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Performance Analysis and Implementation of a PMIPv6-Based Partially Distributed Mobility Management

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Abstract

This paper provides the implementation mechanism of the pmipv6-based partially distributed mobility management (DMM) and performs extensive simulations under various traffic environments for verification and evaluation of the proposed scheme. The simulation results indicated that Mobility Anchor and Access Router (MAAR) could distribute and manage all IP data packet flow between a corresponding node (CN) and mobile node (MN). Therefore, the implementation and performance analysis of proposed mechanism is essential to understand the fundamental features of DMM, which includes a method of detecting MN and managing MN's location.

Keywords*: partially DMM, implementation, performance*

1. Introduction

With the increasing volumes of mobile data traffic and the massive increase in the number of interconnected devices, there has been a demand for "imperceptible latency" with the tactile Internet, and demand millisecond-level latency and nearly 100% reliability with Internet of Things service [1]. However, conventional IP mobility solutions have adopted a centralized approach that represents a single point of failure, poses scalability issues, and in general, leads to suboptimal routing paths between mobile node and corresponding node [2-3].

To solve these problems, distributed mobility management (DMM) has recently emerged as a new paradigm to design a flat and flexible mobility architecture, allowing traffic to be broken out locally closer to the edge (*i.e.*, offloading the network core) and exploiting the use of different gateways for traffic with different connectivity and mobility requirements. Apparently, the DMM approach is a suitable candidate for mobility management in future 5G dense deployments [4].

A number of implementation and performance analyses on DMM network have been proposed in the literature. For the implementation issue, Bernardos *et al.* [5] proposed a method by querying the Central Mobility Database (CMD) to acquire the MN's location information. Yuhong Li *et al.* [6] introduced AAA server and Software Defined Networking (SDN) to manage MN's location information. Kim *et al.* [7] presented the multicast and point-to-point searching scheme to get MN's location. However, those proposed mechanism did not give a specific implementation mechanism and feasibility analysis. For the performance analysis issue, Li Yi *et al.* [8-9] and Kim *et al.* [10] showed signal control and data transmission cost is lower than PMIPv6 protocol. Seo *et al.* [11] proposed multiple LMAs mechanism in DMM and provided lower end-to-end delay. Those performances are useful for study DMM network in cost analysis.

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In this paper, the pmipv6-based partially DMM solution is suggested and the model verification and performance evaluation of the suggested mechanism is implemented while extensive simulations under various traffic environments are also performed.

2. Proposed Scheme Modeling for Partially DMM

2.1. Initial Attachment Procedure

One of the main issues is how Mobility Anchor and Access Router (MAAR) would know MN's attachment, that is, the MAAR should be informed of the MN's attaching exactly to be able to generate the distributed proxy binding update (d-PBU) message. To solve this issue, the data-link layer and IP layer in both MN and MAAR are required to detect MN's attachment. According to the wlan AP association procedure, once MN enters a new network, MN's wlan_mac layer will do a scan procedure to find out an AP (MAAR), and then associate with AP (MAAR) in wlan_mac.SCAN state. From the association procedure, AP (MAAR) will obtain a MN's MAC address (mn_mac_addr) in wlan_mac layer. Then, the wlan_mac layer will interrupt and notify the IP layer with this mn_mac_addr, which will be placed into the d-PBU message as MN_ID. The details for detecting MN's attachment procedure in wlan_mac and IP layer between MN and MAAR are shown in Figure 1.

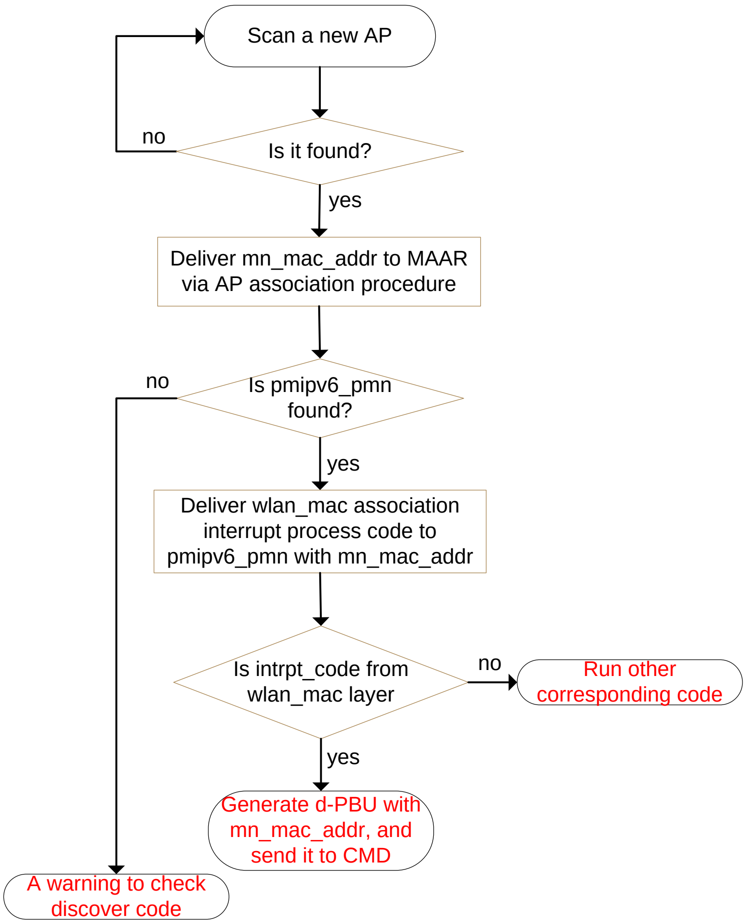

Figure 1. Detect MN's Attachment between MN and MAAR

Upon the MN's attachment to a MAAR1, as in Figure 2, the IP@MAAR1 is sent in a d-PBU with the MN's Identifier (MN_ID: mn_mac_addr) to the CMD according to the MN's detection mechanism (DM) in Figure 2. Since the session is new, the CMD stores a permanent Binding Cache Entry (BCE) containing as main fields the MN_ID, the MN's HoA and MAAR1's address as proxy-CoA, as shown in Figure 3. The CMD replies to MAAR1 with a distributed Proxy Binding Acknowledgement (d-PBA) message. While MAAR1 receives d-PBA message, the Binding Update List Entry (BULE) should be updated with d-PBA message. However, if there is no fresh information included in d-PBA, such as previous-MAAR (p-MAAR) option, the BULE should not be updated in next_hop filed. After that, the MAAR1 acts as plain router for those packets, as no encapsulation or special handling take place.

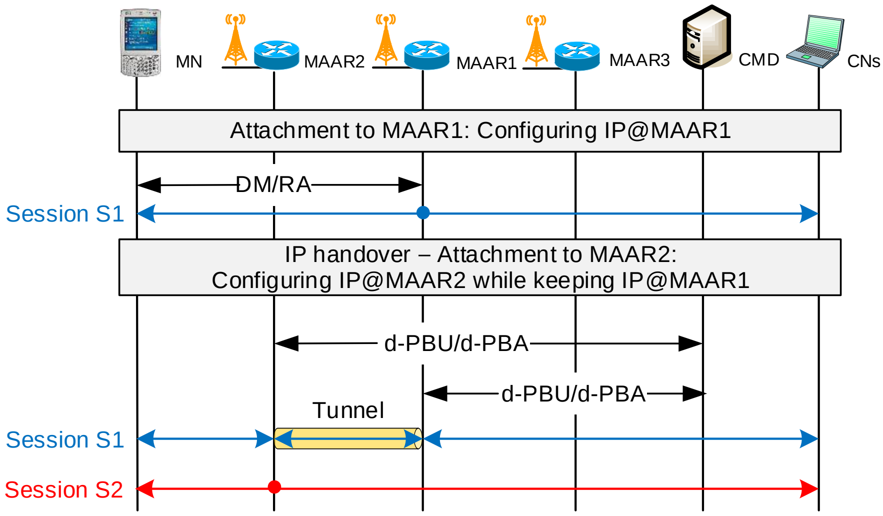

Figure 2. Mobility Management Procedure in Partially DMM Mechanism

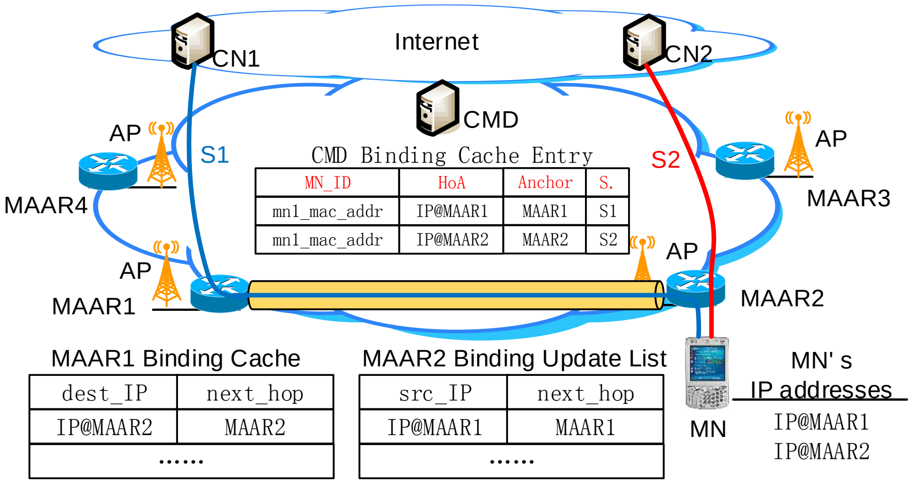

Figure 3. Information Building in Partially DMM Mechanism

2.2. Handover Procedure

When the MN associates with MAAR2, which can be the serving-MAAR (s-MAAR), as seen in Figure 3. Upon d-PBU reception and BCE lookup, the CMD will update its HoA and anchor point field in BCE with IP@MAAR2. Then the CMD will reply to the MAAR2 with d-PBA message with the previous entry field, such as IP@MAAR1 and MAAR1. After that, upon d-PBA arrival, the BULE with src_ip and next_hop field in MAAR2 must be updated with d-PBA message.

Then, the CMD generates a d-PBU to the MAAR1, including s-MAAR's global address (IP@MAAR2) and corresponding anchor point information (*e.g.*, MAAR2). Upon d-PBU reception, MAAR1 can update its BCE with dest_ip and next_hop field by using HoA and s-MAAR's IP address. Finally, a bi-directional tunnel can be established between the two MAARs and new routes are set appropriately to recover the IP flow(s) carrying IP@MAAR1.

Now packets destined to IP@MAAR1 are first received by MAAR1, encapsulated into the tunnel and forwarded to MAAR2, which finally delivers them to their destination. In uplink, when the MN transmits packets using IP@MAAR1 as source address, they are sent to MAAR2, as it is MN's new default gateway, then tunneled to MAAR1 which routes them towards the next_hop to destination. Conversely, packets carrying IP@MAAR2 are routed by MAAR2 without any special packet handling both for uplink and downlink.

For the next movements of MN, the process is repeated except for the number of corresponding previous IP@MAARs involved, which rises accordingly to the number of prefixes that the MN wishes to maintain.

3. Performance Analysis and Discussion

3.1. Distributed Concept in Partially DMM Evaluation

The partially DMM simulation network architecture is shown in Figure 4, where three MAARs are adopted and the distance is 2km between each MAARs. The MN will start 2km away from MAAR1 for testing MAAR's detecting procedure and come back from MAAR3 to MAAR1. In this basic DMM performance, the TCP data packet has been chosen for evaluating the distributed concept in OPNET.

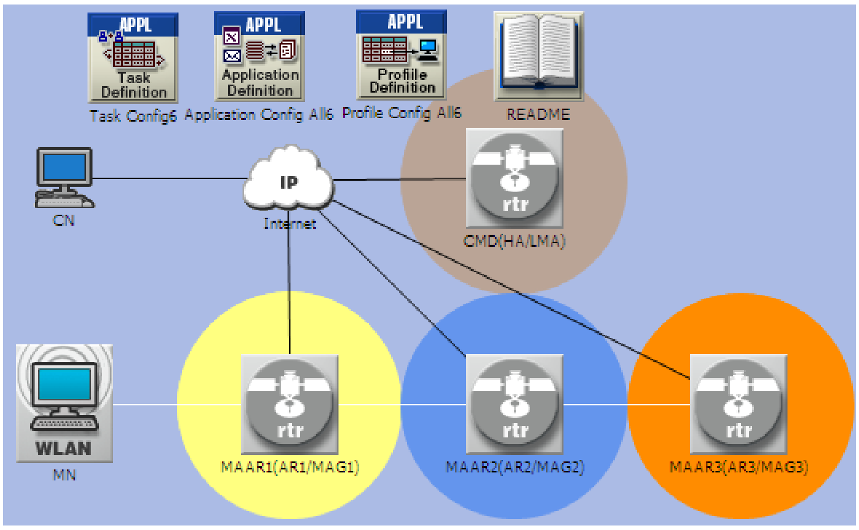

Figure 4. Partially DMM/Mipv6/Pmipv6 Simulation Network Architecture

As seen in Figure 5, CN sends TCP data packets to MN. Once MN moves out of its home domain (*e.g.*, attaching MAAR2), the data packets from CN to MN are intercepted by MAAR1. MAAR1 then sends this tunneled traffic to MAAR2, which will receive this tunneled traffic and then decapsulate this data packet. While MN continues to move to MAAR3, after d-PBU/d-PBA signaling exchange, MAAR1 intercepts this data packet and then tunnels it to MAAR3, which can receive this tunneled data packet and decapsulate it. It can be seen in Figure 5 that MAAR1 intercepted all data packets for MN and then sent those tunneled segmented data packets to MAAR2 and MAAR3.

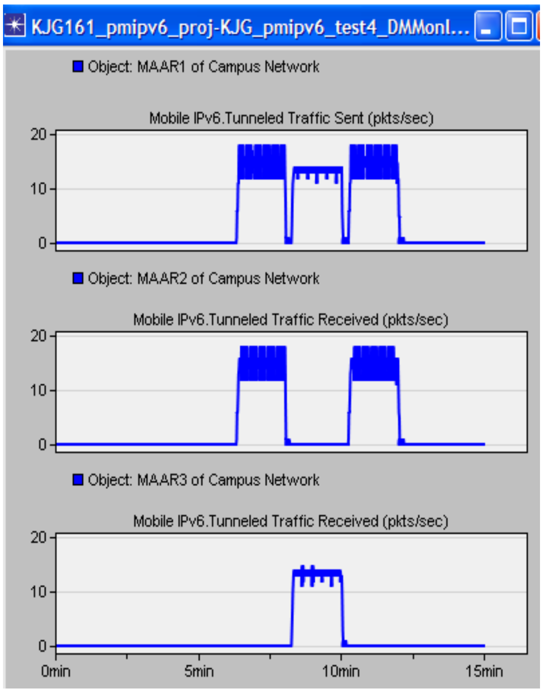

Figure 5. TCP Tunneled Data Traffic Sent/Received

3.2. Comparative Study of MIPv6, PMIPv6 and DMM

Figure 6 shows the global packet network delay performance in each protocol. Packet network delay is the delay of request and response packets in the whole network. The average network delay in DMM is smaller than that of PMIPv6 and MIPv6 because data packets in DMM only go through between MAARs, while data packets in MIPv6 and PMIPv6 have to pass via HA and LMA, respectively.

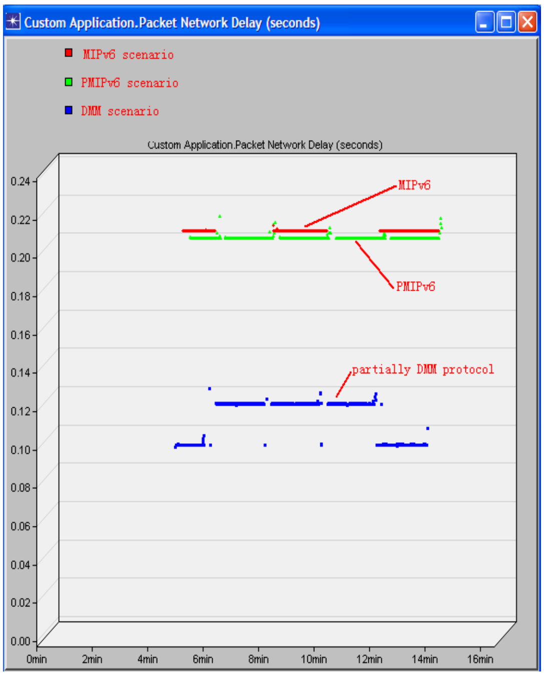

Figure 6. Application Packet Network Delay

For a comparison of CPU utilizations of CMD, LMA and HA in DMM, PMIPv6, and MIPv6 respectively, simulation results are shown in Figure 7. CPU utilization models the IP packet forwarding delays and application processing delays in the node. The more packets to be forwarded, the higher CPU utilization to be achieved. In the result graphs, CPU utilization of CMD node in DMM protocol (around 0.004s) is much lesser than those of HA in MIPv6 and LMA in PMIPv6 (around 0.04s) because data packets in DMM are distributed across all MAARs while all data traffic in PMIPv6 and MIPv6 are transmitted by way of an LMA and an HA, respectively.

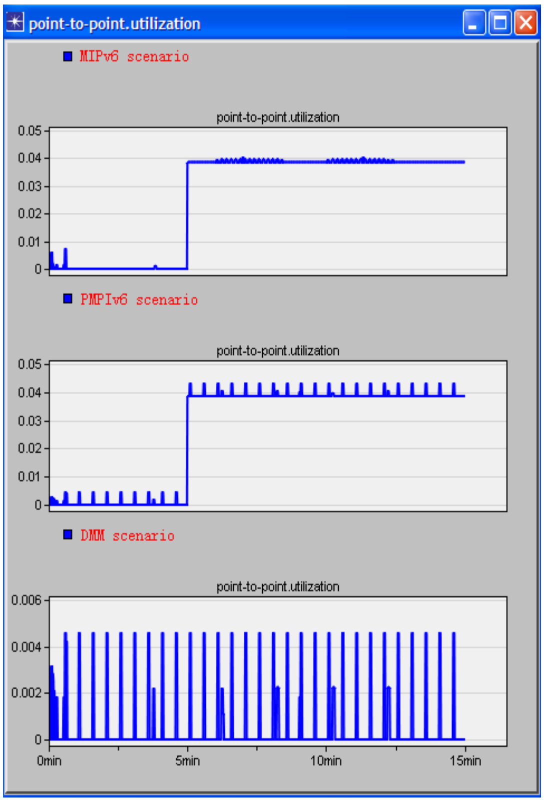

Figure 7. CPU Utilization in MIPv6/PMIPv6/Partially DMM

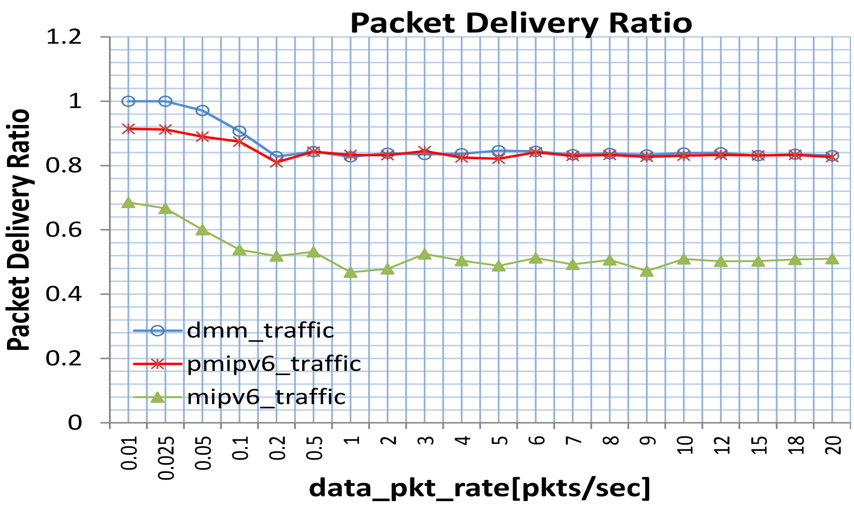

Figure 8. Effect of Data Traffics on Packet Delivery Ratio at 1 Node

One of the important motivations of DMM mechanism is for solving the increasing volumes of mobile data traffic. In order to better understand DMM performance with the increasing data traffic, the data traffic generated rate is changed from 0.01packet/sec to 20packets/sec. Meanwhile, the mobile node is moving at 60 km/h with 1 and 10 nodes around MAARs. The performance metric with Packet Delivery Ratio (PDR) is adopted, which is the ratio between the number of packets delivered to the receiver and the number of packets sent by the source. With the increasing volumes of data traffic, Figures 8-9 show the similar trend of PDR in DMM/PMIPv6/MIPv6.

However, while the mobile nodes increased, the PDR also decreased, but DMM is performing better than PMIPv6/MIPv6 in PDR. This is because the extra control traffic in PMIPv6/MIPv6 caused less available bandwidth for data traffic and while increasing chances of packet loss due to congestion. It is revealed that DMM mechanism is well suited for higher density network with much more data traffic.

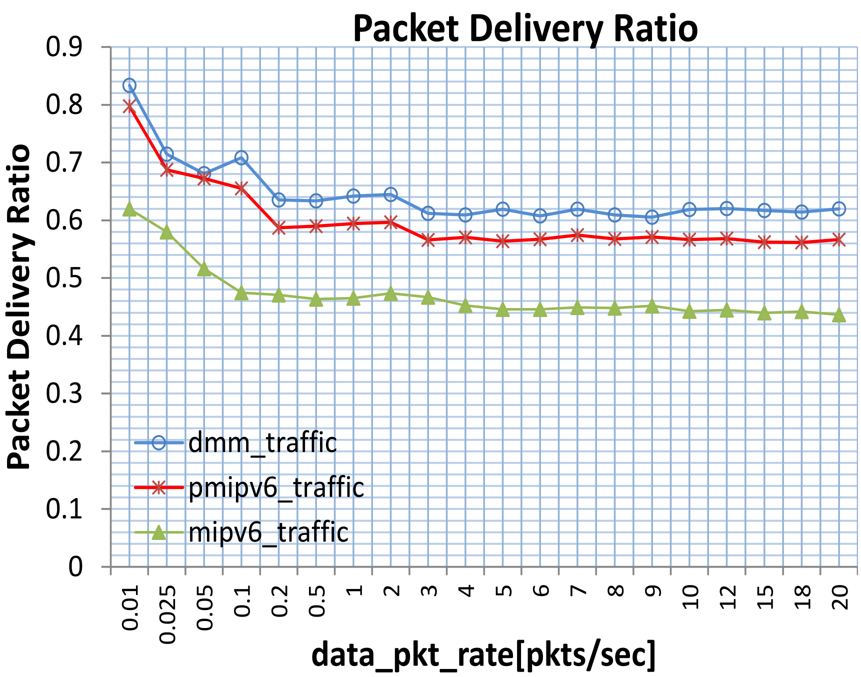

Figure 9. Effect of Data Traffic on Packet Delivery Ratio at 10 Nodes

4. Conclusion

DMM is expected to meet the requirements of increasing data traffic volumes and millisecond-level latency. The objective of this mechanism is to alleviate the scalability issue of PIMv6 and MIPv6; it intends to distribute and confine the mobility support functions (or part of them) at the Access Routers level, keeping the rest of the network unaware of the mobility events and their support.

In this paper, as performance results, MAARs in DMM can distribute and manage all IP data packet flow between CN and MN, which is based on where IP data packet flow is established. According to analyses on the simulation performance with TCP tunneled data packet, packet network delay, CPU point-to-point utilization, and PDR, it is concluded that the new modification concept and developed simulation models are logically correct and very useful for studying DMM mechanism.

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