A Hierarchical Anchor Selection Scheme for Distributed Mobile Network Architecture

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Abstract— **In this paper, we propose distributed mobile core network architecture and anchor allocation scheme to provide fine-grained mobility management depending on the requirements of user's application. For each case for different types of IP address, we analyze IP allocation and handover procedure.**

***Keywords*— Distributed Mobility Management(DMM), Anchoring, Distributed Mobile Architecture.**

I. INTRODUCTION

The main object of the 5G mobile network is to process a large amount of data traffic in a more flexible and efficient way at a lower cost. To process huge traffic with different characteristics generated by the existing typical mobile device (e.g. smartphone) and different types of mobile access devices (e.g. IoT devices, vehicles, etc.), the current 4G network architecture is facing with challenges from highly centralized and static architecture to more flexible and scalable manner. In order to overcome the above limitations of the current mobile network, 5G mobile network is proposed with distributed core network, while increasing density of radio access network.

In centralized networks, session continuity for mobile user is provided by forwarding all data packets through a central anchor point. Between the anchor and access router, GPRS Tunneling Protocol (GTP) [1] or Proxy Mobile IPv6 (PMIPv6) [2] is used for establishing tunnel interface to support routing packet to current location of mobile nodes. In future 5G, mobile network is expected that mobility management entities are split and located closer to the edge of network where mobile users are connected. Distributing mobility management entities can solve problems suffered from centralized mobility network such as single point failure, scalability issue and sub-optimal routing. Such a solution is currently being discussed in the Distributes Mobility Management (DMM) working group [3] of Internet Engineering Task Force (IETF). According to the charter of DMM working group, they define protocol semantic and deployment models considering new network trends, such as separation of control/data plane Software Defined Networking (SDN) and Network Function Virtualization (NFV) technology.

Additionally, in the future 5G mobile network architecture, mobile network operator will be able to provide different sets of network entities and user traffic through variable connection points to the Internet. For example, data traffic can be allowed to be broken out to the edge network. Another example is on-demand mobility support in which the session continuity is provided selectively based on characteristics of data flow. To provide different services based on the fine-grained policy, IETF DMM working group defines three types of IP address and a solution for the applications running on mobile devices to indicate whether they need IP session continuity or IP address reachability [4].

In this paper, based on the definition of IP address types, we propose a novel scheme for session-based anchor assignment in distributed mobile architecture. We first design a distributed mobile architecture including two types of core network in a partially hierarchical manner: central core network and edge core network. Based on the level of mobility demand, different types of IP address are assigned by different anchors.

II. RELATED WORKS

A. Network Architecture Considerations

4G mobile network architecture [5], standardized in 3GPP, is composed of Evolved Packet Core (EPC) and Radio Access Network (RAN). The EPC includes network components for control plane such as the Mobility Management Entity (MME), Home Subscriber System (HSS) and Policy Charging and Rules Function (PCRF), and for data plane such as Serving Gateway (SGW) and Packet Gateway (PGW). The EPC architecture is designed in centralized and hierarchical manner, in which the PGW is an anchor point of network to forward all data packets through the external Internet. To support mobility, tunnel establishment protocol such as GTP or PMIPv6 is using between the SGW and PGW. Since all of network entities in the EPC are generally deployed in dedicated hardware tightly coupled with their functionality, current mobile network architecture causes significant cost for scaling infrastructure to meet demands of increasing data traffic.

The most important objective of 5G mobile network design is to increase scalability with flexible resource management for taking into account explosion of mobile device and data traffic. Recently, many researches are going on for studying and designing 5G network architecture [6]. To achieve the objective, SDN and NFV technologies are emerging as a promising solution. SDN [7] is a networking paradigm that separates the control plane form packet forwarding device (i.e. switch and router) and lifts up control function to a centralized controller. NFV [8] provides virtualized network functions and their migration from stand-alone hardware based on dedicated hardware to software appliances running on a cloud infrastructure. Nowadays, many researches of SDN/NFV based mobile core network design have been proposed [9-10].

With evolutionary changes of core network architecture, 5G mobile network aspect for RAN is emerging as more heterogeneous and ultra-dense network. In order to ensure bandwidth capacity for huge increasing of mobile devices and distribute their traffic, RAN has been developed in to a dense network of different network access technology while reducing the size of cells. Research of distributed architecture is proposed in [11].

B. Distributed Mobility Management (DMM)

Studies of IETF DMM working group is currently divided into 4 work items [3];

- Distributed mobility management deployment models and scenarios: describe network deployment models where DMM protocol would apply. They define 4 types of network entities as in accordance with the control or data plane and the role of anchor or access point.
- Enhanced mobility anchoring: defines protocol solutions for a gateway and mobility anchor assignment and mid-session mobility anchor switching.
- Forwarding path and signaling management: define protocol semantics for managing the forwarding stat associated with a mobile node's IP traffic. They consider Control Plane (CP)/Data Plane (DP) separation architecture.
- Exposing mobility state to mobile nodes and network nodes: defines solutions that allow, for example, mobile nodes to select either a care-of address or a home address depending on an application' mobility needs. Currently they defined new flags in IPv6 socket-API for selecting IPv6 address type based on mobility demands.

Unlike current per-user IP allocation, the DMM enables to assign IP address to each session of mobile users in order to provide a fine-grained mobility levels based on their mobility needs. Three types of IP addresses are defined with respect to mobility management [4]: Fixed IP address, Session-lasting IP address and Non-persistent IP address. Fixed IP address guarantees to be valid for a very long time, regardless of whether it is being used in any packet to/from the mobile host, or whether or not the mobile host is connected to the network. It is required by applications that need both IP session continuity and IP address reachability. Session-lasting IP address guarantees to be valid through-out the IP session(s) for which it was requested even after the mobile host had moved from point to attachment to another. It only supports IP session continuity. Non-persistent IP address does not provide both IP session continuity and IP address reachability. It is not maintained across gateway changes and replaced or released by a new IP address when the IP gateway changes.

III. HIERARCHICAL ANCHOR SELECTION IN DISTRIBUTED MOBILE NETWORK ARCHITECTURE

In this chapter, we propose a novel hierarchical anchor selection scheme for distributed mobile network architecture. Firstly, we describe our proposed architecture in which core network is deployed in a distributed and hierarchical manner. After that, based on different IP address types as mentioned in previous section, we define an anchor point for each address type and analyze handover scenario for each case.

A. The proposed architecture

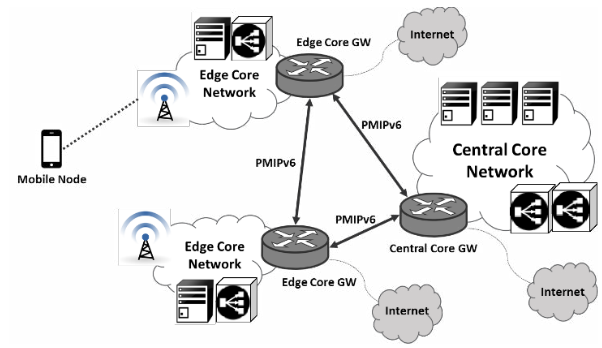

Figure 1. Distributed mobile network architecture

Our proposed architecture of distributed mobile network is presented in Fig. 1. We define two types of core network: central and edge core network. Edge core network is deployed with various access networks such as LTE, Wifi, etc. In those networks, several network functions (i.e., S/P gateway, MME, etc.) can be deployed to support session establishment, mobility management and local break-out for their traffic to the Internet. Additionally, the edge core network can include specific functions for low-latency and intra-domain communication services. For example, cache server or V2V (Vehicle-to-Vehicle) application server in the edge network can reduce latency for end-to-end communication and Internet of Things (IoT) gateway at the edge network can provide local communication. Central core network includes all core network entities defined in 3GPP and manages the entire network based on policies. Even if traffic of a mobile user does not pass through the central core network, information of the user, which is based on consistent policies and management requirements, is managed by the central core network regardless of connected location of the user. The edge core GW and the central core GW are interconnected for exchanging user data traffic and control messages. The edge core GW also provides interface to the Internet directly.

Based on three types of IP address defined in [4], different types of IP address are assigned by the different core network in this architecture. A fixed IP address is assigned by the central core GW, and the edge core network assigns both session-lasting IP address and non-persistent IP address. For requesting IP address type based on attributes of user's application, a MN can send DHCPv6 request message which extends option for IP address selection [12]. Since the fixed IP address should be provided both IP address reachability and IP session continuity, the central core network supports to track the location of user's

Identify applicable sponsor/s here. If no sponsors, delete this text box. (sponsors) fixed IP address by receiving signaling from the edge core network. To support mobility management, PMIPv6 protocol can be used between the central core GW and the edge core GW, and among different edge core GWs. Detail procedure is explained in the next section.

Figure 2.

B. *Procedures for IP allocation and handover*

Fig. 2 is described IP allocation procedure based on different IP address type. A non-persistent IP address and A session-lasting IP address are allocated by the edge core network where a MN attaches. In this case, there is no signaling message to configure interface for MN's traffic. However, in the case of the session-lasting IP address, address information mapped with assigned anchor is required to be updated to the central core network for handover scenarios. When the MN requests a fixed IP address, the edge core GW captures this packet and sends a Proxy Binding Update (PBU) message to the central core network to establish interface using PMIPv6 tunnel. After finishing IP allocation procedure, traffic using session-lasting IP address or non-persistent IP address can be locally broken out to the edge core GW whereas traffic using the fixed IP address is connected the Internet through the central core GW.

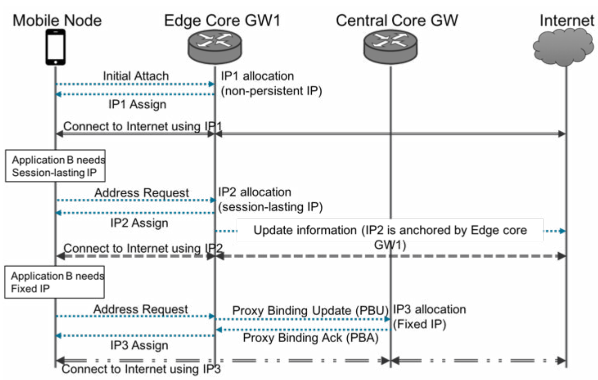

Figure 3. IP allocation procedures

Fig.3 illustrates handover procedure based on different types of IP address. In case of the non-persistent IP address, since this address type does not support IP session continuity, IP address is released when the MN moves to another edge core network. To support mobility of the session-lasting IP address, when the MN moves to a new edge core network, the new edge core GW firstly requests information of anchor for MN's address based on that information. After that, the new edge core GW sends a PBU message to the previous edge core GW. In case of the fixed IP address, the new edge core GW sends a PBU message to the central core GW for updating binding table in the central core GW. After receiving PBA message at the new edge core GW, traffic using the fixed IP address can be forwarded through PMIPv6 tunnel created between the new edge core GW and the central core GW.

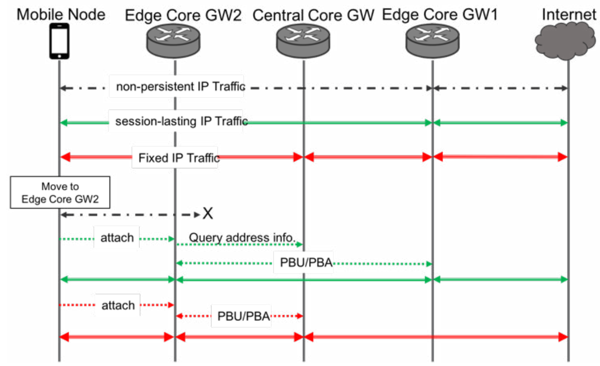

Figure 4. Handover procedures

IV. Numerical Analysis

In this chapter, depending on different types of IP address, we analyze costs for IP address allocation and handover procedure in our proposed architecture. We assume that the MN requests specific IP address type using DHCPv6 message and the edge core GW performs as DHCPv6 server which allocates IP address to its clients. Table 1 displays the list of parameters defined for our analysis.

TABLE I. Parameters

Parameter	Description
AC_x	IP allocation cost for x type of IP address
HC_x	Handover cost for x type of IP address
T_{a-b}	Transmission cost of a packet between nodes a and b
P_c	Processing cost of node c for binding update or lookup
T_{setup}	Setup time of PMIP connection between GWs
H_{a-b}	Hop count between nodes a and b in network
$S_{control}$	Size of a control packet (in bytes)

IP allocation costs for each address type are represented as

$$AC_{fixed} = (S_{DHCP} \times 2T_{MN-EGW} + P_{EGW}) + (T_{setup} + S_{PMIP} \times 2T_{EGW-CGW} + P_{CGW})$$

$$AC_{session-lasting} = (S_{DHCP} \times 2T_{MN-EGW} + P_{EGW}) + (S_{control} \times T_{EGW-CGW} + P_{CGW})$$

$$AC_{non-persistent} = S_{DHCP} \times 2T_{MN-EGW} + P_{EGW}$$

Handover costs for each address type are represented as

$$HC_{fixed} = T_{setup} + S_{PMIP} \times 2T_{EGW-CGW} + P_{CGW}$$

$$HC_{session-lasting} = (S_{control} \times 2T_{EGW-CGW} + P_{CGW}) + (T_{setup} + S_{PMIP} \times 2T_{EGW-EGW} + P_{EGW})$$

For numerical results, default parameter values referred to [13]. With this values, costs of each address type are simply shown in Table 2. According the results, proposed scheme provides different IP allocation costs and handover costs depending on type of IP address.

TABLE II. NUMERICAL RESULTS

IP Address Type	IP Allocation Costs	Handover Costs
Fixed IP Address	618	514
Session-lasting IP Address	558	1014
Non-persistent IP Address	304	-

V. CONCLUSION

In this paper, we proposed distributed mobile network architecture with hierarchical manner and define allocation procedure for different types of IP address. Depending on IP address type, different anchor is assigned to the mobile traffic for providing fine-grained policy of mobility supports. From the simple numerical analysis, we show that the IP allocation costs and handover costs can be different for each IP address type. However, one issue is that the handover cost of session-lasting IP address is significantly higher than the case of fixed IP address because procedure for updating user information mapped with the anchor of IP address is required. Further, in future work, we will enhance this scheme for reducing handover costs for session-lasting IP address and analyze in detail about message procedures.

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