Assay of Multipath TCP for Session Continuity in Distributed Mobility Management

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***Abstract*—The evolution of wireless access networks flat IP architecture implies a key-role for IP mobility management in providing the ubiquitous always-on network access services. In particular the connection-oriented transport services requires an optimized routing by gateway relocation during the user's mobility. This paper proposes distributed co-located mobility and IP anchors in the core network to solve the problem of unnecessary long routes and delay. Session continuity in connection with user mobility also require for a single connection to be capable of using multiple network paths, the proposed architecture applied Multipath TCP (MPTCP) functions for the simultaneous exchange of IP traffic through the transient use of multiple distributed IP anchors. We describe the important call control flows being exchanged across the various network elements of the proposed architecture due to mobility of mobile nodes. It also provides an evaluation of MPTCP enabled IP mobility to show how it can be systematically exploited to gain session continuity.**

Keywords—Distributed Mobility Management; IP Mobility; Distributed Anchors; Multiple PDN connections; Multipath TCP;

I. INTRODUCTION

The continuous improvement to the radio access networks (RAN) architecture is becoming increasingly important to support the performance requirements for the ubiquitous wireless connections. More and more people see their handheld devices as an annex of their workspace while on move. Support mobility is one of the major challenges in vehicular networks for intelligent transportation systems (ITS) applications supporting, infotainment (information and entertainment), road safety and traffic efficiency through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. Some of ITS applications particularly need to be continuously connected to internet. In addition vehicular communications have some unique features, in terms of generation patterns, delivery requirements, communication primitives, and spatial scope. These growing demand of wireless communication with user mobility for Service continuity implies enabling seamless IP mobility as an integral implementation of ubiquitous wireless access.

There are ongoing attempts to provide IP mobility management, such as Mobile IPv6 (MIPv6) [1], Dual Stack MIPv6 (DSMIPv6) [2], Proxy MIPv6 [3] and GPRS tunneling protocol [4]. Global reachability and session continuity is enabled by introducing an entity located at the home network of the Mobile Node (MN) which anchors the permanent IP address. When the MN is away from its home network, the MN acquires a temporal IP address from the visited network and informs the home IP anchor about its current location. Depending on the mobility management approach (client or network based) the traffic between MN and home IP anchor is redirected by bi-directional tunnel between the corresponding nodes.

Several limitations of these centralized mobility management approaches have been identified when compared to the always-on network access service requirements of seamless mobility. With centralized network architectures, incoming user traffic will always need to go first to the home network and then to the corresponding service node, adding unnecessary delay and wasting resources. Since the mobile node (MN) use the single address anchored at central IP gateway, the traffic always traverses the central anchor, leading to paths that are in general longer than the direct one between the MN and its corresponding node. This poses excessive traffic concentration on a single gateway element and possibly un-optimized routing leading in turn higher latency. Centralized solutions are probable to have reliability problem, as the central entity is potentially a single point of failure. Central IP mobility anchor have to deal with higher user traffic simultaneously, thus need to have enough processing and routing capabilities implies several scalability and network design problems [5].

To cope with these issues: we followed the concept of distributed mobility management (DMM) in contrast to centralized anchors in a hierarchical model. There are number of design approaches that can be considered to extend and apply on distribution of mobility functions, the Access, the Remote and the core IP anchoring by terminals [6]. In this paper, to limit the potentially huge design space and the envisioned research towards a common core network architecture we focus mainly on provision of IP session continuity that can be realized by distribution of GWs within current 3GPP core network architecture. Figure 1 shows the reference architecture of distributed Serving Gateway (S-GW)

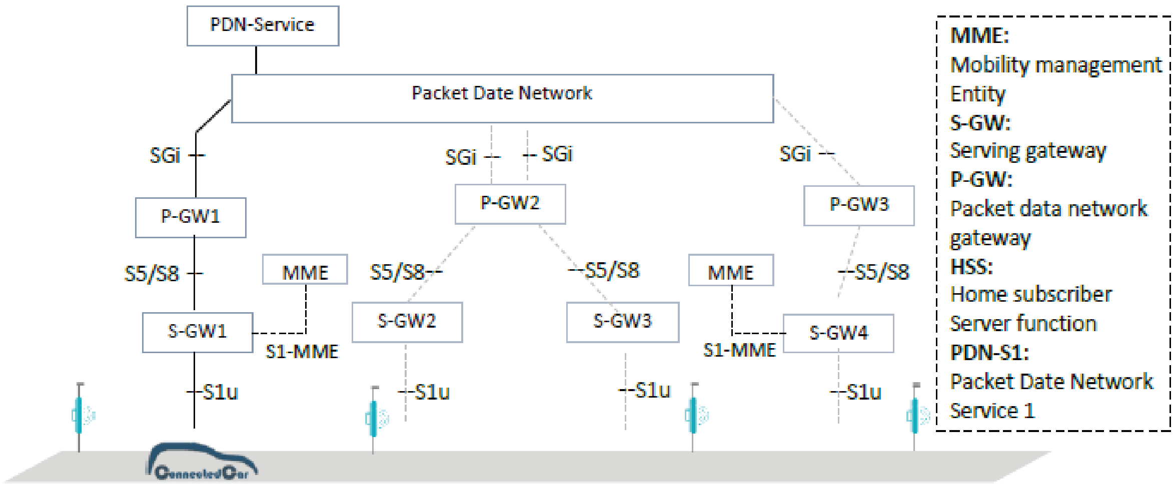

Figure 1: Baseline architecture for distributed mobility management.

and Packet Data network Gateway (P-GW), a common IP-based core network to provide MNs seamless mobility and service continuity. The basic idea is to select and re-locate when necessary P-GWs that are topologically/geographically close to the MN.

Among other considerations different types of future ITS applications require multiple different dimensions of distributing the IP flows with respect to their mobility management needs [6]. Some applications (e.g., instant messengers) can deal with IP address changes on their own. Such applications detect a host's IP address change and notify their corresponding nodes of the new IP address. Flows used by certain server application (e.g., in-vehicle camera serving remote system) require a fixed IP address allocation on its local end so that the incoming connections can find the server application at a published IP address. Some floating car data (FCD) applications (e.g., environmental monitoring sensors) do not need a fixed IP address, as they are the originator of the communication. They can choose any available IP address as the source address for communication. However, certain applications for transmissions of information collected by vehicles, from internal and external sensors to remote management servers require that the IP address changes does not interrupt an ongoing IP session. Furthermore, some flows need neither a fixed IP address nor IP session continuity.

In order to address these particular challenges associated with distribution of mobility functions, in this paper we intend to make the following contributions:

- Propose a MPTCP-based DMM architecture with distributed co-located S-GW and P-GW in the core network to solve the problem of unnecessary long routes and delay.
- Describe how MPTCP guarantee session continuity during GW relocation without the use of bi-directional tunnels between the source and target GWs, avoiding signaling overhead.
- Explore how MPTCP-based DMM can help for the exchange of IP traffic through the use of distributed P-GWs and select the right one for use in the following cases. i) The MN acts as a server and requires a static IP address for incoming IP flows. Static anchoring at the home P-GW will be required. ii) No fixed IP address, i.e. the MN acts as client, but IP session continuity: No static anchoring at the home P-GW will be required. iii) No fixed IP address and no IP session continuity: no static anchoring at the home P-GW will be required
- Evaluate whether an MPTCP-based solution can indeed support seamless mobility for MNs and significantly reduce signaling and delay compared to tunnel and routing based approaches and identify the research directions.

The rest of this paper is organized as follows. The paper first gives an overview of different approaches introduced by different standards that can be relevant, extended or applied for DMM. We then proceed with an MPTCP-based solution for distribution of mobility anchors and gateway functions and describe proposed architecture. In the next section we present important call control flows being exchanged across the various network elements of the proposed architecture for session continuity. The last section provides an evaluation of the concept and concludes the paper.

II. Related Work

In this section we provide an overview of current IP mobility management initiatives with in IETF and 3GPP and their extensions that are complement to distributed anchoring. Based on IP mobility protocols such as MIPv6, PMIPv6 and GTP there are two main approaches for distributed GWs anchoring client-based approach and network-based approach.

A. *Client-based IP Mobility management*

In client based mobility management approach (MIPv6), session continuity is enabled by an entity called Home Agent (HA) which anchors the permanent IP address used by the MN, called the Home Address (HoA). As MN moves away from its home network, it acquires a temporal IP address from the visited network called Care of Address (CoA). The HA is responsible to maintain the MN's HoA and redirect traffic to and from the MN's current location. Following the proposal of distributing the anchoring IETF specified some extensions to MIPv6 [7]. As shown in figure 2, multiple HAs are deployed at the edge of access network. The MN initially attaches to the distributed anchor HA/AR1 and configures the IPv6 address HoA1 to communicate with a correspondent PDN-Service. If MN moves to new HA/AR2, the MN have to keep bind home (while maintaining the reachability for those IP addresses that are still in use by active communications) address and configure the locally-anchored address to start new communications which is actually playing the role of care-of address in these bindings. Session continuity is guaranteed by the use of bi-directional tunnels between the MN and each one of the home agents anchoring in-use addresses.

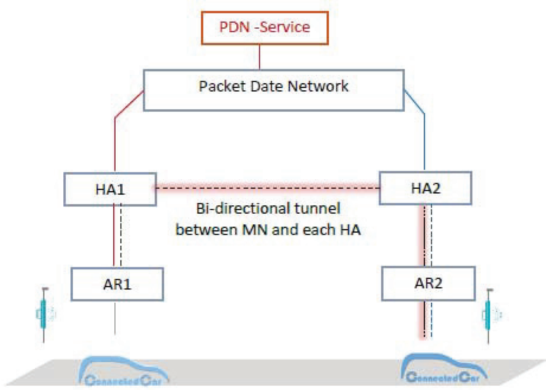

Figure 2: Client-based Distributed IP Mobility Management

This approach requires additional intelligence on the mobile node side, as it has to manage multiple addresses simultaneously, select the right one to use for each communication, keep track of those addresses which need mobility support, and perform the required maintenance operations (i.e., binding signaling and tunneling) [8].

B. *Network-based IP Mobility management*

With network-based approach such as in PMIPv6 as well as the GTP, mobility management is provided without involvement of mobile users. Movement detection and signaling functionalities are performed through a network functional entity. Referred as Mobile Access Gateway (MAG)/ S-GW in IETF/3GPP context respectively. An example of the operation of a generic network-based DMM solution is shown in Figure 3. Mobility anchors are moved to the edge of the access network thus anchoring and routing the local traffic for a given user. Furthermore whether the control plane and the data plane are tightly coupled or not, there are two sub variants of network based solutions fully and partially distributed. In a fully distributed model and using the PMIv6 terminology each access router implements both control and data plane functions and for each user the access router could behave as a local mobility anchor. In a partially distributed model, data plane and control plane are separated and only the data plane is distributed [9]. In this sense, the operations are similar to 3GPP networks where the control plane is managed by the Mobility Management Entity (MME) and the data plane by the S-GW and P-GW.

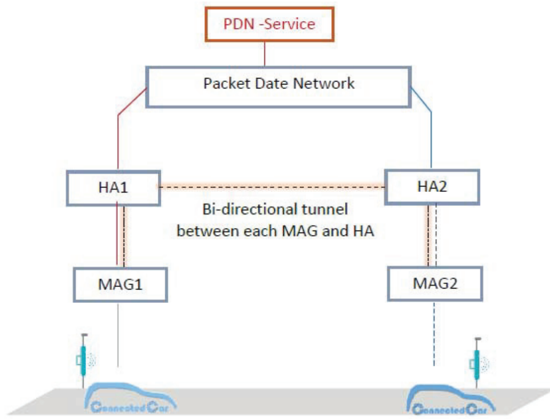

Figure 3: Network-based Distributed IP mobility management.

C. *Multipath TCP*

The IP mobility management through the use of multiple distributed IP anchors implies a key role involvement of transport layer protocols to enables simultaneous exchange of IP traffic flows. MPTCP is an ongoing effort within IETF to support multipath operation, a set of extensions to enables a regular TCP connection to use multiple different IP addresses and interfaces [10]. In the mobility context, when MN moves

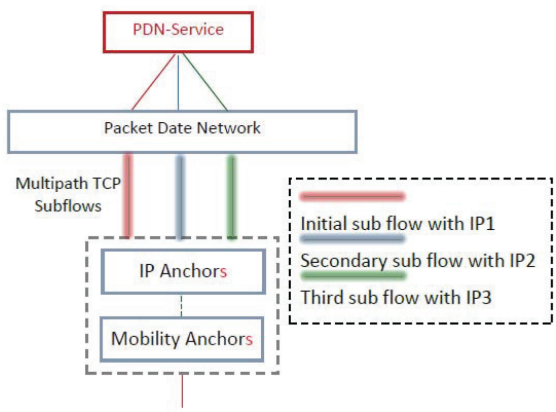

Figure 4: Multipath TCP multipath operations.

from one point of attachment (in 3GPP terminology P-GW) to another i.e., it receives or configures a new IP address through new network attachment. MPTCP enable multiple IP addresses

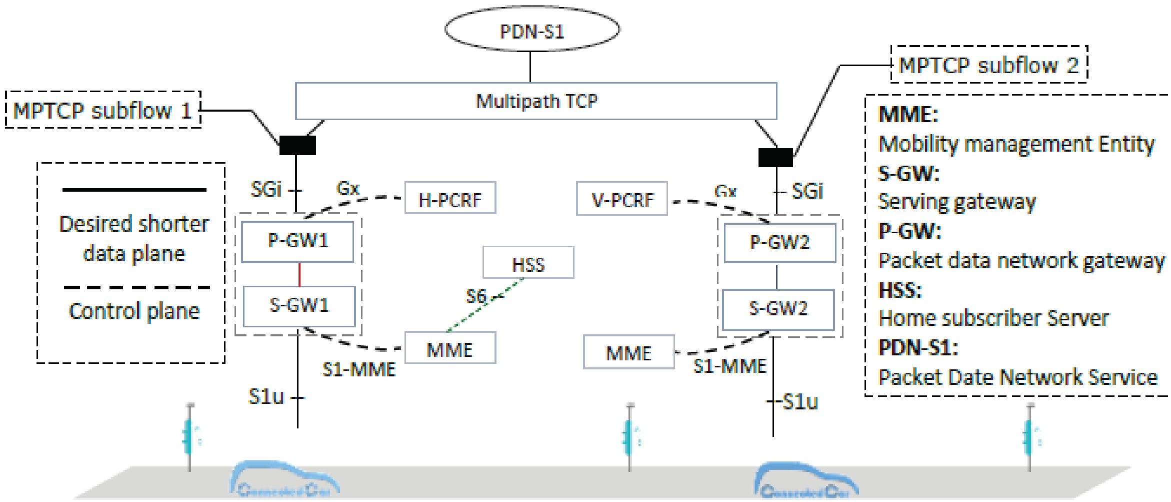

Figure 5: Proposed mobility management with distributed flat IP architecture.

by adding subflows. Each sub-flow behaves as a separate regular TCP connection inside the network. Subflows can be added and removed at any point of time, in any MPTCP ongoing communication, with the help of ADD_ADDR option and REMOVE_ADDR option for any interface [10]. To maintain the ongoing communication MPTCP support "make before break" method and uses MP-PRIO option to specify any subflow as backup mode. In Fig. 4, in the mobility scenario, With the MN have multiple IP addresses so in this case MPTCP can create multiple subflows and the MN is connected to Packet Data Network (PDN) service. Defined by MPPRIO option MPTCP support different flow modes, in the single-path mode only one TCP sub-flow is used at any time or using all subflows simultaneously between two communication nodes or uses only a subset of subflows for transmission of data packets.

III. Proposed Architecture

To fully appreciate the particular issues identified above; this paper proposes distribution of mobility anchors and gateway functions to select P-GW that is topologically/geographically close to the MN. We proposed twofold IP mobility management, at the core network we adopt distributed co-located S-GW and P-GW to solve the problems of unnecessary long routes and delays and at the transport layer applied the Multipath TCP functions that enables the use of multiple IP addresses. Figure 5 illustrate the proposed architecture, MN is connected to PDN-Service1 (ITS Application) with co-located S-GW and P-GW, with established MPTCP connection of MPTCP capable MN and PDN-Service1 and will be able to synchronize the user traffic using different IP addresses.

In the following we describe the important call control flows being exchanged across the various network elements of the proposed architecture to show how it can be systematically exploited to gain benefits:

A. *Multiple PDN connections enablement*

Followed by 3GPP initial attach procedures [11] (attach request/response, identification, S-GW assignment, create session request/response and EPS bearer setup), after the Attach Accept message, the MN has obtained a PDN address and MN can then sends uplink data towards the eNodeB which will be tunneled to S-GW and P-GW. The first step of multiple PDN enablement is to establish MPTCP connection. Figure 6 shows the signaling diagram illustrating an expression of proposed architecture to establish initial MPTCP subflow, with implied MPTCP capable MN and PDN-Service1, MN initiates an initial subflow through S-GW1 onto P-GW1 with its IP address and sends SYN segment to PDN-Service1. This SYN segment may include different options most particularly MP-JOIN option that declares MN is capable of MPTCP and wish to add subflow on this particular connection. Amid to three way handshake PDN-Service1 replies with SYN+ACK segment. MPTCP use unique identifier called Token to make a subflows global to link with other subflows. MN add its token within SYN segment which is local identifier inside the MPTCP connection and PDN-Service1 provide its own token. In this way the need for the maintaining a tunnel between source and target anchors is not required to link different flows for session continuity. Furthermore considering the expected handover with MN mobility, The MME in cooperation with the S-GW1 and P-GW1 notify the needed support for GW relocation and keep the established PDN-Connection context.

B. *GW Relocation*

During the movement of MN several events occur (e.g., eNodeB handover over X2 interface, selection of relevant S-GW) that tag along with P-GW relocation and it must connect a set of appropriate GWs that are close to the MN as an additional MPTCP subflow. The MPTCP based signaling for GW relocation is shown in Figure 7. Typically MME

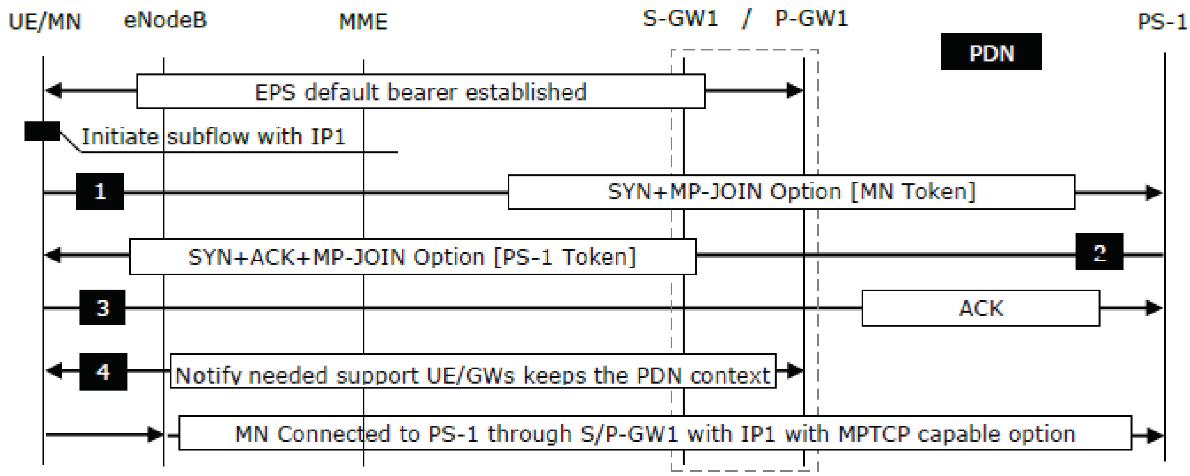

Figure 6: MPTCP connection establishment between MN and PDN-Service1 through S/P-GW1

implemented S/P-GW relocation with reactivation message during Tracking Area Update (TAU) when a MN is in idle mode. To ensure the continuity of active communication and to prevent MN from idle mode as conferred in [12], we take in to shift the relocation decision from MME to S-GW that triggered the GW relocation with create session request to new S-GW. The new S-GW sends a modify bearer request to new P-GW, Together with this procedure MN gets a new IP address (IP2) to be used in the MPTCP new subflow. Since the PDN context is maintained when handing over the MN as notified above, a great deal of signaling is avoided, As a result latency is greatly reduced since the rounds of communications in the EPC between network nodes such as updates with HSS, create session with S-GW/P-GW and perform Policy and Charging Rules Function (PCRF), no longer must be performed.

After the bearer modification, MN initiates new subflow in the same way the MP_CAPABLE handshake and sends SYN segment through S-GW2 onto P-GW2 with its new IP address to PDN-Service1. The new subflow needs to differ at least one of elements of four-tuples (MN IP address, PDN-S1 IP address, MN port and PDN-S1 port). With pre included local identifier (token) carried as an MP-JOIN option of SYN segment, both MN and PDN-S1 are linked to existing MPTCP connection. After the subflows has been established the PDN-Service1 will be able to synchronize the MN's traffic using different IP addresses distributed on MPTCP sub-flows. To provide reliable byte stream on different subflow MPTCP uses two levels of sequence numbers (Regular TCP sequence number and Data sequence number which is corresponds to each byte stream) and maintains one window flow control shared among all subflows relative to last acked data (Data Ack), In this way avoid any loss of inflight packets during the end-to-end state convergence. Packets not acknowledged by corresponding service are retransmitted by another subflow. The presented architecture proposes enhancements in default MPTCP scheduler [13] that decide and direct data to different subflows. The enhanced scheduler can manage different cases of IP flows. The data packets from service requiring static IP anchoring are directed to initial subflow, so the MN is enabled to keep the initially assigned IP address despite its location changes and where no static anchoring at the P-GW1 is required, the MN uses the new subflow for active communication, while maintaining the reachability for the IP address that is still in use.

C. Release connection with long route/delay

As soon communication is successfully established over new subflow, the subflow of long route/delay is set as backup with MP-PRIO option. The old P-GW checks the MN activity, as no traffic is carried in the initial subflow (during the timer interval) the P-GW starts the releases procedure for the removal of initial IP address from the PDN-S1 IP list. The MN could generate a FIN segment/RST flag to close a subflow. Unlike regular TCP that does not allow sending a RST while the connection is in a synchronized state [14], with MPTCP the RST only has the scope of subflow and only close the concerned subflow but not affect the remaining subflows. The release cause tag along the session management and perform the GW binding information update.

IV. Conclusions

In this paper we have presented improvements for distributed network connections to enable seamless IP mobility, novel perspective to maintain session continuity during the movement of MN that tag along GW relocation. The MPTCP protocol is used to remove the chains of IP preservation of current mobility management solutions, leading in turn seamless IP mobility. Distributed co-located S-GW/P-GW is adopted for optimal data paths, the transport path length between the corresponding nodes has thus dwindled significantly in the architecture presented. The proposed solution further comprises maintaining PDN context for GW relocation, the pictorial call control flows thus created has shown a significant decrease in signaling and delay compared to tunnel and routing based approaches of

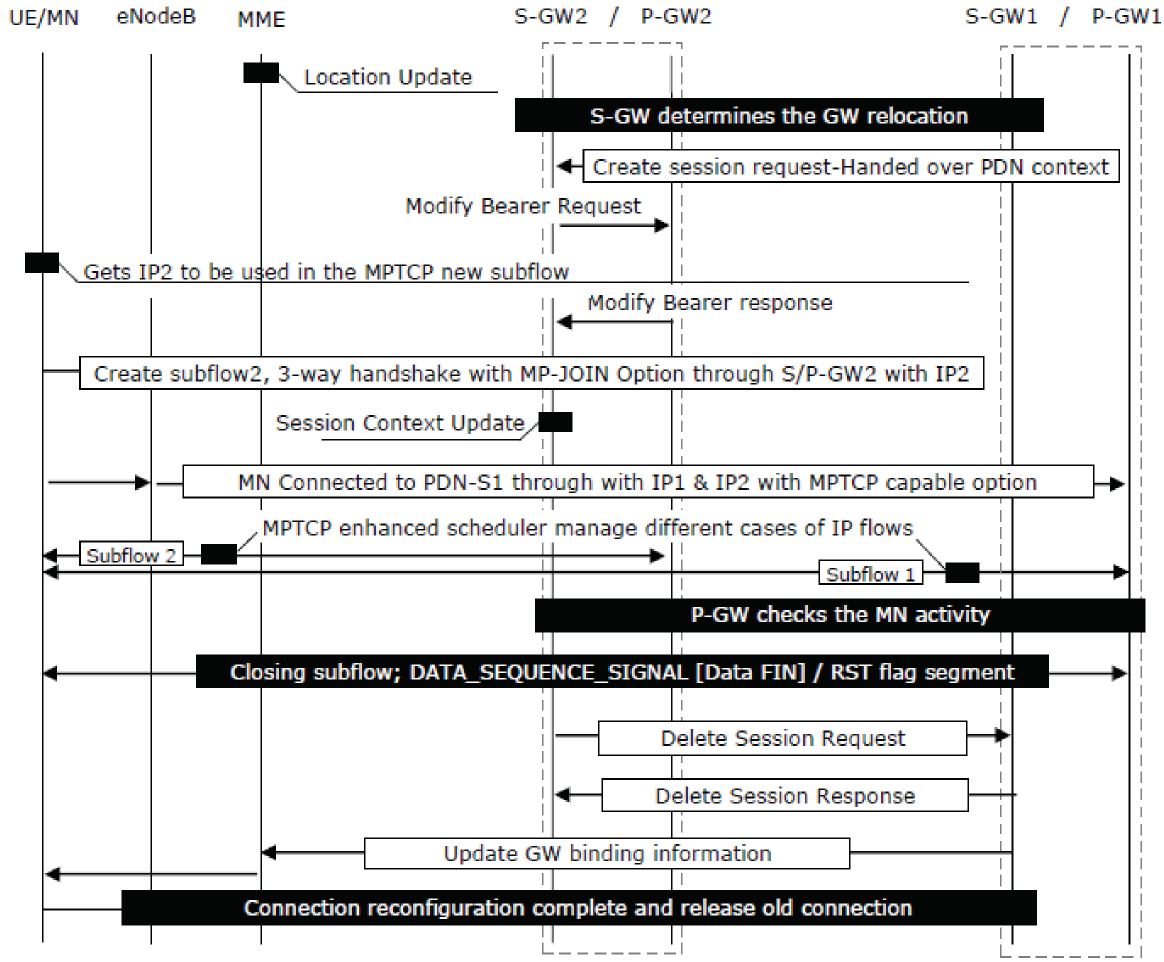

Figure 7: S-GW initiated Gateway relocation with location update.

distributed mobility management. MPTCP provides an overall umbrella and a longer evolution perspective of using simultaneously multiple network path, In future work we intend to enhance the MPTCP default scheduler to manage different types of IP flows and evaluate the proposed solution in an experimental setup in order to illustrate further system realization of the architecture presented.

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