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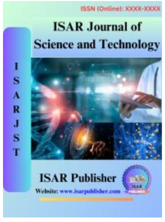

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Critical Upgrades to Elevate PMIPv6 Capabilities

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Abstract: Mobility IP protocols are intended to ensure that mobile nodes remain reachable while traversing the Internet. There are two primary approaches to mobility management: host-based and network-based. Mobile IPv6 (MIPv6), a host-centric mobility management protocol, stands out as a significant initiative proposed by the Internet Engineering Task Force (IETF) to serve as the main protocol for mobility management at the IP layer. To address the shortcomings of the host-based MIPv6 protocol, including issues such as suboptimal routing, delivery delays, packet loss, and the risk of a single point of failure, the IETF has standardized the Proxy Mobile IPv6 (PMIPv6) protocol. This document outlines the fundamental specifications of PMIPv6 and examines various extensions that has been proposed by standardization organizations and researchers to enhance the core PMIPv6 protocol. These enhancements aim to provide a more comprehensive mobility experience, incorporating features such as aggregation, rapid delivery, path optimization, support for network mobility, and load balancing. The research conducted on these extensions is evaluated to pinpoint critical considerations that should be taken into account during their design.

Keywords: *MIPv6, fast handoff, load sharing, NEMO, PMIPv6, route optimization*.

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I. Introduction

Rapid developments in communication technologies are generating opportunities across various application domains, owing to their capacity to manage substantial internet traffic, enhance mobility, improve security, and facilitate seamless transitions [1].

IP mobility protocols are specifically designed to ensure that mobile nodes remain accessible while traversing the Internet. There are two primary approaches to mobility management: host-based and network-based[2].

In mobility management, mobile nodes play a key role in the control process. This involves exchanging IP traffic to relay messages between the mobile node and its network connection point, which helps establish and maintain the connection between the mobile node and its home and location. This process enables the vehicle to travel from the base station to the mobile home location and from there to its destination, the MIPv6 Specification in[2],details the support for IP mobility by IPv6 hosts. The host-based protocols category includes the host-based Internet Protocol version 6 (HMIPv6) and the Layered Mobile Internet Protocol Fast Handover version 6 (FHMIPv6). In contrast, network mobility management techniques have been developed to overcome the limitations associated with mobility management. Examples of network protocols include Fast Proxy Mobile Internet Protocol Version 6 (FPMIPv6) and PMIPv6 [3].

MIPV6 is considered as a host mobility management standard and is an important first step proposed by the Internet Engineering Task Force (IETF) to make IP layer a mobility management standard [4].

When migrating from one network to another, MN can control reachability using its IP address. To achieve this, MIPv6 adopts a host-based approach where MN participates in the routing process. In MIPv6, each MN is always identified by its Home Address (HoA). The MN's distance from its location is also related to location maintenance Care-of-Address (CoA). The Home Agent (HA) manages the MN binding between HoA and CoA. It is also a mobile connection point for MN. Therefore, it is considered as a central location in terms of both information and mobile control. It is usually implemented in a router and advertises itself as HA by setting the "H bit" in the Router Advertisement (RA) message [5]. Frequent switching of ports by a mobile node introduces a significant overhead in terms of retransmission delays, packet loss, and signaling costs. Moreover, if the MN cannot send movement-related signals, host-based control mechanisms will no longer work. Therefore, reducing the load on the mobile device in participating in mobile operations and minimizing transfer delays, packet loss, and communication paths are important to provide continuous and ongoing communication to nodes [6].

The NETLMM team is dedicated to solving these problems related

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to the host's travel process. PMIPv6 adds two additional functions, namely Mobile Access Gateway (MAG) and Local Mobility Gateway (LMA). PMIPv6 is a communication protocol in which routing is performed by Local Mobility Gateway (LMA) and Mobile Access Gateway (MAG). The discovery and authentication process of mobile node (MN) is the responsibility of MAG, while the reachability of MN is managed by LMA. The network solution avoids the complex problems on the MN side, providing better mobility and easier deployment. Through the basic features of PMIPv6, researchers have improved the capabilities of PMIPv6 protocol and maximized its advantages in terms of routing and buffering costs, switching delays, mobility, etc. Therefore, many extensions of PMIPv6 have been proposed. For example, FMIPv6 reduces transmission delays by estimating the delivery time of MN, which can be MN-assisted or network-assisted. In MN-assisted solution, MN helps the previous MAG to estimate the candidate's target MAG. On the other hand, in PMIPv6 network service plan, the load on MN is reduced and the target is achieved through cooperation of LMA and MAG. However, the main problem with these solutions is the need for price points. Many parameters such as extensions for packets not sent to MN are requested to solve the packet loss problem. However, if the target prediction is incorrect, these plans will be further affected. During migration, PMIPv6 can access the LMA during communication. To improve the performance, researchers proposed a further optimization method. Furthermore, researchers also provided various network interfaces to add group support to the simple PMIPv6 protocol [7].

This paper explain the architecture and functionality of PMIPv6 while surveying and analyzing the research efforts aimed at enhancing PMIPv6 to offer advanced features necessary for delivering an enriched mobility experience. The enhancements discussed encompass proposed strategies for reducing LMA load, facilitating fast handovers, optimizing routing, supporting network mobility, and achieving load balancing.

II. Basic Pmipv6 Protocol

A. PMIPv6 Architecture:

Fig. 1 illustrates the network entities in PMIPv6 protocol and their operating mechanism in the local mobility domain.

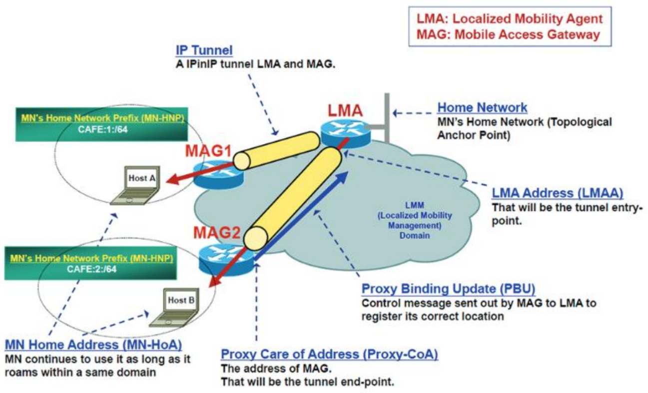

Fig. 1. PMIPv6 architecture[3].

PMIPv6 is based on the design of MIPv6 [2]. It avoids tunneling in the route, which can lead to significant increases in latency. This latency can be seen in MIPv6 [17]. The process starts with a mobile network (MN) moving and connecting to a router called a mobile access gateway (MAG). Once authentication is complete, the MAG can identify the MN The MAG retrieves the MN's configuration file containing the home address and sends a Change Certificate (PBU) to the Local Patient Representative (LMA) on behalf of the MN. If the MAG receives an acknowledgment (ACK) from the LMA, it first sends a router advertisement containing the MN's home network. If the MAG does not receive an Acknowledgement (ACK) from the LMA, it waits and resends a new Certificate Update to the LMA [3].

Message Flow of PMIPv6: When an MN enters its PMIPv6 domain and upon the completion of access authentication, the serving network assigns a unique Home Network Prefix (HNP) to the node. This network prefix is unique for each MN and will be retained wherever it moves inside the PMIPv6 domain.

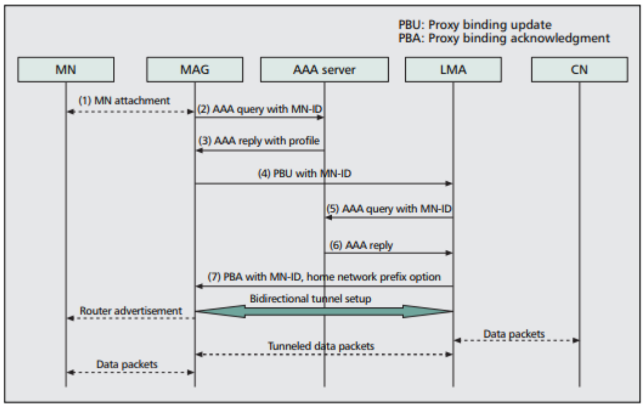

Fig. 2. PMIPv6 message flow [6].

The MN connection, authentication and registration functions in PMIPv6 are shown in Figure 2 [6].

Step 1 and 2: When the MAG detects the MN connection, it sends an authentication challenge containing the unique MN code (MN-ID). This challenge is performed by the MAG to ensure that the MN has the right to access the network. The MN configuration file contains the necessary information of the MN, such as the MN-ID, the LMA address corresponding to the MN and the address. The LMA of the MN sends a PBU message to register or update the information of the MN to the corresponding LMA. If accepted by the AAA, it accepts the PBU message. It sends a PBA message containing the MN's home network prefix, which the MN can use to hold its IPv6 address. The LMA then establishes a bidirectional tunnel with the corresponding MAG for traffic to and from the MN. Once the MAG receives the required information of the MN from the PBA message, it will send an RA message containing the HNP to the MN, and the MN will use this message to configure its IP address [6].

Limitations of PMIPv6:

The following points highlight the limitations of PMIPv6, and these limitations have led researchers to propose necessary modifications and extensions to improve its performance. PMIPv6. Participate in management and packet delivery. This made it possible for the LMA to be widely available to modify the BCE and send it to the mailing list while the MN was still running, which ultimately led to a conflict within the LMA. The decision should be made by the LMA, which is far away from the MAG. Moreover, since the basic PMIPv6 specification does not consider any buffering mechanism, packets sent to the MN may be lost during transmission via LMA, even though both communicate within the same PMIPv6 domain. All packets should pass through the tunnel between LMA and MAG, which will provide the best communication path between MNs. It is a system where many sensor nodes are fixed on the patient and the moving vehicle, and many passengers are connected to the mobile network. However, PMIPv6 is designed to support only MN mobility and does not consider group mobility in its specification. MN. However, since there is no resource balance, MAG will be overloaded when there are many MNs connected to MAG. Therefore, it is necessary to propose a good product balance to distribute the products of MAGs equally[6].

III. Clustering

Initially, the concept of managing micro-mobility and macro-mobility separately was introduced by HMIPv6 protocol, which aims to reduce the routing load and transmission delay. Interact with MIPv6 protocol using network protocol stacks. The purpose of introducing Mobility Connection Point (MAP) is to monitor micro-mobility and thus reduce the registration load of mobile network (MN). However, HMIPv6 protocol still faces problems such as delayed transmission and packet loss. In addition, MN needs to participate in the mobility process, which requires the mobility process to be configured by MN. Based on the HMPIPv6 principle, various initial studies have been conducted to reduce the load on Local Mobility Connection Points (LMA) in PMIPv6 domains [6].

Nguyen et al[8]. A group-based PMIPv6 framework is established for wireless mesh networks, where LMA acts as the group leader and Mobile Access Gateway (MAG) acts as the group member. They proposed a multi-LMA environment in which multiple LMAs are involved in all communication and communications. Hwang et al.[9] Introduced the local control method for PMIPv6, which aims to solve the physical problems by supporting local exchange and optimization with fast switching and hierarchical architecture. This is done in a switch state, thus reducing the switching delay. However, this approach imposes a heavy burden on the MAG, since the MAG has to manage the communication and distribution between its own MAG and related MNs, which can lead to long delays. Moreover, their approach needs many updates as the nesting level increases, especially when starting to register MNs.

IV. Handoff Delay

When MN moves to a new network that is entered into PMIPv6 domain, it will not experience packet loss or HO delay Figure.3 until it receives MN-HNP report from n-MAG. Fast HO based 802.11 is recommended.

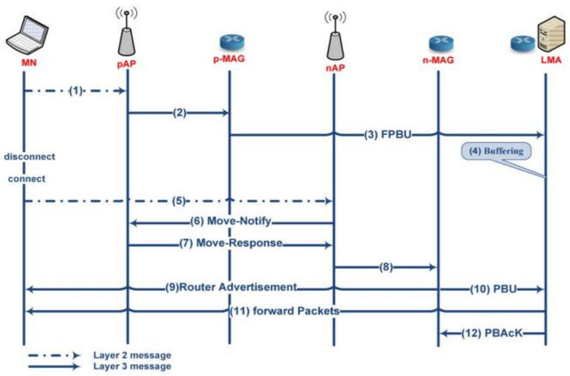

Fig. 3. Message flow of fast HO in PMIPv6.

In PMIPv6 network, the context information such as MN and HNP identities are carried using the Inter-Access Point Protocol (IAPP). Figure 2 shows the sequential instructions associated with the fast HO scheme for PMIPv6. The MN detects its movement by measuring the received signal strength (RSS) value. When the RSS value is higher than a predetermined threshold, it sends a DM containing the MN's entry to the media (MAC) address of the AP it is currently connected to. Step 2: Send to MN ID. After receiving the DM sent by the MN, the affected AP [previous AP (pAP)] sends the ID (MAC address) of the MN to the MAG (p-MAG) to which it is currently connected. FPBU) language. Then, after the p-MAG receives the ID of the MN, it sends an FPBU message to the LMA containing the Network Access Identity (NAI) option of the MN. After receiving the FPBU message, the LMA starts buffering the data to be sent to the MN. When the MN connects to a new connection [New AP (nAP)], an RA message is sent to the AP indicating the MAC address of the MN and the previous service configuration ID of the pAP. information. When the RA message is received, the MOVE notify message will be sent from the nAP to the pAP via distribution (DS). Then, the context data (encapsulated in the MOV response) containing the HNP and authentication information is sent back from the pAP to the nAP. After the nAP receives the MOVE response message, the MN sends the context information to the n-MAG. When the context information of the MN is sent to the n-MAG, the nAP sends the RA message to the MN, which causes the MN's router to be restarted. After the context information is received, the MN creates PBU messages using the context information and sends them to the LMA. When the LMA receives the PBU message, it establishes a path to the MN and starts sending redundant data. In the Fast HO method [8], Lee et al. propose to set IAPP to reduce the "Access Authentication/Get MN Profile" time in the overall HO delay[11]. However, dynamic packet information may still be lost during HO. This development borrows a similar concept from FMIPv6 Fast HO. It has two working modes: predictive mode or reactive mode, depending on whether Layer 2 HO (L2 HO) routing is performed in the previous link. During predictive mode, p-MAG transfers the contents to n-MAG using HO Initiation (HI) messages. In reactive mode, n-MAG uses FBU messages instead of requesting MN content information from p-MAG. Finally, a bidirectional tunnel is designed to send buffered packets once the HO process is completed[12].

V. Route Optimization

The advantage of PMIPv6 protocol is to reduce the transmission delay and relieve the transmission load on mobile node (MN). However, it also has some disadvantages due to its dependence on a single and centralized Localized Mobility Anchor (LMA). In PMIPv6, all packets must pass through LMA even if the communication nodes are nearby. This results in the worst-case scenario and causes end-to-end packet delay. In addition, all project applications require the participation of LMA, which causes delays in obtaining revision approval after application. Although the simple PMIPv6 protocol is mentioned in local routing for two MNs connected to the same Mobile Access Gateway (MAG), it does not mean localized routing for MNs connected to different MAGs regardless of whether they are connected to the same or different MAGs. . Therefore, the main goal of the local solution is to establish a method that enables packets to be sent between MAGs that communicate directly, bypassing The Lma. The main points in the design of the Optimization RO method are:

i) How to determine the addresses (MAG addresses) of the two sides of the conversation to be able to directly control the location of the communicating MAGs.

ii) How to restore the good path after the MN changes to the new destination MAG. The aim of these experiments is to reduce the communication overhead, but they differ in terms of control channels, RO initialization relations, and the method of restoring the RO state after the transition. The RO concept is proposed, which allows multiple MAGs to communicate directly without the participation of the LMA. In their proposed RO model, LMA initiates the RO process by sending the necessary RO message to the MAG pair after receiving the ROT. LMA sends the ROinit message to MAG2 to inform it that LMA is the controlling RO and it needs to control the competition better than the MN route between CN. The LMA then sends a RO setup message to MAGn informing it of the destination MAG address (MAG2), thus establishing a direct bidirectional connection between the MAGs. The LMA then sends the RO setup message to MAG2 to inform it that MAGn is ready to establish an RO with it.

These techniques are considered RO-intensive techniques because they require extensive guidance to complete the RO process. When the MN connects to the MAG domain, the MAG and the LMA establish a bidirectional connection by exchanging Proxy Binding Update (PBU) messages and Proxy Binding Acknowledgement (PBA) messages. RO then occurs when the first data sent from the MN to the CN reaches the LMA. The instructions include the MN identifier and the MAG address. The new LMA received RO instructions, which led to the management of the RO. In most cases, the delay in the RO route is smaller than the delay in the traditional route. In TCP networks, unusual problems cause packets to be retransmitted frequently. In the case of UDP, although RO in PMIPv6 can reduce packet delivery delays, reliable services are not currently supported. To resolve the conflict, The OTP solution is a solution that limits the production area when designing the RO method. The EF-MIPv6 concept is one of the solutions that uses Fast Forwarding Base (EF-BU) in MIPv6. However, the EF-MIPv6 solution cannot be applied to PMIPv6 because EF-BU requires simple control message transformation and only works in MIPv6 [6].

The OTP solution cannot provide reliable services to MNs because the time limit for OTP to pass is difficult to predict. To solve this problem, many articles have prepared complicated procedures, but none of them have solved the problem. Therefore, a new algorithm is proposed to provide more reliable service to MNs. It uses packet size to reduce transmission delays.

To evaluate the scheme, it is compared with well-known RO-enabled PMIPv6 and OTP schemes through computer simulations and testbed measurements. The proposed solutions address the out-of-system problem in both ways (simulation and system measurement). Moreover, this solution also reduces the delays in packet reception after the RO path is established[13].

VI. Network Mobility

Hosts can move together as a group, such as in healthcare where multiple sensor nodes are connected to patients or in mobile vehicles where multiple passengers are connected to a mobile network. Yes. When a mobile station moves, it is inefficient for all MNs to perform the self-processing process at the same time. Also, not all MNs are capable of running mobility protocols such as MIPv6. Therefore, the IETF Network Mobility Working Group developed the Network Mobility (NEMO) protocol as a MIPv6-based network communication protocol. The mobile network consists of multiple mobile nodes (MNNs) connected to a mobile router (MR).

NEMO instructs the MR to perform the signaling operations required to connect the MNN members to the access router (AR). The MNN uses the Mobile Network Prefix (MNP) broadcast by the MR to configure its IP address. Even if an MR moves from one access point to another, its MNP does not change, causing the MNN to move. The MNN is unaware of this handover and all packets flow through both the MR and its HA nodes. NEMO ensures that all MNs in the mobile network, regardless of their capacities, do not lose ongoing conversations during handover. Three types of MNNs can be identified: Local Mobile Nodes (LMNs) that can move within or between networks, Local Fixed Nodes (LFNs) that are fixed nodes, and Access Mobile Nodes (VMNs) that come from other networks in the mobile network. Packets sent from CN to the host are forwarded to the HA of the MR (HA-MR) and then forwarded to the MR using a bidirectional design. The MR receives the packet, decapsulates it, and then forwards it to the destination host node. The NEMO protocol addresses the shortcomings of MIPv6, such as long signaling delay and discovery time. Furthermore, all MNNs will be affected by MR handover delays. Therefore, supporting NEMO in PMIPv6 will reduce the signaling overhead required for MR registration[6].

Currently, there are many proposed works to support NEMO in PMIPv6. However, their scenarios assume that MR configures MIPv6 protocol and they do not consider the MNN mobility between MR and MAG [15]. [16] described the problem of supporting network connectivity in PMIPv6 domain. The analysis of existing technologies (NEMO and PMIPv6) has shown that these models cannot provide full support for NEMO in PMIPv6 networks. The main problem encountered in the connection of NEMO with PMIPv6 is that the address space used by mobile phones is MNP, while PMIPv6 uses a different HNP space. Therefore, MN has to change its address when it moves from MR to MAG. Jeon et al. Establishing a new office called mMAG, which is responsible for detecting the movement of MNs and registering new MNs to LMA. Its model supports continuous IP communication when MN moves between MR and MAG. mMAG is considered as a normal MN by LMA and as a stable MAG by connected MNNs. MNN. In case of registration and deregistration to LMA, mMAG is considered as a normal mobile node. When MNN is connected to mMAG, it uses HNP prefix to provide HNP required by MNN to reduce the signal of PBU/PBA exchange with LMA. To reduce the packet tunneling cost, LMA uses its HNP to send data to mMAG, and mMAG then forwards the packet to the destination MNN.

VII. Load Balancing

In PMIPv6, the responsibility of limiting mobility is assigned to the MAG at the base of the MN. All MNs need to connect to the same MAG, which can easily lead to MAG overload. MAG overload can cause dropouts, end-to-end delays, and tree corruption. Therefore, various studies have been conducted to reduce the load on overloaded MAGs by reducing the load shedding mechanism of MAGs so as not to affect the overall system performance. The standard. IEEE 802.21 optimizes the handover process by combining advanced technology with the flexibility of middleware and providing users with network-based messaging. This process is to determine the load at the Point of Failure (PoA). There are also cases where the PoA is overloaded and TMAG is used to reduce the load. This can happen when the MAG is only loading from one of its PoA (BS/AP). Therefore, understanding the target PoA load is important to minimize it. These technologies have been shown to provide significant benefits in terms of queuing delays and transmission costs.

Load balancing method proposed by Kong et al. To increase the effective loading of MAGs. Their approach identified MAG targets that require low signal strength. Each MAG learns the load status of neighboring MAGs by exchanging features in the domain. Then, MAG generates a MAG candidate list based on the received data to select the best TMAG for HMN. Active load balancing is performed by selecting the MAG with the lowest load according to the load data during the initial connection of MN. This is done before MAG is overloaded. Therefore, by preventing MAG overload, benefits such as packet loss reduction and low latency will be obtained. However, during this process, HMN has experienced additional delays, especially in emergency situations, because MAG service needs time to determine the best TMAG. In order for HMN to act under MAG load. Not thinking about real-time conversations reduces physical activity. In addition, this method creates limitations in this scenario, as it requires MNs with multiple interfaces to be connected to two different networks. In addition, this work does not consider multiple locations in the same domain, which requires additional guidance for MN to move to different locations, which results in slower competition and low transmission speed. To solve the MAG overloading problem in PMIPv6 networks. It reduces the load on the overloaded MAG by moving the transaction, agents from one location to another. The mobile agent reduces the communication overhead by, accessing a MN to collect its data and then moving to other MNs,associated with the MAG to obtain the transmission key. MN selection, depends on some criteria, MNs with live communication will not be selected,,MNs with high data connectivity will be targeted for routing. Although there are, many benefits of using MN agents, there are also some problems. Estimating MNs in the equation will increase the load on MNs and make the operation difficult. This is achieved by selecting the MN to access other MNs in the MAG collection to collect similar packets, which requires some information between the MN and the affected MNs. Also, the Δ threshold used by LMA in this operation depends on the size of the minified data sent from MAG to LMA. This situation causes MAG overload, because MAG is connected to many MNs but there is no similar information among them or there is less information than the initial source, which cannot affect the state of MAG. Moreover, not including PMIPv6 protocol stack in its implementation may lead to interference in different ways. It distributes the load fairly among PMIPv6 domains. The proposed work improves the overall performance in terms of average queuing delay, packet loss, and end-to-end delay while increasing the transmission speed. The authors use heartbeat messages to enable a MAG to understand the status of neighboring MAGs. Modify the heartbeat message to ensure the balanced operation of the load fields. Similarly, MAGs send music including the loading conditions to LMAs. The LMA module stores the received items in BCE users and its overall performance is good. When the load on the LMA module exceeds a certain limit, the LMA will send a heartbeat message to the loaded MAG. Then the open MAG module completes the loading and selects the MN that can be selected to switch ports. The MAG content is determined by the MAG module, which monitors the received power (RSS) and the load provided by the MN. This function blocks the Handover MN Selection (HMN) process by blocking the MAG module provided by the MN that meets this function in time. The authors analyzed and improved their own generator, and the results showed a better performance compared to the original PMIPv6.

Ghalib et al. proposed PMIPv6 protocol and its extensions to provide conflict management in communication. This is achieved by keeping MN away from any kind of problems that may arise due to organizational change. This is achieved by adding a new MAG that uses LMA instead of MN for transmission guidance. Also, MAG establishes a tunnel with LMA and receives MN packets. However, to establish a new connection, MN needs to join a specific MAG. This relationship may cause additional MAG load. Therefore, the LB-CPMIPv6 mechanism is structured to distribute the load fairly among MAGs. The main goal of LB-CPMIPv6 is the speed of the group leader in the group, which does not include other special meetings. This removes all network services. Also, CSPMIPv6 proposals are requested to change the clock and keep it up-to-date. Also, LPBA, PBA, heart rate and registration number sharing messages are modified to adapt to the new measurement engine. The LBM-PMIPv6 loading mechanism and CSPMIPv6 protocol have been evaluated in terms of the latency and end-to-end latency required for large-scale intelligence compared to the deployment, and the feasibility and LB-CPMIPv6 mechanism are ready. Therefore, the new loading method is expected to improve the performance by reducing the game-continuation latency, end-to-end latency and loading cost [19].

VIII. Conclusion

PMIPv6 is of interest to researchers and standards organizations, including the IETF, as it plays a key role in the development of future mobile networks. This article examines the PMIPv6 protocol and reviews research efforts to improve its performance. The research covers everything from eliminating local transportation bottlenecks (LMAs) to promoting rapid deployment, streamlining, encouraging collaboration, and achieving balanced supply chains. For each area of interest or research focus, we describe the motivation and solutions to address issues associated with PMIPv6.

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