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BGP App Metadata for 5G Edge Computing Service
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Abstract

This draft describes a new AppMetaData subTLV carried by Tunnel Encap[RFC9012] Path Attribute for egress router to advertise the running status and environment of the directly attached 5G Edge Computing servers. The AppMetaData can be used by the ingress routers in the 5G Local Data Network to make intelligent path selection for flows from UEs. The goal is to improve latency and performance for 5G Edge Computing services.

The extension enables a feature, called soft anchoring, which makes one Edge Computing Server at one specific location to be more preferred than others for the same application to receive packets from a specific source (UE).

This Internet-Draft will expire on April 7, 2021.

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1. Introduction

This document describes a new subTLV, AppMetaData, for egress routers to advertise the running status and environment of the directly attached Edge Computing servers. The AppMetaData can be used by the ingress routers in the 5G Local Data Network to make intelligent path selection for flows from UEs. The goal is to improve latency and performance for 5G Edge Computing services.

1.1. 5G Edge Computing Background

In 5G Edge Computing (EC), one Application can be hosted on multiple Application Servers in different EC data centers that are close in proximity. The network connecting the EC data centers with the 5G Base stations consists of small number of routers dedicated for the 5G Local Data Network (LDN), to minimize latency and optimize the user experience.

When a User Equipment (UE) initiates application packets using the destination address from a DNS reply or its cache, the packets from the UE are carried in a PDU session through 5G

Core [5GC] to the 5G UPF-PSA (User Plan Function - PDU Session Anchor). The UPF-PSA decapsulates the 5G GTP outer header and forwards the packets from the UEs to its directly connected Ingress router of the 5G LDN. The LDN for 5G EC, which is the IP Networks from the 5GC perspective, is responsible for forwarding the packets to the intended destinations.

When the UE moves out of coverage of its current gNB (next-generation Node B) (gNB1), handover procedures are initiated, and the 5G SMF (Session Management Function) selects a new UPF-PSA. The standard handover procedures described in 3GPP TS 23.501 and TS 23.502 are followed. When the handover process is complete, the UE is anchored to the new UPF-PSA, meaning the packets to/from the UE is carried by the GTP tunnel to the new UPF-PSA. The UE usually maintains its IP address when anchored to the new UPF-PSA unless the new UFP-PSA belongs to different mobile operators. 5GC may maintain a path from the old UPF to new the UPF for a short time for the SSC [Session and Service Continuity] mode 3 to make the handover process more seamless.

1.2. 5G Edge Computing Network Properties

In this document, 5G Edge Computing Network refers to multiple Local IP Data Networks (LDN) in one region that interconnect the Edge Computing data centers. Those IP LDN networks are the N6 interfaces from 3GPP 5G perspective.

The ingress routers to the 5G Edge Computing Network are the routers directly connected to 5G UPFs. The egress routers to the 5G Edge Computing Network are the routers that have a direct link to the Edge Computing servers. The servers and the egress routers are co-located. Some of those Edge Computing Data centers may have Virtual switches or Top of Rack switches between the egress routers and the servers. But transmission delay between the egress routers and the Edge Computing servers is too small to be considered in this document.

When one EC data center has multiple EC Servers attached to one App Layer Load Balancer, only the App Layer Load Balancer is visible to the 5G Edge Computing Network. How the App Layer

Load balancer manages the individual servers is out of the scope of the network layer.

The 5G EC Services are specially managed services optimized by utilizing the network topology and multiple servers with the same IP address (ANYCAST) in multiple EC Data Centers. Many services by the UEs are not part of the registered 5G EC Services.

```
   +--+
   |UE|---\+---------+                 +------------------+
   +--+    |  5G     |     +--------+  |   S1: aa08::4450 |
   +--+    | Site +--+-+---+        +----+                |
   |UE|----|  A   |PSA1| Ra|        | R1 | S2: aa08::4460 |
   +--+    |      +----+---+        +----+                |
  +---+    |         |  |           |  |   S3: aa08::4470 |
  |UE1|---/+---------+  |           |  +------------------+
  +---+                 |IP Network |       L-DN1
                        |(3GPP N6)  |
     |                  |           |  +------------------+
     | UE1              |           |  |  S1: aa08::4450  |
     | moves to         |          +----+                 |
     | Site B           |          | R3 | S2: aa08::4460  |
     v                  |          +----+                 |
                        |           |  |  S3: aa08::4470  |
                        |           |  +------------------+
                        |           |      L-DN3
   +--+                 |           |
   |UE|---\+---------+  |           |  +------------------+
   +--+    |  5G     |  |           |  |  S1: aa08::4450  |
   +--+    | Site +--+--+----+       +----+                |
   |UE|----|  B   |PSA2| Rb |       | R2 | S2: aa08::4460 |
   +--+    |      +--+-+----+       +----+                |
   +--+    |         |  +-----------+  |  S3: aa08::4470  |
   |UE|---/+---------+                 +------------------+
   +--+                                    L-DN2
```

Figure 1: App Servers in different edge DCs

1.3. Problem#1: ANYCAST in 5G EC Environment

Increasingly, Anycast is used extensively by various application providers and CDNs because ANYCAST makes it possible to dynamically load balance across server locations based on network conditions.

Using Anycast address leverages the proximity information present in the network (routing) layer. It eliminates the single point of failure and bottleneck at the DNS resolvers and application layer load balancers. Another benefit of using the ANYCAST address is removing the dependency on UEs. Some UEs (or clients) might use their cached IP addresses, instead of querying DNS, for an extended period.

But, having multiple locations of the same ANYCAST address in the 5G EC environment can be problematic because all those EC Data Centers can be close in proximity. There might be a very small difference in the routing cost to reach the Application Servers in different EC DCs. This list elaborates the issues in detail:

a) Path Selection: When a new flow comes to an ingress node (Ra), how to select the optimal egress router to reach an ANYCAST server.

   The mechanism described in this draft is for solving this Path Selection problem.

b) How Ingress node keeps the packets from one flow to the same ANYCAST server.

   a.k.a. Flow Affinity, or Flow-based load balancing, which is supported by many commercial routers.

   The ingress node, (Ra/Rb) uses Flow ID (in IPv6 header) or UDP/TCP port number combined with the source address to enforce packets in one flow being placed in one tunnel to one Egress router. No new features are needed.

c) When a UE moves to a new Cell Tower, a method is needed to stick the flow to the same ANYCAST server, which is required by 5G Edge Computing: 3GPP TR 23.748.

This problem is Out of scope for this draft. [5g-edge-compute-sticky-service] describes several approaches to solve this problem.

From BGP perspective, the multiple servers with the same IP address (ANYCAST)attached to different egress routers is the same as multiple next hops for the IP address.

This draft describes the BGP UPDATE to enable ingress routers to take the App Server load, the capacity index, and the location preference into consideration when computing the optimal path to egress routers.

1.4. Problem #2: Unbalanced Anycast Distribution due to UE Mobility

UEs frequent moving from one 5G site to another can make it difficult to plan where and how many to deploy the App servers. When one App server is heavily utilized, other servers of the same App close-by can be very underutilized. Since the condition can be short-lived, it is difficult for the application controller to anticipate the move and adjust.

1.5. Problem 3: Application Server Relocation

When an Application Server is added to, moved, or deleted from a 5G EC Data Center, the routing protocol needs to propagate the changes to 5G PSA or the PSA adjacent routers. After the change, the cost associated with the site might change as well.

Note: for ease of description, the Edge Application Server and Application Server are used interchangeably throughout this document.

2. Conventions used in this document

A-ER: Egress Router to an Application Server, [A-ER] is used to describe the last router that the Application Server is attached. For a 5G EC environment, the A-ER can be the gateway router to a (mini) Edge Computing Data Center.

Application Server: An application server is a physical or virtual server that hosts the software system for the application.

Application Server Location: Represent a cluster of servers at one location serving the same Application. One application may have a Layer 7 Load balancer, whose address(es) are reachable from an external IP network, in front of a set of application servers. From an IP network perspective, this whole group of servers is considered as the Application server at the location.

Edge Application Server: used interchangeably with Application Server throughout this document.

EC: Edge Computing

Edge Hosting Environment: An environment providing the support required for Edge Application Server's execution.

NOTE: The above terminologies are the same as those used in 3GPP TR 23.758

Edge DC: Edge Data Center, which provides the Edge Computing Hosting Environment. An Edge DC might host 5G core functions in addition to the frequently used application servers.

gNB next generation Node B

L-DN: Local Data Network

PSA: PDU Session Anchor (UPF)

SSC: Session and Service Continuity

UE: User Equipment

UPF: User Plane Function

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Usage of App-Meta-Data for 5G Edge Computing

3.1. Assumptions

From IP Layer, the Application servers are identified by their IP (ANYCAST) addresses. Here are some assumptions about the 5G EC services:

- Only the registered EC services, which are only a small portion of the services, need to include the AppMetadata in path selection.
- The 5G EC controller or management system push down the policies (e.g., ACLs) on the relevant routers to filter out those registered EC services.
- The ingress routers' local BGP path compute algorithm includes a special plugin that can compute the path to the optimal Next Hop (egress router) based on the BGP AppMetaData TLV received for the registered EC services.

The proposed solution is for the egress routers, i.e. A-ER, that have direct links to the Application Servers to collect various measurements about the Servers' running status [5G-EC-Metrics] and advertise the metrics to other routers in 5G EC LDN (Local Data Network).

3.2. IP Layer Metrics to Gauge Application Behavior

[5G-EC-Metrics] describes the IP Layer Metrics that can gauge the application servers running status and environment:

- IP-Layer Metric for App Server Load Measurement:
  The Load Measurement to an App Server is a weighted combination of the number of packets/bytes to the App Server and the number of packets/bytes from the App Server which

are collected by the A-ER to which the App Server is directly attached.
The A-ER is configured with an ACL that can filter out the packets for the Application Server.

- Capacity Index
  a numeric number, configured on all A-ERs in the domain consistently, is used to represent the capacity of the application server attached to an A-ER. At some sites, the IP address exposed to the A-ER is the App Layer Load balancer that have many instances attached. At other sites, the IP address exposed is the server instance itself.
- Site preference index:
  is used to describe some sites are more preferred than others. For example, a site with higher bandwidth has a higher preference number than other.

In this document, the term "Application Server Egress Router" [A-ER] is used to describe the last router that an Application Server is attached. For the 5G EC environment, the A-ER can be the gateway router to the EC DC where multiple Application servers are hosted.

From IP Layer, an Application Server is identified by its IP (ANYCAST) Address. Those IP addresses are called the Application Server IDs throughout this document.

3.3. AppMetaData Constrained Optimal Path Selection

The main benefit of using ANYCAST is to leverage the network layer information to select an optimal path among multiple application Server locations of the same application identified by its ANYCAST addresses.

For the 5G EC environment, the ingress routers to the LDN need to be notified of the Load Index and Capacity Index of the App Servers at different EC data centers to make the intelligent decision on where to forward the traffic for the application from UEs.

Here is an algorithm that computes the cost to reach the App Servers attached to Site-i relative to another site, say Site-b. When the reference site, Site-b, is plugged in the formula, the cost is 1. So, if the formula returns a value less than 1, the cost to reach Site-i is less than reaching Site-b.

```
             CP-b * Load-i                Pref-b * Network-Delay-i
Cost-i= (w *(----------------) + (1-w) *(-------------------------))
             CP-i * Load-b                Pref-i * Network-Delay-b
```

Load-i: Load Index at Site-i, it is the weighted combination of the total packets or/and bytes sent to and received from the Application Server at Site-i during a fixed time period.

CP-i: capacity index at Site-i, a higher value means higher capacity.

Delay-i: Network latency measurement (RTT) to the A-ER that has the Application Server attached at the site-i.

Pref-i: Preference index for the Site-i, a higher value means higher preference.

w: Weight for load and site information, which is a value between 0 and 1. If smaller than 0.5, Network latency and the site Preference have more influence; otherwise, Server load and its capacity have more influence.

3.4. BGP Protocol Extension to advertise Load & Capacity

The goal of the protocol extension:

- Propagate the Load Measurement Index for the attached App Servers to other routers in the LDN.

- Propagate the Capacity Index &

- Propagate Site Preference Index.

The BGP extension is to include the Load Index Sub-TLV, Capacity Sub-TLV, and the Site Preference Sub-TLV in the Tunnel Encap Path Attribute associated with the routes.

3.5. Ingress Node BGP Path Selection Behavior

3.5.1. AppMetaData Influenced BGP Path Selection

In this scenario, an ingress router will receive one ANYCAST address's multiple routes from different egress routers that have the direct links to the ANYCAST servers. The ingress router's BGP engine will do path selection, select the best route, and download to FIB. And BGP engine will also download the other paths to FIB that with the AppMetaData taken into the consideration.

Assume that both Ra and Rb in Figure-1 have BGP Multipath enabled. As a result, Dst Address: S1:aa08::4450 is resolved via multiple NextHop: R1, R2, R3.

Suppose the local BGP special Plugin for AppMetaData finds R1 is the best for the flow towards S1:aa08::4450. Then this special Plugin can insert a higher weight for the path R1 so that BGP Best Path is locally influenced by the weight parameter based on the local decision.

3.5.2. Forwarding Behavior

When the ingress router receives a packet and lookup the FIB, it gets the destination prefix's whole path and AppMetaData. The Forwarding Plane will do computing for the packet and choose the suitable path as the result of the computing. Then the Forwarding Plane encapsulates the packet destined towards the optimal egress node.

For subsequent packets belonging to the same flow, the ingress router needs to forward them to the same egress router unless the selected egress router is no longer reachable. Keeping packets from one flow to the same egress router, a.k.a. Flow Affinity, is supported by many commercial routers.

How Flow Affinity is implemented is out of the scope for this document. Here is one example to illustrate how Flow Affinity can be achieved. This illustration is not to be standardized.

For the registered EC services, the ingress node keeps a table of

- Service ID (i.e., ANYCAST address)
- Flow-ID
- Sticky Egress ID (egress router loopback address)
- A timer

The Flow-ID in this table is to identify a flow, initialized to NULL. How Flow-ID is constructed is out of the scope for this document. Here is one example of constructing the Flow-ID:

- For IPv6, the Flow-ID can be the Flow-ID extracted from the IPv6 packet header with or without the source address.
- For IPv4, the Flow-ID can be the combination of the Source Address with or without the TCP/UDP Port number.

The Sticky Egress ID is the egress node address for the same flow. [5G-Sticky-Service] describes several methods to derive the Sticky Egress ID.

The Timer is always refreshed when a packet with the matching EC Service ID (ANYCAST address) is received by the node.

If there is no Stick Egress ID present in the table for the EC Service ID, the forwarding plane computes the optimal path to an egress (NextHop) with the AppMetaData taken into consideration. The forwarding plane encapsulates the packet with a tunnel to the chosen egress (NextHop). The chosen NextHop and the Flow ID are recorded in the table entry of the EC Service ID.

When the selected optimal egress router is no longer reachable, refer to Section 6 Soft Anchoring on how another path is selected.

3.5.3. Forwarding Behavior after a UE moving to a new 5G Site

When a UE moves to a new 5G Site, the new ingress router might use the pre-computed Egress Router which is passed from the neighboring router. [5G-Edge-Sticky] describes the method for the ingress router connected to the UPF in the new site to take into consideration the information passed from other ingress routers in selecting the optimal paths. The detailed algorithm is out of the scope of this document.

4. The Sub-TLVs for App-Meta-Data

The App-Meta-Data attribute is encoded in an optional subTLV within the Tunnel Encap [RFC9012] Path Attribute.

4.1. Load Measurement sub-TLV format

Two types of Load Measurement Sub-TLVs are specified. One is to carry the aggregated cost Index based on a weighted combination of the collected measurements; another one is to carry the raw measurements of packets/bytes to/from the App Server address. The raw measurement is useful when the egress routers cannot be configured with a consistent algorithm to compute the aggregated load index and the raw measurements are needed by a central analytic system.

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Type (TBD1)           |               Length          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Measurement Period                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Aggregated Load Index to reach the App Server       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
          Figure 2: Aggregated Load Index Sub-TLV
```

Raw Load Measurement sub-TLV has the following format:

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Type (TBD2)         |               Length          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Measurement Period                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           total number of packets to the AppServer            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           total number of packets from the AppServer          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           total number of bytes to the AppServer              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           total number of bytes from the AppServer            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
              Figure 5: Raw Load Measurement Sub-TLV
```

Type =TBD1: Aggregated Load Measurement Index derived from the Weighted combination of bytes/packets sent to/received from the App server:

Index=w1*ToPackets+w2*FromPackes+w3*ToBytes+w4*FromBytes

Where wi is a value between 0 and 1; w1+ w2+ w3+ w4 = 1;

Type= TBD2: Raw measurements of packets/bytes to/from the App Server address;

Measure Period: BGP Update period or user-specified period.

4.2. Capacity Index sub-TLV format

The Capacity Index sub-TLV has the following format:

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Type (TBD3)         |               Length          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Capacity Index                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Note: "Capacity Index" can be more stable for each site. If those values are configured to nodes, they might not need to be included in every BGP UPDATE.

4.3. The Site Preference Index sub-TLV format

The site Preference Index is used to achieve Soft Anchoring [Section 5] an application flow from a UE to a specific location when the UE moves from one 5G site to another.

The Preference Index sub-TLV has the following format:

```
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           Type (TBD4)         |               Length          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                   Preference Index                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Note: "Site Preference Index" can be more stable for each site. If those values are configured to nodes, they might not need to be included in every BGP UPDATE.

5. AppMetaData Propagation Scope

AppMetaData is only to be distributed to the relevant ingress nodes of the 5G EC local data networks. Only the ingress routers that are configured with the 5G EC services ACLs need to receive the AppMetaData for specific services.

For each registered EC service, a corresponding filter group can be formed on RR to represent the interested ingress routers that are interested in receiving the corresponding AppMetaData information.

6. Soft Anchoring of an ANYCAST Flow

"Sticky Service" in the 3GPP Edge Computing specification (3GPP TR 23.748) requires a UE to a specific ANYCAST location when the UE moves from one 5G Site to another.

"Soft Anchoring" is referring to forwarding the Application flow from a UE to a preferred location of the ANYCAST servers when the preferred location is in good condition. But if there is any failure reaching the preferred location, the Application flow from the UE will be forwarded to another location of the ANYCAST servers.

This section describes a solution that can softly anchor an application flow from a UE to a preferred location.

Lets assume one application "App.net" is instantiated on four servers that are attached to four different routers R1, R2, R3, and R4 respectively. It is desired for packets to the "App.net" from UE-1 to stick with one server, say the App Server attached to R1, even when the UE moves from one 5G site to another. When there is a failure reaching R1 or the Application Server attached to R1, the packets of the flow "App.net" from UE-1 need to be forwarded to the Application Server attached to R2, R3, or R4.

We call this kind of sticky service "Soft Anchoring", meaning that anchoring to the site of R1 is preferred, but other sites can be chosen when the preferred site encounters a failure.

Here are the details of this solution:

- Assign a group of ANYCAST addresses to one application. For example, "App.net" is assigned with 4 ANYCAST addresses, L1, L2, L3, and L4. L1/L2/L3/L4 represents the location preferred ANYCAST addresses.
- For the App.net Server attached to a router, the router has four Stub links to the same Server, L1, L2, L3, and L4 respectively. The cost to L1, L2, L3, and L4 is assigned differently for different routers. For example,
  - o When attached to R1, the L1 has the lowest cost, say 10, when attached to R2, R3, and R4, the L1 can have a higher cost, say 30.
  - o ANYCAST L2 has the lowest cost when attached to R2, higher cost when attached to R1, R3, R4 respectively.
  - o ANYCAST L3 has the lowest cost when attached to R3, higher cost when attached to R1, R2, R4 respectively, and
  - o ANYCAST L4 has the lowest cost when attached to R4, higher cost when attached to R1, R2, R3 respectively
- When a UE queries for the "App.net" for the first time, the DNS reply has the location preferred ANYCAST address, say L1, based on where the query is initiated.
- When the UE moves from one 5G site-A to Site-B, UE continues sending packets of the "App.net" to ANYCAST address L1. The routers will continue sending packets to R1 because the total cost for the App.net instance for ANYCAST L1 is lowest at R1. If any failure occurs making R1 not reachable, the packets of the "App.net" from UE-1 will be sent to R2, R3, or R4 (depending on the total cost to reach each of them).

If the Application Server supports the HTTP redirect, more optimal forwarding can be achieved.

- When a UE queries for the "App.net" for the first time, the global DNS reply has the ANYCAST address G1, which has the same cost regardless of where the Application servers are attached.
- When the UE initiates the communication to G1, the packets from the UE will be sent to the Application Server that has the lowest cost, say the Server attached to R1. The Application server is instructed with HTTPs Redirect to reply with a location-specific URL, say App.net-Loc1. The client on the UE will query the DNS for App.net-Loc1 and get the response of ANYCAST L1. The subsequent packets from the UE-1 for App.net are sent to L1.

7. Manageability Considerations

To be added.

8. Security Considerations

To be added.

9. IANA Considerations

To be added.

10. References

10.1. Normative References

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