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Transport Network aware Mobility for 5G
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Abstract

This document specifies a framework and a mapping function for 5G mobile user plane with transport network slicing, integrated with Mobile Radio Access and a Virtualized Core Network. The integrated approach is specified in a way to fit into the 5G core network architecture defined in [TS23.501].

It focuses on an optimized mobile user plane functionality with various transport services needed for some of the 5G traffic needing low and deterministic latency, real-time, mission-critical services. This document describes, how this objective is achieved agnostic to the transport underlay used (IPv6, MPLS, IPv4) in various deployments and with a new transport network underlay routing, called Preferred Path Routing (PPR).

Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119](#) [[RFC2119](#)].

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[1.](#) Introduction

3GPP Release 15 for 5GC is defined in [[TS.23.501-3GPP](#)], [[TS.23.502-3GPP](#)] and [[TS.23.503-3GPP](#)]. User Plane Functions (UPF) are the data forwarding entities in the 5GC architecture. The architecture allows the placement of Branching Point (BP) and Uplink Classifier (ULCL) UPFs closer to the access network (5G-AN). The 5G-AN can be a radio access network or any non-3GPP access network, for example, WLAN. The IP address is anchored by a PDU session anchor UPF (PSA UPF).

N3, N9 Interfaces: The interface between the BP/ULCL UPF and the PSA UPF is called N9 [[TS.23.501-3GPP](#)]. While in REL15, 3GPP has adopted GTP-U for the N9 interface, new user plane protocols along with GTP-U are being investigated for N9 interface in REL16, as part of [CT4SID]. Concerning to this document another relevant interface is N3, which is between the 5G-AN and the UPF. N3 interface is similar to the user plane interface S1U in LTE [[TS.23.401-3GPP](#)]. This document:

- o Do not need architectural change to[TS.23.501-3GPP] to provide 3GPP slice, QoS support in transport plane
- o and can work with any encapsulation (including GTP-U) for the N9 interface.

[1.1.](#) Problem Statement

[TS.23.501-3GPP] and [[TS.23.502-3GPP](#)] define network slicing as one of the core capability of 5GC with slice awareness from Radio and 5G Core (5GC) network. The 5G System (5GS) as defined, do not consider the resources and functionalities needed from transport network for the selection of UPF. This is seen as independent functionality and currently not part of 5GS.

However, the lack of underlying Transport Network (TN) awareness may lead to selection of sub-optimal UPF(s) and/or 5G-AN during 5GS procedures. This could also lead to inability to meet SLAs for real-

time, mission-critical or latency sensitive services. 5GS procedures including but not limited to Service Request, PDU Session Establishment, or User Equipment (UE) mobility need same service level characteristics from the TN for the Protocols Data Unit (PDU) session, similar to as provided in Radio and 5GC for the various Slice Service Types (SST) and 5QI's defined in [[TS.23.501-3GPP](#)].

1.2. Solution Approach

This document specifies 2 approaches to fulfil the needs of 5GS to transport user plane traffic from 5G-AN to UPF for all service continuity modes [[TS.23.501-3GPP](#)] in an optimized fashion. This is done by, keeping mobility procedures aware of underlying transport network along with slicing requirements.

[Section 2](#) describes in detail on how TN aware mobility can be built irrespective of underlying TN technology used. Using Preferred Path Routing (PPR), applicable to any transport network underlay (IPv6, MPLS and IPv4) is detailed in [Section 3](#). How other IETF TE technologies applicable for this draft is specified in [Section 4](#). At the end, [Appendix B](#) further describes the applicability and procedures of PPR with 5G SSC modes on N3 and N9 interfaces.

1.3. Acronyms

5QI	-	5G QoS Indicator
5G-AN	-	5G Access Network
AMF	-	Access and Mobility Management Function (5G)
BP	-	Branch Point (5G)
CSR	-	Cell Site Router
DN	-	Data Network (5G)
eMBB	-	enhanced Mobile Broadband (5G)
FRR	-	Fast ReRoute
gNB	-	5G NodeB
GBR	-	Guaranteed Bit Rate (5G)
IGP	-	Interior Gateway Protocols (e.g. IS-IS, OSPFv2, OSPFv3)
LFA	-	Loop Free Alternatives (IP FRR)

mIOT	-	Massive IOT (5G)
MPLS	-	Multi Protocol Label Switching
QFI	-	QoS Flow ID (5G)
PPR	-	Preferred Path Routing
PDU	-	Protocol Data Unit (5G)
PW	-	Pseudo Wire
RQI	-	Reflective QoS Indicator (5G)
SBI	-	Service Based Interface (5G)
SID	-	Segment Identifier
SMF	-	Session Management Function (5G)
SSC	-	Session and Service Continuity (5G)
SST	-	Slice and Service Types (5G)
SR	-	Segment Routing
TE	-	Traffic Engineering
ULCL	-	Uplink Classifier (5G)
UPF	-	User Plane Function (5G)
URLLC	-	Ultra reliable and low latency communications (5G)

2. Transport Network and Slice aware Mobility on N3/N9

Currently specified Control Plane (CP) functions - the Access and Mobility Management Function (AMF), the Session Management Function (SMF) and the User plane (UP) components gNB, User Plane Function (UPF) with N2, N3, N4, N6 and N9 interfaces are relevant to this document. Other Virtualized 5G control plane components NRF, AUSF, PCF, AUSF, UDM, NEF, and AF are not directly relevant for the discussion in this document and one can see the functionalities of these in [\[TS.23.501-3GPP\]](#).

From encapsulation perspective, N3 interface is similar to S1U in 4G/LTE [\[TS.23.401-3GPP\]](#) network and uses GTP-U [\[TS.29.281-3GPP\]](#) to transport any UE PDUs (IPv4, IPv6, IPv4v6, Ethernet or Unstructured).

Unlike S1U, N3 has some additional aspects as there is no bearer concept and no per bearer GTP-U tunnels. Instead, QoS information is carried in the PDU Session Container GTP-U extension header.

TN Aware Mobility with optimized transport network functionality is explained below with approaches specified in [Section 2.1](#) and [Section 2.2](#). How PPR fits in this framework in detail along with other various TE technologies briefly are in [Section 3](#) and [Section 4](#) respectively.

[2.1](#). Integrated Approach with TNF in SBI

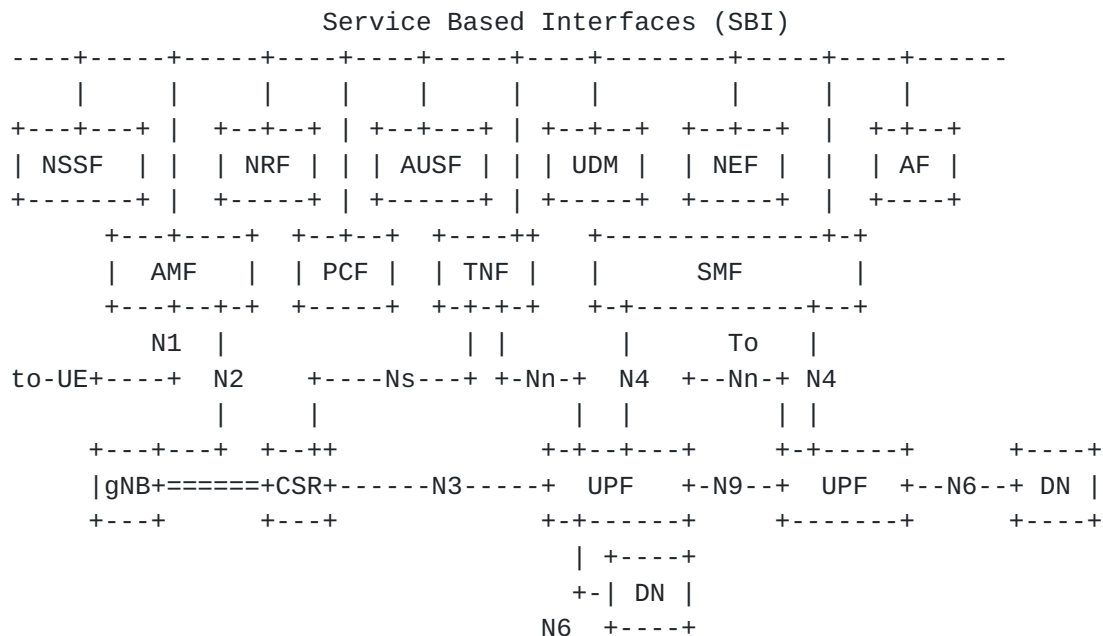


Figure 1: 5G Service Based Architecture

The above diagrams depicts one of the scenarios of the 5G network specified in [\[TS.23.501-3GPP\]](#) and with a new and virtualized control component Transport Network Function (TNF). A Cell Site Router (CSR) is shown connecting to gNB. gNB is an entity in 5G-AN. Though it is shown as a separate block from gNB, in some cases both of these can be co-located. This document concerns with backhaul TN, from CSR to UPF on N3 interface or from Staging UPF to Anchor UPF on N9 interface.

Network Slice Selection Function (NSSF) as defined in [\[TS.23.501-3GPP\]](#) concerns with multiple aspects including selecting a

network slice instance when requested by AMF based on the requested SNSSAI, current location of UE, roaming indication etc. It also notifies NF service consumers (e.g AMF) whenever the status about the slice availability changes. However, the scope is only in 5GC (both control and user plane) and NG Radio Access network including the N3IWF for the non-3GPP access. The network slice instance(s) selected by the NSSF are applicable at a per PDU session granularity. An SMF and UPF are allocated from the selected slice instance during the PDU session establishment procedure.

2.1.1. Transport Network Function and Interfaces

To assuage the above situation, TNF is described (Figure 1) as part of control plane. This has the view of the underlying transport network with all links and nodes as well as various possible underlay paths with different characteristics. TNF can be seen as supporting PCE functionality [[RFC5440](#)] and optionally BGP-LS [[RFC7752](#)] to get the TE and topology information of the underlying IGP network.

A south bound interface Ns is shown which interacts with the 5G Access Network (e.g. gNB/CSR). 'Ns' can use one or more mechanism available today (PCEP [[RFC5440](#)], NETCONF [[RFC6241](#)], RESTCONF [[RFC8040](#)] or gNMI) to provision the L2/L3 VPNs along with TE underlay paths from gNB to UPF. Ns and Nn interfaces can be part of the integrated 3GPP architecture, but the specification/ownership of these interfaces SHOULD be left out of scope of 3GPP.

A north bound interface 'Nn' is shown from one or more of the transport network nodes (or ULCL/BP UPF, Anchor Point UPF) to TNF as shown in Figure 1. It would enable learning the TE characteristics of all links and nodes of the network continuously (through BGP-LS [[RFC7752](#)] or through a passive IGP adjacency and PCEP [[RFC5440](#)]).

These VPNs and/or underlay TE paths MUST be similar on all 5G-AN/CSRs and UPFs concerned to allow mobility of UEs while associated with one of the Slice/Service Types (SSTs) as defined in [[TS.23.501-3GPP](#)].

Proposed TNF as part of the 5GC shown in Figure 1 can be realized using Abstraction and Control of TE Networks (ACTN). ACTN architecture, underlying topology abstraction methods and manageability considerations of the same are detailed in [[RFC8453](#)].

2.1.2. Functionality for E2E Management

With the TNF in 5GS Service Based Interface, the following additional functionalities are required for end-2-end slice management including the transport network:

- o The Specific Network Slice Selection Assistance Information (SNSSAI) of PDU session's SHOULD be mapped to the assigned transport VPN and the TE path information for that slice.
- o For transport slice assignment for various SSTs (eMBB, URLLC, MIoT) corresponding underlay paths need to be created and monitored from each transport end point (gNB/CSR and UPF).
- o During PDU session creation, apart from radio and 5GC resources, transport network resources needed to be verified matching the characteristics of the PDU session traffic type.
- o The TNF MUST provide an API that takes as input the source and destination 3GPP user plane element address, required bandwidth, latency and jitter characteristics between those user plane elements and returns as output a particular TE path's identifier, that satisfies the requested requirements.
- o Mapping of PDU session parameters to underlay SST paths need to be done. One way to do this is to let the SMF install a Forwarding Action Rule (FAR) in the UPF via N4 with the FAR pointing to a "Network Instance" in the UPF. A "Network Instance" is a logical identifier for an underlying network. The "Network Instance" pointed by the FAR can be mapped to a transport path (through L2/L3 VPN). FARs are associated with Packet Detection Rule (PDR). PDRs are used to classify packets in the uplink (UL) and the downlink (DL) direction. For UL GTP-U TEID and/or the QFI marked in the GTPU packet can be used for classifying a packet belonging to a particular slice characteristics. For DL, at a PSA UPF, the UE IP address is used to identify the PDU session, and hence the slice a packet belongs to and the IP 5 tuple can be used for identifying the flow and QoS characteristics to be applied on the packet.
- o If any other form of encapsulation (other than GTP-U) either on N3 or N9 corresponding QFI information MUST be there in the encapsulation header.
- o In some SSC modes [Appendix B](#), if segmented path (gNB to staging/ULCL/BP-UPF to anchor-point-UPF) is needed, then corresponding path characteristics MUST be used. This includes a path from gNB/CSR to UL-CL/BP UPF [[TS.23.501-3GPP](#)] and UL-CL/BP UPF to eventual UPF access to DN.
- o Continuous monitoring of transport path characteristics and reassignment at the endpoints MUST be performed. For all the affected PDU sessions, degraded transport paths need to be updated dynamically with similar alternate paths.

- o During UE mobility event similar to 4G/LTE i.e., gNB mobility (Xn based or N2 based), for target gNB selection, apart from radio resources, transport resources MUST be factored. This enables handling of all PDU sessions from the UE to target gNB and this requires co-ordination of gNB, AMF, SMF with the TNF module.

Integrating the TNF as part of the 5GS Service Based Interfaces, provides the flexibility to control the allocation of required characteristics from the TN during a 5GS signaling procedure (e.g. PDU Session Establishment). If TNF is seen as part of management plane, this real time flexibility is lost. Changes to detailed signaling to integrate the above for various 5GS procedures as defined in [\[TS.23.502-3GPP\]](#) is beyond the scope of this document.

2.2. TNF as part of existing 5G Control Function

Another solution approach with TNF in [Section 2.1](#) and transport provisioning for an engineered IP transport that supports 3GPP slicing and QoS requirements in [\[TS.23.501-3GPP\]](#) is described in this section.

During a PDU session setup, the 3GPP AMF using input from the NSSF selects a network slice and SMF. The SMF with user policy from Policy Control Function (PCF) sets 5QI (QoS parameters) and the UPF on the path of the PDU session. While QoS and slice selection for the PDU session can be applied across the 3GPP control and user plane functions as outlined above, the transport underlay across N3 and N9 segments do not have enough information to apply the resource constraints represented by the slicing and QoS classification. Current guidelines for interconnection with transport networks [\[IR.34-GSMA\]](#) provide an application mapping into DSCP. However, apart from problems with classification of encrypted packets, these recommendations do not take into consideration other aspects in slicing like isolation, protection and replication.

Transport networks have their own slice and QoS configuration based on domain policies and the underlying network capability. Transport networks can enter into an agreement for virtual network services (VNS) with client domains using the ACTN [\[RFC8453\]](#) framework. The 3GPP mobile network, on the other side, defines a Network Slice Selection Management Function (NSSMF) [\[TS 28.533\]](#) that interacts with a TN domain manager (that is out of scope of 3GPP).

The ACTN VN service can be used across the 3GPP and transport networks to provision and map between slices, QoS in the two domains. An abstraction that represents QoS and slice information in the mobile domain and mapped to ACTN VN service in the transport domain is represented here as MTNC (Mobile Transport Network Context)

identifiers. Details of how the 3GPP domain derives the MTNC identifiers and how it programs it across its control and user plane functions are for 3GPP standards to define. For completeness, some minimal outlines are provided in the description below.

When the 3GPP user plane function (gNB, UPF) does not terminate the transport underlay protocol (e.g., MPLS), it needs to be carried in the IP protocol header from end-to-end of the mobile transport connection (N3, N9). [[I-D.ietf-dmm-5g-uplane-analysis](#)] discusses these scenarios in detail.

Figure 2 shows a view of the functions and interfaces for provisioning the MTNC identifiers. The focus is on provisioning between the 3GPP management plane (NSSMF), transport network (SDN-C) and carrying the MTNC identifiers in PDU packets for the transport network to grant the provisioned resources.

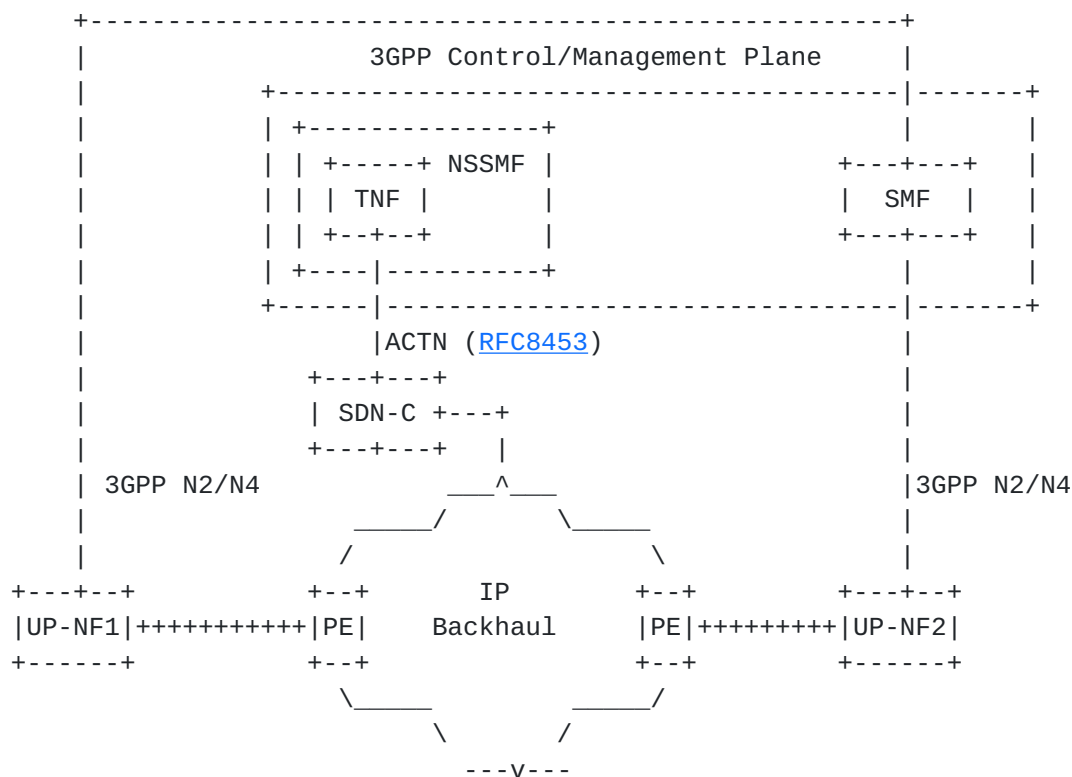


Figure 2: 5G Transport Plane Provisioning

In Figure 2, the TNF (logical functionality within the NSSMF) requests the SDN-C in the transport domain to program the TE path using ACTN [[RFC 8453](#)]. The SDN-C programs the Provider Edge (PE) routers and internal routers according to the underlay transport technology (e.g., PPR, MPLS, SRv6). The PE router inspects incoming

PDU data packets for the MTNC identifier, classifies and provides the VN service provisioned across the transport network.

The detailed mechanisms by which the NSSMF provides the MTNC identifiers to the control plane and user plane functions are for 3GPP to specify. Two possible options are outlined below for completeness. The NSSMF may provide the MTNC identifiers to the 3GPP control plane by either providing it to the Session Management Function (SMF), and the SMF in turn provisions the user plane functions (UP-NF1, UP-NF2) during PDU session setup. Alternatively, the user plane functions may request the MTNC identifiers directly from the NSSMF.

In this approach, TNF can be seen as a logical entity that can be part of NSSMF in the 3GPP management plane [[TS.28.533-3GPP](#)]. The NSSMF may use network configuration, policies, history, heuristics or some combination of these to derive traffic estimates that the TNF would use. How these estimates are derived are not in the scope of this document. The focus here is only in terms of how the TNF and SDN-C are programmed given that slice and QoS characteristics across a transport path can be represented by an MTNC identifier. The TNF requests the SDN-C in the transport network to provision paths in the transport domain based on the MTNC identifier. The TNF is capable of providing the MTNC identifier provisioned to control and user plane functions in the 3GPP domain. Detailed mechanisms for programming the MTNC identifier should be part of the 3GPP specifications.

2.2.1. Mobile Transport Network Context and Scalability

The MTNC (Mobile Transport Network Context) represents a slice, QoS configuration for a transport path between two 3GPP user plane functions. The Mobile-Transport Network Context Identifier (MTNC-ID) is generated by the TNF to be unique for each path and per traffic class (including QoS and slice aspects). Thus, there may be more than one MTNC-ID for the same QoS and path if there is a need to provide isolation (slice) of the traffic. It should be noted that MTNC are per class/path and not per user session (nor is it per data path entity). The MTNC identifiers are configured by the TNF to be unique within a provisioning domain.

Since the MTNC identifiers are not generated per user flow or session, there is no need for unique MTNC identifiers per flow/session. In addition, since the traffic estimation not performed at the time of session establishment, there is no provisioning delay experienced during session setup. The MTNC identifier space scales as a square of the number sites between which 3GPP user plane functions require paths. If there are T traffic classes across N sites, the number of MTNC identifiers in a fully meshed network is

$(N*(N-1)/2) * T$. For example, if there are 3 traffic classes between 25 sites, there would be at most 900 MTNC identifiers required. Multiple slices for the same QoS class that need to be fully isolated, will add to the MTNC provisioning. An MTNC identifier space of 16 bits (65K+ identifiers) can be expected to be sufficient.

2.2.2. MTNC Identifier in the Data Packet

When the 3GPP user plane function (gNB, UPF) and transport provider edge are on different nodes, the PE router needs to have the means by which to classify the PDU packet. IP header fields such as DSCP (DiffServ Code Point) or the IPv6 Flow Label do not satisfy the requirement as they are not immutable.

Different options for carrying the MTNC identifier in the IP data packet or in the existing user plane overlay like GTP-U [[TS.29.281-3GPP](#)] or a new overlay like GUE [[I-D.ietf-intarea-gue-extensions](#)] are possible. There are various trade-offs in terms of packet overhead, support in IPv4 and IPv6 networks as well as working across legacy and evolving transport networks that need to be considered. These considerations will be addressed in future revisions.

3. Using PPR as TN Underlay

In a network implementing source routing, packets may be transported through the use of Segment Identifiers (SIDs), where a SID uniquely identifies a segment as defined in [[I-D.ietf-spring-segment-routing](#)]. [Section 5.3](#) [[I-D.bogineni-dmm-optimized-mobile-user-plane](#)] lays out all SRv6 features along with a few concerns in [Section 5.3.7](#) of the same document. Those concerns are addressed by a new backhaul routing mechanism called Preferred Path Routing (PPR), of which this section provides an overview.

The label/PPR-ID refer not to individual segments of which the path is composed, but to the identifier of a path that is deployed on network nodes. The fact that paths and path identifiers can be computed and controlled by a controller, not a routing protocol, allows the deployment of any path that network operators prefer, not just shortest paths. As packets refer to a path towards a given destination and nodes make their forwarding decision based on the identifier of a path, not the identifier of a next segment node, it is no longer necessary to carry a sequence of labels. This results in multiple benefits including significant reduction in network layer overhead, increased performance and hardware compatibility for carrying both path and services along the path.

Details of the IGP extensions for PPR are provided here:

- o IS-IS - [[I-D.chunduri-lsr-isis-preferred-path-routing](#)]
- o OSPF - [[I-D.chunduri-lsr-ospf-preferred-path-routing](#)]

3.1. PPR with Transport Awareness for 5GS on N3/N9 Interfaces

PPR does not remove GTP-U, unlike some other proposals laid out in [[I-D.bogineni-dmm-optimized-mobile-user-plane](#)]. Instead, PPR works with the existing cellular user plane (GTP-U) for both N3 and any approach selected for N9 (encapsulation or no-encapsulation). In this scenario, PPR will only help providing TE benefits needed for 5G slices from transport domain perspective. It does so without adding any additional overhead to the user plane, unlike SR-MPLS or SRv6. This is achieved by:

- o For 3 different SSTs, 3 PPR-IDs can be signaled from any node in the transport network. For Uplink traffic, the 5G-AN will choose the right PPR-ID of the UPF based on the S-NSSAI the PDU Session belongs to and/or the QFI (e.g. 5QI) marking on the GTP-U encapsulation header. Similarly in the Downlink direction matching PPR-ID of the 5G-AN is chosen based on the S-NSSAI the PDU Session belongs to. The table below shows a typical mapping:

QFI (Ranges)	SST in S-NSSAI	Transport Path Info	Transport Path Characteristics
Range Xx - Xy X1, X2(discrete values)	MIOT (massive IOT)	PW ID/VPN info, PPR-ID-A	GBR (Guaranteed Bit Rate) Bandwidth: Bx Delay: Dx Jitter: Jx
Range Yx - Yy Y1, Y2(discrete values)	URLLC (ultra-low latency)	PW ID/VPN info, PPR-ID-B	GBR with Delay Req. Bandwidth: By Delay: Dy Jitter: Jy
Range Zx - Zy Z1, Z2(discrete values)	EMBB (broadband)	PW ID/VPN info, PPR-ID-C	Non-GBR Bandwidth: Bx

Figure 3: QFI Mapping with PPR-IDs on N3/N9

- o It is possible to have a single PPR-ID for multiple input points through a PPR tree structure separate in UL and DL direction.
- o Same set of PPRs are created uniformly across all needed 5G-ANs and UPFs to allow various mobility scenarios.
- o Any modification of TE parameters of the path, replacement path and deleted path needed to be updated from TNF to the relevant ingress points. Same information can be pushed to the NSSF, and/or SMF as needed.
- o PPR can be supported with any native IPv4 and IPv6 data/user planes ([Section 3.2](#)) with optional TE features ([Section 3.3](#)) . As this is an underlay mechanism it can work with any overlay encapsulation approach including GTP-U as defined currently for N3 interface.

3.2. Path Steering Support to native IP user planes

PPR works in fully compatible way with SR defined user planes (SR-MPLS and SRv6) by reducing the path overhead and other challenges as listed in [[I-D.chunduri-lsr-isis-preferred-path-routing](#)] or Section 5.3.7 of [[I-D.bogineni-dmm-optimized-mobile-user-plane](#)]. PPR also expands the source routing to user planes beyond SR-MPLS and SRv6 i.e., native IPv6 and IPv4 user planes.

This helps legacy transport networks to get the immediate path steering benefits and helps in overall migration strategy of the network to the desired user plane. It is important to note, these benefits can be realized with no hardware upgrade except control plane software for native IPv6 and IPv4 user planes.

3.3. Service Level Guarantee in Underlay

PPR also optionally allows to allocate resources that are to be reserved along the preferred path. These resources are required in some cases (for some 5G SSTs with stringent GBR and latency requirements) not only for providing committed bandwidth or deterministic latency, but also for assuring overall service level guarantee in the network. This approach does not require per-hop provisioning and reduces the OPEX by minimizing the number of protocols needed and allows dynamism with Fast-ReRoute (FRR) capabilities.

4. Other TE Technologies Applicability

RSVP-TE [[RFC3209](#)] provides a lean transport overhead for the TE path for MPLS user plane. However, it is perceived as less dynamic in some cases and has some provisioning overhead across all the nodes in N3 and N9 interface nodes. Also it has another drawback with excessive state refresh overhead across adjacent nodes and this can be mitigated with [[RFC8370](#)].

SR-TE [[I-D.ietf-spring-segment-routing](#)] does not explicitly signal bandwidth reservation or mechanism to guarantee latency on the nodes/links on SR path. But, SR allows path steering for any flow at the ingress and particular path for a flow can be chosen. Some of the issues around path overhead/tax, MTU issues are documented at Section 5.3 of [[I-D.bogineni-dmm-optimized-mobile-user-plane](#)]. SR-MPLS allows reduction of the control protocols to one IGP (with out needing for LDP and RSVP-TE).

However, as specified above with PPR ([Section 3](#)), in the integrated transport network function (TNF) a particular RSVP-TE path for MPLS

or SR path for MPLS and IPv6 with SRH user plane, can be supplied to SMF for mapping a particular PDU session to the transport path.

5. Acknowledgements

Thanks to Young Lee for discussions on this document including ACTN applicability for the proposed TNF. Thanks to Sri Gundavelli and 3GPP delegates who provided detailed feedback on this document.

6. IANA Considerations

This document has no requests for any IANA code point allocations.

7. Security Considerations

This document does not introduce any new security issues.

8. Contributing Authors

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[Appendix A](#). New Control Plane and User Planes

[A.1](#). Slice aware Mobility: Discrete Approach

In this approach transport network functionality from the 5G-AN to UPF is discrete and 5GS is not aware of the underlying transport network and the resources available. Deployment specific mapping function is used to map the GTP-U encapsulated traffic at the 5G-AN (e.g. gNB) in UL and UPF in DL direction to the appropriate transport slice or transport Traffic Engineered (TE) paths. These TE paths can be established using RSVP-TE [[RFC3209](#)] for MPLS underlay, SR [[I-D.ietf-spring-segment-routing](#)] for both MPLS and IPv6 underlay or PPR [[I-D.chunduri-lsr-isis-preferred-path-routing](#)] with MPLS, IPv6 with SRH, native IPv6 and native IPv4 underlays.

As per [TS.23.501-3GPP] and [TS.23.502-3GPP] the SMF controls the user plane traffic forwarding rules in the UPF. The UPFs have a concept of a "Network Instance" which logically abstracts the underlying transport path. When the SMF creates the packet detection rules (PDR) and forwarding action rules (FAR) for a PDU session at the UPF, the SMF identifies the network instance through which the packet matching the PDR has to be forwarded. A network instance can be mapped to a TE path at the UPF. In this approach, TNF as shown in Figure 1 need not be part of the 5G Service Based Interface (SBI). Only management plane functionality is needed to create, monitor, manage and delete (life cycle management) the transport TE paths/transport slices from the 5G-AN to the UPF (on N3/N9 interfaces). The management plane functionality also provides the mapping of such TE paths to a network instance identifier to the SMF. The SMF uses this mapping to install appropriate FARs in the UPF. This approach provide partial integration of the transport network into 5GS with some benefits.

One of the limitations of this approach is the inability of the 5GS procedures to know, if underlying transport resources are available for the traffic type being carried in PDU session before making certain decisions in the 5G CP. One example scenario/decision could be, a target gNB selection during a N2 mobility event, without knowing if the target gNB is having a underlay transport slice resource for the S-NSSAI and 5QI of the PDU session. The Integrated approach specified below can mitigate this.

Appendix B. PPR with various 5G Mobility procedures

PPR fulfills the needs of 5GS to transport the user plane traffic from 5G-AN to UPF in all 3 SSC modes defined [TS.23.501-3GPP]. This is done in keeping the backhaul network at par with 5G slicing requirements that are applicable to Radio and virtualized core network to create a truly end-to-end slice path for 5G traffic. When UE moves across the 5G-AN (e.g. from one gNB to another gNB), there is no transport network reconfiguration required with the approach above.

SSC mode would be specified/defaulted by SMF. No change in the mode once connection is initiated and this property is not altered here.

B.1. SSC Mode1

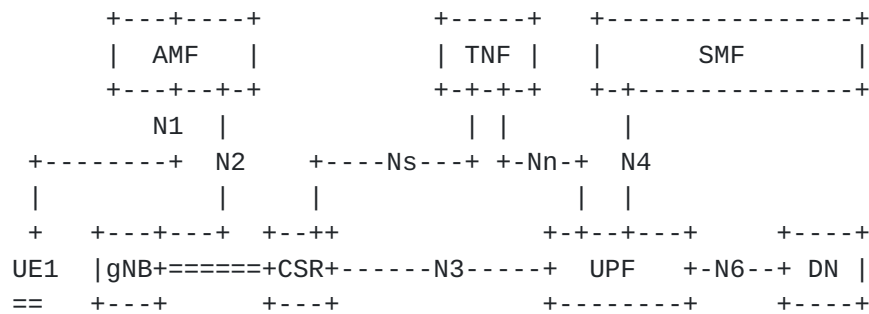


Figure 4: SSC Mode1 with integrated Transport Slice Function

After UE1 moved to another gNB in the same UPF serving area

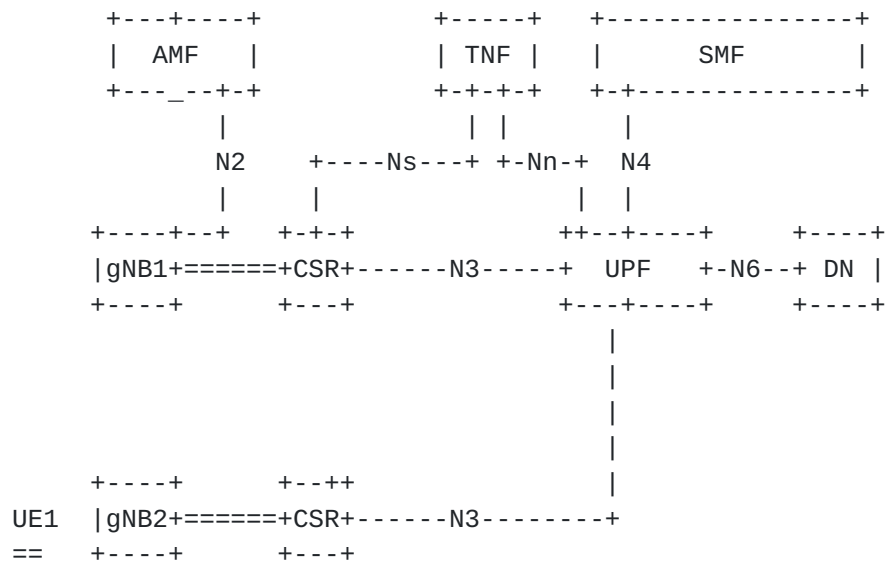


Figure 5: SSC Mode1 with integrated Transport Slice Function

In this mode, IP address at the UE is preserved during mobility events. This is similar to 4G/LTE mechanism and for respective slices, corresponding PPR-ID (TE Path) has to be assigned to the packet at UL and DL direction. During Xn mobility as shown above, source gNB has to additionally ensure transport path's resources from TNF are available at the target gNB apart from radio resources check (at decision and request phase of Xn/N2 mobility scenario).

B.2. SSC Mode2

In this case, if IP Address is changed during mobility (different UPF area), then corresponding PDU session is released. No session continuity from the network is provided and this is designed as an

application offload and application manages the session continuity, if needed. For PDU Session, Service Request and Mobility cases mechanism to select the transport resource and the PPR-ID (TE Path) is similar to SSC Mode1.

B.3. SSC Mode3

In this mode, new IP address may be assigned because of UE moved to another UPF coverage area. Network ensures UE suffers no loss of 'connectivity'. A connection through new PDU session anchor point is established before the connection is terminated for better service continuity. There are two ways in which this happens.

- o Change of SSC Mode 3 PDU Session Anchor with multiple PDU Sessions.
- o Change of SSC Mode 3 PDU Session Anchor with IPv6 multi-homed PDU Session.

In the first mode, from user plane perspective, the two PDU sessions are independent and the use of PPR-ID by gNB and UPFs is exactly similar to SSC Mode 1 described above. The following paragraphs describe the IPv6 multi-homed PDU session case for SSC Mode 3.

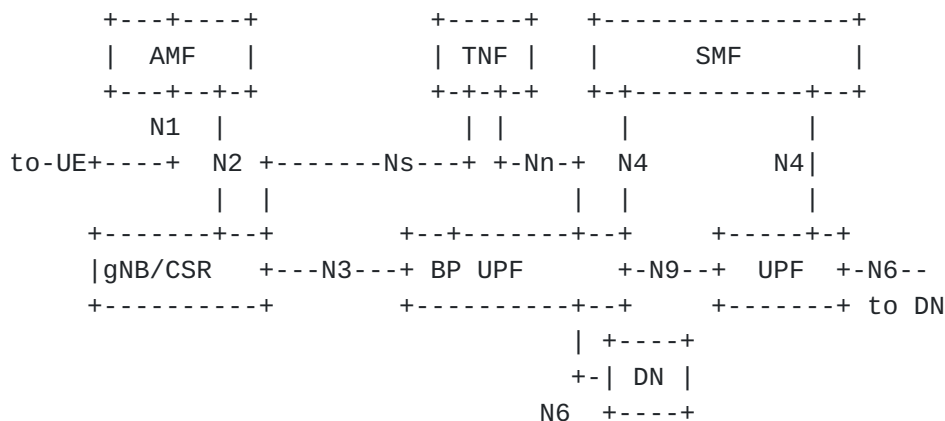


Figure 6: SSC Mode3 and Service Continuity

In the uplink direction for the traffic offloading from the Branching Point UPF, packet has to reach to the right exit UPF. In this case packet gets re-encapsulated by the BP UPF (with either GTP-U or the chosen encapsulation) after bit rate enforcement and LI, towards the anchor UPF. At this point packet has to be on the appropriate VPN/PW

to the anchor UPF. This mapping is done based on the S-NSSAI the PDU session belongs to and/or the QFI marking in the GTP-U encapsulation header (e.g. 5QI value) to the PPR-ID of the exit node by selecting the respective TE PPR-ID (PPR path) of the UPF. If it's a non-MPLS underlay, destination IP address of the encapsulation header would be the mapped PPR-ID (TE path).

In the downlink direction for the incoming packet, UPF has to encapsulate the packet (with either GTP-U or the chosen encapsulation) to reach the BP UPF. Here mapping is done based on the S-NSSAI the PDU session belongs to, to the PPR-ID (TE Path) of the BP UPF. If it's a non-MPLS underlay, destination IP address of the encapsulation header would be the mapped PPR-ID (TE path). In summary:

- o Respective PPR-ID on N3 and N9 has to be selected with correct transport characteristics from TNF.
- o For N2 based mobility SMF has to ensure transport resources are available for N3 Interface to new BP UPF and from there the original anchor point UPF.
- o For Service continuity with multi-homed PDU session same transport network characteristics of the original PDU session (both on N3 and N9) need to be observed for the newly configured IPv6 prefixes.

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