User Plane Protocol and Architectural Analysis on 3GPP 5G System

draft-hmm-dmm-5g-uplane-analysis-00

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Overview

- Motivation
  - Share IETF understanding on User Plane of 3GPP 5G System
  - Intend to be a part of the LS reply to User Plane Protocol Study in 3GPP

- Way to work
  - Analysis to clarify:
    - GTP-U specifications (TS29.281)
    - 5G architectural requirements (TS23.501, 502, 503, etc.,)
  - Try to derive evaluation aspects for candidate protocols

- Results
  - 13 observations on GTP-U and extract 6 requirements from 5G architecture
  - 7 evaluation aspects are derived
  - Find some potential gaps on the current UP protocol to the requirements

GTPv1-U Observation (1/2)

3.2.6. Observations Summary

[GTP-U-1]: A Point-to-Point tunneling protocol.

[GTP-U-2]: Supports Point-to-Multipoint tunneling.

[GTP-U-3]: Supports load balancing by using dynamic UDP port allocation.

[GTP-U-4]: Does not support UDP zero checksum in IPv6 transport case.

[GTP-U-5]: Does not support to response ICMP PTB for Path MTU Discovery.

[GTP-U-6]: Supports sequence number option and sequence number flag in the header, but it is not recommended to be used by almost GTP-U entities.

[GTP-U-7]: Supports carrying QoS Identifiers transparently for Access Networks in extension headers.

GTPv1-U Observation (2/2)

[GTP-U-8]: Supports DSCP marking based on the QFI.

[GTP-U-9]: Does not specify the rule for the extension header order.

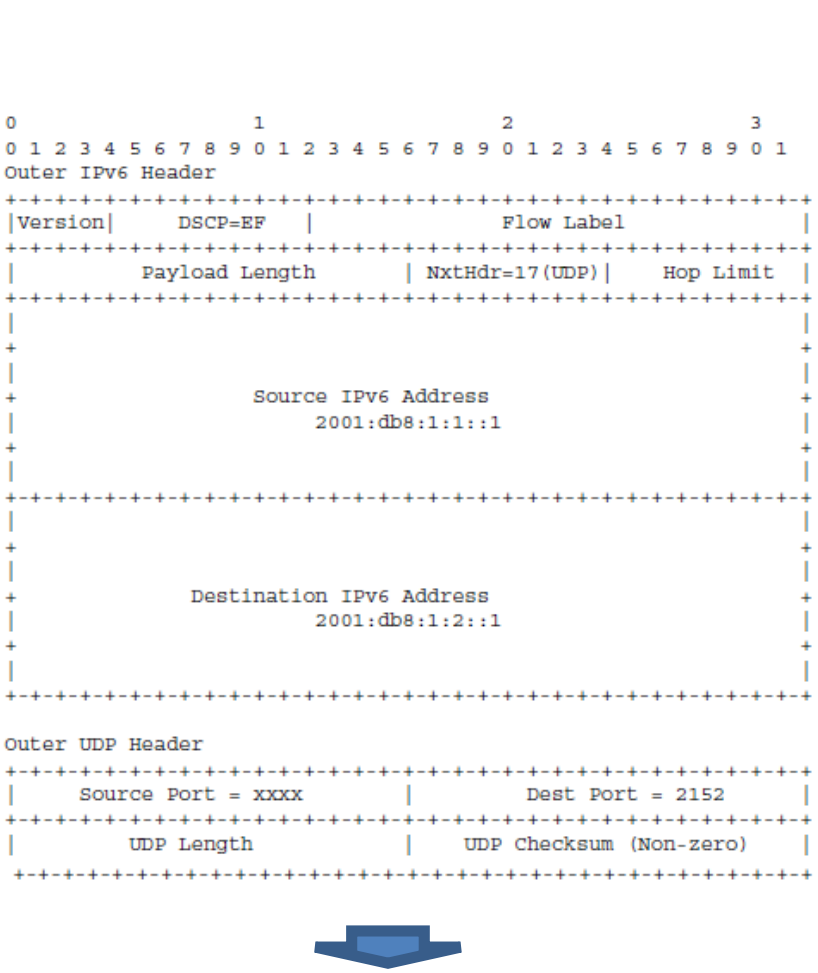
[GTP-U-10]: Does not support an indication of next-header type.

[GTP-U-11]: Supports active OAM as a path management message "Echo Request/Response".

[GTP-U-12]: Supports tunnel management messages "Error Indication".

[GTP-U-13]: Supports tunnel management messages "End Marker".

GTP-U Packet Format Illustration



Architectural Requirements (1/2)

ARCH-Req-1: Supporting IPv4, IPv6, Ethernet and Unstructured PDU

The 5G system defines four types of PDU session as IPv4, IPv6, Ethernet, and Unstructured. Therefore, UP protocol must support to convey all of these PDU session types. This is described in [TS.23.501-3GPP].

Note: In TS 23.501 v15.2.0, IPv4v6 is added as a PDU session type.

ARCH-Req-2: Supporting IP connectivity for N3, N6, and N9 interfaces

The 5G system requires IP connectivity for N3, N6, and N9 interfaces. The IP connectivity is assumed that it comprises of IP routing and L1/L2 transport networks which are outside of 3GPP specifications.

ARCH-Req-3: Supporting deployment of multiple UPFs as anchors for a single PDU session

The 5G system allows to deploy multiple UPFs as anchors for a single PDU session, and supports multihoming of a single PDU session for such anchor UPFs.

Architectural Requirements (2/2)

ARCH-Req-4: Supporting flexible UPF selection for PDU

The appropriate UPFs are selected for a PDU session based on parameters and information such as UPF's dynamic load or UE location information. Examples of parameters and information are described in the section 6.3.3 of [TS.23.501-3GPP].

ARCH-Req-5: No limitation for number of UPFs in a data path

The number of UPF in the data path is not constrained by 3GPP specifications. This specification is described in the section 8.3.1 of [TS.23.501-3GPP].

ARCH-Req-6: Supporting aggregation of multiple QoS Flow indicated with QFI into a PDU Session

Against to the previous generation, 5G enables UPF to multiplex QoS Flows, equivalent with IP-CAN bearers in the previous generation, into one single PDU session. That means that a single tunnel includes multiple QFIs contrast to just one QoS Flow (a bearer) to one tunnel before 5G. This specification is described in 5.7.1 of [TS.23.501-3GPP].

Evaluation Aspects

Supporting PDU Type	• Cover every PDU session types • Simplify management of the system
Nature of Data Path	• Support MP2P data path to reduce number of path states
Supporting Transport Variations	• Support PMTUD on UPF and dynamic PMTU size adjustment
Data Path Management	• Reduce data path management load on both UP and CP • Data path optimization
QoS Control	• QFI bits space in the ID in stable header place
Traffic Detection/Handling	• Reduce redundant flow detection load in UPFs • Enough ID space to indicated detected flow
Supporting Network Slice Diversity	• Indicate network slice in UP packet • Enough ID space to indicated slice

Feedback from the last 3GPP CT4 meeting

Feedback from 3GPP (1/2)

Sl.No	Section and Text From IETF draft-hmm-dmm-5g-uplane-analysis-00	Comment
1	Section 3.1 Figure 1 and Figure 2	This representation is not accurate. From 3GPP point of view the inner IPv4/IPv6 together with its upper layer data is called the PDU. See figure 8.3.1-1 of TS 23.501.
2	Section 3.1 [GTP-U-4]: UDP zero checksum is not available in case of IPv6 transport.	CT4 thanks IETF DMM for highlighting the availability of a later RFC 8200. While it is true that introducing support for UDP zero checksum with IPv6 underlying transport in later release of 3GPP may need to consider interoperability issues, CT4 would like to highlight that solutions for handling such issues can be identified by 3GPP CT4 (E.g Negotiation of UPF feature capabilities via control plane)
3	Section 3.1 [GTP-U-5]: GTP-U does not support to response ICMP PTB for Path MTU Discovery. "Unnecessary fragmentation should be avoided" is recommended and to avoid the fragmentation operator should configure MTU size at UE [TS.29.281-3GPP]. However, there's no reference and specification of Path MTU Discovery for IPv6 transport. If encapsulated IPv6 packet is too big on a network link between tunnel endpoint nodes, UE may not receive ICMPv6 Packet Too Big message and causes Path MTU Discovery black hole. and Section 5.3: The expected evaluation points from this aspect should be that the candidate protocols are able to dynamically adjust path MTU size with appropriate MTU size discovery mechanism. It also should be that how the candidate protocols leverage IPv6 to deal with header size increasing.	Clause 4.2.2 of 3GPP TS 29.281 states *Recommendations on how to set the default inner MTU size at the PDN GW and UE/MS to avoid IP fragmentation of both inner IP packets (in the PDN GW or UE/MS) and outer IP packets in the backbone are specified in clause 9.3 of 3GPP TS 23.060 [4].* And clause 9.3 of 3GPP TS 23.060 states *The PDP PDUs shall be routed and transferred between the MS and the GGSN or P-GW as N-PDUs. In order to avoid IP layer fragmentation between the MS and the GGSN or P-GW, the link MTU size in the MS should be set to the value provided by the network as a part of the IP configuration. The link MTU size for IPv4 is sent to the MS by including it in the PCO (see TS 24.008 [13]). The link MTU size for IPv6 is sent to the MS by including it in the IPv6 Router Advertisement message (see RFC 4861 [98]).* The MTU between RAN and the P-GW or UPF is discovered by offline means and the operator takes into account the MTU that is transferrable on the radio interface and based on this the operator configures the right MTU to be used. This is then signalled to the UE either via PCO (for IPv4 case) or the IPv6 RA message (for IPv6 case). **Hence for the uplink transfer the UE is aware of the link MTU (at least the recommended MTU for 3GPP link)**. See also Annex C of 3GPP TS 23.060 where link MTU considerations for the UE when GTPU tunnelling over IPv6 is done is explained.

4	[GTP-U-6]: Supports sequence number option and sequence number flag in the header, but it is not recommended to be used by most GTP-U entities.	In 3GPP, the in sequence delivery is required only during handover procedure. The in sequence delivery is used by the RAN entities only, to ensure to transmit packets in the correct order when forwarding packets from the source to the target. For other scenarios, the in sequence delivery is not needed as applicable protocol (as payload of GTP-U, e.g. TCP) address that.
5	Section 3.2 [GTP-U-8]: GTP-U supports DSCP marking based on the QFI. DSCP marking on outer IPv4 or IPv6 shall be set by sender tunnel endpoint node based on the QFI. This specification is described in section 4.4.1 of [TS.29.281-3GPP]. However in [TS.29.281-3GPP] "DSCP marking based on QCI" is specified but "DSCP marking based on QFI" has not been noted. To support QFI of 5G QoS framework, it seems to need to update [TS.29.281-3GPP].	CT4 thanks IETF DMM for this observation. CT4 has taken note of it and intends to update the specification accordingly. Also this is a system level feature and not a protocol level feature. This has been specified by SA2 but CT4 has not yet aligned the protocol change.
6	Section 3.2 [GTP-U-9]: GTP-U does not specify extension header order.	CT4 would like IETF DMM to kindly refer the following NOTE under Figure 5.2.1-3 of the latest 3GPP TS 29.281 (V15.3.0) as of June 2018 *NOTE 4: For a G-PDU with several Extension Headers, the PDU Session Container should be the first Extension Header.* Since the PDU Session Container has information that is essential for faster processing and forwarding of the data (e.g QFI), it is recommended to be included as the first extension header.
7	[GTP-U-10]: Does not support an indication of next-header type.	Since GTP-U is a tunnelling protocol and the entire payload of GTP-U is treated as a PDU to be transferred by the RAN to the UE (for downlink direction) or to be routed from PDU Session Anchor UPF to the DN (for uplink direction), there is no need for identifying the type of payload.
8	Section 4.2 ARCH-Req-5: No limitation for number of UPFs in a data path Putting multiple UPFs, which provides specific function, in a data path enables flexible function deployment to make sure load distribution optimizations, etc.	While it is true that 3GPP does not constrain the number of UPFs in a data path, CT4 would like to highlight to IETF DMM that all UPFs that are in the data path shall be controlled by an SMF and hence shall have an N4 interface.
9	Section 5.2 Supporting MP2P data path by GTP-U could be a gap in terms of single PDU session multi-homing, since GTP-U is a point-to-point tunneling protocol as it is described in Section 3.	CT4 would like to highlight IETF DMM that GTP-U allows the same F-TEID be used as the destination tunnel endpoint for tunnels from multiple sources. For example: 1. Even In EPC, in Tracking Area Update procedure with SGW change and data forwarding there is already a use case where the eNB exposes single FTEID for receiving downlink data from 2 source end points (new and old SGWs). See clause 5.3.3.1A of 3GPP

http://www.3gpp.org/ftp/tsg_ct/WG4_protocollars_ex-CN4/TSGCT4_85bis_Sophia_Antipolis/Docs/C4-185491.zip

Feedback from 3GPP (2/2)

		CT4 would like to highlight IETF DMM that The support for using the same FTEID as destination FTEID also applies for 5G as given below in the 5G use cases. 2. Dual connectivity in 5G system where the Master and Slave gNB can use the same uplink FTEID of the UPF for uplink traffic of the same PDU session. 3. For the IPv6 multihoming case, the downlink traffic from multiple PDU Session Anchors of the same PDU session may use the same N9 F-TEID of the branching point UPF. CT4 intends to clarify these aspects in 3GPP TS 29.281.
10	Section 5.6 As similar with QoS flow lookup described in Section 5.5, UPFs along the path are repeatedly detecting an specified traffic flow in inner PDU. It could increase redundant flow detection load on every UPFs that could be avoided if the upstream UPF put some identifier which abstracts the detected flow into the packets. It enables following UPFs just find the ID to detect the indicated flow from the packet.	CT4 would like to highlight that there is no requirement in 3GPP to do repeated inner packet based classification in every UPF along the packet path of a PDU session. PDU based classification happens at PSA UPF. Intermediate UPFs operate based on TEIDs and QFI which is assumed to exist in the first extension header, as they are required to only forward the packets.
11	Section 5.7 That's just one way for network slicing, but it helps to reduce the operational burden while there's no 3GPP specification for slice lifecycle managements, such as create, update, and delete operations for slices.	CT4 would like to point out the following 3GPP specifications that specify slice lifecycle management a. 3GPP TS 28.530 - Management and orchestration of networks and network slicing; Concepts, use cases and requirements b. 3GPP TS 28.531 - Management and orchestration of networks and network slicing; Provisioning; Stage 1 c. 3GPP TS 28.532 - Management and orchestration of networks and network slicing; Provisioning; Stage 2 and stage 3 d. 3GPP TS 28.533 - Management and orchestration of networks and network slicing; Management and orchestration architecture

http://www.3gpp.org/ftp/tsg_ct/WG4_protocollars_ex-CN4/TSGCT4_85bis_Sophia_Antipolis/Docs/C4-185491.zip

QFI now be in the first extension header

~ V15.2.0 of TS29.281 GTP-U (~2018/03)

Next Extension Header Field Value	Type of Extension Header
0000 0000	No more extension headers
0000 0001	Reserved - Control Plane only.
0000 0010	Reserved - Control Plane only.
0010 0000	Service Class Indicator
0100 0000	UDP Port. Provides the UDP Source Port of the triggering message.
1000 0001	RAN Container
1000 0010	Long PDCP PDU Number
1000 0011	Xw RAN Container
1000 0100	NR RAN Container
1000 0101	PDU Session Container
1100 0000	PDCP PDU Number [4]-[5]. See NOTE 1.
1100 0001	Reserved - Control Plane only.
1100 0010	Reserved - Control Plane only.

NOTE 1: As an exception to the comprehension rule specified above, for a G-PDU with a Next Extension Header Field set to the value "1100 0000", the SGW shall consider this corresponding extension header as 'comprehension not required'.

Figure 5.2.1-3: Definition of Extension Header Type

V15.**3**.0 of TS29.281 GTP-U (2018/06)

Next Extension Header Field Value	Type of Extension Header
0000 0000	No more extension headers
0000 0001	Reserved - Control Plane only.
0000 0010	Reserved - Control Plane only.
0000 0011	Long PDCP PDU Number. See NOTE 2.
0010 0000	Service Class Indicator
0100 0000	UDP Port. Provides the UDP Source Port of the triggering message.
1000 0001	RAN Container
1000 0010	Long PDCP PDU Number. See NOTE 3.
1000 0011	Xw RAN Container
1000 0100	NR RAN Container
1000 0101	PDU Session Container. See NOTE 4.
1100 0000	PDCP PDU Number [4]-[5]. See NOTE 1.
1100 0001	Reserved - Control Plane only.
1100 0010	Reserved - Control Plane only.

NOTE 1: As an exception to the comprehension rule specified above, for a G-PDU with a Next Extension Header Field set to the value "1100 0000", the SGW shall consider this corresponding extension header as 'comprehension not required'.

NOTE 2: This value shall be used by a source eNB or gNB complying with this release of the specification.

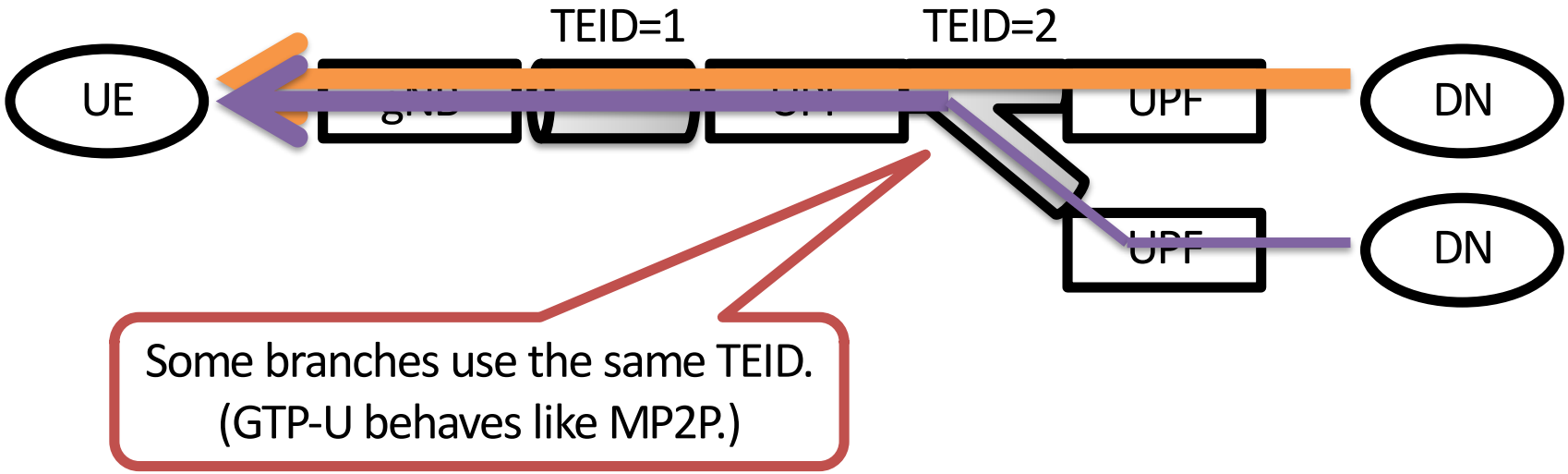
NOTE 3: This value shall not be used by a source eNB or gNB complying with this release of the specification. It may be received from a source eNB complying with an earlier release of the specification, i.e. not

NOTE 4: For a G-PDU with several Extension Headers, the PDU Session Container should be the first Extension Header.

Figure 5.2.1-3: Definition of Extension Header Type

Implementation of GTP-U in 3GPP

- TS29.281 defines GTP-U is P2P tunneling protocol.
- In some cases, GTP-U allows the same F-TEID be used as the destination tunnel endpoint for tunnels from multiple sources.



Next Step

- Reflect feedbacks from 3GPP and blush up the contents
- Be a part of the LS reply
- Should be a WG document after more discussion?

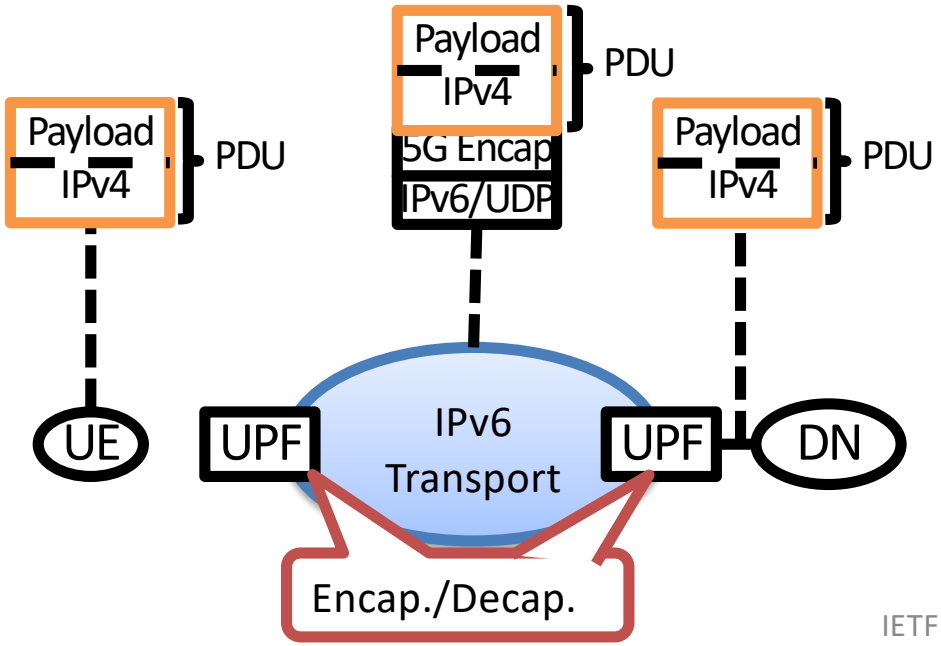
Thank you

Appendix

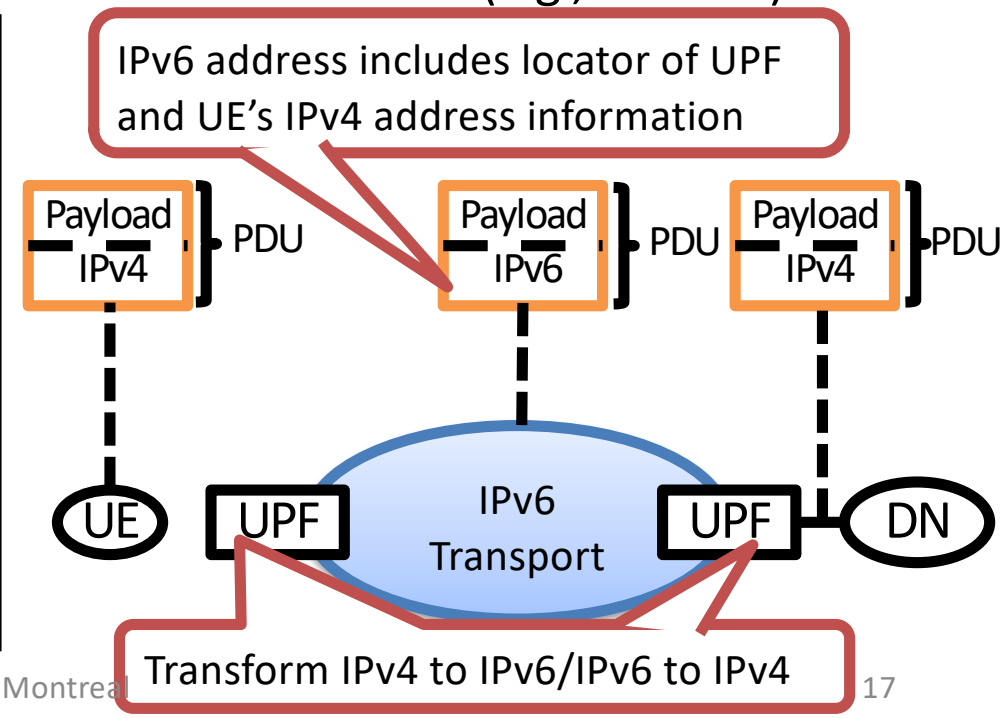
Evaluation Aspects 1

- Supporting PDU Session Types
  - To cover each PDU session type
  - To simplify management of the system

◆ Encap. Pattern (e.g., GTP-U, MAP-E)



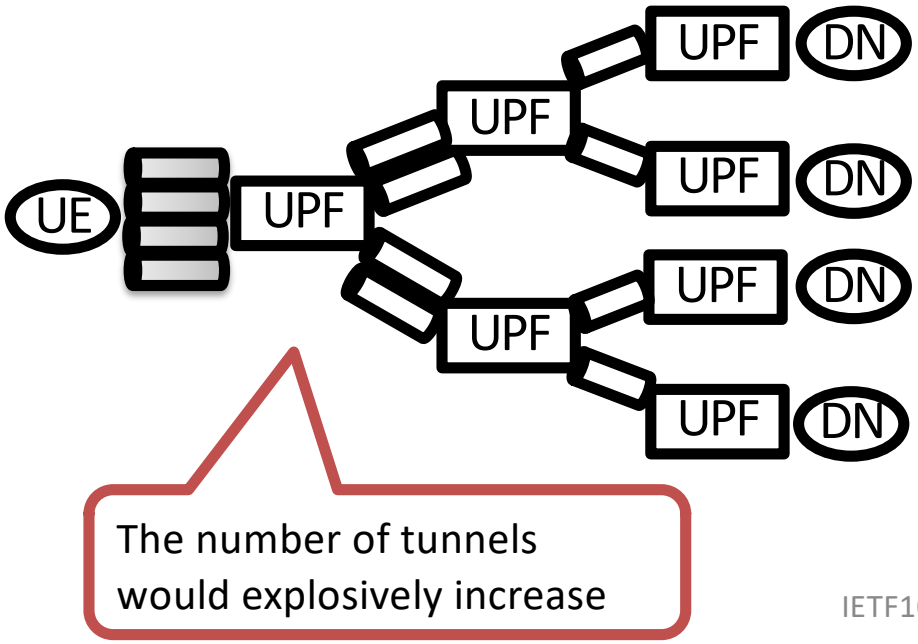
◆ Transform Pattern (e.g., 464xLAT)



Evaluation Aspects 2

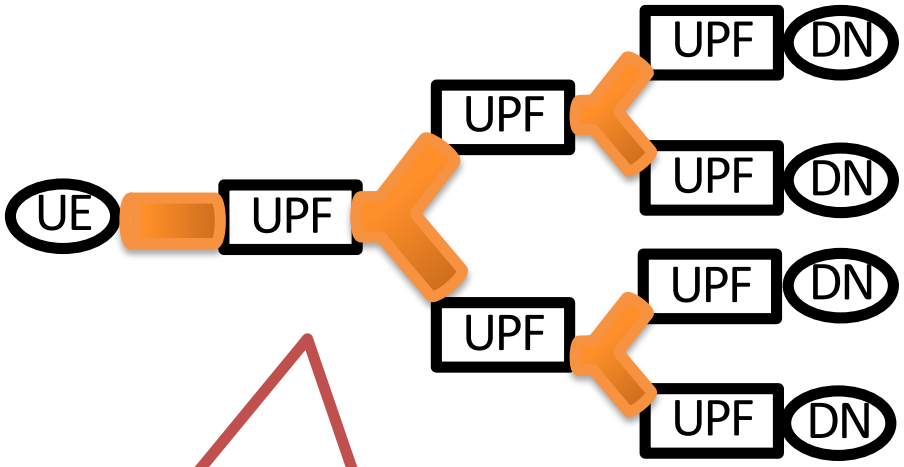
- Nature of Data Path
  - Need to utilize MP2P data-path to meet the requirement for single PDU session multi-homing in DL
  - Could work to reducing the number of data paths on multi-homing

◆ P2P Tunneling



The number of tunnels would explosively increase

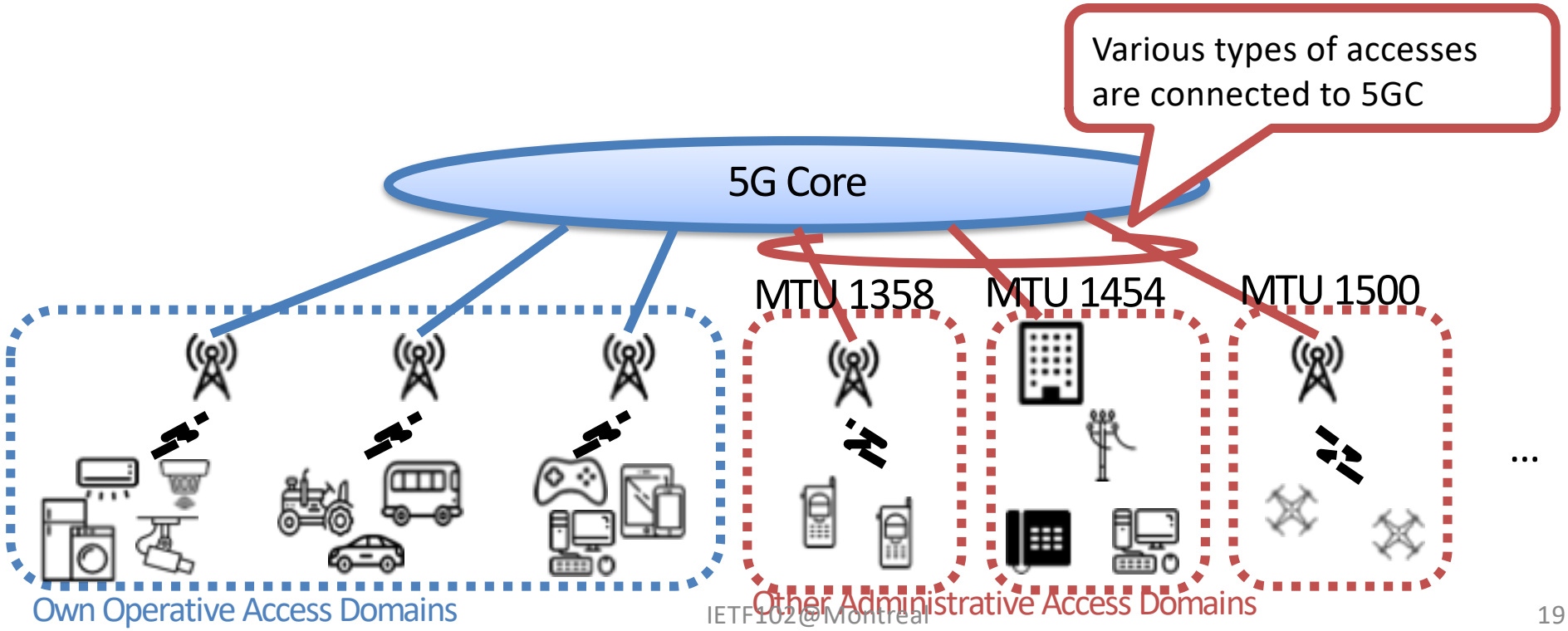
◆ MP2P Tunneling



MP2P tunneling enables to reduce the numbers of tunnels

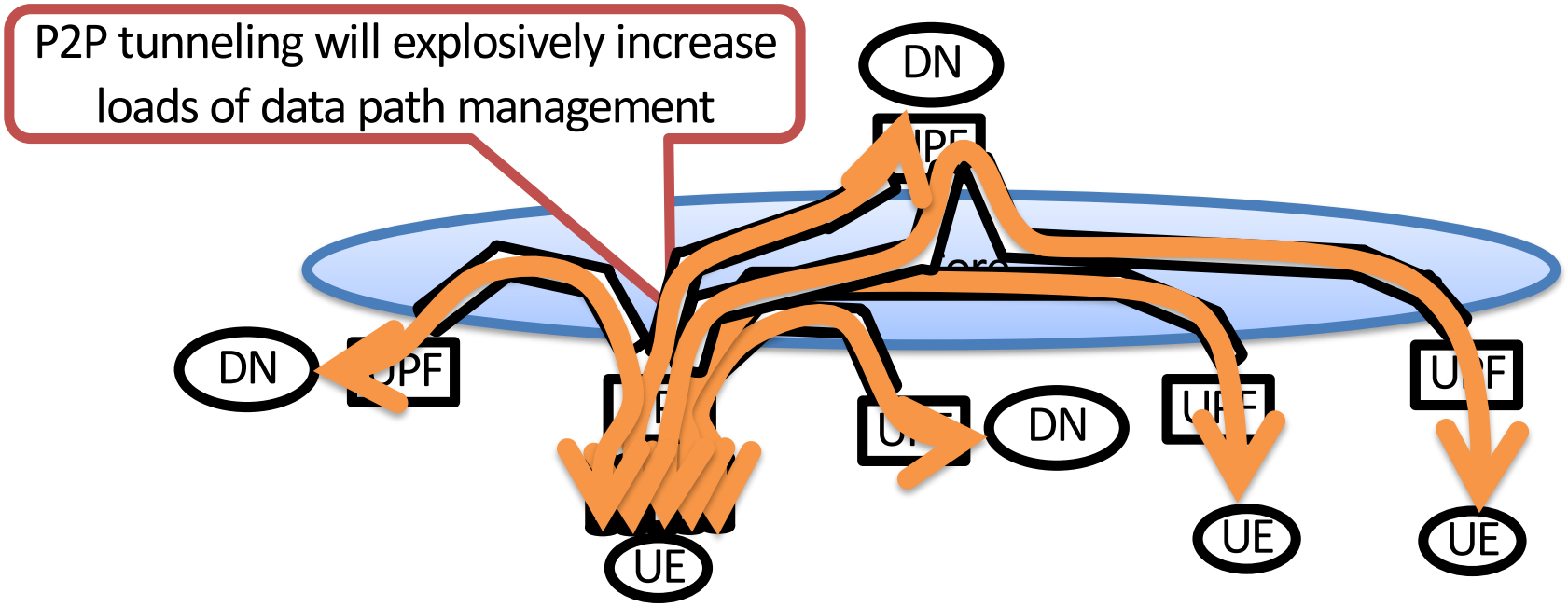
Evaluation Aspects 3

- Supporting Transport Variations
  - To dynamically adjust path MTU size with MTU size discovery mechanism
  - To leverage IPv6 to deal with header size increasing



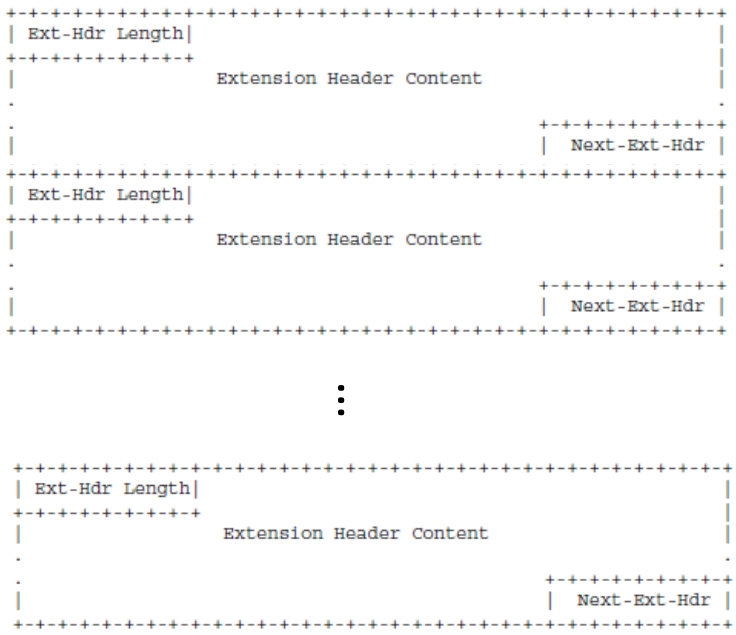
Evaluation Aspects 4

- Data Path Management
  - The amount of loads of data-path management on CP-NFs and UPFs to be reduced
  - To optimize UP data-path



Evaluation Aspects 5

- QoS Control
  - To provide ID space for QFI (6-bits space)
  - The place of QFI is fixed

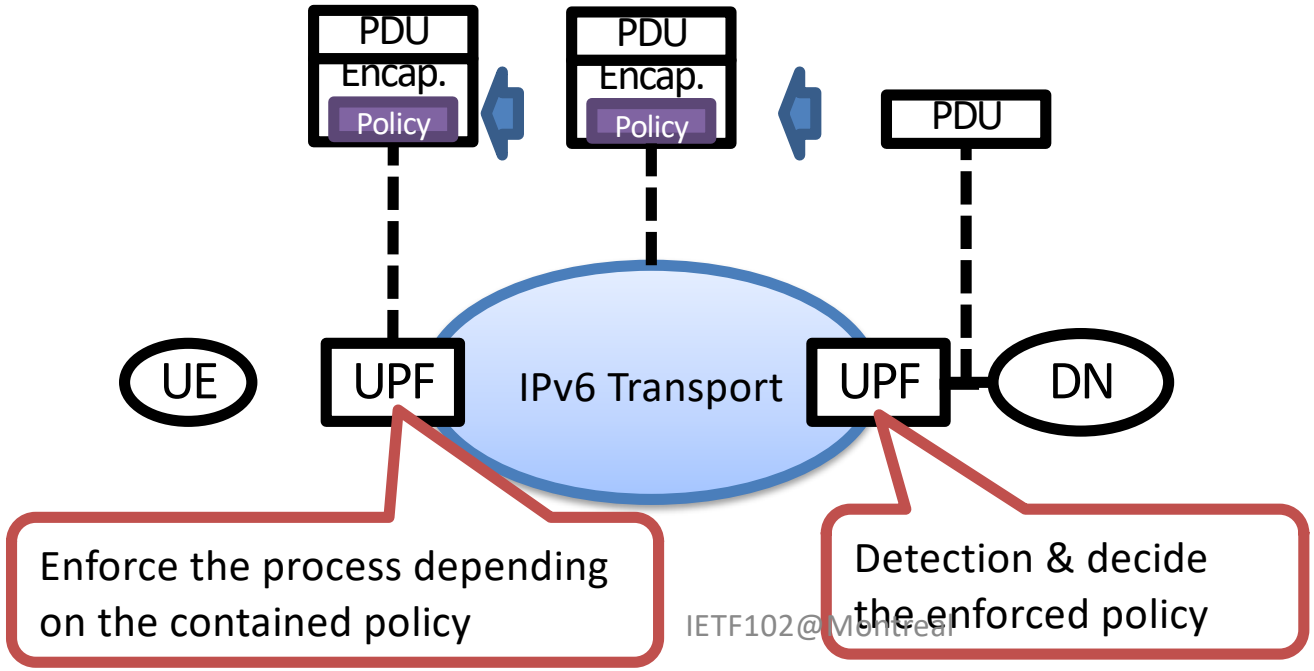


Which contains QFI?

GTP-U specification doesn't define the order of extension header containing QFI.
=> This may cause reduction of hardware performance

Evaluation Aspects 6

- Traffic Detection and Flow Handling
  - To reduce flow detection processes
    i.g., Containing identifier in enough bits space on stable ID space



Evaluation Aspects 7

- Supporting Network Slicing
  - To indicate the assigned slice in the UP packets
    i.g., Containing slice identifier or forwarding policy in enough bit space on stable ID space