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Mobility Management for 5G Network Architectures Using Identifier-locator Addressing

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Abstract

This specification describes Mobility Management Architecture for 5G Networks Using Identifier-Locator Addressing in IPv6 for virtualized mobile telecommunication networks. Identifier-locator addressing differentiates between location and identity of a network node. The approach presented in this draft enables mobility management on Layer 3, and provides a simplified and more efficient architecture with less core network utilization compared to traditional architecture.

Status of this Memo

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1. Introduction and Problem Statement

The Internet Protocol (IP) has been overloaded in its functionality in the sense that it has been used as a service locator and service identifier at the same time. Since changes of the associated IP address in a connection-oriented TCP session causes a service interruption, mobility has become a challenge. Mobility has been a challenge for IP based network since the area of smart phones began and has been addressed with Layer 2 and Layer 3 tunneling. One big challenge of mobility is to ensure seamless and transparent mobility for mobile devices among different locations and in between several Radio Access Technologies. Due to the deployment of micro-service architectures, another dimension in the complexity of mobility occurs, in which single IP addressable tasks might change their physical location within a (virtualized) data center architecture, too. Therefore mobility on both ends of the End-to-End (E2E) connections can be observed, which requires an large number of service registry (e.g. DNS) updates and the state synchronization between registries eventually located in different (geographical) locations. In regards of current research and development on Mobile Edge Cloud and 5G, key requirements such as high availability, low delay and ultra high bandwidth are required to ensure the reachability of the massive amount of communicating instances ranging from cellular's, high-definition multimedia streaming, Internet-of-Things (IoT), critical infrastructures among others.

This specification describes a mobility management architecture for 5G Networks using Identifier-Locator Addressing (ILA) ([nvo3]) in IPv6 for (virtualized) mobile telecommunication networks. The ILA concept used in this specification extends the Identifier-Locator Network Protocol (ILNP) ([RFC6740], [RFC6741]) defines a protocol and operations model for identifier-locator addressing in IPv6. The key advantages of the presented ILA mobility solution are:

1) Backwards-compatibility within existing IPv6 network architectures such as the AT&T network,
2) Enablement of very low-delay Mobile-Edge-Cloud (MEC) services,
3) Tunnel-less and flatter architecture with less protocol overhead and less hops between,
4) Proven applicability of ILA within the Facebook data centers and related networks.

1.1. Terminology

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 RFC 2119 [RFC2119].

The following terminology will be referred to in the document.

* SIR: As defined in ([nvo3ila]): "In order to maintain compatibility with existing networking stacks and applications, identifiers are encoded in IPv6 addresses using a standard identifier representation (SIR) address. A SIR address is a combination of a prefix which occupies what would be the locator portion of an ILA address, and the identifier in its usual location."

* ILA ID or only ID: Unique identifier in ILA terms that is used for public routing and addressability. This ID can be generated on a per session basis with the effect, to secure the privacy of the end point. The International Mobile Subscriber Identity (IMSI) can be used for ID generation. The ID is comparable with the Globally Unique Temporary UE Identity (GUTI) in the mobile space.

* ILA Locator (LOC): Either an International Mobile Equipment Identity (IMEI) or an IP address that has been assigned to a single UE. The locator is represented in the prefix of the SIR address.

* ILA host: An end host that is capable of performing ILA translations for both sending and receiving. An ILA host uses the ILA resolver protocol to get identifier to locator mappings for destinations in communication.

* ILA router: A network device that performs ILA translations. ILA routers participate in distribution protocol mapping and consists of the two functions: Network Virtualization Edge (NVE) and Network Virtualization Authority (NVA).

* User Equipment (UE): A device with an identifier such as a mobile phone, IoT gateway or another SIM equipped mobile device.

* Access Point (AP) and Base Station (BS): A network element such as evolved-NodeB (eNB) in 4G.

* Gateway (GW): A network element such as Serving-Gateway (SWG) or Packet-Data-Network-Gateway (PGW) in 4G.

* Application Function (AF): refers to the 3GPP terminology and

stands for any IP addressable endpoint such as service or task.

2. Related Work, Protocols and Concepts This section provides an overview on the state-of-the-art on related Work, protocols and concepts for mobility management on mobile networks. In particular the 4th Generation (4G) of mobile telecommunication networks has been taken into comparison for this draft for functional and conceptual comparison.

2.1. Mobile IPv6 The IETF specified Mobile IPv6 ([MIPv6]) to ensure connectivity and reachability in case of client mobility within an IPv6 network. Mobility is solved by assigning an additional IPv6 address - the Care-of-Address (CoA) - next to the current IPv6 address that as been assigned in the home network. Therefore a UE is equipped with a home address together with a primary CoA in case of foreign network attachment. IPv6 is classified as host-based mobility protocol, due to the fact, that the UE is in charge of announcing its mobility to the network. In particular it is the client's responsibility for sending binding updates to the Home Agent (HA). In order to ensure reachability, the UE communicates its new assigned CoA(s) to the HA, which acts as a router and registrar for UEs. Connection requests are intercepted and re-routed in case CoA entries for a UE exists. A tunnel is established between the UE at the CoA and the HA for securely exchanging packets. Per default, the first packet is routed from the correspondent UE towards the CoA of the UE via the HA. This route is not always the shortest path. All consecutive packets of the same data stream will follow on the same path, which might include a detour, but hides the new location of the UE for privacy reasons. The feature of route optimization allows the UE to directly contact the correspondent UE, therefore cuts out the HA from the communication path and forwards packets on a shorter route. Security of the Mobile IPv6 is enhanced through IPSec for binding updates to avoid spoofing of CoA for a UE.

2.2. Proxy Mobile IPv6 (PMIPv6) The IETF specified PMIPv6 ([PMIPv6]) provides network-based mobility management for UEs and extends the Mobile IPv6 in the way, that host-based mobility management functionalities in Mobile IPv6 are excluded from the client into the network in Proxy Mobile IPv6. The Local Mobility Anchor (LMA) acts as topological anchor point and manages the UE's binding state. The Mobile Access Gateway (MAG) manages the mobility-related signaling on behalf of the UE at the access router. It is responsible for tracking the UE's movements to and from the access

link for signaling the UE's local mobility anchor.

2.3. Host Identity Protocol (HIP) HIP ([hip]) is provisioning a secure solution for identifier/locator-split by adding a new host identity layer into protocol stack. A cryptographic namespace build upon a host identity as public key allows scalability and multi-homing within the network. An extensions of DNS supports rendezvous server functionality for secure host identity lookup. A secure channel is establishment over Diffie-Hellmann-key exchange between two communicating entities. The communication setup is considered as robust against DOS, due to a riddle solved at the requestor side. On the other side a high overhead for the secure communication establishment due to key exchange has to be taken into consideration. HIP requires an additional protocol layer between L2 and L3 for encapsulation.

2.4. Locator/ID Separation Protocol (LISP) LISP is a network-layer-based protocol that enables separation of IP addresses into two new numbering spaces: Endpoint Identifiers (EIDs) and Routing Locators (RLOCs). Tunnel router encapsulates and encapsulates packets.

2.5. Identifier-Locator Addressing (ILA) ILA is outlined in detail in ([nvo3]), ([nvo3ila]) as well as in this document. In a nutshell, the concept of ILA splits IPv6 addresses into a locator and an identifier, eliminates the need for tunneling and therefore reduces the header size. Network Virtualization Edges (NVE) creates and maintains local state about each Virtual Network for which it is providing service on behalf of a tenant system.

2.6. Comparison of ILA to alternative approaches This section compares the ILA approach to some alternatives that have been discussed in 5gangip list.

2.6.1. Identifier Locator Network Protocol (ILNP) ILNP ([rfc6741]) is an experimental protocol that splits and IPv6 address into a locator and identifier. ILA is fundamentally based on ILNP.

The key differences between ILA and ILNP are:

* ILNP requires changes to the transport layer. This limits ILNP to be used only on hosts and every transport protocol implementation would need to be modified to use ILNP. Presumably

to overcome the limitation above, some sort of ILNP proxy could be defined to perform ILNP in a middlebox.

* ILA does not require changes to the transport layer.

* Checksum neutral translation means that transport layer does not need to be parsed to perform ILA. This also ensures that existing device offloads (like checksum offload) work seamlessly.

* ILNP employs IPv6 extension headers which are mostly considered non-deployable. ILA does not use these.

* Core support for ILA is in upstream Linux, to date there is no publicly available source code for ILNP.

* ILNP involves DNS to distribute mapping information, ILA assumes mapping information is not part of naming.

2.6.2. Locator Identifier Separation Protocol

Locator Identifier Separation Protocol (LISP ([rfc6830)) is an IP encapsulation protocol where the destination address in the outer IP header is a locator and the destination address in the inner header is an identifier.

The key differences between ILA and LISP are:

* ILA is not encapsulation so there is not associate encapsulation overhead. For instance IPv6/IPv6 in LISP would have 52 bytes of overhead whereas ILA translation has zero.

* LISP may not work with some network device offloads whereas ILA works with all stateless offloads (ILA is transparent to the network so that it would just see TCP/IP packets for instance).

* ILA has been accepted into Linux, LISP has not been accepted.

* ILA can run either on end hosts (ILA hosts) or in the network (ILA routers). In ILA hosts the mapping database is a cache to optimize communications.

* ILA defines locators and identifiers to be 64 bits whereas LISP allows them to be full 128 bit address making for for memory needed in mapping table.

* ILA is not encapsulation so there is not associate encapsulation overhead. For instance IPv6/IPv6 in LISP would have fifty-six

bytes of overhead whereas ILA translation has zero.

* The process of ILA translation is much more efficient than performing LISP. The translation path is:

  1) Parse IP header and extract the destination address

  2) Lookup destination in a hash table (obviated with cached route for ILA hosts)

  3) Write new destination address (16 byte copy)

  4) Forward to new destination (or receive at final destination).

  LISP processing is more involved. To do encapsulation, 1) outer IP header, 2) UDP header and 3) LISP header need to be inserted. Tunnel fragmentation and MTU need to be considered [RFCXXXX] (i.e. increasing the size of a packet may exceed tunnel MTU). At the remote tunnel end point, the outer IP header must be validated and a lookup done on the destination address to see if it is a local address. A lookup must be done on the destination UDP port to find that it is a LISP port. If the UDP checksum is not zero that must also be validated. The LISP header must also be processed. Once the encapsulation is verified, the headers are removed and the inner packet is either forwarded or received.

3. Mobility Management Architectures for 5G Networks Using ILA This section outlines the ILA protocol structure and architecture

supporting ILA in mobile networks. The main functional blocks for connectivity, mobility support, security and charging are presented. Message flows for basic use cases executed by the mobile UE such as attachment, data transport with session handover and detachment are outlined.

3.1. Address format for ILA mobile

The address format is derived out of the ILA draft in ([nvo3]) and is used without modifications.

The IPv6 canonical address format is:

```
|          64 bits           |          64 bits       |
+----------------------------+------------------------+
| IPv6 Unicast Routing Prefix |  Interface Identifier  |
+----------------------------+------------------------+
```

The address format using ILA is:

```
+-------------------------------------------------------+
|           64 bits          |3 bits|1|    60 bits      |
+----------------------------+------------------------+
|          Locator           | Type |C|    Identifier   |
+-------------------------------------------------------+
```

The C bit is used to indicate that checksum-neutral mapping has been performed ([nvo3]).

3.2. Architecture with Functional Elements and Reference Points

The presented architecture in Fig 1 is aligned on the 3GPP Evolved Packet System (EPS) ([23401], [23402]) following the separation of control plane and data plane. Whereas 3GPP EPS addresses mobility through Layer 2 tunneling with GTP, this approach provides a Layer 3 mobility approach utilizing the ILA concepts for mobility.

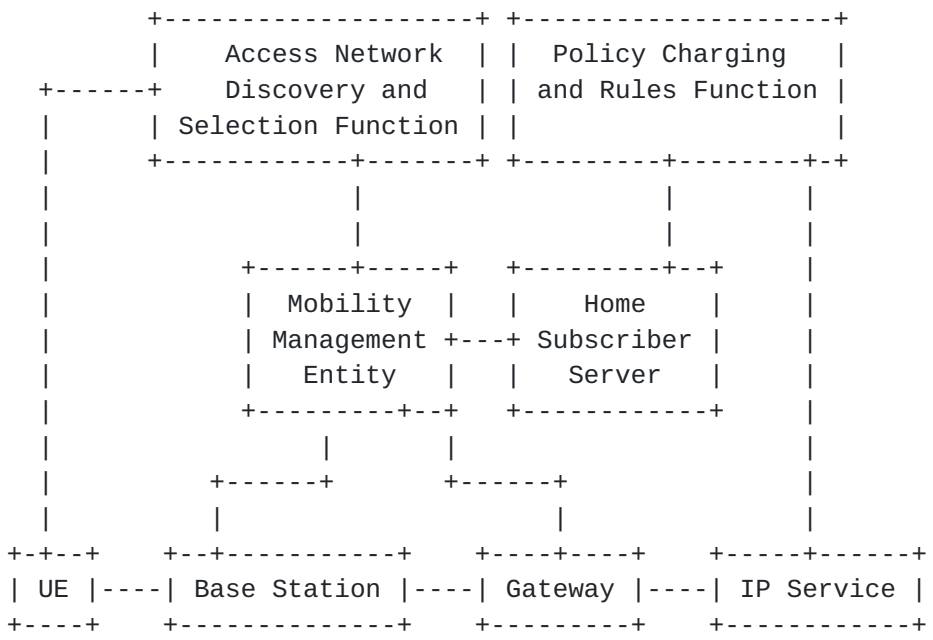


Fig 1: ILA-Based Architecture for Improved Mobility

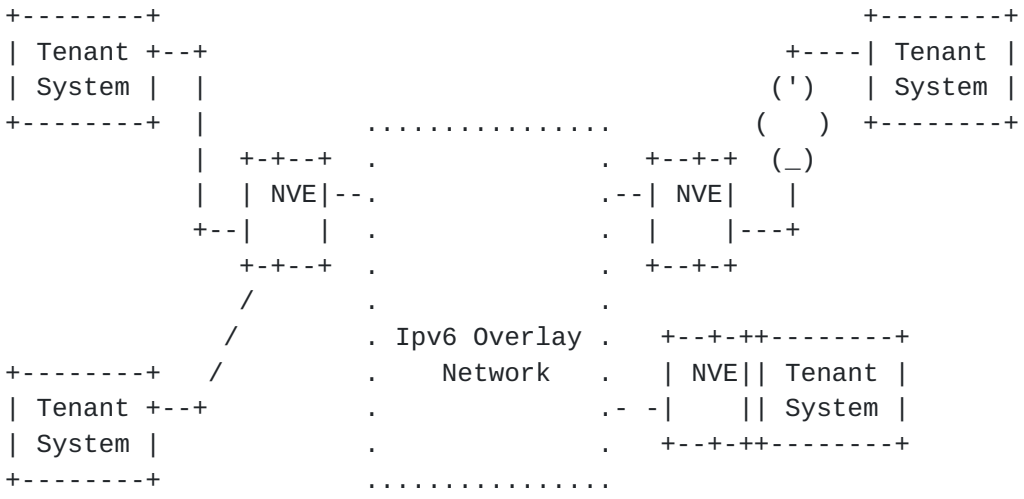


Fig 2: Distributed ILA Network Architecture [nvo3ila]

3.3. Functional Elements

This subsection summarizes the key functional elements of the ILA Mobility architecture.

* The User Equipment (UE) is the SIM enabled mobile device (cellular, gateway, etc.) executing services such as apps on the device, binding apps to the ID as communication endpoints, handling the bindings of all associated LOC/ID's and performing mobility as described below. The UE performs security related functions via its (embedded) SIM handing at least one or multiple identifiers provisioned by one or multiple network operators. Security related functions include authentication of the UE towards the network (more specifically the BS) and certificate management for establishing secure transport connections. Either the UE supports IPv6 or ILA for handling locator and ID bindings and updates or the network is handling ILA functionality on behalf of the UE. Storage and management of multiple locators for multi-path and multi-homing is supported by the UE support.

* The Base Station (BS) or Access Point (AP) is the first point of contact from the UE when attaching over radio to the network. Its main purpose is routing, gating and forwarding data and control packets. The Radio Access Technology (RAT) is independent of the proposed concept and therefore out of scope of this document. 3G, 4G, 5G or WiFi are applicable RATs. The BS is also capable of caching of content and state as close as possible to the user at the edge of the network. Another aspect of the cache is to support transparent handovers, during which

buffering of packets at the target BS is required. Therefore a X2-like connection between BSs is required. The BS supports a support a policy enforcement function (PEF) as well as a Event Reporting Function (ERF) aligned on the 3GPP defined Policy Control and Charging (PCC) functionality for the EPS in ([23203], [29212]). Uplink QoS management is handled by the BS, too. In order to differentiate between multiple types of data traffic, signaling, high-priority, real-time and non-real-time connections can be distinguished and the order of packet processing in the BS can be influenced for uplink. The same concept applies for downlink in the GW. Forward Error Correction (FEC), IP header compression, encryption of user data stream are supported by the BS, too. Traffic filtering, gating, legal interception on the BS, to include the case, in which traffic re-routed only by the BS and is not traversing the GW.

* The Gateway (GW) encompasses management and policy enforcement functions as well. Its main purpose is routing, gating and forwarding data and control packets. Therefore functionalities such as downlink QoS enforcement, APN management and charging is performed by each GW.

* The Application function (AF) or IP Service is an example of any IP addressable service in network. Other than in the 3GPP defined architecture, the IP service does not need to reside in the SGi LAN reachable only after terminating the GTP tunnel in the PGW. Furthermore services can be reached directly after the RAN connection is terminated within the BS.

* The Mobility Management Entity (MME) handles the initial authentication, authorization and mobility management of UE's over the control plane. The MME is responsible for tracking the UE's mobility and is in charge for updating the registries with near real-time status updates for LOC/ID mapping. ID and LOC assignment are performed by the MME.

* The Home Subscriber Server (HSS) stores and manages user profile information. These include the static information such as the assigned ID, security credentials as well as dynamic information LOC and the current Tracking Area.

* The Policy Charging and Rules Function (PCRF) controls data flows in the network architecture according to pre-defined

rules. Such rules can be created by the network operator such as an upper limited for the data rate or total bytes transferred given a time interval (e.g. 2GB per month data plane with unlimited speed and a reduction of bandwidth after reaching the limit of 2G). Other rules differentiate between class of services for various traffic flow types identified on their Traffic Flow Template (TFT) characteristics such as source, destination, port and protocol information. The PCRF is handling charging for traffic flows using online (pre-paid) and offline (post-paid) charging. Both charging modes include a charging based on metrics such as service invocations, online time, data transferred, or no-charging. Out of credit events may influence the current connectivity for online charging, whereas offline charging is accumulating charging records which are usually processed in a monthly period.

* The Access Network Discovery and Selection Function (ANDSF) is a database used for mapping the user location with available access networks. With this information, the ANDSF is capable of signaling suggestions for handovers to UE's. A UE is therefore able to operate only on one interface at a time to save resources. In case of the availability of adjacent RAT and after reception of a handover suggestion from the ANDSF, the UE is able to enable the suggested interface, perform a scan and finally decide whether or not to attach to the new targeted RAT. The database can be filled using device monitoring/telemetry statistics signaled from the UE to the network or by active measurements of the environment.

3.4. Signaling and Data Flow

3.5.1. Provisioning A Subscriber Identity Module (SIM)-card is provisioned by the network operator with a unique and secure

identifier that is comparable to the IMSI in 3GPP telco architectures (2G, 3G and 4G). This draft is no differentiating between a physical or an embedded SIM. In addition, security credentials and preferred network identifier are provisioned for authentication as well as network selection are provisioned. The matching information to the SIM card is stored in the HSS.

3.5.2. Attachment After powering on the device, a scan for available networks is performed on the device, which selects the network

(e.g. with the strongest signal) and performs a network attachment procedure aligned on ([23401], [23401]) towards the

BS using security parameters, ID, last MME associated with (GUMMEI) and last GUTI assigned by MME with ID GUMMEI - the Packet Temporary International Mobile Subscriber Identity (M-TSMI). A secure identifier on the SIM is used to generate a temporarily ID (the ILA ID), which is only valid for one session, hides the privacy of the UE in the network and unambiguous identifies the UE within the global network, is used for identification, authentication, authorization and charging purposes.

For each network attachment and due to privacy concerns for not revealing the identify of the UE towards the public, a new ID is generated.

The BS derives the last MME association out of the network attachment request sent by the UE and queries the last or a new MME based on availability of information for UE authentication. The MME performs a lookup in the user database of the network operator, which is the Home Subscriber Server (HSS) and/or Home Location Register (HLR) and receives a profile in return. Hereby the MME is able to query the NVA for existing mappings or to retrieve a unique ID for the UE.

In the following, the MME selects and configures the BS and GW according to the profile received and signals the profile including the ID towards the BSs of a certain tracking area and GW.

The BS allocates a LOC for the UE, binds the ID-LOC combination locally in a cache, publishes its binding in the MME/NVA and signals the ID-LOC towards the client.

Quality of Service (QoS) and charging related policies are installed in the BS and GW. The BS handled uplink and the GW downlink related traffic shaping functions. Charging can be performed in both functional elements (BS or GW), whereas a centralized charging in case of multi-path streaming is preferred.

After the successful attachment, a service can be invoked.

3.5.3. Five Communication Scenarios for an End-to-End Data Transport Session

After the attachment, applications can start communicating in the network using its assigned ILA by constructing IPv6 packets with the SIR source information (ID+LOC) and the mandatory target ID. The target LOC can be either set directly or can be

defined as a broadcast message, in which the target LOC will be determined at the edge of the target.

5 main high level use cases have been defined. The use cases can be distinguished into the following cases:
1) UE accessing a service in the AF,
2) UE is communicating with another UE attached to the same base station,
3) UE is communicating with another UE attached to a different base station,
4) Mobile-Edge-Computing,
5) Gateway mobility

The five example use cases are outlined below in details and the differences compared to today's networks are discussed. The communication form can be multicast, broadcast, anycast or unicast.

TODO: Include schema as in nvo3 - 5.3 Reference network for scenarios

1) E2E connection between the UE to AF

Considering a communication scenario in which a UE (source) queries a website (target) e.g. "http://about.att.com/innovation/foundry" in a browser. A target_ID is retrieved in return from the DNS or NVA.

UE[Task UE_T1] -> DNS // request ID and LOC for a given URL

DNS -> UE[Task UE_T1] // retrieve a target_ID and optional target_LOC associated with the given URI

The sequence for traversing the network looks as follows for an example that Task UE_T1 is communicating with Task AF_T1.

UE:[Task UE_T1] <-> BS <-> GW <-> AF[Task AF_T1]

The request is forwarded to the BS, which performs ILA router functionality. In case a broadcast address has been selected as a target LOC, a cache lookup in a local lookup table is performed. Depending on finding an entry in the local cached lookup table, the routing is influenced and the packet is redirected. Otherwise the packet is routed on to the destination ILA SIR address (LOC/ID).

2) UE_1 to UE_2 attached to distinct BSs

Considering a communication scenario in which one mobile device (UE1) is contacting a second mobile device (UE2). Both UEs are connected to different BSs. ILA routing is done in the BS.

Two communication path are possible. Either the connection between the two UEs is routed via a GA or in-between the respective BSs directly. A direct connection between BS_1 and BS_2 is required.

UE1[Task UE1_T1] <-> BS_1 <-> GW <-> BS_2 <-> UE2[Task UE2_T1]

UE1[Task UE1_T1] <-> BS_1 <-> BS_2 <-> UE2[Task UE2_T1]

3) UE_1 to UE_2 attached to the same BS

Considering a communication scenario in which two communicating entities are attached to the same BS and therefore are in close proximity. The solution for routing traffic in today's network is the establishment of the data path from the UE over the access network (e.g. eNB) through the core network (e.g. EPC) into the AF (any IP addressable service or task) and backwards to the access network and finally terminated at the UE. Charging needs to be performed in the BS for this data flow. This communication pattern in today's networks creates a delay caused by the bearer concept of 3GPP network, which encapsulate and de-capsulate data in Layer 2 tunnels between the eNB and the PGW.

A practical use case is the communication between autonomous vehicles (e.g. self-driving cars or self-organized and autonomous drone swarms) through a telecommunication infrastructure. A very low delay is required for the interaction and precise management. In order to reach such a low delay, the communication needs to stay local in order to result in a low delay.

The presented solution on ILA mobility allows to keep traffic local for the case in which the communicating parties attached to the same BS.

UE_1[Task UE1_Tx] <-> BS <-> UE_2[Task UE2_Ty]

Due to a lower amount of hops between UE_1 and UE_2, a lower latency can be achieved which results in a lower delay.

4) UE to Mobile Edge Cloud (MEC) Service

Considering a use case in which a UE is accessing a service with ultra-low latency requirements in the network such as image recognition, Virtual Reality (VR) or 5G services. Other examples include vehicle control (drone or truck-fleet, traffic information, robot or power grid). In order to provide a high quality of experience for the user and customer, latency in the communication between the mobile device and the service has to be reduced in order to achieve a lower delay. Where multimedia streaming has an acceptable latency requirement of ~100ms, ultra-low latency services have strict requirements on the communication with under 10ms or even close to 1ms. Classic cloud approaches that concentrate services centralized in the network are not applicable for ultra-low delay services due to the fact, that E2E latency is even too high. Violations of latency requirements result in motion sickness for VR users, outdated traffic information for autonomous self-driving cars, accidents with robotics in factories and the development of a new type of MEC services is hindered.

UE[Task UE_T1] <-> DNS // request ILA SIR (ID and LOC) for a given URL

Firstly, a DNS lookup resolves the URL into a ID to identify the closest service instance. The lookup process may be resolve to a service co-located at the BS or trigger the deployment of that service instance within a data center co-located or attached to the BS.

* DNS <-> MEC_orchestrator // retrieve the ILA SIR mapped to the URI and closest to the UE. Eventually a new service is deploy and its endpoint is returned.

Finally a request is created and addressed with the source LOC/ID and targeted towards the destination LOC/ID.

UE[Task UE_T1] <-> AF[Instance I_1 Task AF_T1]

The innovative point in this use case is the fact that the URL invocation may trigger a service deployment at the network edge instructed by the MEC_orchestrator and a policy decision. The policy decision is the outcome of the reasoning process within the MEC_orchestrator which takes context, user behavior, system load (throughput, latency, packet-loss, etc.), network topology map, distance between UE and service measured in hops, and other available metrics into account. Geographical load-balancing is therefore possible and enabled. Even when the first set packets of the connection are exchanged with a remote service, a context handover towards a closer service instance (out of the same type

or load-balancing group) can be applied.

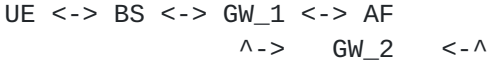
UE[Task UE_T1] <-> AF[Instance I_2 Task AF_T1]

Therefore the number of hops in the network are reduced and a lower delay on the data path is achieved.

5) Gateway Mobility This use case covers situations in which the user stays connected to a BS but the core network is mobile. One example would be a BS that is attached to a vehicle (drone, car/bus, train, cargo ship, etc). The user facing side provides cellular service, backhaul is either WLAN, satellite, laser, MMWave or temporary a fixed connection.

Gateway mobility requires the update of forwarding entries in related BS and AF to continuously forward the packets on the data path.

The network setup looks as follows in which both gateways (GW_1 and GW_2) both have connections to the same BS and AF.



Service interruptions may occur during the time of detaching from GW_a and attaching to GW_b when using a single radio interface for wireless backhauling. The capabilities of the 3GPP MME are extended with the ability to select the target GW for the BS, management of the BS-GW handover by reserving resources on the target GW_b and releasing resources on the source GW_a. GW_a caches packets during handover and forwards them to GW_b until packets are transported on the new uplink and downlink paths.

3.5.4. Homogeneous Handover Client mobility using the same access network technology caused by physical location changes is

referred to as homogeneous handover. Triggers for homogeneous handovers may be variations in signal strength received at the UE or network based handover due to network policies such as UE load balancing on the BSs.

The status information (the list of signals received from adjacent BSs including their signal strength) signaled from the UE towards the BS indicates enables positioning via triangulation as well as the selection of alternative BS's to

which the UE may connect to.

Reasons for handovers may be evacuation/preemption of resources on the BS due to emergency scenarios or higher priority calls, UE/BS/service load balancing or physical mobility of the UE among the network. Current resource utilization (e.g. data rates) of the UE or historical traffic pattern may influence the handover and the BS selection process.

Mainly the MME selects a target BS (BS_target) as target for the handover of the UE away from the current BS (BS_source). The decision is signaled to related BS's and the UE. BS_source starts de-allocating resource blocked by the UE and BS_target blocks resources required by the UE. Since most UE's are considered to have only a single RAT of each type (one WLAN or one LTE interface) an interruption in the connection while handover is to be expected. In order to avoid packet loss at the UE, buffering at the BS_target as well as packet forwarding from BS_source to BS_target are supported. Only after UE successfully establishes connectivity at the BS_target, previously blocked resources at BS_source are freed up, which are used as handover role-back in case of failure. Finally the MME announces the new ILA ID (BS_target_LOC)/ID for the UE as an update at GW and in the DNS.

New incoming connections are forwards directly towards the UE over BS_target using the proclaimed ILA ID (LOC/ID).

Homogenous handovers with one radio technology interface supported have interruptions during the handover. Nevertheless those interruptions are relatively small due to techniques such as improved handovers (802.11x, 802.11k, 802.11r, and 802.11v) or context handover via X2 in 4G.

3.5.5. Heterogeneous Handover

Client mobility may involve various Radio Access Technologies (RAT), in which the client is handed off from RAT_1 to RAT_2. The client is not required to move physically for heterogeneous mobility. Instead measurements on the UE or suggestion from the network (signaled over the ANDSF) may trigger handovers to alternative networks even when the UE is physically not moving. Such a handover can be done between WiFi, 4G and 5G.

Heterogeneous handover are motivated for optimizing connectivity between UE and AF/service to move a multimedia connection with high bandwidth requirements from cellular (4G/5G) towards WLAN or a security sensitive bank transaction from WLAN towards

cellular.

Heterogeneous (compared to homogenous) handovers may be performed seamlessly with establishing a second alternative connection in parallel to the existing active connection and tearing down the old connection only, after successfully establishing the new connection. In order to provide higher bandwidth over multi-path, both connections may be kept open in parallel. In this regard, the MME adds another LOC'/ID as update to the existing entry LOC/ID in the registry on the gateways and DNS.

3.5.6. Detachment A detachment from the network can happen gracefully by shutting down the phone and de-registering it from the BS or suddenly due to a loss of connection. In both situations, a de-registration from the UE out of the list of active users attached to the BS is done directly or indirectly (after inactivity for a predefined timeframe). Resource reservations are freed up again after detachment.

3.5.6. Idle-mode and paging Power saving methods are working transparent to the ILA mobility concept such as in ([23401], [23402]) The device toggles from active to inactive mode in idle-mode in order to reduce the communication interval between device and antenna. Resource reservations in the network are kept alive in order to allow a fast weak-up and connection re-establishment caused by paging of the BS towards the device.

4. Discussion, Evaluation and Summary New low-delay services are appearing with AR/VR, drone communication, self-driving cars and robot control that have requirements, which cannot be fulfilled by todays network and cloud architectures. New ultra-low latency is a key requirement on connectivity that is enabling a new services. One way of improving the End-to-End (E2E) connectivity is to improve the underlying technology and to make it more efficient. Part of this improvement is described in Moore's-law, which highlights that the number of components per integrated circuit is doubling every 18 month. Another approach is to reduce the E2E latency by reducing the physical distance between device and service measured in number of hops and at the same time provide a backwards compatible solution for WiFi and 4G networks.

This draft is addressing the above mentioned challenges and

provides a solution in form of an Identifier-Location Addressing (ILA) mobility based architecture. ILA decouples the identity from locator within an IPv6 address. Therefore mobility can be achieved by presuming the same ID at the endpoint and only adapting the locator used routing.

ILA mobility enables multiple new and innovative use cases compared to legacy telecommunication networks. Summarizing, the above presented "Five communication scenarios for data transport for an End-to-End session" outlines ways to improve connectivity, optimize routing and enable a new type of service: MEC services. Firstly, the improved data path has less hops to traverse between UE <-> AF enabled by edge computing or locally between UE_1 <-> UE_2 due to the flatter architecture. Secondly, less overhead is created due to the reduction of GTP tunnels between network elements. Thirdly, the presented approach of ILA mobility is backwards compatible with todays IPv6 based fixed and mobile telecommunication networks.

5. References

5.1. Normative References

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