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U. Chunduri, Ed.
Intel Corporation
J. Kaippallimalil, Ed.
Futurewei
S. Bhaskaran
Rakuten Symphony
J. Tantsura
Nvidia
L.M. Contreras
Telefonica
15 October 2024

Mobility-aware Transport Network Slicing for 5G

[draft-ietf-dmm-tn-aware-mobility-11](#)

Abstract

Network slicing in 5G ~~enables~~ logical networks for communication services of multiple 5G customers to be multiplexed over the same infrastructure. While 5G slicing covers logical separation of various aspects of 5G ~~infrastructure and~~ services, user's data plane packets over the ~~radio~~ ~~Radio access Network~~ (RAN) and ~~mobile~~ ~~eCore~~ network ~~Network~~ (5GC) use IP ~~transport~~ in many segments of ~~the~~ ~~an~~ end-to-end 5G slice. When end-to-end slices in a 5G ~~system~~ ~~System~~ use ~~IP~~ ~~network resources~~, they are mapped to corresponding IP transport network slice(s) which in turn provide the bandwidth, latency, isolation, and other criteria ~~requested~~ ~~required for the realization of by a thea~~ 5G slice.

This document describes mapping of 5G slices to IP or Layer 2 transport network slices when the IP transport network (slice provider) is separated by an "attachment circuit" from the networks in which the 5G network functions are deployed, for example, 5G functions that are distributed across data centers. The slice mapping ~~proposed~~ ~~defined~~ here is supported transparently when a 5G user device moves across 5G attachment points and session anchors.

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].

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Commenté [MB1]: Do you exclude MPLS?

Commenté [MB2]: As there are other mapping schemes discussed in TEAS, I wonder whether a clarification can be included to better highlight the «mobility-aware» mention in the draft.

I understand this might be too subtle for an abstract. So feel free to consider such clarification in the introduction.

Commenté [MB3]: To be updated to use the latest boilerplate.

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1. Introduction

| 3GPP architecture for 5G System (5GS) in [TS.23.501-3GPP], [TS.23.502-3GPP] and
| [TS.23.503-3GPP] for 5GC (5G Core), and the NG-RAN architecture
| defined in [TS.38.300-3GPP] and [TS.38.401-3GPP] describe slicing as
| one of the capabilities for the communication services that 5G
| systems offer. Slice types defined in-by the 3GPP and offered to its

~~clients (UEs)~~ include enhanced mobile broadband (eMBB) communications, ultra-reliable low latency communications (URLLC), massive internet of things (MIoT), vehicle-to-X (V2X) ~~i~~ and high performance machine type communications (HMTC). Other types can and can be extended defined in the future to include new slice types.

Slices in 3GPP are logical sets of 3GPP resources that may include multiple segments across 3GPP control and user plane functions in the core and radio access networks. For example, a 5G slice instance requested by an end-user may be realized by multiple slice subnets that span user plane network functions including the UPF (User Plane Function), gNB-CU (generalized Node-B Centralized Unit), and gNB-DU (generalized Node-B Distributed Unit) and corresponding 3GPP interfaces N3, N9, and F1-U. However, considering the IP transport network aspects for realizing 3GPP slicing 5G slices:

- * 3GPP standards do not specify the technical capabilities needed by underlying IP ~~transport network or slices~~.
- * 3GPP standards define how interfaces N3, N9, F1-U are (re)selected but they do not specify the underlying transport network (re)selection.
- * Slice details in 3GPP, ATIS or NGMN do not specify how slice characteristics for QoS, hard /soft isolation, protection and other aspects should be satisfied implemented in IP transport networks.

A transport underlay network across 3GPP interfaces N3, N9 and F1U may use multiple technologies or network providers ~~on path, and the~~ The slice in the 3GPP domain is mapped in each corresponding transport domain. 5G system slices for distributed infrastructures that make up the 5GS system, and 5G slices offered to its end users (via UE) are mapped to transport domain network slices to provide the corresponding level of bandwidth, isolation, and other capabilities. The gNB-CU maintains the upper layer functionality of the radio access network while the gNB-DU runs the lower layers of the radio access network stack (e.g., RLC, MAC and PHY based on the split), typically called the BBU (Base Band Unit). Thus, a 3GPP F1-U slice subnet instance would typically be used to carry all user traffic between a gNB-DU and gNB-CU. The N3 and N9 transport segments between the gNB and UPF(s) on the other hand handle user traffic based on the subscribed/offered level of service. Thus, an end-user's traffic for eMBB service and assigned 3GPP slice may be mapped to a different IP transport TN slice across

N3 and N9 segments than traffic for URLLC service. Mapping and binding between 3GPP slices and a new IP transport TN slice happens transparently as the end-user moves across attachment points in the radio network and session anchors in 5GC. Unlike mapping of a fronthaul 3GPP slice to an IP transport slice, the IP transport slice that F1-U/N3/N9 slice is mapped to is aware of the slice characteristics of the UE session during initial setup (user initiates 3GPP connectivity session) and following mobility. For example, a UE served by the 3GPP system for high throughput, low latency service, and related 3GPP slice should be mapped to an IP transport TN slice that offers the

Commenté [MB4]: Consider leveraging the definition in <https://datatracker.ietf.org/doc/html/draft-ietf-teas-5g-ns-ip-mpls-13#name-5g-network-slicing-versus-t>

Commenté [MB5]: To be defined first.

Commenté [MB6]: Consider referring the [draft-ietf-teas-5g-ns-ip-mpls-13](https://datatracker.ietf.org/doc/html/draft-ietf-teas-5g-ns-ip-mpls-13) for the definition of «TN slice».

Commenté [MB7]: To be consistent with 3GPP terminology.

Commenté [MB8]: Consistent terminolgy vs. teas

corresponding characteristics even after handover.

Slicing in this document mainly refers to user plane slices as these are used by the 3GPP network to provide the level of service offered to a user. For example, 5GS that sets up a session for a user for eMBB service would need to provide the guarantees for the service across the user plane segments including F1-U, N3 and N9. During the session setup phase, the control plane signaling may use other 5G provider slices for messages that carry session signaling, or to carry signaling data between 5G network functions. The techniques described here can be applied to control plane in the same manner as it is applied for transport segments of the user plane. The slicing requirements for the control plane are defined by the 5G service provider and not specified by a 3GPP standard. Slice mapping using UDP source port numbers may be used in IP transport networks for public or non public 3GPP networks.

Several network scenarios and mechanisms to map 3GPP and IETF network slices are found in [I-D.ietf-teas-5g-network-slice-application]. This document describes the case when a 3GPP function (like gNB-CU, UPF) is separated from the slice provider by an "attachment circuit" described in [I-D.ietf-opsawg-teas-attachment-circuit]. 3GPP slice management ([TS.28.541-3GPP]) supports the capability to use attachment circuits as described in [I-D.ietf-opsawg-teas-attachment-circuit]. The use of UDP source Port numbers in GTP-U header to map between a 5G slice and corresponding IETF network slice segments is described in detail here.

The main considerations in the mapping methods proposed-defined here-in this document include simplicity (i.e., use of Layer 2 VLAN across a Layer-2 network) and efficiency of inspecting the slice mapping parameters on a per-per-packet basis (i.e., source UDP port number across routed IP networks) when the IP transport network (slice provider) is separated from the networks in which the 5G network functions are deployed (for example, 5G functions distributed across data centers). Section 3 describes these methods in detail.

[RFC9543] draft defines the 'IETF Network slice', its scope and characteristics. It lists use cases where IETF technologies can be used for slicing solutions, for various connectivity segments. RFC

9543 IETF Network slice-Slice in [RFC9543] and IP transport slice in this document are the same in the context of descriptions here. When applied to 5G, they both refer to slices for the connectivity segments between various 5G functions (i.e. 5G-AN which includes NG-RAN, ULCL UPF, BP UPF and PSA UPF).

2. Terminology

5G-AN – 5G Access Network

Commenté [MB9]: The transition to UDP is not that evident.

I would define first the various mapping method, and then focus on udp source + motivate the restriction.

Commenté [MB10]: Should be defined earlier as you already use «IETF network slice» in previous para.

Commenté [MB11]: Please note this is slightly diff from the ip-mpls realization in teas.

5GS – 5G System

AC – Attachment Circuit

AMF – Access and Mobility Management Function (5G)

BP – Branch Point (5G)

CSR – Cell Site Router

CP – Control Plane (5G)

CU – Centralized Unit (5G, gNB)

DN – Data Network (5G)

DU – Distributed Unit (5G, gNB)

eMBB – enhanced Mobile Broadband (5G)

gNB – Next Generation Node B

GBR – Guaranteed Bit Rate (5G)

GTP-U – GPRS Tunneling Protocol – User plane (3GPP)

MIoT – Massive IOT (5G)

MPLS – Multi Protocol Label Switching

NG-RAN – Next Generation Radio Access Network (i.e., gNB, NG-eNB – RAN functions which connect to 5GC)

NSC – Network Slice Controller

NSS – Network Slice Subnet

NSSAI – Network Slice Selection Assistance Information

NSSI – Network Slice Subnet Identifier

NSSF – Network Slice Selection Function

NSSMF – Network Slice Selection Management Function

PDU – Protocol Data Unit (5G)

PW – Pseudo Wire

SDP – Service Demarcation Point

SMF – Session Management Function (5G)

S-NSSAI – Single Network Slice Selection Assistance Information

SST – Slice and Service Types (5G)

SR – Segment Routing

TE - Traffic Engineering

UP - User Plane(5G)

UPF - User Plane Function (5G)

URLLC - Ultra reliable and low latency communications (5G)

3. Mapping 3GPP Slices to IP Network Slices

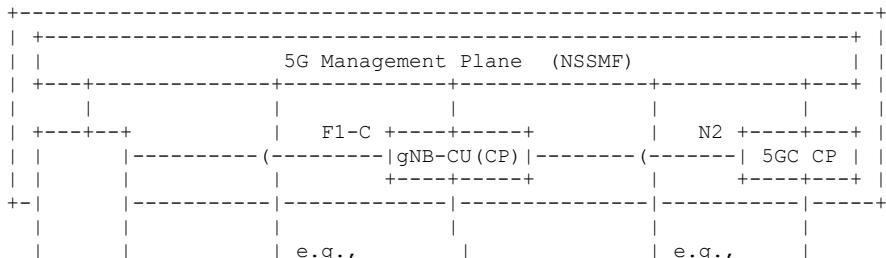
3.1. Overview of 5G End-to-End Network Slicing

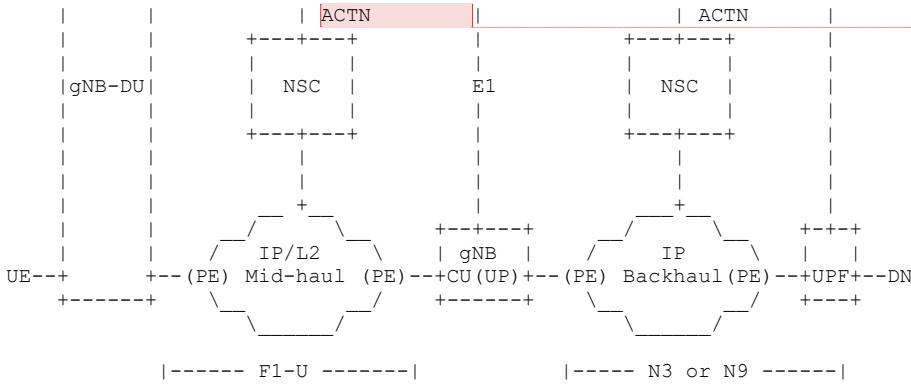
3GPP architecture in [TS.23.501-3GPP], [TS.23.502-3GPP] specify slicing in a **5G System (5GS)** and an overview is provided here. 5GS comprises of control plane network functions and user plane network functions in radio and mobile core networks. Communication services offered to 3GPP clients (UE) are associated to one or more slices represented by NSSAI (Network Slice Selection Assistance Information) in the control plane and the user plane. The NSSAI is configured through the 5G management plane using network slice subnet (NSS), for example, a network slice subnet that contains network function instances of the core network control plane functions (e.g., SMF, NRF), user plane network functions (e.g., UPF), radio network slice common functions (e.g., gNB-DU, gNB-CU-CP) and and radio network (e.g., gNB-CU-UP). Within the 3GPP domain, the control plane slicing is end-to-end between two network functions and user plane slices consist of multiple IP network segments between the radio network (NG-RAN) the UPF that anchors the UE session. User plane slicing beyond the UPF towards IP services is outside the scope of 3GPP and is addressed in [I-D.mcd-rtgwg-extension-tn-aware-mobility]. 3GPP documents mention transport network in the context of network slice subnets, but do not provide further details. The application of 5GS slices in transport network for backhaul, mid-haul and front haul are not explicitly covered in 3GPP and is the topic here. To support specific characteristics in backhaul (N3, N9), mid-haul (F1) and front haul, it is necessary to provision corresponding resources in the transport domain and carry a slice identifier that is understood by both the customer (3GPP network) and the provider (transport network). This section provides an overview and subsequent sections describe how to provision the mapping information in the transport network and apply it so that user plane packets can be provided the transport resources (QoS, isolation, protection, etc.) expected by the 5GS slices.

Commenté [MB12]: We used to provide an overview in some teas doc, but the 3GPP prefers to avoid that (per a LS reply received from them).

Commenté [MB13]: This is expired

5G Control and Management Planes





Commenté [MB14]: Why this example? Why not the Network Slice Service Model?

Figure 1: Backhaul and Mid-haul Transport Network for 5G

Figure 1 depicts a ~~5G System~~ (5GS) expanded to show the IP transport and PE (Provider Edge) routers providing IP transport service to 5GS user plane entities 5G-AN (e.g., gNB) and UPF. ~~The Provider Edge Each +PE~~ represents hosts the Service Demarcation Points (SDPs) to the transport

network that provides the slice capabilities. The IETF Network Slice Controller (NSC) interfaces with the 3GPP network (customer network) that requests for transport network slices (IETF network slice). The 5G management plane in turn requests the Network Slice Controller (NSC) to setup resources and connectivity in the transport network to realize the particular network slice. 5G network slice orchestration is defined in [TS.28.533-3GPP] and is represented in Figure 1 as Network Slice Selection Management Function (NSSMF) which is a part of 5G Management system responsible for managing network slice subnets. The 3GPP network (customer network) requests for IP transport network slice (slice provider network) based on estimated demand. The 5G management plane slice orchestration functionality in

3GPP requests for transport slices via the NSC and may use ACTN [RFC8453]. The Network Data Analytics Function (NWDAF), Network Slice Selection Management Function (NSSMF) and other 3GPP functions in the control and management planes provide data and functionality to estimate slice capabilities required from the transport network. The slices provisioned in the IP transport network correspond to 3GPP slices represented by NSSAI (set of 3GPP slices) available at 3GPP access/data networks and locations. During 3GPP procedures for session initialization, the network grants an S-NSSAI (single one out of the NSSAI) based on the user's session request. The S-NSSAI for the UE's session is signaled to the user plane nodes (gNB, UPF) during the session setup and used to associate to the corresponding IP transport slice. An overview of the sequence of operations from when a user (UE) requests during session setup to how it relates to the fronthaul, mid-haul and backhaul transport network slices is provided below.

Prior to 3GPP user (UE) signaling to setup a session, the UE attaches to the radio access network and has the parameters for operation configured. During this sequence of operation, the signaling is

Commenté [MB15]: See the comment in the figure

between the UE and the gNB. When the gNB functionality is split between a central unit (CU) and a distributed unit (DU), a mid-haul transport segment provides the connectivity as shown in Figure 1. Further, the gNB central unit can be split into the control plane (CP) and user plane (UP) logical functions as shown in Figure 1. If the RAN uses lower layer split architecture as specified by O-RAN alliance, then the user plane path from UE to DN also includes the fronthaul interface. The fronthaul interface carries the radio frames in the form of In-phase (I) and Quadrature (Q) samples using eCPRI encapsulation over Ethernet or UDP over IP. An important point to note is that signaling and data transport over the fronthaul transport has no notion of an end-user/UE session, but is rather defined by low latency and other requirements required for processing radio signaling and data transport between the network entities that compose gNB. For the front-haul described further in Section 3.2, an Ethernet transport with VLANs can be expected to be the case in many deployments.

Following the radio access setup and attach, the 3GPP user (UE) signals to setup a session. 5G core network (5GC) functionality to handle access mobility (AMF), UE session management (SMF), policy (PCF) and various other assisting functionality including 3GPP slice selection (NSSF) is used to authenticate the UE and setup the data plane to transport the UE PDU (Protocol Data Units). The N3, N9 and F1-U user planes use GTP-U [TS.29.281-3GPP] to transport UE PDUs (IPv4, IPv6, IPv4v6, Ethernet or Unstructured). From an IP transport network perspective, these GTP-U connections can be viewed as multiple overlay connection segments between each of the 3GPP data plane entities (gNB, UPF) on a per UE basis. The GTP-U/overlay transport capabilities required are signaled between the RAN and 5GC during UE session setup. Note that unlike the slice requirements for mid-haul segment (F1-U), the slice requirements for the backhaul (N3, N9) are setup in the 3GPP network on a per UE basis. Thus, in the backhaul, an IP transport slice with capabilities corresponding to the S-NSSAI negotiated between UE 5GC is provided. For example, a UE that sets up an eMBB session may require high bandwidth but can tolerate delay whereas a URLLC session requires low latency, low jitter and low error rates. Slice capabilities along the user plane path between the (R)AN and UPFs such as a low latency path, jitter, protection and priority need to be provided by the IP transport network. 3GPP core network entities may be deployed across multiple data centers and in such cases require the IP transport network to provide the resources and connectivity for each of the slice segments.

3.2. Fronthaul and Mid-Haul Transport Network

The O-RAN Alliance defined a lower layer split at the physical layer of the radio access network whereby the gNB-DU is split into two entities (O-RU and O-DU) and has specified the fronthaul interface between the O-RU and the O-DU in [ORAN-WG4.CUS-O-RAN]. The radio layer information, in the form of In-phase (I) and Quadrature (Q) samples are transported using ~~Enhanced-enhanced~~ Common Public Radio Interface

(eCPRI) framing over Ethernet or UDP. On an Ethernet based fronthaul interface, the network slice instance (NSI) information is carried in the Ethernet header through the VLAN tags and/or PCP marking. The Ethernet switches in the fronthaul transport network inspects the

slice information (VLAN tag and/or PCP marking) in the Ethernet header and provide the provisioned capabilities. The mapping of I and Q samples of different radio resources (radio resource blocks or carriers) to different slices and to their respective VLAN tags and or PCP marking on the fronthaul interface is controlled by the O-RAN fronthaul C-Plane and M-Plane interfaces. The fronthaul transport network is latency and jitter sensitive. The provisioned slice capabilities in the fronthaul transport network MUST take care of the latency and jitter budgets of the specific slice for the fronthaul interface. The provisioning of the fronthaul transport network is handled by the NC pertaining to the fronthaul transport. 3GPP functions gNB-CU (user plane) and gNB-DU may also be distributed and have a mid-haul transport between the two 3GPP network functions. If an IP based mid-haul interface is used, the network slice instance (NSI) information can be MPLS, SRv6 based as defined in [TS.28.541-3GPP]. However, if the 3GPP network function (slice customer) is physically separated from the slice provider network (e.g., a gNB-CU (user plane) with baseband units deployed in a data center), the MPLS, SRv6 information may not be practical to carry across to the separated IP transport network (slice provider). In this case, the source UDP port number of the GTP-U can be used to indicate the slice in the IP-transport network (slice provider).

3.3. Backhaul Transport Network

The backhaul transport over which the protocols for N3 and N9 interfaces run are described in [TS.23.501-3GPP] and [TS.23.502-3GPP]. The end-user (UE) sessions (IP, Ethernet, unstructured) are carried over GTP-U transport protocol over the N3 and N9 interfaces. GTP-U between the 3GPP network functions (gNB, UPF) serves as an overlay protocol across one or more MPLS, SRv6 or Ethernet transport networks in between. During UE session setup, a number of parameters for context management are configured in the gNB, UPF and that includes network slice (S-NSSAI). On an Ethernet based backhaul interface, the slice information is carried in the Ethernet header through the VLAN tags. If an IP based backhaul interface is used, the network slice instance (NSI) information can be MPLS, SRv6 based as defined in [TS.28.541-3GPP]. However, if the 3GPP network function (slice customer) is physically separated from the slice provider network (e.g., a gNB-CU (user plane) or UPF, or both are deployed in a data center), the MPLS, SRv6 information may not be practical to carry across to the separated IP transport network (slice provider). In this case, the source UDP port of the GTP-U can be used to indicate the slice in the IP transport network (slice provider).

3.4. Slice Mapping using UDP Source Port Number

Communication services offered by 3GPP-5G and the concepts used to provision and manage it are described in [TS.28.530-3GPP]. A brief overview is given here with the intent to describe how it is related to an IP transport slice and the mapping between it and the 3GPP slice. Communication services (e.g., an eMBB service) may be realized in a 3GPP network using one or more slices identified by NSSAI (Network Slice Selection Assistance Information) in the 3GPP control plane signaling. In the 3GPP management plane, the network slice identified by NSSAI is realized in a Network Slice Subnet

Commenté [MB16]: 3gpp does not offer these 😊

(NSS). For example, a slice S-NSSAI is available to a user at different locations (and even PLMNs) and maybe realized in an NSS at that a location. An NSS consists of sets of functions from 5GC and RAN that belong to the NSS. Network interfaces of functions in an NSS may be associated to one or more slice subnets. These relationships are illustrated in Figure 2. From the viewpoint of IP transport slicing and mapping to 3GPP slices, an IP transport network slice is associated to 3GPP core or RAN network functions in a 3GPP Network Slice Subnet (NSS). Thus, it can represent a slice of a transport path for a tenant between two 3GPP user plane functions.

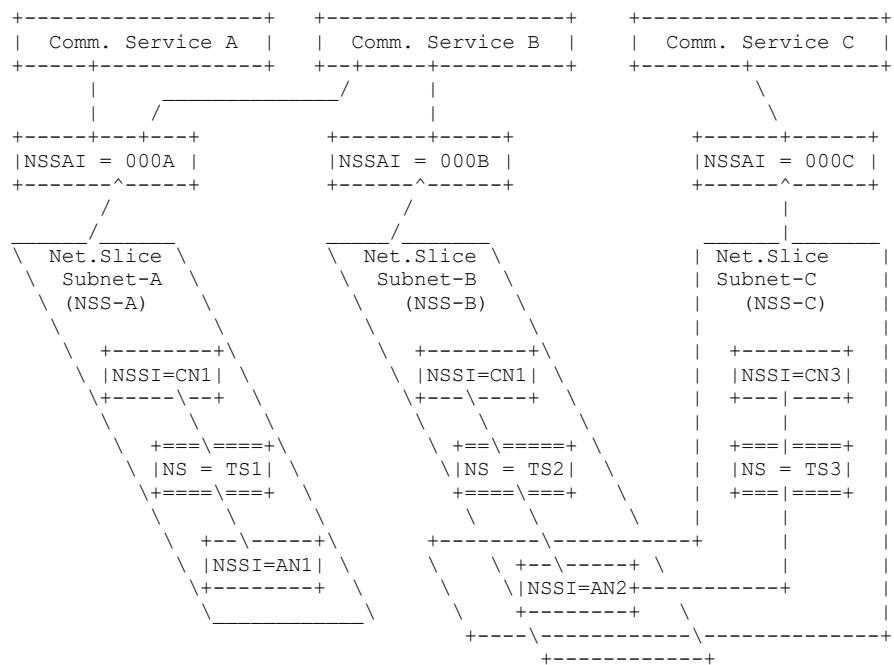
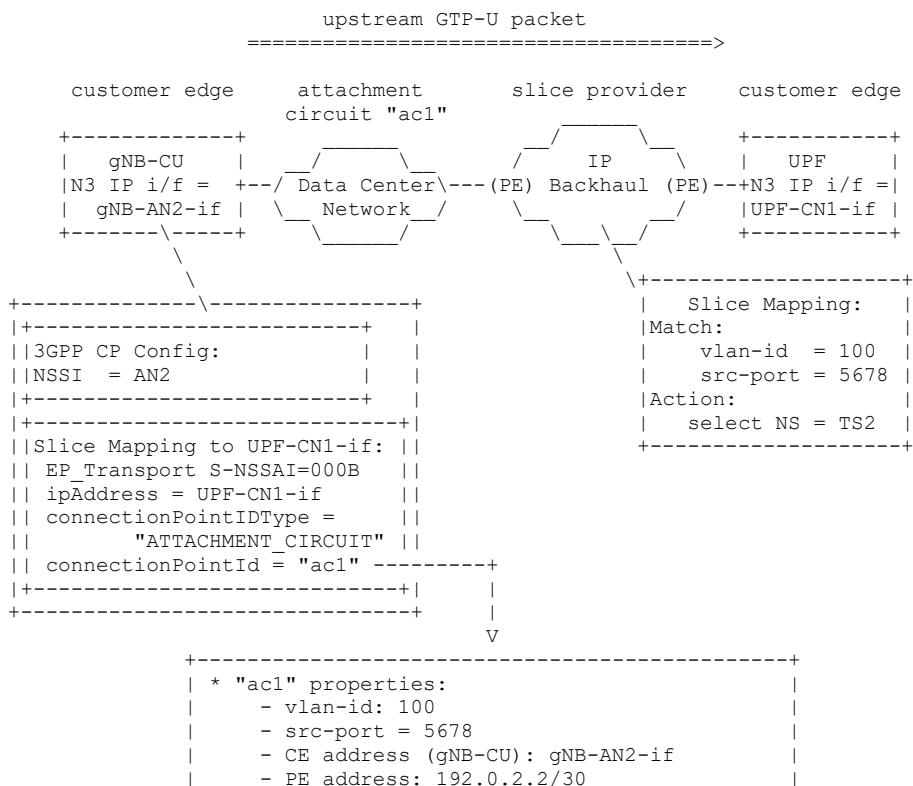


Figure 2: Slice Configuration

Figure 2 shows the slice hierarchy described in [TS.28.530-3GPP] with 3 communication services enhanced to show the IP transport slice instances (TS1, TS2, TS3). As an example, when a UE registers with 5GC with NSSAI 000A, 000B and others, the AMF may select NSSAI 000B in list of NSSAI allowed for the UE. One of the factors in selecting the NSSAI is whether the UE may move to another location during the lifetime of the session. In this case, the NSSAI should be such that it has a mapping to IP transport network slice during initial attach, and following handover. For example, a UE that attaches to 5GC with S-NSSAI = 000B and served by user plane instances CN1 and AN2 uses IP transport network slice NS = TS2 to provide the resources in the IP network that corresponds to the UE session. Following handover with S-NSSAI = 000B, the UE may be served by user plane instances CN1' and AN2' over an IP slice TS2' in the new location.

When ~~the-a~~ 3GPP user plane function (5G-AN, UPF) and IP transport provider edge PE are on different nodes or separated across a network, the PE router needs to have the means by which to classify the IP packet from 3GPP entity based on some header information. In [RFC9543] terminology, this is a scenario where there is an Attachment Circuit (AC) between the 3GPP entity (customer edge) and the SDP (Service Demarcation Point) in the IP transport network (provider edge). The Attachment Circuit (AC) may~~u~~ for example, be between a UPF in a data center to a (provider edge) router that serves as the service demarcation point for the transport network slice. The identification information is provisioned between the 5G provider and IP transport network and corresponding information should be carried in each IP packet on the F1-U, N3, N9 interface. For IP transport edge nodes to inspect the transport context information efficiently, it should be carried in an IP header field that is easy to inspect. It may be noted that the F1-U, N3 and N9 interfaces in 5GS are IP interfaces. This is illustrated in Figure 3.



```

|      - Routing: static 198.51.100.0/24 via      |
|          192.9.2.1 tag primary_UP_slice |
+-----+

```

Figure 3: Slice Mapping using UDP source port

Figure 3 shows the configuration and mapping applied to network instances in a 3GPP network slice subnet and corresponding IP transport network instances for sending an upstream GTP packet from gNB-CU (user plane) to UPF. The gNB-CU (user plane) function is in a data center (site 1) and separated from the IP transport slice provider by an attachment circuit ("acl" in [Figure 3](#)). The attachment circuit ("acl") is for an 'EP_Transport' configured as specified in [TS.28.541-3GPP] and realized using [I-D.ietf-opsawg-teas-attachment-circuit] and related extensions for GTP in Section 5.

In this example, a GTP-U packet at gNB-CU (user plane) is from a UE session with S-NSSAI = 000B (and thus associated to 3GPP and IP transport network instances in the figure for providing slice resources). Since the GTP-U packet belongs to a session with S-NSSAI = 000B, the gNB-CU (UP) maps it to UDP port 5678 in the GTP-U header (outer encapsulation source port) and uses VLAN ID 100 based on the slice mapping to EP_Transport and "acl" as shown in the figure. The GTP-U packet is forwarded by the data center network to the PE router at IP backhaul network. The PE matches on VLAN ID of GTP-U packet and IP source port to select the provisioned slice (NS = TS2). The GTP-U packet is then forwarded to the UPF. For a downstream GTP-U packet, the UPF customer edge may similarly be attached to a PE and have similar slice configuration and mapping (details are not shown in the figure).

PEs routers can thus be provisioned with a policy based on the source UDP port number (and other identifiers like VLAN) to the underlying transport path and then deliver the QoS/slice resource provisioned in the transport network. The source UDP port number that is encoded is the outer IP (corresponding to GTP-U header) while the inner IP packet (UE payload) is unaltered. The source UDP port number is encoded by the node that creates the GTP-U encapsulation and therefore, this mechanism has no impact on UDP checksum calculations.

3GPP network operators may use IPsec-IPsec gateways (SEG) to secure packets between two sites - for example over an F1-U, N3 or N9 segment. The IP network slice identifier in the GTP-U packet should be in the outer IP source port number even after IPsec-IPsec encryption for PE transport routers to inspect and provide the level of service provisioned. Tunnel mode - which is the case for SEG/IPSec gateways - adds an outer IP header in both AH (Authenticated Header) and ESP (Encapsulated Security Payload) modes. Mechanisms described in [I-D.xu-ipsecme-esp-in-udp-lb] may be used to encapsulate the ESP packet in UDP for better load balancing and this can also be used to preserve the UDP source port of GTP-U packet.

4. Transport Network Underlays

Traffic engineered underlay networks are an essential component to realize the slicing defined in this document. Transport networks should be able to realize midhaul, backhaul and control plane slices shown in Figure 1. This section outlines how GTP/UDP source ports are used to map to slice types. [RFC9543] (section 7) describes in more detail how a network slice can be realized over different transport network technologies including enhanced VPN, IP/MPLS and SR-TE.

An example with different user plane slice types and transport paths is shown in the figure. In this case with 3 different SSTs, 3 transport TE paths are setup. For uplink traffic, an underlying TE transport path may be from a gNB-CU to a UPF for example. A similar downlink path and underlying transport from UPF to gNB-CU is configured. The figure shows UDP port ranges, SST, transport path (in this example pseudowire/VPN) and transport path characteristics.

Commenté [MB17]: To be defined

GTP/UDP SRC PORT	SST	Transport Path	Transport Path
Range Xx - Xy	Info	Characteristics	
X1, X2(discrete values)	MIoT I _o E _T	PW ID/VPN info, TE-PATH-A	GBR (Guaranteed Bit Rate) Bandwidth: Bx Delay: Dx Jitter: Jx
Yx - Yy	URLLC (ultra-low latency)	PW ID/VPN info, TE-PATH-B	GBR with Delay Req. Bandwidth: By Delay: Dy Jitter: Jy
Zx - Zy			

Z1, Z2(discrete values)	EMBB (broadband)	PW ID/VPN info, TE-PATH-C	Non-GBR Bandwidth: Bx
-------------------------	------------------	---------------------------	-----------------------

Figure 4: Mapping of Transport Paths on F1-U/N3/N9

In some E2E scenarios, security is desired granularly in the underlying transport network. In such cases, there would be a need to have separate sub-ranges under each SST to provide the TE path in preserving the security characteristics. The UDP source Port-port range captured in Figure 4 would be sub-divided to maintain the TE path for the current SSTs with the security. The current solution doesn't provide any mandate on the UE traffic in selecting the type of security.

There are many possible transport network technologies that may be used to realize these slices. These are described in [RFC9543].

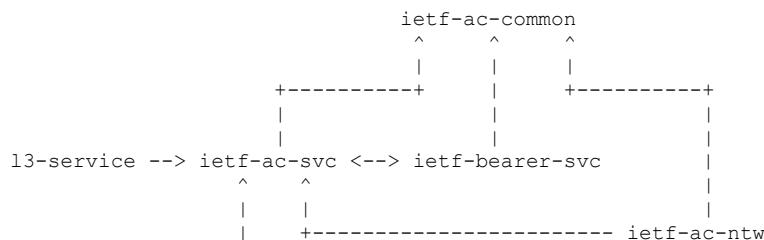
5. Attachment Circuit as a Service Extension for L3 Service

5.1. Attachment Circuit Extension

Section 3.4 provided an overview of how a GTP-U connection can be mapped using source address and port to an IETF transport slice service. The slice service in this case is provided by a PE (~~Provider Edge~~) of a transport network. To facilitate slice capabilities within a provider network, the attachment circuit is a means to bind the slice service that is previously agreed between the customer (i.e., 3GPP network) and provider (i.e., IP network provider). This section uses provisioning of attachment circuits described in [I-D.ietf-opsawg-teas-attachment-circuit] and extends it to support GTP.

The model for provisioning slices uses IETF Network Slice Service defined in [RFC9543].

The `ietf-ac-svc` module in [I-D.ietf-opsawg-teas-attachment-circuit] defines a set of reusable groupings that ~~is-are~~ used and extended in this document to compose an attachment circuit based on a GTP bearer as shown in Figure 5 ~~below~~.



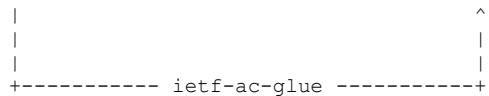


Figure 5: AC Data model extended for L3 Service

The "13-service" extends [ietf-ac-svc](#) as shown in [the figure](#)[Figure 5](#) and may be used for UDP tunnels including GTP-U and with [IPSee-IPsec](#) (ESP) with UDP encapsulation as in [I-D.xu-ipsecme-esp-in-udp-lb]. The 13 tunnel services defined here are general enough for other UDP encapsulations like GRE, VXLAN, GENEVE if the bearer is configured or setup with signaling as in GTP-U bearer establishment. This the 13-service module inherits other capabilities from [ietf-ac-servicesvc](#). Bearers are defined in [\[I-D.ietf-opsawg-teas-attachment-circuit\]](#) [ietf-ac-svc](#) based on mechanisms below layer 3.

This document however uses a GTP (layer 3) bearer ([TS.29.281-3GPP]) that is dynamically established by 3GPP signaling during initial session setup or following a mobility event. The 'l3-service' module is defined in Section 5.2.

The attachment circuit used by the PE (or SAP - Service Attachment Point) should allow a GTP-U encapsulated connection and its UDP source address/port to be used to bind it to the slice provided by the PE. The procedures to provision a service in the service provider network depends on the practice of the service provider. This includes the workflows for the provisioning of network services and how they are bound to an attachment circuit.

The YANG module extensions for "13-service" and "13-tunnel-service" is-are described described in Section 5.2.

5.2. Attachment Circuit Extension YANG ~~Mr~~modules

The overall tree structure of the AC service in [I-D.ietf-opsawg-teas-attachment-circuit] is extended to support attachment circuits that are encapsulated layer 3 such as GTP, GRE, and IPsec. The 13 nodes here are for GTP and the structure allows the possibility to extend in future for other 13 encapsulations.

```
+--rw specific-provisioning-profiles
    |
    |   ...
    |
    +--rw service-provisioning-profiles
    |
    |   ...
    |
    +--rw attachment-circuits
        |
        +--rw ac-group-profile* [name]
        |
        |   ...
        |
        +--rw placement-constraints
        |
        |   ...
        |
        +--rw ac* [name]
            |
            +...
            |
            +--rw l2-connection {ac-common:layer2-ac}?
```

```
| ...
+-rw ip-connection {ac-common:layer3-ac}?
| ...
+-rw 13-service
| ...
+-rw routing-protocols
| ...
+-rw oam
| ...
+-rw security
| ...
+-rw service
...
...
```

Commenté [MB18]: Should be positioned under ip-connection

Figure 6: Extended AC Service Tree—Tree with UDP Tunnel

The "13-service" and "13-tunnel-service" extension to attachment circuits structure in [I-D.ietf-opsawg-teas-attachment-circuit] is used to configure the relevant layer 3 tunnel properties of an AC. Both IPv4 and IPv6 properties for UDP encapsulation, source/destination address and port are supported. UDP encapsulation is supported in "13-tunnel-service" and includes GTP, IPsec, GRE, etc.

The "l3-service" and "l3-tunnel-service" tree structure for IPv4 is below.

```
| ...
+--rw ac* [name]
...
+--rw ip-connection {ac-common:layer3-ac}?
| ...
| +--rw (l3-service)?
|   +--:(l3-tunnel-service)
|     +--rw encapsulation? identityref
|       +--rw udp-v4tunnel {vpn-common:ipv4}?
|         +--rw ipv4-src-address?
|           |      inet: ipv4-address
|             +--rw (source-port)?
|               +--:(source-port-range-or-operator)
|                 +-- source-port-range-or-operator
|                   +-- (port-range-or-operator)?
|                     +--:(range)
|                       |      +-- lower-port      inet:port-
|                         |      +-- upper-port      inet:port-
|                           |      +--:(operator)
|                             +-- operator?      operator
|                               +-- port      inet:port-
|
|       +--rw (destination-port)?
|         +--:(destination-port-range-or-operator)
|           |      +-- destination-port-range-or-operator
|             |      +-- (port-range-or-operator)?
|               |      +--:(range)
|                 |      +-- lower-port      inet:port-
```

Commenté [MB19]: There is something broken here.

```

number      |      |      |      |  +-+ upper-port    inet:port-
           |      |      |      |  +-+: (operator)
           |      |      |      |  +-+ operator?    operator
           |      |      |      |  +-+ port        inet:port-
number      |      |      |      +-+rw udp-v6tunnel {vpn-common:ipv6}?
           |      |      |      |  ...
+-+rw oam
           |  ...
+-+rw security
           |  ...
+-+rw service
           ...

```

Figure 7: UDP Encapsulated IPv4 Tree Structure

The "13-service" and "13-tunnel-service" tree structure for IPv6 is below.

```

|  ...
+-+rw ac* [name]
  ...
  +-+rw ip-connection {ac-common:layer3-ac}?
  |  |...
  |  +-+rw (13-service)?
  |  |  +-+: (13-tunnel-service)
  |  |  |  +-+rw encapsulation?      identityref
  |  |  |  +-+rw udp-v4tunnel {vpn-common:ipv4}?
  |  |  |  |  ...
  |  |  |  +-+rw udp-v6tunnel {vpn-common:ipv6}?
  |  |  |  |  +-+rw ipv6-src-prefix?
  |  |  |  |  |  inet: ipv6-prefix
  |  |  |  |  +-+: (source-port-range-or-operator)
  |  |  |  |  |  +-+ source-port-range-or-operator
  |  |  |  |  |  |  +-+ (port-range-or-operator)?
  |  |  |  |  |  |  |  +-+: (range)
  |  |  |  |  |  |  |  +-+ lower-port    inet:port-
number      |  |  |  |  ...
number      |  |  |  |  |  +-+ upper-port    inet:port-
           |  |  |  |  |  +-+: (operator)
           |  |  |  |  |  +-+ operator?    operator
           |  |  |  |  |  +-+ port        inet:port-
number      |  |  |  |  ...
           |  |  |  |  |  +-+rw (destination-port)?
           |  |  |  |  |  +-+: (destination-port-range-or-operator)
           |  |  |  |  |  |  +-+ destination-port-range-or-operator
           |  |  |  |  |  |  |  +-+ (port-range-or-operator)?
           |  |  |  |  |  |  |  |  +-+: (range)
           |  |  |  |  |  |  |  |  +-+ lower-port    inet:port-
number      |  |  |  |  ...
number      |  |  |  |  |  +-+ upper-port    inet:port-
           |  |  |  |  |  +-+: (operator)
           |  |  |  |  |  +-+ operator?    operator
           |  |  |  |  |  +-+ port        inet:port-
number      |  |  |  |  ...

```

Commenté [MB20]: There is something broken here.

```
++-rw oam
| ...
++-rw security
| ...
++-rw service
...
```

Figure 8: UDP Encapsulated IPv6 Tree Structure

The UDP/IP encapsulation in l3-tunnel-service source address/port in this section is used for identifying 3GPP slice (customer) at the provider edge. In this document its use in GTP-U or IPSee-IPsec (ESP) with

UDP outer tunnel as in [I-D.xu-ipsecme-esp-in-udp-lb] is described in Section 3.4. The l3-tunnel-service maybe also be used for other encapsulations such as GRE, GENEVE, VXLAN and others but is not further described here.

6. Acknowledgements

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7. IANA Considerations

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

8. Security Considerations

This document does not introduce any new security issues.

Commenté [MB21]: You should at least refer to the sections of the key technologies used in the core document.

9. Contributing Authors

The following people contributed substantially to the content of this document and should be considered co-authors.

Praveen Muley
Nokia
440 North Bernardo Ave
Mountain View CA 94043
USA
Email: praveen.muley@nokia.com

Richard Li
Independent
Email: richard.li@seu.edu.cn

Xavier De Foy
InterDigital Communications, LLC
1000 Sherbrooke West
Montreal
Canada

Email: Xavier.Defoy@InterDigital.com

Reza Rokui
Ciena

Email: rrrokui@ciena.com