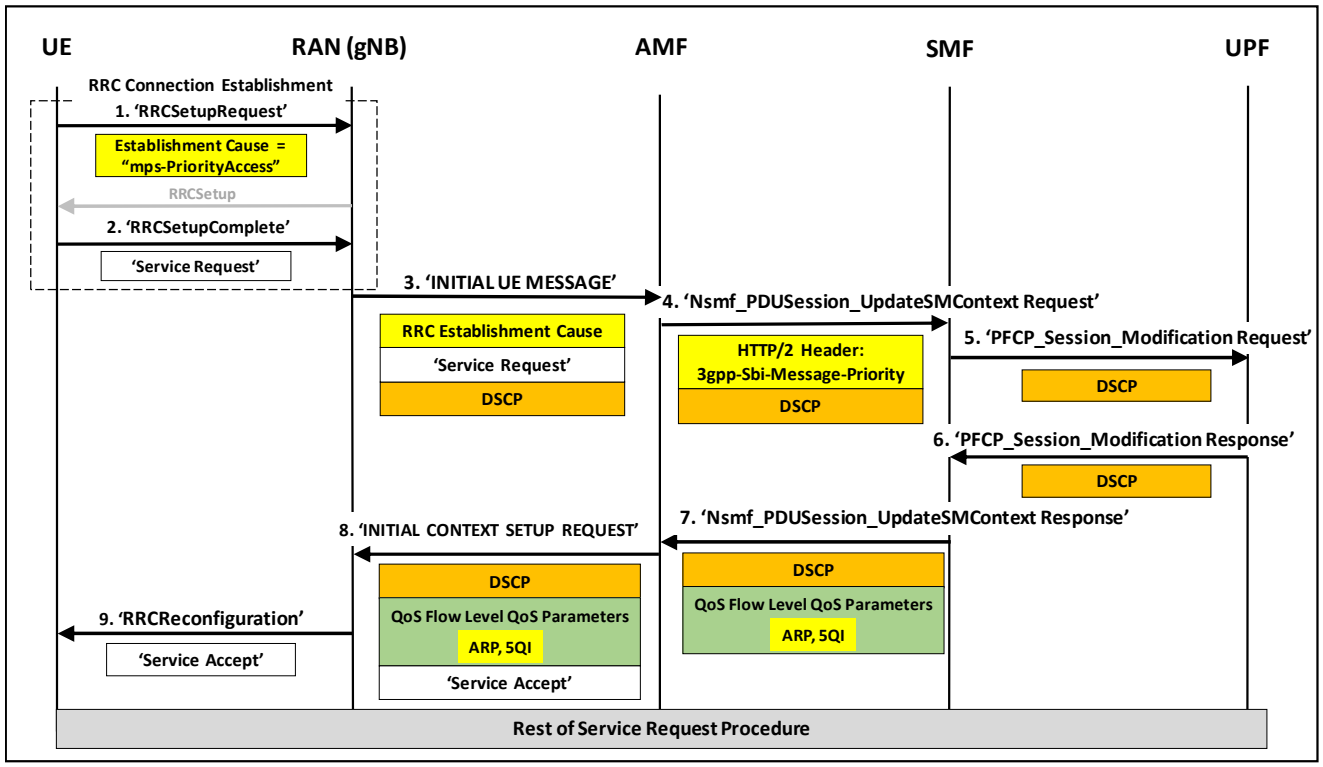

Figure 6-2: Service Request Procedure Message Flow Components that Support NS/EP NGN-PS

1. The UE sets up an RRC connection to the Radio Access Network (RAN) (i.e., gNB) via an "RRCSetupRequest" message that includes the "Establishment Cause" IE. For UEs subscribed to NS/EP NGN-PS, the "Establishment Cause" IE is set to the "mps-PriorityAccess" value which results in priority being given in the allocation of SRB1 radio bearer resources, and the selection of an AMF.

2. Following receipt of an "RRCSetup" message from the gNB, the UE sends an "RRCSetupComplete" message that includes an encapsulated "Service Request" message. The gNB handles the message with priority if the "Establishment Cause" in the previously received "RRCSetupRequest" message was set to the "mps-PriorityAccess" value, and may set the DSCP value to indicate priority for packets sent towards the AMF.

3. The RAN sends an "INITIAL UE MESSAGE" message towards the AMF and includes within the "RRC Establishment Cause" IE, the "mps-PriorityAccess" value received in message 1. The RAN also includes the "Service Request" message received in message 2. The AMF notes the "RRC Establishment Cause" set to the "mps-PriorityAccess" value and processes requests relating to this UE with priority for all subsequent messages for this procedure. In addition, the AMF may set a priority DSCP value for outgoing control-plane (CP) packets associated with this UE. For all SBA interface messages between the AMF and other FEs, the AMF (based on the "RRC Establishment Cause" received) may also mark the packets with the "3gpp-Sbi-Message-Priority" HTTP header value.

4. The AMF determines the PDU Session(s) to be activated and sends a "Nsmf_PDUSession_UpdateSMContext Request" to the SMF(s) associated with the PDU Session(s) for the establishment of user plane resources on the N3 interface.

5. The SMF sends an N4 "PFCP Session Modification Request" message to the UPF to change the "Gate Status" to reestablish the user plane over the N3 interface. In addition, the SMF may set a priority DSCP value to indicate priority treatment of this message at intermediate routers.

6. The UPF replies to the SMF using an N4 "PFCP Session Modification Response" message which may also contain a priority DSCP value.

7. The SMF sends a “Nsmf_PDUSession_UpdateSMContext Response” to the AMF. The Response message includes the “PDU Session Resource Setup Request Transfer” IE containing the “QoS Flow Level QoS Parameters” which for NS/EP NGN-PS, includes the NS/EP NGN-PS appropriate ARP and 5QI.
8. The AMF sends an “INITIAL CONTEXT SETUP REQUEST” message to the gNB transparently passing the “PDU Session Resource Setup Request Transfer” IE received in Step 7 containing the “QoS Flow Level QoS Parameters” which for NS/EP NGN-PS, includes the NS/EP NGN-PS appropriate ARP and 5QI. A “Service Accept” is encapsulated as part of the “INITIAL CONTEXT SETUP REQUEST” message.
9. The gNB performs RRC Connection Reconfiguration considering the QoS Information for all of the QoS Flows in active PDU Sessions and sends an “RRCReconfiguration” message to the UE. If the “INITIAL CONTEXT SETUP REQUEST” message from the AMF in Step 8 included a “Service Accept” message, the gNB encapsulates the “Service Accept” message within the “RRCReconfiguration” message to the UE.

6.1.6 Paging for Delivery of Downlink User-Plane Data

Figure 6-3 illustrates the use of the Paging procedure to support delivery of downlink user-plane data to a UE which is in 5GMM-IDLE mode.

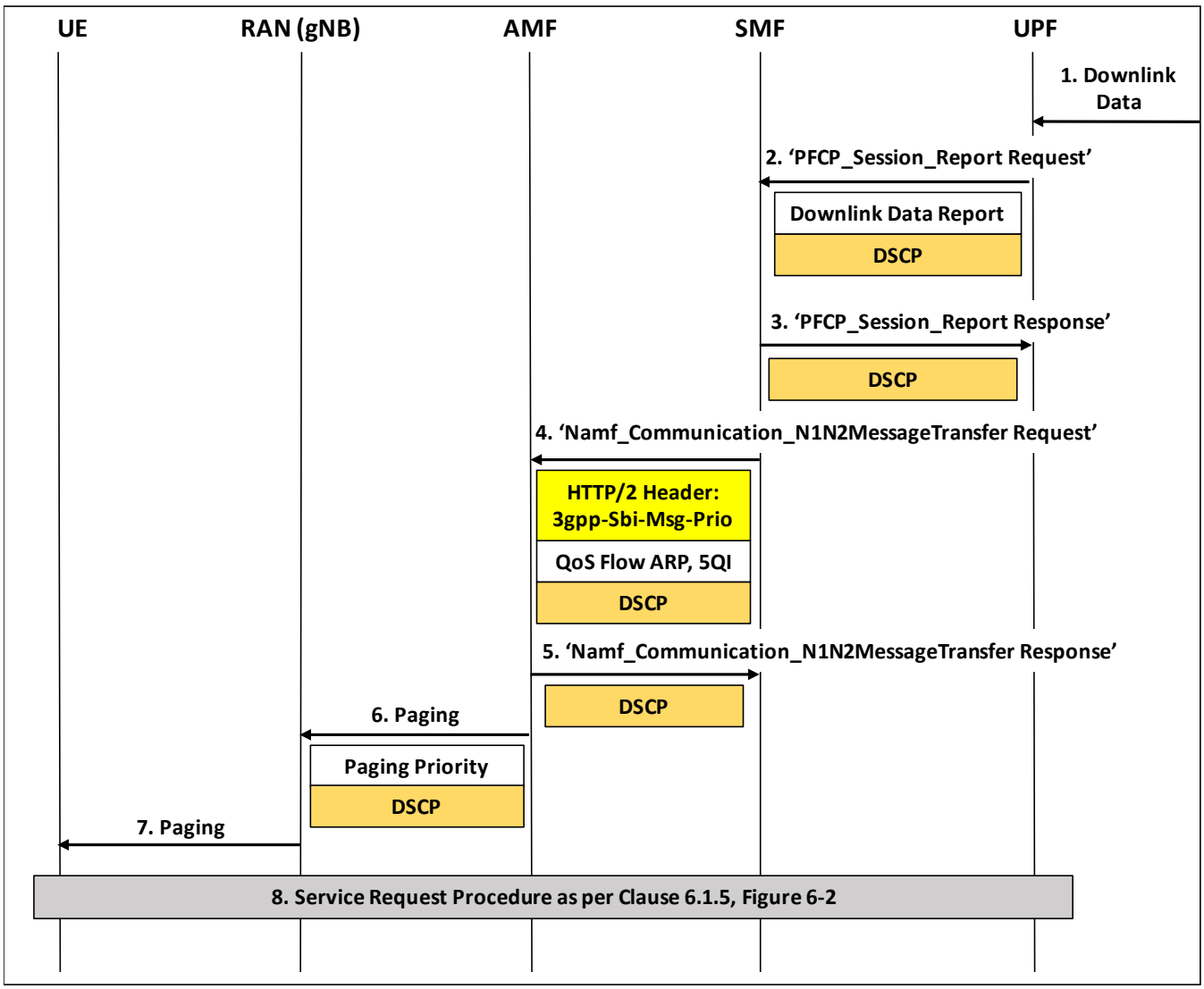

Figure 6-3: Paging Procedure Message Flow Components that Support NS/EP NGN-PS when the Paging is for Delivery of Downlink User-Plane Data

Paging for delivery of downlink data is triggered when the UPF receives a downlink packet for a UE and there is no active user-plane connection associated with the corresponding data flow to deliver the data.

1. The UPF receives a downlink IP data packet whose handling is specified by the triggered Packet Detection Rule (PDR). This call flow assumes there is no active N3 connection to forward the data, as marked by the gate status of the installed QoS Enforcement Rule (QER), and that the Forwarding Action Rule (FAR) indicates to buffer the packet at the UPF.
2. The UPF sends a “PFCP Session Report Request” message to the SMF and includes the “Downlink Data Report” IE which identifies the PDR(s) which detected a received downlinking IP data packet(s). This message does not have any MPS specific identification. The UPF may mark the data packet with an NS/EP NGN-PS appropriate DSCP, based on knowledge that the PDR is associated with NS/EP NGN-PS.
3. The SMF uses the PDR(s) identified in the “PFCP Session Report Request” message to recognize, via examination of the stored QoS parameters associated with the PDR(s), that an NS/EP NGN-PS packet is buffered at the UPF. The SMF replies to the UPF using a “PFCP Session Report Response” message and includes an NS/EP NGN-PS appropriate DSCP.
4. The SMF sends an “Namf_Communication_N1N2MessageTransfer Request” message to the AMF which includes the QoS Flow ARP to trigger NS/EP NGN-PS paging priority. The SMF may mark the packets carrying the “N1N2 Message Transfer Request” message with the “3gpp-Sbi-Message-Priority” HTTP header value, and use an NS/EP NGN-PS appropriate DSCP marking.
5. The AMF sends an “Namf_Communication_N1N2MessageTransfer Response” message to the SMF. The AMF may mark the packets carrying the “Namf_Communication_N1N2MessageTransfer Response” message with the “3gpp-Sbi-Message-Priority” HTTP header value, and use an NS/EP NGN-PS appropriate DSCP marking.
6. The AMF sends the RAN an NGAP “Paging” message containing a “Paging Priority” IE. The AMF determines the Paging Priority based on the ARP received in the “N1N2 Message Transfer Request” message from the SMF.
7. The RAN pages the UE using a “Paging” message taking into account the Paging Priority received in Message 6.
8. The UE responds to the page using the Service Request as described in Clause 6.1.5.

6.1.7 PDU Session Establishment

The Registration procedure in 5GS does not establish connectivity between the UE and a destination network. In order establish such connectivity, the UE needs to perform a PDU Session Establishment procedure. During PDU session establishment, since the UE is already registered, the AMF has already retrieved the user subscription data from the UDM. As described in Clause 6.1.2, if the UE set the “Establishment Cause” IE to “mps-PriorityAccess” value during the Registration procedure, this value is delivered to the AMF in the “RRC Establishment Cause” IE, and the AMF remembers the UE as MPS-subscribed. This saved MPS indication at the AMF allows the AMF to apply an appropriately high priority to signaling messages involving the UE during PDU Session Establishment.

Figure 6-4 and Figure 6-5 illustrate the PDU Session Establishment procedure in which a UE requests IP connectivity to a specified Data Network. It is assumed that the UE is in RRC_CONNECTED state and 5GMM-CONNECTED mode, else a Service Request procedure of Clause 6.1.5 must first be performed.

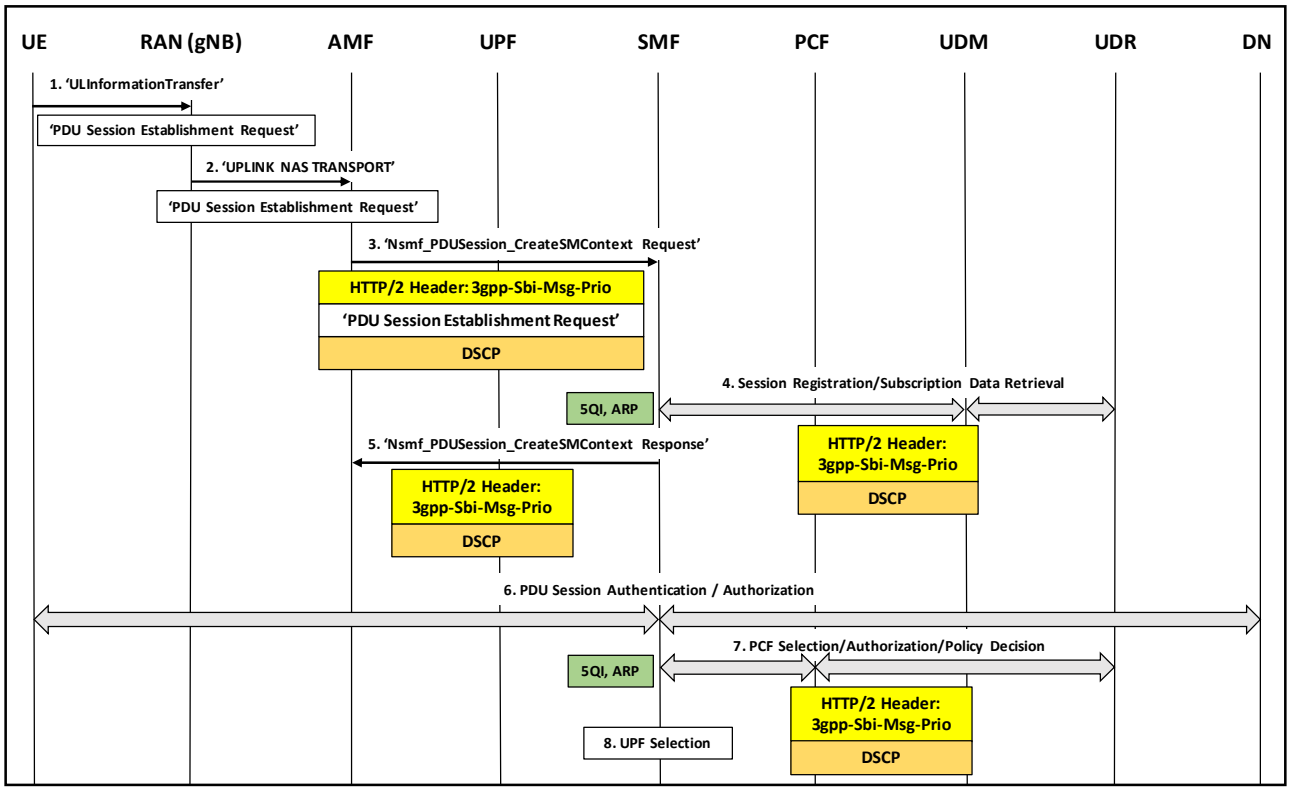

Figure 6-4: PDU Session Establishment (1 of 2)

1. The UE initiates a PDU Session Establishment procedure by transmitting a NAS "PDU Session Establishment Request" message, which is carried over the air interface in the "dedicatedNAS-message" IE of an RRC "ULInformationTransfer" message. The NAS message includes the DNN towards which the UE wishes to establish IP connectivity. If the UE is establishing a PDU session for IMS and the UE is configured to discover the P-CSCF address during connectivity establishment, the UE includes an indicator that it requests a P-CSCF IP address within the SM container.

2. The RAN transparently forwards the "PDU Session Establishment Request" message in the "NAS-PDU" IE of a "UPLINK NAS TRANSPORT" message.

   The AMF determines that the message corresponds to a request for a new PDU Session (based on the Request Type indicating "initial request"). The AMF selects an SMF. The SMF selection depends on whether the UE is roaming or not, and if roaming, whether the routing is via home network or local breakout.

   For MPS-subscribed UEs, based on the "RRC Establishment Cause" previously received, e.g., in the Registration or Service Request procedure, the AMF handles the request with priority, and for all SBA interface messages between the AMF and other NFs, the AMF may mark the packets with the "3gpp-Sbi-Message-Priority" header value, and set a priority DSCP value at the IP layer. The corresponding response messages may also be marked with this DSCP value.

3. The AMF sends a "Nsmf_PDUSession_CreateSMContext Request" to the selected SMF, encapsulating the NAS "PDU Session Establishment Request" received from the UE in step 2. The "Nsmf_PDUSession_CreateSMContext Request" includes the DNN towards which the UE wishes to establish IP connectivity.

4. For MPS-subscribed UEs, to ensure SMF exemption from NAS-level congestion (which would, otherwise, result in the failure of the PDU session establishment attempt), the AMF may include a priority access indication via a "3gpp-Sbi-Message-Priority" value, and mark the associated IP packets with an NS/EP NGN-PS appropriate DSCP value. If Session Management Subscription data for the corresponding DNN is not available, the SMF retrieves it by sending a "Nudm_SDM_Get_sm-data Request" towards the UDM. The UDM may get this requested information from the UDR by using a "Nudr_DataRepository_Query_SubscriptionData_sm-data Request" and receive the results in an

associated response. The UDM provides the Session Management Subscription in a "Nudm_SDM_Get_sm-data Response" towards the SMF. The Session Management Subscription includes the "5gQoSProfile" containing the UE's 5GS subscribed QoS profile for that DNN.

In the case of MPS-subscribed UEs, the 5QI and ARP associated with the 5GS QoS profile may have values appropriate for MPS. Alternatively, they may be obtained via the PCC mechanisms shown in step 7. For communication between the SMF and UDM, and between the UDM and the UDR, messages may be marked with a "3gpp-Sbi-Message-Priority" value to enable priority handling. Also, the packets carrying these messages may be marked with an NS/EP NGN-PS appropriate DSCP value.

5. The SMF creates an SM context and responds to the AMF with a "Nsmf_PDUSession_CreateSMContext Response" message.

   In the case of MPS-subscribed UEs, the "Nsmf_PDUSession_CreateSMContext Response" message may be marked with a "3gpp-Sbi-Message-Priority" value to enable priority handling. Also, the packets carrying this message may be marked with an NS/EP NGN-PS appropriate DSCP value.

6. The SMF may perform secondary authorization/authentication during the establishment of the PDU Session by a DN-AAA server by triggering the PDU Session establishment authentication/authorization procedure.

7. If dynamic PCC is deployed, which is required to support MMTEL services, the SMF performs PCF selection; otherwise, the SMF applies local policy. The SMF may send an "Npcf_SMPolicyControl_Create Request" message to get the authorized default PCC rules for the PDU session. If the PCF does not have the appropriate subscription data, it may query the UDR using a "Nudr_DataRepository_Query_PolicyData_sm-data" message to retrieve this information. The PCF sends its the authorized default QoS to the SMF in the "Npcf_SMPolicyControl_Create Response" message.

   In the case of MPS-subscribed UEs, the 5QI and ARP associated with the authorized default QoS profile will have values appropriate for MPS. For communication between the SMF and PCF, and between the PCF and the UDR, messages may be marked with a "3gpp-Sbi-Message-Priority" value to enable priority handling. Also, the packets carrying these messages may be marked with an NS/EP NGN-PS appropriate DSCP value.

8. The SMF selects a UPF to support the PDU session and allocates an IP address/prefix for the PDU Session.

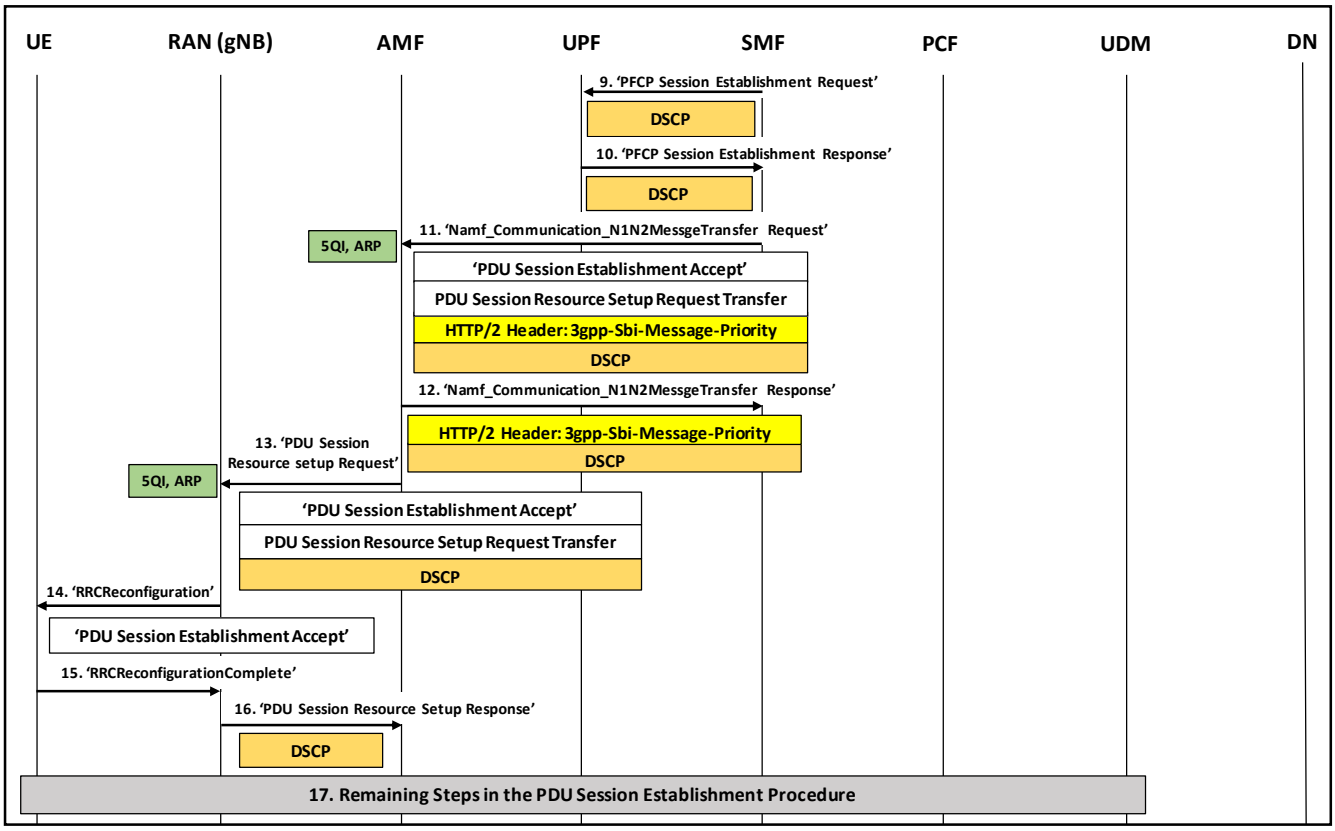

Figure 6-5: PDU Session Establishment (2 of 2)

9. The SMF initiates an N4 Session Establishment procedure with the selected UPF by sending a "PFCP Session Establishment Request" messages and provides Packet detection, enforcement and reporting rules to be installed on the UPF for this PDU Session. If CN Tunnel Info is allocated by the SMF, the Tunnel ID and the endpoint IP address of the N3 tunnel associated with the PDU session, are provided to UPF in this step.

   In the case of MPS-subscribed UEs, "PFCP Session Establishment Request" messages between the SMF and UPF may be marked with an NS/EP NGN-PS appropriate DSCP value.

10. The UPF acknowledges by sending a "PFCP Session Establishment Request" message.

    In the case of MPS-subscribed UEs, "PFCP Session Establishment Request" messages between the UPF and SMF may be marked with an NS/EP NGN-PS appropriate DSCP value.

11. The SMF sends a "Namf_Communication_N1N2MessageTransfer Request" message to the AMF that includes N2 SM information and an N1 SM container.

    a. The N2 SM information carries information that the AMF forwards to the RAN in a "PDU Session Resource Setup Request Transfer" IE which includes the PDU Session ID, QFI(s), QoS Flow Level QoS parameters, Session-AMBR, PDU Session Type, CN Tunnel Info, etc.

    b. The N1 SM container contains the "PDU Session Establishment Accept" message sent by the AMF towards the UE. The "PDU Session Establishment Accept" message includes QoS Rule(s), QoS descriptions, DNN, Session-AMBR, etc. If the UE requested P-CSCF discovery then the message also includes the P-CSCF IP address as determined by the SMF.

    In the case of MPS-subscribed UEs, the "Namf_Communication_N1N2MessageTransfer Request" message may be marked with a "3gpp-Sbi-Message-Priority" value to enable priority handling, and the packets carrying this message may be marked with an NS/EP NGN-PS appropriate DSCP value.

12. The AMF responds to the SMF with a "Namf_Communication_N1N2MessageTransfer Response" message.

13. The AMF sends a “PDU Session Resource Setup Request” message to the RAN. The message includes the “PDU Session Resource Setup Request Transfer” information described in step 11a, and the “PDU Session Establishment Accept” message described in step 11b. The “PDU Session Resource Setup Request Transfer” information includes the QoS Flow Level QoS parameters for the PDU session and CN Tunnel Info, which the RAN uses as the UPF address to which it sends the uplink data.
14. The RAN performs signaling exchange with the UE that is related to the information received from the SMF only if the necessary RAN resources are established and the allocation of RAN Tunnel Info are successful. An “RRCReconfiguration” message is sent by the RAN to the UE to establish the necessary RAN resources related to the QoS Rules for the PDU Session being set up. The “RRCRecongifuration” message contains the “PDU Session Establishment Accept” message received in step 13 which includes the QoS rules and QoS descriptions. The RAN also allocates AN Tunnel Info, which represents the address of the RAN-side end-point of the N3 tunnel associated with the PDU Session. This address is used by the UPF to direct the downlink data associated with the PDU session.
15. The UE responds to the RAN with an “RRCReconfigurationComplete” message.
16. The RAN replies to the “PDU Session Resource Setup Request” message received in step 13 with a “PDU Session Resource Setup Response” message.
17. The remaining steps in the PDU Session Establishment procedure, which involve bookkeeping at the SMF, conveying the AN Tunnel Info to the UPF, the SMF registration with the UDM, etc., are not shown. The uplink and downlink packets start flowing between the UE and the UPF during this step.

6.1.8 Mobile Call Origination

The call-flow for MMTEL voice establishment is given in Figure 6-6 below. In order to support MMTEL voice, a UE connected to a 5G System (5GS) needs to have access to an IMS Data Network (IMS DN) via an established PDU Session, and must have registered with the IMS system.

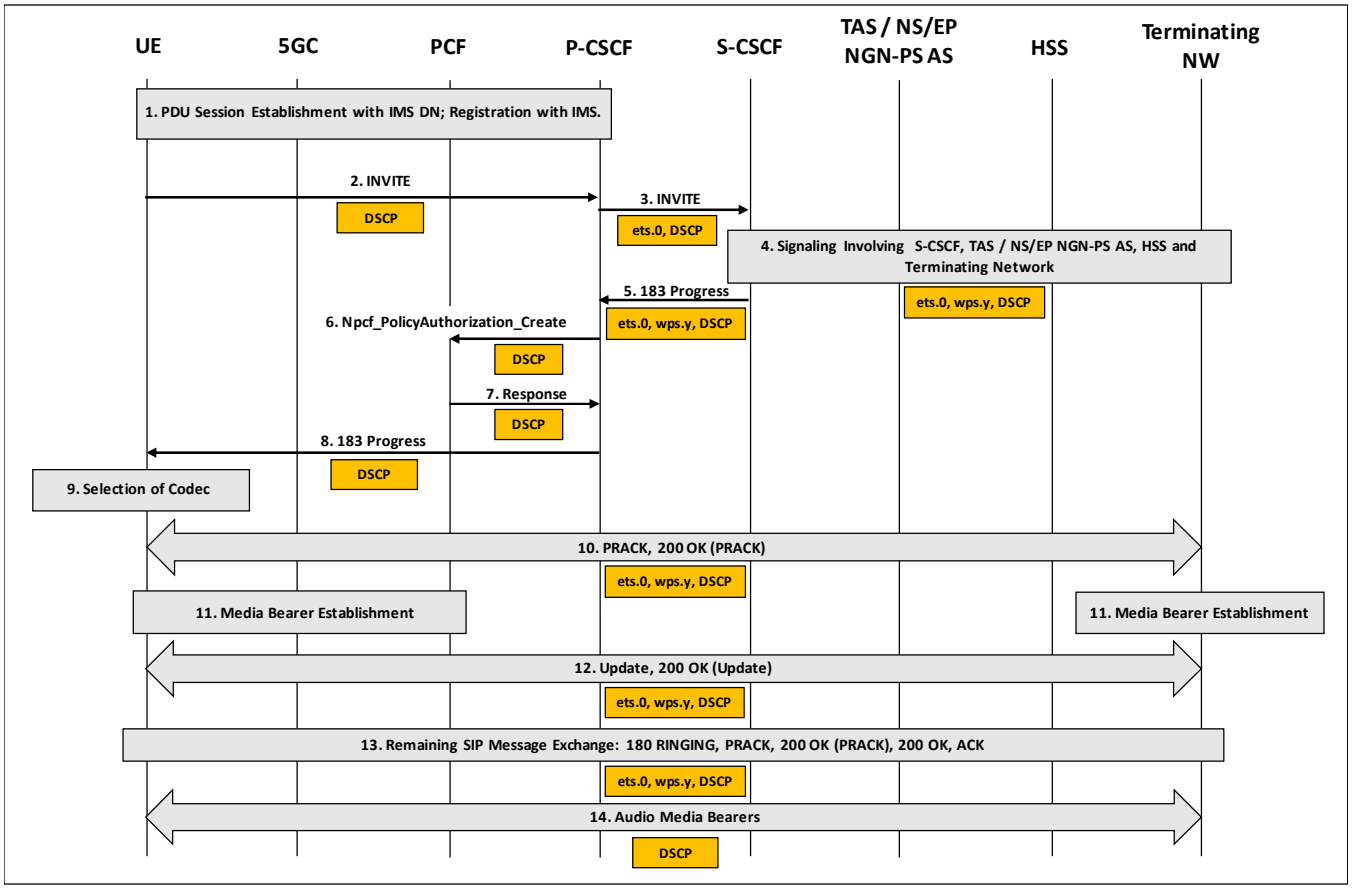

Figure 6-6: Mobile-Originated Voice Call Establishment

1. The (Originating) UE establishes a PDU session with the IMS DN and then registers with the IMS system. The procedure for PDU session establishment is provided in Figure 6-4. For subscribed UEs, the signaling messages associated with PDU session establishment may be handled at a higher priority by the network functions involved in the procedure. Also, when a subscribed UE establishes a PDU session with the IMS DN, the default QoS flow associated with that PDU session receives appropriately high 5QI and ARP values. Since the messages involved in the IMS registration procedure are carried over this default QoS flow, they are handled at appropriately high priority during the transport between the UE and the IMS.

   During registration with the IMS, the S-CSCF accesses the HSS via the Nhss Service Based Interface to retrieve the Priority Level and the Initial Filter Criteria associated with the subscribed UE.

2. The UE sends an INVITE message to the P-CSCF (Proxy-Call Session Control Function) over the default QoS flow within the PDU session between the UE and the IMS DN. The INVITE message contains the destination number (and may include a feature code prefix to designate an NS/EP NGN-PS call), the supported codecs and an SDP offer that includes an indication of the media being established (voice) and the IP address and port numbers where the UE wants to receive the media streams. This QoS flow has appropriately high 5QI and ARP values which may be mapped by 3GPP FEs to an NS/EP NGN-PS appropriate DSCP. As a consequence, the INVITE message as well as the subsequent signaling messages between the UE and the IMS DN receive a high priority at the transport level.

3. The P-CSCF detects the feature code prepended to the destination number in the INVITE message, and inserts a Resource Priority Header (RPH) with the provisioned ets.0 into the header of the INVITE message before forwarding the INVITE to the S-CSCF. At the transport level, DSCP marking appropriate for NS/EP NGN-PS may be used for this message.

4. The S-CSCF forwards the INVITE message to the TAS / NS/EP NGN-PS AS without making any changes to the RPH. The TAS / NS/EP NGN-PS AS may optionally request subscriber information from the HSS by sending an Sh/Dh Interface UDR (User Data Request) command toward the HSS. This command

includes the “DRMP” AVP that is set to the configured value for NS/EP NGN-PS. The HSS responds with a UDA (User Data Answer) message containing the requested subscriber information. At the transport level, DSCP marking appropriate for NS/EP NGN-PS may be used in this message exchange.

Using the subscription information retrieved from the HSS, the TAS provides basic service control, and the NS/EP NGN-PS AS handles NS/EP NGN-PS authorization. The NS/EP NGN-PS AS removes the feature code from the SIP INVITE, and sends the INVITE message to the S-CSCF with the RPH containing both the ets.0 and wps.y fields. The “y” within the wps.y field indicates the Service User Priority Level. The S-CSCF then forwards the INVITE message to the Terminating Network, which ultimately delivers the message to the Terminating UE.

5. The Terminating UE responds to the INVITE with a 183 Progress message, which the Terminating Network forwards to the IMS core on the origination side. The originating S-CSCF forwards this message to the originating P-CSCF. The 183 Progress message contains the answer from the Terminating UE including the supported codecs. It also contains the parameters ets.0 and wps.y within the RPH. This message benefits from appropriate DSCP marking during its transport from the IMS functional entities on the termination side to the S-CSCF and P-CSCF on the origination side.

6. The P-CSCF utilizes the “Npcf_PolicyAuthorization_Create” service offered by the PCF to perform the “Initial Provisioning of Service Information” operation. The P-CSCF begins this procedure by sending an “HTTP POST” request to the PCF providing the relevant data for the session being established. For an NS/EP NGN-PS call, the P-CSCF may include the information elements “mpsId” and “resPrio” (Reservation Priority) to respectively indicate that the call being established is an NS/EP NGN-PS call and the corresponding priority level. The IP packets carrying the HTTP POST request may be marked with a DSCP value configured for NS/EP NGN-PS users by the service provider.

7. The PCF authorizes the request, and responds with a “201 Created” message. The PCF will accord an appropriately high priority in the allocation of resources for NS/EP NGN-PS calls if the request received from the P-CSCF includes the corresponding information elements (mpsId and resPrio). The “201 Created” message includes the context data for the call session being set up. The IP packets carrying the PCF’s response may also be marked with a DSCP value configured for NS/EP NGN-PS users by the service provider.

8. The P-CSCF sends the 183 Progress message to the (Originating) UE. However, the P-CSCF removes the RPH from the message before forwarding it to the UE. (It retains the RPH for use in subsequent messages involving the UE.) Since the 183 Progress message, too, is carried over the default QoS flow in the PDU session set up between the UE and the IMS DN, it benefits from an appropriately high 5QI as it traverses the 5G system. At the transport level, DSCP marking appropriate for NS/EP NGN-PS may be used for this message based on the 5QI and, optionally, ARP values associated with the corresponding QoS flow.

9. The (Originating) UE examines the common codec list in the 183 Progress message and selects one of them for the audio call being established.

10. The Originating UE sends a PRACK message to the Terminating UE, informing the latter of the selected codec. The PRACK message benefits from the 5QI associated with subscribed UEs over the 5GS. Once the PRACK message reaches the P-CSCF, the latter inserts the RPH into the message which enables it to receive a high priority within the IMS. At the transport level, DSCP marking appropriate for NS/EP NGN-PS may be used for this message based on the contents of the RPH. The originating P-CSCF forwards the PRACK to the originating S-CSCF and onwards towards the Terminating UE. The Terminating UE acknowledges the PRACK with a 200 OK message. The 200 OK message follows the path traversed by the 183 Progress message in Step 8, and receives the same priority treatment as was given to that message. In fact, all subsequent signaling messages sent by the Originating UE follow the same path and receive the same priority treatment as the PRACK message. Similarly, all subsequent signaling messages sent by the Terminating UE follow the same path and receive the same priority treatment as the 183 Progress message. The priority treatment in both cases includes DSCP markings appropriate for NS/EP NGN-PS.

11. On both the origination and termination sides, the PCF, based on the information received from the P-CSCF, determines the QoS policy (including ARP, 5QI) for the media, and requests the 5GC (specifically, the SMF) to establish media bearers for the requested session. On the originating side, this immediately

follows step 6. A Network Requested PDU Session Modification procedure is carried out to establish the QoS flows to support the media streams.

12. The Originating UE may send an UPDATE message towards the Terminating UE at any time to renegotiate the SDP. The Terminating UE responds to the UPDATE message with a 200 OK message. These messages, too, will benefit from DSCP markings appropriate for NS/EP NGN-PS within the IMS network as well as the 5GC. Within the IMS network, the presence of RPH will ensure that these messages receive the appropriate DSCP markings at the transport layer; within the 5GC, the appropriate DSCP markings will be provided as a function of the 5QI and, optionally, ARP values associated with the corresponding QoS flow.
13. The Terminating UE notifies the corresponding subscriber by activating “ringing,” and sends a 180 Ringing message towards the Originating UE. The Originating UE sends a PRACK message to the Terminating UE, acknowledging the receipt of the “Ringing” message. The Terminating UE responds with a 200 OK message, acknowledging the PRACK. When the subscriber answers the call, the Terminating UE sends a 200 OK message to the Originating UE, notifying the latter that the call has been answered. The Originating UE responds with an ACK. All of these messages follow the paths and receive priority treatment described earlier in Step 10. All of these messages will benefit from appropriate DSCP markings at the transport layer as described in Step 12 above.
14. Conversation between the caller and called parties begins over the established media bearers. In the case of subscribed users, the QoS flows supporting the media bearers have a priority level determined by the 5QI associated with NS/EP NGN-PS voice calls. Within the 5GC, the media packets associated with the call will receive DSCP markings appropriate for NS/EP NGN-PS based on the 5QI and, optionally, ARP values associated with the corresponding QoS flow.

6.1.9 Mobile Call Termination

We assume that the originating UE has an NS/EP NGN-PS subscription, and that it has set up a PDU session with the IMS DN and has registered itself with the IMS DN. The default QoS flow within this PDU session has ARP and 5QI parameters appropriate for NS/EP NGN-PS and packets carried over the default QoS flow within this PDU session have appropriate DSCP markings. In the call scenario being considered here, we further assume that the terminating UE is an ordinary UE, i.e., it has no NS/EP NGN-PS subscription.

The scenario of interest is where the originating UE with NS/EP NGN-PS subscription invokes priority treatment for the call by prepending a feature code before the destination number in the INVITE message it sends to the IMS. The IMS on the originating side detects the feature code, verifies that the caller has NS/EP NGN-PS subscription, inserts an RPH into the INVITE and forwards it towards the IMS on the terminating side. The RPH in the INVITE forwarded to the terminating side contains the fields ets.0 and wps.y where “y” represents a priority level based on the originating subscriber's NS/EP NGN-PS subscription. The INVITE and the subsequent SIP messages involved in the call scenario are treated with priority within the IMS system, including appropriate DSCP markings when these messages are transported within the IMS system.

When the INVITE message arrives at the P-CSCF on the terminating side, it strips the RPH from the header before forwarding the INVITE to the terminating UE. However, the RPH informs the P-CSCF that the media flows associated with the call being set up should have appropriately high priority. In case the PDU session set up by the terminating UE with the IMS DN does not have 5QI and ARP values appropriate for NS/EP NGN-PS, the P-CSCF on the terminating side, via the PCF and SMF, may upgrade these parameters by invoking the PDU Session Modification procedure. The QoS flow to be established to carry the media packets associated with the voice call will also have 5QI and ARP values appropriate for NS/EP NGN-PS. As a consequence, the subsequent SIP messages associated with the call and the media packets (once the call is established) will have, within the terminating 5GC, DSCP markings appropriate for NS/EP NGN-PS.

The rest of this call scenario is similar to the call origination scenario described earlier.

7 Packet Scheduling

This clause provides guidance as to how 5QI, Priority Level, and ARP influence packet scheduling at the gNB. The clause also describes the order in which these QoS parameters are considered by the gNB for relative prioritization in performing packet scheduling.

7.1 Procedures

The gNB is responsible for scheduling packets belonging to the same UE as well as packets belonging to different UEs. The gNB schedules the packets belonging to a QoS Flow to meet the packet delay budget (PDB) associated with the QoS Flow. Under normal traffic situations, the gNB is able to meet the PDB's associated with the traffic belonging to different QoS Flows.

Every 5QI (GBR and Non-GBR) is associated with a set of QoS characteristics which include Priority Level and PDB. The lowest Priority Level value corresponds to the highest priority. The Priority Level values are used to differentiate between QoS Flows associated with the same UE, and are also used to differentiate between QoS Flows from different UEs. In addition, every QoS Flow is also associated with an ARP. The ARP includes a Priority Level which is also used to determine the priority of QoS Flows during times of congestion as specified in 3GPP TS 23.501 [Ref 1].

Scheduling between different QoS Flows is primarily based on the PDB. However, if the target set by the PDB can no longer be met for one or more QoS Flows across all UEs that have sufficient radio channel quality, then the 5QI Priority Level can be used to differentiate between QoS Flows.

7.2 Solution Considerations

This clause provides considerations as to how 5QI, the 5QI Priority Level (if explicitly signaled), and ARP might be used to support NS/EP NGN-PS, analogous to considerations for 4G and in accordance with the general provisions in FCC 47 CFR § 64 Appendix B [Ref 14].

The 5QI Priority Level associated with 5G QoS characteristics indicates a relative priority in scheduling resources among QoS Flows. The lowest 5QI Priority Level value corresponds to the highest relative priority. The 5QI Priority Level is used to differentiate between QoS Flows of the same UE, as well as to differentiate between QoS Flows from different UEs.

The gNB schedules packets belonging to different QoS Flows as follows:

- As packets arrive, the gNB places the packets in the scheduler queue in the same order as they were received.
- Each packet is monitored vs. its target Packet Delay Budget (PDB). If the target PDB can no longer be met for one or more packets, packets associated with 5QI Priority Level N are given priority over packets with 5QI Priority Level N+1 (i.e., lower 5QI Priority Level values signify a higher relative priority of the packet).
- If there are multiple packets having the same 5QI Priority Level, then the gNB packet scheduler assigns relative packet priority based on the ARP Priority Level as follows: the scheduler gives precedence to meeting the PDB of a QoS Flow with ARP Priority Level N over meeting the PDB of QoS Flows with an ARP Priority Level greater than N, until the Priority N QoS Flow's GBR (in case of a GBR QoS Flow) has been satisfied.
- In the event that multiple packets have the same 5QI Priority Level and ARP Priority Level, then packets will be prioritized by the scheduler based on the order in which the packets arrived.

The scheduler may prioritize QoS Flows based on other parameters (e.g., resource type, radio condition) in order to optimize application performance and network capacity.

Every standardized 5QI is associated with a default value for the Priority Level as specified in TS 23.501 [Ref 1] Table 5.7.4-1. The 5QI Priority Level may also be signaled together with a standardized 5QI to the RAN, and if it is received, it shall be used by the gNB scheduler instead of the default 5QI value.

The 5QI Priority Level may also be signaled together with a pre-configured 5QI to the RAN, and if it is received, it shall be used by the gNB scheduler instead of the pre-configured 5QI value.

8 Conclusions and Recommendations

8.1 Conclusions

FEs mark packets with a DSCP value assigned for priority services based on 5QI, the 5QI Priority Level (if explicitly signaled), and optionally on ARP, or other associated parameters as described in Clause 6.1. This helps to ensure that NS/EP NGN-PS packets get forwarding priority over non-NS/EP NGN-PS traffic. Similarly, during times of congestion when the gNB cannot meet the target PDB for one or more QoS Flows within a UE and/or across all UEs that have sufficient radio channel quality, the gNB scheduler takes the 5QI Priority Level into account and gives priority handling to NS/EP NGN-PS traffic.

8.2 Recommendations

The gNB and the AMF may be configured to mark packets with a DSCP value assigned for priority services based on their receipt of messages with an Establishment Cause set to the “mps-PriorityAccess” value. Once the gNB and AMF become aware of the 5QI, the 5QI Priority Level (if explicitly signaled), ARP, or other parameters used to designate that the packets are associated with NS/EP NGN-PS, then the gNB and AMF should be configured to mark packets carrying signaling messages with a DSCP value based on these parameters. If more than one DSCP value is allocated for NS/EP NGN-PS, the DSCP marking based on 5QI and ARP should override the DSCP value based on the Establishment Cause.

All FEs (gNB, AMF, SMF, PCF, UDM) should be configured to mark packets with the DSCP value associated with NS/EP NGN-PS based on the 5QI, the 5QI Priority Level (if explicitly signaled), and, optionally, ARP. During any 5GS procedure (Initial Registration, Periodic and Mobility Registration Update, Service Request, Network-triggered Service Request, PDU Session Establishment, Network-requested PDU Session Modification) or a SIP procedure (Call Origination, Call Termination), once an FE detects a condition that warrants priority marking (Establishment Cause, 5QI/ARP, SIP RPH, MPS-Identifier AVP/Reservation-Priority AVP) all further outgoing signaling messages from that FE should be marked with the appropriate DSCP value for NS/EP NGN-PS.

All FEs interacting via the service-based interface should be configured to mark packets carrying signaling messages associated with UEs identified as having NS/EP NGN-PS subscription with the “3gpp-Sbi-Message-Priority” header value.

In case the service-based N5 interface is being used between an AF (e.g., a P-CSCF) and a PCF, then the AF should be configured to include the IEs “mpsId” and “resPrio” (both set to appropriate values) in the policy authorization requests sent to the PCF if the policy authorization request involves an NS/EP NGN-PS session.

If the Diameter-based Rx interface between the AF and PCF is used, then for any procedure involving these FE’s, once a condition is detected that warrants priority marking (SIP RPH, MPS-Identifier AVP/Reservation-Priority AVP) all further packets exchanged over this interface that belong to the session for which the priority condition was detected should be marked with the appropriate DRMP value selected by the Service Provider for NS/EP NGN-PS use.

Table 8-1 provides a non-inclusive summary of how DSCP marking over various interfaces may be based on 5QI, 5QI Priority Level (if explicitly signaled), ARP, and other associated parameters.

Table 8-1: Methods for Marking DSCP

Parameter	Applicable Interface(s) (Reference Point Representation)	Applicable Interface(s) (Service-Based Architecture)
5QI + 5QI PL (if explicitly signaled) + ARP	N2, N7, N8, N10, N11, N12, N13, N14, N16, N24, N35, N36, Xn	Nudm, Nsmf, Namf, Nausf, Nudr, Npcf
Establishment Cause	N2	–
HTTP2 Header	N7, N8, N10, N11, N12, N13, N14, N15, N16, N17, N24, N35, N36, N37	Nudm, Nsmf, Namf, Nausf, Nudr, Npcf
MPS-Identifier AVP and Reservation-Priority AVP	Rx	–
mpsId and resPrio attributes, and HTTP2 header	N5	Npcf
Dialed Digits	Carried in SIP INVITE	–

NOTE 1: DSCP can be used on other interfaces not shown in this report (e.g., for support of Legacy SMS).

Each FE should follow the guidelines specified in RFC 5865 [Ref 13] for admitting packets and processing and forwarding of admitted packets to ensure that NS/EP NGN-PS packets with higher-priority DSCP values receive priority treatment over non-NS/EP NGN-PS traffic with lower-priority DSCP values.

If the gNB cannot meet the target PDB for one or more QoS Flows for a particular UE or across all UEs, then the gNB uses the 5QI Priority Level to determine the relative priority of packets for processing, and scheduling. If there is a shortage of resources, ARP is used to make decisions regarding admission of new calls/sessions and retention of existing calls/sessions.