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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 specified in a way to address all the mobility scenarios defined in [TS23.501] and to be backward compatible with LTE [TS.23.401-3GPP] network deployments.

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 (IPv4, IPv6, MPLS) 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 and Problem Statement

3GPP Release 15 for 5GC is defined in [TS.23.501-3GPP], [TS.23.502-3GPP], [TS.23.503-3GPP]. A new user plane interface N9 [TS.23.501-3GPP] has been created between 2 User Plane Functionalities (UPFs). While user plane for N9 interface being finalized for REL16, both GTP-U based encapsulation or any other compatible approach is being considered [CT4SID]. Concerning to this document another relevant interface is N3, which is between gNB and the UPF. N3 interface is similar to the user plane interface S1U in LTE [TS.23.401-3GPP]. This document:

- o does not propose any change to existing N3 user plane encapsulations to realize the benefits with the approach specified here
- o and can work with any encapsulation (including GTP-U) for the N9 interface.

[TS.23.501-3GPP] defines various Session and Service Continuity (SSC) modes and mobility scenarios for 5G with slice awareness from Radio and 5G Core (5GC) network. 5G System (5GS) as defined, allows transport network between N3 and N9 interfaces work independently with various IETF Traffic Engineering (TE) technologies.

However, lack of underlying Transport Network (TN) awareness can be problematic for some of the 5GS procedures, for real-time, mission-critical or for any deterministic latency services. These 5GS procedures including but not limited to Service Request, PDU Session, 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 various 5QI's defined in [TS.23.501-3GPP] .

### 1.1. Acronyms

5QI	-	5G QoS Indicator
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)

## 1.2. Solution Approach

This document specifies a mechanism to fulfil the needs of 5GS to transport user plane traffic from gNB 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. TN with mobility awareness described here in a way, which does not erase performance and latency gains made with 5G New Radio(5G NR) and virtualized cellular core network features developed in [TS.23.501-3GPP].

Section 2 describes two methods, with which Transport Network (TN) aware mobility can be built irrespective of underlying TN technology used. Using Preferred Path Routing (PPR) as TN Underlay is detailed in Section 3. Section 3.4 further describes the applicability and procedures of the same with 5G SSC modes on N3 and N9 interfaces. At the end, Section 6 recapitulates the benefits of specified approach in mobile networks.

## 2. Transport Network (TN) and Slice aware Mobility on N3/N9

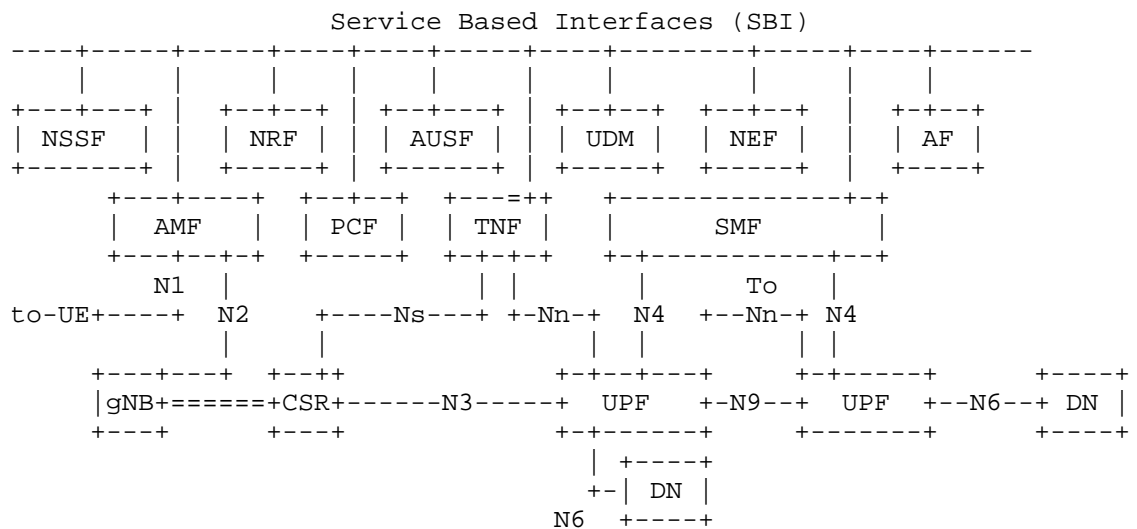


Figure 1: 5G Service Based Architecture

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. 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.

Currently specified Control Plane (CP) functions Access and Mobility Management Function (AMF), Session Management Function (SMF) and User plane (UP) components gNodeB (gNB), User Plane Function (UPF) with N2, N3, N4, N6 and N9 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].

N3 interface is similar to S1-U in 4G/LTE [TS.23.401-3GPP] network and uses GTP-U [TS.29.281-3GPP] encapsulation to transport any UE PDUs (IPv4, IPv6, IPv4v6, Ethernet or Unstructured). N9 interface is a new interface to connect UPFs in SSC Mode3 Section 3.4.3 and right user plane protocol/encapsulation is being studied through 3GPP CT4 WG approved study item [CT4SID] for REL-16.

TN Aware Mobility with optimized transport network functionality is explained below. 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. Discrete Approach

In this approach transport network functionality from gNB 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 gNB at 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.

In this case, the encapsulation provided by GTP-U helps carry different PDU session types (IPv4, IPv6, IPv4IPv6, Ethernet and Unstructured) independent of the underlying transport or user plane (IPv4, IPv6 or MPLS) network. Mapping of the PDU sessions to TE paths can be done based on the source UDP port ranges (if these are assigned based on the PDU session QCI, as done in some deployments with 4G/LTE) of the GTP-U encapsulated packet or based on the 5QI or RQI values in the GTP-U header. Here, 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 gNB to UPF (on N3/N9 interfaces). 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 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 in Xn mobility in SSC Model, without knowing if the target gNB is having a underlay transport slice resource for the 5QI of the PDU session. The below approach can mitigate this.

## 2.2. Integrated Approach

Network Slice Selection Function (NSSF) as defined in [TS.23.501-3GPP] concerns with multiple aspects related to creation, selection, mobility, roaming and co-ordination among other CP functions in 5GS. However, the scope is only in 5GC (both control and user plane) and NG Radio Access network including N3IWF for non-3GPP access. Slice functionality is per PDU session granularity. While this fully covers needed functionality and resources from UE registration, Tracking Area (TA) updates, mobility and roaming, resources and functionalities needed from transport network is not specified. This is seen as independent functionality though part of 5GS. If transport network is not factored in an integrated fashion w.r.t available resources (with network characteristics from desired bandwidth, latency, burst size handling and optionally jitter) some of the gains made with optimizations through 5G NR and 5GC can be degraded.

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 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.

These VPNs and/or underlay TE paths MUST be similar on all gNB/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]. 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]).

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 In the Network Slice Selection Assistance Information (NSSAI) PDU session's assigned transport VPN and the TE path information is needed.
- 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 Mapping of PDU session parameters to underlay SST paths need to be done. One way to do this is through 5QI/QFI information in the GTP-U header and map the same to the underlying transport path (including VPN or PW). This works for uplink (UL) direction.
- o For downlink direction RQI need to be considered to map the DL packet to one of the underlay paths at the UPF.
- o If any other form of encapsulation (other than GTP-U) either on N3 or N9 corresponding 5QI/QFI or RQI information MUST be there in the encapsulation header.
- o If SSC Mode3 Section 3.4.3 is used, segmented path (gNB to staging/ULCL/BP-UPF to anchor-point-UPF) with 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 effected 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 require co-ordination of AMF, SMF with the TNF module.

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.

### 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 Slicing aware Mobility on N3/N9

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 (encap or no-encap). 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 signaled from any node in the transport network. For Uplink traffic, gNB will choose the right PPR-ID of the UPF based on the 5QI value in the encapsulation header of the PDU session. Similarly in the Downlink direction matching PPR-ID of the gNB is chosen for the RQI value in the encapsulated SL payload. The table below shows a typical mapping:

5QI (Ranges)/ RQI (Ranges)	SST	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 2: 5QI/RQI 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 gNBs 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, AMF and 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.

### 3.4. PPR with various 5G Mobility procedures

PPR fulfills the needs of 5GS to transport the user plane traffic from gNB 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 from one gNB to another gNB, there is no transport network reconfiguration require 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.

### 3.4.1. SSC Model

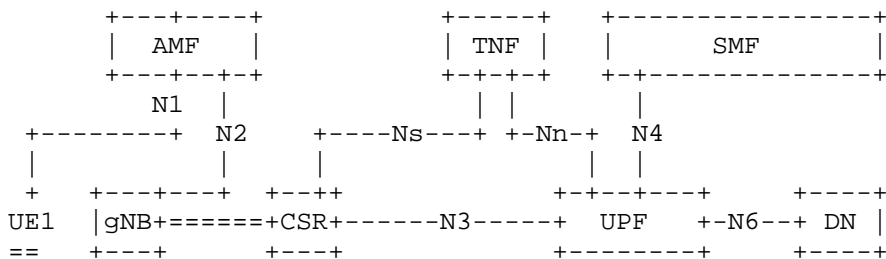


Figure 3: SSC Model with integrated Transport Slice Function

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

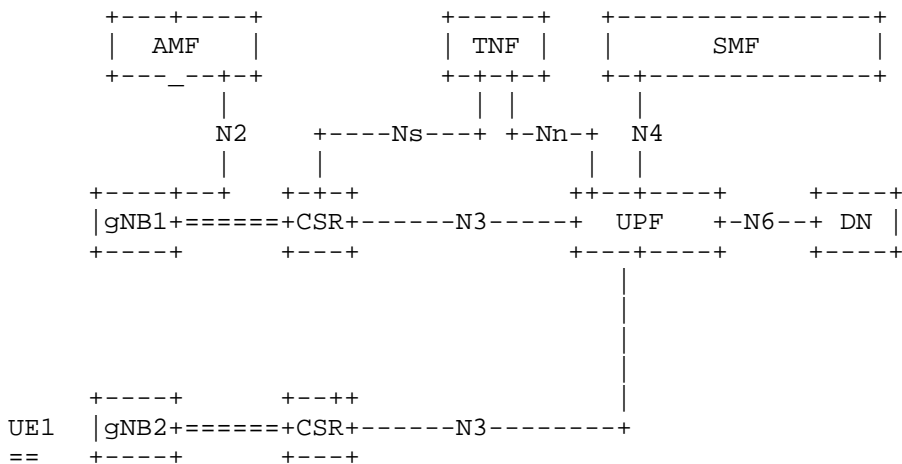


Figure 4: SSC Model with integrated Transport Slice Function

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, AMF 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).

## 3.4.2.    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 Model.

## 3.4.3.    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.

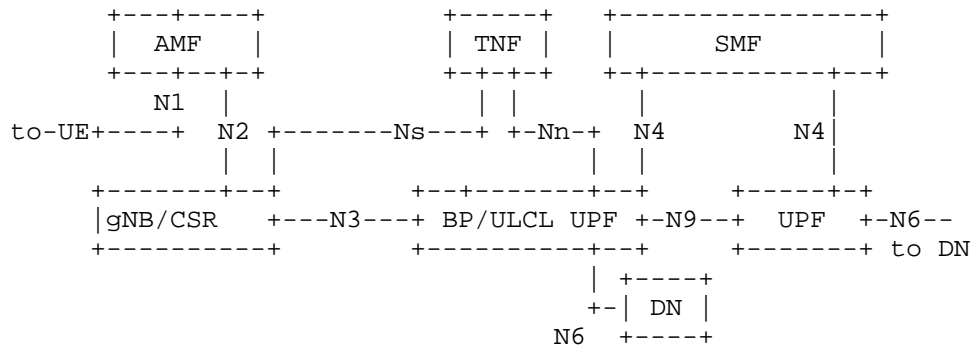


Figure 5: SSC Mode3 and Service Continuity

In the uplink direction for the traffic offloading from UL/CL case, packet has to reach to the right exit UPF. In this case packet gets re-encapsulated with ULCL marker (with either GTP-U or the chosen encapsulation) after bit rate enforcement and LI to 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 5QI 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/ULCL UPF. Here mapping is done for RQI parameter in the encapsulation header to PPR-ID (TE Path) of the BP/ULCL 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 AMF/SMF has to ensure transport resources are available for N3 Interface to new ULCL 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 created PDU session.

#### 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 neither bandwidth reservation nor 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]. Also SR allows reduction of the control protocols to one IGP (with out needing for LDP and RSVP).

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 NSSF/AMF/SMF for mapping a particular PDU session to the transport path.

## 5. New Control Plane and User Planes

### 5.1. LISP and PPR

PPR can also be used with LISP control plane for 3GPP as described in [I-D.farinacci-lisp-mobile-network]. This can be achieved by mapping the UE IP address (EID) to PPR-ID, which acts as Routing Locator (RLOC). Any encapsulation supported by LISP can work well with PPR. If the RLOC refers to an IPv4 or IPv6 destination address in the LISP encapsulated header, packets are transported on the preferred path in the network as opposed to traditional shortest path routing with no additional user plane overhead related to TE path in the network layer.

Some of the distinct advantages of the LISP approach is, its scalability, support for service continuity in SSC Mode3 as well as native support for session continuity (session survivable mobility). Various other advantages are documented at [I-D.farinacci-lisp-mobile-network].

### 5.2. ILA and PPR

If an ILA-prefix is allowed to refer to a PPR-ID, ILA can be leveraged with all the benefits (including mobility) that it provides. This works fine in the DL direction as packet is destined to UE IP address at UPF. However, in the UL direction, packet is destined to an external internet address (SIR Prefix to ILA Prefix transformation happens on the Source address of the original UE packet). One way to route the packet with out bringing the complete DFZ BGP routing table is by doing a default route to the UPF (ILA-R). In this case, how TE can be achieved is TBD (to be expanded further with details).

## 6. Summary and Benefits with PPR

This document specifies an approach to transport and slice aware mobility with a simple mapping function from PDU Session to transport path applicable to any TE underlay.

This also describes PPR [I-D.chunduri-lsr-isis-preferred-path-routing], a transport underlay routing mechanism, which helps with goal of optimized user plane for N9 interface. PPR provides a method for N3 and N9 interfaces to support transport slicing in a way which does not erase the gains made with 5G NR and virtualized cellular core network features for various types of 5G traffic (e.g. needing low and deterministic latency, real-time, mission-critical or AR/VR traffic). PPR provides path steering, optionally guaranteed services with TE, unique Fast-

ReRoute (FRR) mechanism with preferred backups (beyond shortest path backups through existing LFA schemes) in the mobile backhaul network with any underlay being used in the operator's network (IPv4, IPv6 or MPLS) in an optimized fashion.

## 7. Acknowledgements

TBD.

## 8. IANA Considerations

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

## 9. Security Considerations

This document does not introduce any new security issues.

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