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March 18, 2018

Co-existence of 3GPP 5GS and Identifier Locator Separation Solution
draft-homma-dmm-5gs-id-loc-coexistence-00

Abstract

This document describes an approach to introduce Identifier Locator Separation solution into 3GPP 5GS with low-impact on its specification, and shows the features and considerations of this approach.

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1. Introduction

Identifier Locator Separation (ID-LOC) solutions, including LISP, ILA, ILNP, etc, are technologies that provide new numbering spaces, identifier of end point and locator for routing, within IP framework and enables to make management of networks, devices, or sessions be easier. ID-LOC solutions are also expected to be used for optimizing user-plane of mobile netowrk [I-D.bogineni-dmm-optimized-mobile-user-plane], and ways to introduce ID-LOC systems into the next generation mobile network, especially it often indicates 3GPP 5GS (5th Generation System), are considered in the related IETF WGs.

On the other hand, the discussion of the architecture of 5GS Rel.15 including NG-RAN and 5GC (5th Generation Core) was completed on December 2017, and thus it would be difficult to push an ID-LOC

solution that requires major changes of the architecture or specifications. From this reason, an approach that enables to introduce an ID-LOC mechanism into 5GS without change of its specifications and to support migration into ID-LOC native network would be required. Here, ID-LOC native network means a network which functionalities of ID-LOC mechanism are integrated into as a fundamental forwarding mechanism.

The goal of this document is providing one of such approaches and clarifying the features and benefits.

2. Definition of Terms

As a matter of convenience, this document uses the definitions of LISP (Locator Identifier Separation Protocol) to express functionalities regarding ID-LOC systems. The detailed specifications of LISP are described in [RFC6830], [RFC6831], [RFC6832], [RFC6833], [RFC6836], [RFC7215], [RFC8061], and [RFC8111]. Moreover, definitions and specifications of another approach to introduce LISP into 3GPP 5GS is described in [I-D.farinacci-lisp-mobile-network].

This document also referes definitions of 3GPP 5GS [TS.23.501-3GPP]. Some of such terms which are used in this document are listed in this section.

2.1. Terms of LISP

Ingress/Egress Tunnel Router (xTR): An xTR is a LISP node that has both Ingress Tunnel Router (ITR) and Egress Tunnel Router (ETR) functionalities. An ITR is a router which forwards packets to the ETR, which is assigned the appropriate RLOC, with some encapsulation (such as LISP header) depending on the result of EID-to-RLOC mapping. An ETR is a router and it has an RLOC. An ETR strips the encapsulation attached by an ITR and forwards packets depending on their EIDs. An xTR has interface to EID-to-RLOC mapping system.

Endpoint Identifier (EID): An EID is an identifier of end point such as UE or VM instance. An EID is a 32-bit (for IPv4) or 128-bit (for IPv6) value used in the source and destination IP address fields of an IP packet sent from an UE or a VM instance.

Routing Locator (RLOC): An RLOC is an IPv4 or IPv6 address of an xTR (ETR).

Mapping System: A Mapping System is a system which stores EID-to-RLOC mapping database. This system uses Map-Register, Map-

Request, Map-Reply, and Map-Notify messages from xTRs to talk to Map-Resolvers and Map-Servers that make up the Mapping System. More details are described in [RFC6833].

EID-to-RLOC Cache: The EID-to-RLOC Cache is a short-lived, ondemand table in an xTR (ITR) that stores, tracks, and is responsible for timing out and otherwise validating EID-to-RLOC mappings.

EID-to-RLOC Database: The EID-to-RLOC Database is a global distributed database that contains all known EID-to-RLOC mappings. Each xTR (ETR) typically contains a small piece of the database. In this document, each Mapping System has full of the database.

2.2. Terms of 5GS

User Plane Function (UPF): An UPF handles the user plane paths. An UPF is connected to SMF with N4 interface. More detailed information is described in [TS.23.501-3GPP]. This document defines two types of UPF, Central UPF (cUPF) and Distributed UPF (dUPF). Their features are described in Section 3

Uplink Classifier (ULCL): An ULCL is an UPF functionality that aims at diverting Uplink traffic, based on filter rules provided by SMF, towards Data Network (DN).

Data Network (DN): A DN is a network where network functions and entities, including operator or 3rd party services, are deployed. This document defines two types of DN, Central DN (cDN) and Distributed DN (dDN). Their features are described in Section 3.

Radio Access Network (RAN): A RAN is an access network where radio baarer sent by UEs traverse. A RAN encupsulate users' packets with GTP-U.

Session Management Function (SMF): An SMF is a function which provides control plane functionalities for handling user traffic.

Application Function (AF): An AF is a control plane functionality and connected to SMF with Naf interfaces.

3. Mechanism on Data Plane

This approach achieves traffic forwarding with optimized path and session continuity by using ID-LOC and ULCL for particular communication including UE-2-UE or MEC (Mobile Edge Computing) communication. ULCL is one of fundamental functions of 5GC Rel.15 and it provides functionalities of packet filtering and divert for uplink packets sent by UEs.

The overview of the assumed 5GC architecture of data plane where the proposal approach works is shown in Figure 1. The details of numbered interfaces in the figure are described in [TS.23.501-3GPP].

```
                             .--.
                            (    )-.
                          .'  cDN/  '
                         (  Internet )
                          (         -'
                           '-(     )
                              '---'
                                |N6
                          +-----+-----+
                          |   cUPF    |                           ===
                          +-----+-----+                            ^
                                |N9                                |
        ,-----------------------+-----------------------.          |
       /                                                 \         |
       |              Transport Network                  |         |
       \                                                 /         |
        `----+---------------------------+--------------'          |
             |N9                         |N9                   Connected
       +-----+-----+    ,-----.    +-----+-----+    ,-----.       with
       |   dUPF#1  |N6 /       \   |   dUPF#2  |N6 /       \     GTP-U
       |       [UL]+---| dDN#A |   |       [UL]+---| dDN#B |..
       |       [CL]|   \       /   |       [CL]|   \       /       |
       +-----+-----+    `-----'    +-----+-----+    `-----'        |
             |N3                         |N3                       |
                                                                   |
          (( o ))                     (( o ))                      |
             A                           A                         v
            /-\  RAN                    /-\  RAN                  ===
           /-|-\                       /-|-\

             |                           |

          [ UE ] ..                   [ UE ] ..


                                                dUPF: Distributed UPF
                                                cUPF: Central UPF
                                                 dDN: Distributed DN
                                                 cDN: Central DN
```

Figure 1: Assumed 5GC Network Architecture

This network has following features;

- A Central UPF (cUPF) is deployed at a connecting point to Central DN (cDN). A cUPF becomes anchor point for UEs and it assigns IP addresses for each UE. The traffic transmitted from UEs are basically sent to the cUPF.

- Distributed UPFs (dUPFs) and Distributed DNs (dDNs) are deployed and geographically distributed at user edge side. A unique address space (it's not necessarily globally unique) is assigned to dDN. When a dUPF forwards an UE's uplink packet, and if the subnet of the destination address is the same as the one assigned to dDN at proximity, then dUPF, with the help of ULCL, may divert the packet to that dDN. Here, the ULCL identifies each encapsulated uplink packet to be diverted, by checking if the destination of the inner packet is one of IP addresses assigned the dDN. A dUPF removes GTP-U header from the packets, and sends them to dDN via N6. When dUPF receives packets from dDN, dUPF encapsulates them with GTP-U header, and merges them into downlink packets from cUPF. An overview of behaviors of dUPF and ULCL is shown in Figure 2.

- Network topology between RAN and dUPF/cUPF adopts tree structure and the section between RAN and dUPF and the section between dUPF and cUPF are connected with GTP-U.

```
         GTP-U packets    GTP-U packets
          from cUPF        to cUPF

               |            ^
               |     N9     |
               |            |
          +----|------------|-----+
          |    |    dUPF    |     |           ,---------.
          |    v            |     | IP packet /           \
          |    o<-----------------------------|           |
          |    |            |     |           |           |
          |    |            |     |    N6     |   dDN     |
          |    |        +------+  |           |           |
          |    |        | ULCL |------------->|           |
          |    |        +------+  | IP packet |           |
          |    |            ^     |           \           /
          +----|------------|-----+            `---------'
               |            |
               |            |
               |    N3      |
               v            |

         GTP-U packets   GTP-U packets
          to UE           from UE
```

Figure 2: Behaviors of dUPF and ULCL

In the proposal approach, an xTR is installed between dUPF and dDN. xTRs are connected with a tunneling protocol (it may be LISP header or other protocol such as SRv6 [I-D.ietf-6man-segment-routing-header]) and each xTR has connectivity with one or more Mapping Systems. The overview is shown in Figure 3.

```
                             .--.
                            (    )-.
                          .'  cDN/  '
                         (  Internet )
                          (         -'
                           '-(     )
                              '---'
                                |N6         ,---------.
                          +-----+-----+     | Mapping |
                          |   cUPF    |     | System  |
                          +-----+-----+     `---------'
                                |N9              .
        ,-----------------------+----------------.---------.
       / Transport Network   . . . . . . . . . . . . . . .  \
       |                     .                           .  |
       \                  #===========================#===  /
        `----+------------#--.-----------+------------#--.-'
             |N9          #  .           |N9          #  .
       +-----+-----+   +-------+   +-----+-----+   +-------+
       |   dUPF#1  |N6 |       |   |   dUPF#2  |N6 |       |
       |       [UL]+---+ xTR#1 |   |       [UL]+---| xTR#2 |..
       |       [CL]|   |       |   |       [CL]|   |       |
       +-----+-----+   +---+---+   +-----+-----+   +---+---+
             |N3           |             |N3           |
                        ,-----.                     ,-----.
          (( o ))      /       \      (( o ))      /       \
             A         | dDN#A |         A         | dDN#B |
            /-\  RAN   \       /        /-\  RAN   \       /
           /-|-\        `-----'        /-|-\        `-----'

             |                           |

          [ UE ] ..                   [ UE ] ..


                                      =====  : Tunnel connects xTRs
                                      . . .  : IF to Mapping System
```

Figure 3: Proposal Network Architecture

Each dUPF has a filter table of ULCL. Each filter table is configured to mach addresses assigned within own network domain (i.e., addresses for UEs assigned by cUPF) or assigned corresponding with address space of some of dDN. UPFs monitor each uplink GTP-U packet with its ULCL and divert it to the connected xTR with decapsulation if the destination address of the inner packet matches the table. When xTR receives a packet from the dUPF, it obtains RLOC

which the destination of the packet (EID) belongs to by looking up its own EID-to-RLOC mapping cache or querying it from the Mapping System according ID-LOC mechanism. Then it sends the packet to peered xTR indicated by the RLOC.

The detailed processing flow with LISP below as an example. In this example, a Mapping System obtains location of each UE from SMF and keeps its own EID-to-RLOC mapping database up to date. Each xTR obtains EID-to-RLOC map information which isn't stored in the cache by sending Map-Request to a Mapping System.

1. xTR (source xTR) receives a packet and identify the EID.

2. The source xTR looks up the EID from its own EID-to-RLOC mapping cache.

3. If there is an entry which matches to the EID, the source xTR sends the packet to the destination indicated by the RLOC of the entry.

4. If there are no entries matches to the EID, xTR sends a request mapping information of the EID (Map-Request) to the Mapping System depending on its own forwarding table.

5. Mapping System receives the request and detect the RLOC which the EID is allocated from its own EID-to-RLOC mapping database.

6. Mapping System sends the request to the xTR assigned the RLOC (peered xTR).

7. The peered xTR recieves the request and registers the EID and RLOC, and sends a reply (Map-reply) to the source xTR.

8. The source xTR receives the reply and register the opponent xTR into own EID-to-RLOC mapping cache.

9. If the peered xTR is the same as Source xTR itself, the source xTR sends the packet to either dDN or dUPF according to the destination of the packets. Otherwise, the source xTR sends the packet to the peered xTR with necessary encapsulation.

10. When an xTR receives packets from other xTRs, it sends them with decapsulation to the appropriate destinations depending on its forwarding table.

From the above processes, forwarding paths of user traffic diverted by ULCL from 5GC to xTR are optimized without changing their IP address (EID).

Further case studies are described in Appendix A.

4. Mechanisms on Control Plane

For ID-LOC mechanism in mobile networks, a control plane mechanism to manage location information of UEs is required. There are mainly three patterns to realize control plane mechanism for ID-LOC as follows:

Pattern 1: Completely Separating

Pattern 2: Interworking with Mapping System as AF

Pattern 3: Conversing SMF to Mapping System

Some of patterns may require to use 5GS interfaces or add some functionalities to functions of 5GC. 5GS architecture and the service-based interfaces are shown in Figure 4. The details of functions and interfaces are described in [TS.23.501-3GPP].

```
      +-----+  +-----+  +-----+     +-----+  +-----+  +-----+
      |NSSF |  | NEF |  | NRF |     | PCF |  | UDM |  | AF  |
      +--+--+  +--+--+  +--+--+     +--+--+  +--+--+  +--+--+
    Nnssf|    Nnef|    Nnrf|       Npcf|    Nudm|        |Naf
      ---+--------+--+-----+--+--------+--+-----+--------+-
                Nausf|    Namf|       Nsmf|
                  +--+--+  +--+--+     +--+--+
                  |AUSR |  | AMF |     | SMF |
                  +-----+  +--+--+     +-----+
                             /|           |
   C-plane                N1/ |N2         |N4

   ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
   D-plane               /    |           |
                     N1 /     |N2         |N4
                       /      |           |
                    +-+-+  +--+--+ N3  +--+--+ N6   +----+
                    |UE +--+(R)AN+-----+ UPF +-----+ DN |
                    +----+ +-----+     +-----+     +----+
```

Figure 4: 5GS Architecture and Service-based Interfaces

4.1. Pattern 1: Completely Separating

In this pattern, control plane of 5GC and EID-to-RLOC mapping mechanism are completely separated. Information of an UE and an xTR which the UE is attached is sent to a Mapping System and registered in the mapping database only when the xTR receives a packet from the UE and the UE is not registered yet.

This pattern does not cause any impacts on 5GC architecture. However, in this pattern, an UE cannot be accessed from other UEs within the same network domain until a packet from the UE is diverted to the xTR by the UPF which the UE is located and the EID and RLOC are registered to the Mapping System.

4.2. Pattern 2: Interworking with Mapping System as AF

In this pattern, a Mapping System interworks with an SMF which manages sessions of each UE. A scheme to inform, that an UE moves and is relocated to another UPF, from SMF to AF via Naf interface is defined in 5GS ([TS.23.502-3GPP])*. A Mapping System is installed as an AF and obtains mobility information of UEs with the above scheme.

* The stage 3 of discussion of 5GS has not been fixed yet and the specification may be changed.

This pattern would not cause any impacts on 5GS architecture, and a Mapping System can always keep the current mobility information of each UE.

4.3. Pattern 3: Conversing SMF to Mapping System

In this pattern, a Mapping System has functionalities of SMF and acts as a part of 5GS. In 5GS architecture, an SMF has a role of session management of UEs, and it updates its own mapping database depending on movement of an UE.

This approach enables to always keep mapping databases the latest status, however, it obviously requires extension or replacement of SMF actually deployed in 5GS network.

5. Features Analysis

5.1. Benefits

o This approach enables to introduce ID-LOC mechanism into 5GC Rel.15 without any impact, and achieves optimized forwarding with session continuity in the assumed use cases such as UE-2-UE or UE-2-dDN communications.

o Regarding communication to the cDN, this approach can keep scalability because it does not change the current mechanism of 5GS. (ID-LOC-native network or full-overlay approaches need to deploy xTR at the cUPF, and thus the EID-to-RLOC mapping cache may not scale up enough in that cases. Here, a full-overlay approach means making an ID-LOC system run over the whole 5GC network.)

5.2. Issues

o dUPF and xTR are separated, and thus an extra hop may occur against the optimized forwarding. However, it can be resolved by implementing dUPF and xTR within a same box or application.

6. Security Considerations

TBD

7. IANA Considerations

This memo includes no request to IANA.

8. Acknowledgement

The authors would like to thank Ryosuke Kurebayashi, Koji Tsubouchi, and Toru Okugawa for their kind reviews and technical feedback.

9. Informative References

[I-D.bogineni-dmm-optimized-mobile-user-plane]
Bogineni, K. and A. Rodriguez-Natal, "Optimized Mobile User Plane Solutions for 5G", draft-bogineni-dmm-optimized-mobile-user-plane-00 (work in progress), March 2018.

[I-D.farinacci-lisp-mobile-network]
Farinacci, D., Pillay-Esnault, P., and U. Chunduri, "LISP for the Mobile Network", draft-farinacci-lisp-mobile-network-02 (work in progress), September 2017.

[I-D.ietf-6man-segment-routing-header]
Previdi, S., Filsfils, C., Raza, K., Dukes, D., Leddy, J., Field, B., daniel.voyer@bell.ca, d., daniel.bernier@bell.ca, d., Matsushima, S., Leung, I., Linkova, J., Aries, E., Kosugi, T., Vyncke, E., Lebrun, D., Steinberg, D., and R. Raszuk, "IPv6 Segment Routing Header (SRH)", draft-ietf-6man-segment-routing-header-08 (work in progress), January 2018.

[I-D.ietf-lisp-eid-mobility]
Portoles-Comeras, M., Ashtaputre, V., Moreno, V., Maino, F., and D. Farinacci, "LISP L2/L3 EID Mobility Using a Unified Control Plane", draft-ietf-lisp-eid-mobility-00 (work in progress), May 2017.

[RFC6830] Farinacci, D., Fuller, V., Meyer, D., and D. Lewis, "The Locator/ID Separation Protocol (LISP)", RFC 6830, DOI 10.17487/RFC6830, January 2013, <https://www.rfc-editor.org/info/rfc6830>.

[RFC6831] Farinacci, D., Meyer, D., Zwiebel, J., and S. Venaas, "The Locator/ID Separation Protocol (LISP) for Multicast Environments", RFC 6831, DOI 10.17487/RFC6831, January 2013, <https://www.rfc-editor.org/info/rfc6831>.

[RFC6832] Lewis, D., Meyer, D., Farinacci, D., and V. Fuller, "Interworking between Locator/ID Separation Protocol (LISP) and Non-LISP Sites", RFC 6832, DOI 10.17487/RFC6832, January 2013, <https://www.rfc-editor.org/info/rfc6832>.

[RFC6833] Fuller, V. and D. Farinacci, "Locator/ID Separation Protocol (LISP) Map-Server Interface", RFC 6833, DOI 10.17487/RFC6833, January 2013, <https://www.rfc-editor.org/info/rfc6833>.

[RFC6836] Fuller, V., Farinacci, D., Meyer, D., and D. Lewis, "Locator/ID Separation Protocol Alternative Logical Topology (LISP+ALT)", RFC 6836, DOI 10.17487/RFC6836, January 2013, <https://www.rfc-editor.org/info/rfc6836>.

[RFC7215] Jakab, L., Cabellos-Aparicio, A., Coras, F., Domingo-Pascual, J., and D. Lewis, "Locator/Identifier Separation Protocol (LISP) Network Element Deployment Considerations", RFC 7215, DOI 10.17487/RFC7215, April 2014, <https://www.rfc-editor.org/info/rfc7215>.

[RFC8061] Farinacci, D. and B. Weis, "Locator/ID Separation Protocol (LISP) Data-Plane Confidentiality", RFC 8061, DOI 10.17487/RFC8061, February 2017, <https://www.rfc-editor.org/info/rfc8061>.

[RFC8111] Fuller, V., Lewis, D., Ermagan, V., Jain, A., and A. Smirnov, "Locator/ID Separation Protocol Delegated Database Tree (LISP-DDT)", RFC 8111, DOI 10.17487/RFC8111, May 2017, <https://www.rfc-editor.org/info/rfc8111>.

[TS.23.501-3GPP]
3rd Generation Partnership Project (3GPP), "3GPP TS 23.501", December 2017, <http://www.3gpp.org/ftp//Specs/archive/23_series/23.501>.

[TS.23.502-3GPP]
3rd Generation Partnership Project (3GPP), "3GPP TS 23.502", December 2017, <http://www.3gpp.org/ftp//Specs/archive/23_series/23.502>.

Appendix A. Case Studies

This Appendix describes detailed processes of the proposal approach in the following types of communications.

1. UE-2-UE Communication

2. UE-2-dDN Communication

A.1. UE-2-UE Communication

In the current architecture, a cUPF becomes an anchor point for UEs, and all packets between UEs even which are located to the same dUPF are transferred through the anchor point. This may cause communication delay and inefficient resource usage. In the proposed procedure, packets can be transferred without through an anchor point, and low latency and efficient resource usage can be achieved.

The UE-2-UE communications include communications between UEs located to different dUPFs (Case 1), and communication between UEs located to the same dUPF (Case 2). In this section, the detailed procedures of the cases are described.

Moreover, in a mobile network, an UE may move during communications. This section describes problems and considerations about UE's handover in such case.

A.1.1. Case 1: UEs allocated different dUPF

```
                       +-------+
                       |Mapping|
                       |System |
                       +-------+
                         .
                         .
                         .
                     (3) .   #===========================#
                         .   #           (4)             #
                         .   #                           V
       +-------+       +-------+      +-------+      +-------+
       | dUPF#1|       | xTR#1 |      | dUPF#2|      | xTR#2 |
       |       |       | RLOC=X|      |+------|<-----| RLOC=Y|
       |   [UL]|       |       |      ||  [UL]|  (5) |       |
       |   [CL]|------>|       |      |v  [CL]|      |       |
       +-------+  (2)  +-------+      +-------+      +-------+
            ^                          |
            | (1)                      |(6)
            |                          v

          [UE#1]                     [UE#2]
          EID=a-1                    EID=a-2
```

Figure 5: Procedure in Case 1

(0) Within this network, addresses are assigned to UEs from a address space [A]. These addresses are described as a-n (n=1,2,..). EID=a-1 and a-2 are assigned to UE#1 and UE#2.

(1) UE#1 sends packets to UE#2 with setting EID=a-2 as the destination IP address.

(2) dUPF#1 monitors inner packet of received GTP-U packet and divert it to xTR#1 with decapsulation if the destination address is one of address space [A].

(3) xTR#1 updates own EID-to-RLOC mapping chace by interaction with Mapping System (if needed).

(4) xTR#1 obtains the RLOC(=Y) of EID=a-2 from the EID-to-RLOC mapping cache, and sends the packets to the xTR#2 with a tunnel with RLOC=Y as the destination address.

(5) xTR#2 decapsulate the packets, and sends them to dUPF#2.

(6) dUPF#2 encapsulate packets with GTP-U header, and sends them to UE#2.

A.1.2. Case2: UEs allocated the same xTR

```
                       +-------+
                       |Mapping|
                       |System |
                       +-------+
                         .
                         .
                         .
                     (3) .
                         .
                         .
       +-------+       +-------+      +-------+      +-------+
       | dUPF#1|       | xTR#1 |      | dUPF#2|      | xTR#2 |
       |+------|<----- | RLOC=X|      |       |      | RLOC=Y|
       ||  [UL]|  (4)  |       |      |   [UL]|      |       |
       |v  [CL]|------>|       |      |   [CL]|      |       |
       +-------+  (2)  +-------+      +-------+      +-------+
        |     ^
    (5) |     | (1)
        v     |

     [UE#2]  [UE#1]
    EID=a-2  EID=a-1
```

Figure 6: Procedure in Case 2

(0) Within this network, addresses are assigned to UEs from a address space [A] These addresses are described as a-n (n=1,2,..). EID=a-1 and a-2 are assigned to UE#1 and UE#2.

(1) UE#1 sends packets to UE#2 with setting EID=a-2 as the destination IP address.

(2) dUPF#1 monitors inner packets of recieved GTP-U traffic and divert it to xTR#1 with decapsulation if the destination address is one of address space [A].

(3) xTR#1 updates own EID-to-RLOC mapping cache by interaction with Mapping System (if needed).

(4) xTR#1 obtains the RLOC(=X) from the EID-to-RLOC mapping cache. Since RLOC=X indicates itself, xTR#1 sends the packets back to dUPF#1.

(5) dUPF#2 encapsulate packets with GTP-U, and sends them to UE#2.

A.1.3. Consideration of Case that UE Moves to under Another xTR

When an UE moves to a serving area of another dUPF during communication with another UE, EID-to-RLOC mapping database of a Mapping System and the tables of the xTR and the peered xTR must be updated. The xTRs can't send packets to the appropriate xTR during the updating, and thus packet drop or stalling may occur.

To mitigate this problem, further consideration is needed. For example, a mechanism that immediately advertise the update of location of UEs to Mapping System and the appropriate xTRs depending on movement of each UE might be required.

A.2. UE-2-dDN Communication

The UE-2-dDN communications basically correspond the communication between an UE and neighbor dDN (Case3). On the other hand, if an UE moved under another dUPF during usage of a statefull application, or the application is not uniformly deployed in every dDN, the UE needs to continue to communicate with the previous dDN (Case4).

In such cases, in the current architecture, all packets are needed to go through the anchor point or dynamic GTP tunnel reconfiguration between dUPF is required. The former solution causes additional communication delay and inefficient resource usage. The latter solution increase the cost of 5GS control plane to dynamically update the GTP tunnel with multiple UPFs and their ULCL filter tables along with the movement of the UE. The propal approach achieves appropriate packet transfer in such cases.

In this section, the detailed procedures of communications between an UE and neighbor dDN and communications between an UE and non-neighbor dDN

A.2.1. Case 3: UE communicates with neighbor dDN

```
                       +-------+
                       |Mapping|
                       |System |
                       +-------+
                         .
                         .
                         .
                     (3) .
                         .
                         .
       +-------+       +-------+      +-------+      +-------+
       | dUPF#1|       | xTR#1 |      | dUPF#2|      | xTR#2 |
       |+------|<----- | RLOC=X|      |       |      | RLOC=Y|
       ||  [UL]|  (6)  |       |      |   [UL]|      |       |
       |v  [CL]|------>|       |      |   [CL]|      |       |
       +-------+  (2)  +-------+      +-------+      +-------+
        |    ^           |  ^
    (7) |    | (1)    (4)|  | (5)
        v    |           v  |
                       ,-------.
        [UE#1]        /  dDN#B  \
        EID=a1        |  |  ^   |
                      |  v  |   |
                      | [APL#1] |
                      \ EID=b-1 /
                       `-------'
```

Figure 7: Procedure in Case 3

(0) Within this network, UEs are assigned their addresses from an address space [A]. These addresses are described as a-n (n=1,2,...). Also, applications in dDN#B are assigned their addresses from a address space [B]. These addresses are described as b-n (n=1,2,..). EID=a-1 and b-1 assigned to UE#1 and APL#1 which is located in dDN#B.

[Uplink Processes]

(1) UE#1 sends packets to dDN#B with setting EID=b-1 as the destination IP address.

(2) dUPF#1 monitors inner of recieved GTP-U packets and divert it to xTR#1 with decapsulation if the destination IP address is one of address space [B].

(3) xTR#1 updates own EID-to-RLOC mapping cache by interaction with Mapping System (if needed). Or xTR#1 may update its own cache by a Map-Notify message when an APL is deployed or deleted in dDB#B.

(4) xTR#1 obtains RLOC(=X) of EID=b-1 from the EID-to-RLOC mapping cache. Since RLOC=X indicates itself and EID=b-1 is within [B], xTR#1 sends the packets to the dDN#B.

[Downlink Processes]

(5) APL#1 in dDN#B sends packets to UE#1 with setting EID=a-1 as the destination IP address.

(6) xTR#1 obtains RLOC of EID=a-1 (i.e., RLOC=X) from the EID-to-RLOC mapping cache. Since RLOC=X indicates xTR#1 itself, xTR#1 sends packets to dUPF#1.

(7) dUPF#2 encapsulates packets with GTP-U, and sends them to UE#1.

A.2.2. Case4: UE communicates with non-neighbor dDN

```
                       +-------+
                       |Mapping|
                       |System |
                       +-------+
                         .
                         .               (7)
                         . #==============================#
                     (3) . # #==========================# #
                         . # #           (4)            # #
                         . V #                          V #
       +-------+       +-------+      +-------+      +-------+
       | dUPF#1|  (8)  | xTR#1 |      | dUPF#2|      | xTR#2 |
       |+------|<------| RLOC=X|      |       | (0)  | RLOC=Y|
       ||  [UL]|       |       |      |   [UL]|<---->|       |
       |v  [CL]|------>|       |      |   [CL]|      |       |
       +-------+  (2)  +-------+      +-------+      +-------+
        |    ^                           ^             |  ^
    (9) |    | (1)                       | (0)      (5)|  | (6)
        v    |                           |             v  |
                         (0)             v           ,-------.
        [UE#1] <= = = = = = = = = = = =[UE#1]       /  dDN#C  \
        EID=a-1 UE#1 moves to the serving area of   |  |  ^    |
              dUPF#1 from the serving area of UPF#2 |  v  |    |
                                                    | [APL#2] |
                                                    \ EID=c-1 /
                                                     `-------'
```

Figure 8: Procedure in Case 4

(0) Within this network, UEs are assigned their addresses from an address space [A]. These addresses are described as a-n (n=1,2,..). And applications in dDN#C are assigned their addresses from an address space [C]. These addresses are described as c-n (n=1,2,..). EID=a-1 and c-1 assigned to UE#1 and APL#2 which is located in dDN#C. UE#1 has movedto the serving area of dUPF#1 from the serving area of UPF#2 while communicating to APL#2.

[Uplink Processes]

(1) UE#1 sends packets to APL#2 with setting EID=c-1 as the destination IP address.

(2) dUPF#1 monitors each inner packet of received GTP-U traffic and divert it to xTR#1 with decapsulation if the destination addressis one of address space [C].

(3) xTR#1 updates own EID-to-RLOC mapping cache by interaction with Mapping System (if needed).

(4) xTR#1 obtains RLOC(=Y) of EID=c-1 from the EID-to-RLOC mapping cache, and sends the packet to the xTR#2 with a tunnel with RLOC=Y as the destination address.

(5) xTR#2 decapsulates the packets received from xTR#1, and sends them to dDN#C depending on its forwarding table.

[Downlink Processes]

(6) APL#2 sends packets to UE#1 with setting EID=a-1 as the destination IP address.

(7) xTR#2 obtains RLOC(=X) of EID=a-1 from the EID-to-RLOC mapping cache, and sends the packets to the xTR#1 with a tunnel with RLOC=X as the destination address.

(8) xTR#1 decapsulates the packets received from xTR#2m and sends them to the dUPF#1 depending on its forwarding table.

(9) dUPF#1 encapsulates the packets with GTP-U and sends packets to UE#1.

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