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A Decision-Based Hybrid Proxy Mobile IPv6 Scheme for Better Resources Utilization

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Abstract: Seamless mobility is always one of the major requirements of modern-day communication. In a heterogeneous and massive IoT environment, efficient network-based mobility protocol such as proxy mobile IPv6 (PMIPv6), is potentially a good candidate for efficient mobility as well as resource utilization efficiency. Several extensions are devised for performance in the research domain. However, a multi-criterion decision-based resource-efficient PMIPv6 extension is required to achieve efficiency when network resources are overloaded. In this research, a multi-criterion decision-based PMIPv6 scheme is devised that provides better performance when the Local Mobility Anchor (LMA) or Mobile Access Gateway (MAG) is overloaded. The objective is achieved by monitoring the load status of MAG or LMA and based on their status, the proposed scheme adapts itself to provide seamless mobility in addition to optimal efficiency. The proposed scheme is compared with the existing LMA and MAG-based mobility management protocol extensions. Based on the analysis of the comparison, the obtained results prove that providing a decision-based PMIPv6 scheme is better for service continuity as well as optimal performance in the context of required buffering, handover efficiency, and necessary signaling cost.

Keywords: Proxy mobile IPv6; LMA; MAG; load balancing; location-based PMIPv6

1 Introduction

Proxy mobile IPv6 protocol got attention from domain experts due to its mobility management and separation of Mobile Node (MN) from mobility signaling [1]. Contrary to the Mobile IPv6 (MIPv6), mobility tasks are performed via additional resources such as LMA and the MAG [2]. The main function of the MAG is to authenticate and detect the attachment of MN, and maintaining reachability to MN is the responsibility of LMA. Overall, the working procedure and mobility management are more efficient compared to the MIPv6 protocol. In addition to its ability for separating MN from mobility signaling and eliminating the software support issues on the MN side, several problems arise due to LMA and MAG [2,3]. These problems include handover latency, network mobility support, packet loss issue, load on resources, an un-optimized path for communication, and signaling required [2,3]. For addressing and solving the problems associated with PMIPv6, experts have provided various protocol extensions [4–6]. Among these extensions, predictive PMIPv6 extensions are much more effective in terms of handover latency. In addition, handover efficiency directly or indirectly affects buffering efficiency, packet loss, and load management [4]. Predictive schemes prepare for handover before its occurrence and such prediction is made based on proper monitoring of various parameters such as signal strength, status updates, etc. [7]. Furthermore, different approaches are followed for better prediction regarding MN handover and a number of extensions are based on Received Signal Strength (RSS) measures [8]. In such schemes, the decision regarding the handover moment is predicted when the RSS value reaches a very low threshold. However, the main problem where such approaches become failed is the RSS error [9]. RSS error occurs when RSS is predicted low due to the surrounding while in reality the MN is not properly located for handover. In such a situation, instead of efficiency, the scheme even performs worst [7,8,10]. In short, the performance of such RSS schemes is based on the accuracy of RSS measure, while in wrong RSS measure, the end result is much worst.

For improving the prediction of RSS-based schemes, various schemes effectively use location information along with RSS measures for the prediction of handover moment [5]. Integrating location with RSS provides a much richer solution for detecting whether the RSS is low due to surrounding or the location for handover is proper. Using the mentioned criteria, such schemes accurately identify the handover possibility and take required measures for handling the handover process. Among effective ones, the handover process may be initiated via MAG or LMA [4]. Upon the occurrence of RSS event and location accurateness, the current or previous MAG (pMAG) is responsible for initiating the handover process such as location-aware FPMIPv6. Similarly, in LMA-based schemes, the LMA is initiating the handover process such as Location-based Hybrid Proxy Mobile IPv6 (LH-PMIPv6) [9].

Irrespective of the schemes, the large number of MN connected may result in overloading the MAG by requesting a number of handover requests in the context of RSS error. Similarly, in the case of LMA-based approaches, the LMA may be overloaded from such requests in addition to handling other mobility communications. In such a situation, if MAG is overloaded then the MAG-based protocol extension may not be able to provide services in case of a large number of requests. On the other hand, the same situation may be possible in the case of LMA-based protocol extensions. Therefore, an efficient solution is necessary that not only provides services to the MNs but also provides efficient performance.

To achieve such an objective, an adaptive scheme is proposed that can adaptively perform necessary actions by monitoring LMA or MAG, and based on the information, the proposed scheme provides efficient resource utilization. The proposed scheme works by monitoring the load status of the network resources such as LMA or MAG and based on the status of the load, an efficient PMIPv6 (PMIPv6) protocol extension will adopt the resource utilization efficiency strategy for mobility management. The first important objective of the proposed solution is to solve the problem of service continuation, and the other is to adopt a resource-efficient PMIPv6 strategy in terms of associated PMIPv6 extension protocols. Overall, the proposed solution provides efficiency in terms of handover latency, the storage required for packet buffering, and signaling efficiency. Following are the main contribution of the presented study.

- To provide an adaptive decision-based PMIPv6 extension that can adapt itself based on the load status of MAG or LMA.
- To provide services efficient PMIPv6 strategy in case of overloading of LMA or MAGs.

- To provide adaptive PMIPv6 extension for providing situation-based mobility in the context of handover latency, buffering cost, signaling required, and load management.

The paper provides details of the related work in Section 2. The proposed scheme, its equations, and internal framework are provided in Section 3. Section 4 discusses the required measure for evaluating the performance of the devised scheme. For deriving meaningful derivations, results and their analysis is discussed in Section 5. In the last Section 6, the conclusion and future work is given.

2 Background and Related Work

Communication advancements and exponential growth of the internet enable portable devices and require a richer mobility protocol that is capable of covering large addresses required for devices in addition to seamless mobility [7]. Contrary to early host-based IP solutions that involve MN in its mobility, the network-based IP solution such as the PMIPv6 protocol received much attention for their adoption [4]. However, PMIPv6 is not prone to longer handover latency, buffering, and high signaling. Various efforts are made for performance enhancement and as a result, different PMIPv6 protocol extensions are proposed [11]. These enhancements include fast handover schemes [12,13], buffering schemes [1,14], load management schemes [6], and schemes for supporting network mobility [15,16]. Among the factors affecting the performance of the PMIPv6 protocol, the prediction of the next MAG is one of the most important factors that have a significant effect on the performance [5]. In such prediction, various extensions use RSS for predicting the handover moment. However, RSS has its issues such as the influence of the environment over its accurate measurement [5].

For addressing such issues, location information in addition to RSS provided a better prediction of network resources [9]. Compare to the RSS-based schemes, location-based schemes solve the problem of wrong handover moment and provide accurate prediction by using the location information of involved resources [5,9]. However, when a large number of MNs become connected to MAG and request for handover, then such a flood of requests may overload the MAGs. The problem becomes more severe for those schemes that are affected by RSS error [5,7,10]. Furthermore, LMA that already performs the overall communication as the traffic goes through LMA, therefore, involvement of LMA in the handover process in such schemes which are affected by RSS error may also overload LMA. In addition, such overloading may result in poor quality of services. The existing RSS MAG-based and LMA-based approaches include the low latency scheme [7], location-aware FPMIPv6 [location], LH-PMIPv6, LH-PMIPv6 (v1), and LH-PMIPv6 (v2). Following are the details of these protocol extensions.

A low latency scheme [7] is devised for the purpose to optimize the process of authentication to enhance the handover process. Based on its foundation on RSS measure, the handover starts when the RSS measure reaches a predefined low threshold value. As a result, De-Reg Proxy Binding Update (DeReg PBU) is forwarded to LMA and then LMA starts buffering the packets. To ensure the preparation for handover, LMA contact the surrounding MAGs by sending an Immediate Handover Request (IHR). LMA reply the DeReg PBU message with De-Reg Proxy Binding Acknowledgment (DeReg PBU). Based on the MN's information received in the IHR message, the MAG to which the MN becomes attached responds to LMA by Proxy Binding Update (PBU) message, and the rest of the handover is performed. However, the low latency scheme is affected by RSS error and may incur additional buffering and signaling.

Experts have provided a more effective solution in terms of accurate prediction for handover in addition to eliminating the effect of RSS error by using location information of resources. In this regard, the location-aware scheme improves the performance by measuring RSS in addition to the location of MN [5]. Even if the RSS error occurs, the location information ensures that the handover process should not be started if MN is not properly located. The location-aware scheme shows significant performance differences from existing RSS-based extensions. Such improvements provide a foundation for devising resource-efficient PMIPv6 extensions using location information. In addition to its effectiveness, the scheme may be overloaded when MAG is requested by a large number of MNs during RSS error. Although the scheme ensures that the handover process will not be initiated, however, handling a large number of requests will engage MAG in additional unnecessary activity.

For solving such a problem, an improved location-based extension is provided that shares the location of MAG's information to the surrounded MNs in advance [9]. Such information exchange ensures that the scheme is protected from RSS error as well as sending additional requests from MNs. The handover procedure is started by pMAG in location-aware extension while in LH-PMIPv6 extensions, LMA performs handover signaling. Furthermore, additional signaling is avoided via shared MAG information where MN checks the location for handover in advance. Such addition eliminates the handling of unnecessary requests from MNs. Overall, the LH-PMIPv6 extension provides better signaling efficiency in addition to the optimal buffering cost. Although the location-based schemes outperform the existing RSS-based schemes, there may be the problem of overloading if a large number of MNs attached to the corresponding MAG.

Despite the performance of a scheme, if the primary entity is overloaded then the extension may not provide services to the MN. Among existing extensions, LMA-based approaches provide better overall signaling however the same may not be much efficient in terms of handover latency, and buffering compared to the MAG-based extensions [5,9]. Therefore, an adaptive PMIPv6 solution is required to provide better services in addition to optimal possible performance when the network resources are overloaded. For this purpose, an efficient PMIPv6 solution is provided when MAG or LMA is overloaded. The proposed solution follows an optimal strategy in the situation when LMA or MAG may be overloaded to provide resource utilization efficiency in addition to service continuity. Furthermore, such mobility solutions can be integrated into various multi-feature learning models for mobility management in various application domains such as massive IoT, 6G-enabled IoT [9], and vehicular mobility [17,18].

3 Proposed Method

Seamless mobility and resource utilization efficiency are one of the main features of PMIPv6 protocol extensions. However, technological improvements and exponential growth of mobility devices demand richer, reliable, secure, and resource-friendly mobility management solutions. Handling such a large volume of traffic and providing services to a large number of MNs, resources must be utilized more efficiently. In the PMIPv6 environment, the main resources are MAG and LMA. Such resources may be overloaded because all the MNs are handled by MAGs and the communication among different nodes goes through LMA. Future communication involves a larger set of MN and demands efficient mobility solutions that should be capable enough to adaptively monitor the load of network resources and provide situation-based efficient mobility. The presented work provides a situation-based decision procedure for providing efficient mobility management by analyzing the load status of network resources.

In case of overloading possibility of MAG or LMA, the proposed solution will adopt a more efficient strategy for mobility management. The proposed scheme works on the foundation of location-based handover procedure by adding the support of decision-based mobility management. Following is the detailed procedure of the proposed solution works.

3.1 Location-based Handover Initiation

The presented scheme considers the handover procedure as follows in the location-based RSS PMIPv6 protocol extensions. Location-based extensions eliminate the early handover initiation by accurately predicting the handover moment from the location of network resources. Existing location-based PMIPv6 include location-aware FPMIPv6 and LH-PMIPv6. In addition, the smart buffering scheme involves LMA for handover signaling and provides comparatively better performance in existing non-location-based RSS protocol extensions. For performance efficiency, the scheme follows handover initiation in the following manner.

For better prediction accuracy, the MAG information such as location is communicated with its surrounding MNs. MNs are responsible to ensure that no unnecessary handover requests are made regarding handover from its corresponding MAG. Such an objective is achieved by analyzing the location information of MAG during roaming. Therefore, prediction accuracy is improved, RSS error is not affecting the handover process, and false handover initiation is eliminated. For handover initiation, the RSS value is compared with a predefined threshold followed by the location of the MN from MAG. Such multi-criteria decision-making ensures the prediction of handover moment prediction. However, when a participating entity such as MAG or LMA becomes overloaded, the MNs may suffer from service interruption. For service continuity and resource utilization efficiency, such entities analyze their load status and performed preliminary arrangements for handling such situations.

In the presented work, the load status of LMA and MAG is analyzed. The objective is achieved with additional control messages that carry the information of load status. Each entity such as LMA or MAG analyzes its capacity for handling the number of requests and handovers from requesting MNs. If any of the entities become overloaded, then the necessary arrangements are taken to adopt the most efficient strategy for performance efficiency. The overall flowchart of the proposed solution is given in Fig. 1. Details of the proposed solution are the following.

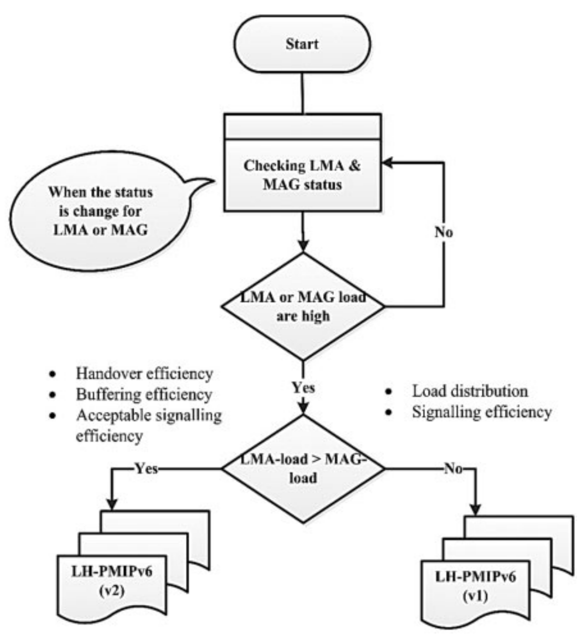

Figure 1: Flow chart of the proposed solution

3.2 Decision-based Solution for Performance Efficiency

The procedure works by monitoring the load status of LMA or MAG and then it adopts the most efficient strategy for mobility management. To avoid overloading, each entity will keep track of the number of devices connected, handover requests, and communication to know the probability of overloading. Generally, the solution works in three phases. These phases include the monitoring of load status, communicating the load status information among network resources, and finally, adopting optimal and resource-efficient strategy for resource utilization efficiency. The overall working algorithm of the same is provided in Tab. 1.

Table 1: Algorithmic representation of the proposed scheme's working

Algorithm 1: Algorithm for decision-based PMIPv6 load optimization for resource and performance efficiency

Result: Situation based resource utilization based on load status of MAG and LMA
While $(Load\_MAG = Load\_LMA\ != High)$ {
Rule A:
if $(Load\_MAG = Normal)$ ***AND*** $(Load\_LMA = Normal)$ ***then***
select efficient $PMPIv6$ *extension based on* {
// *The resultant decision is based on the following three parameters* *Overall signaling cost;*
Overall handover latency;
Overall buffering cost;
}
Rule B:
if $(Load\_MAG = High)$ ***AND*** $(Load\_LMA = Normal)$ ***then***
adopt LMA *based* $PMIPv6$ *strategy*
{
// *The resultant decision is based on the following three parameters*
Overall signaling cost;
Overall handover latency;
Overall buffering cost;
}
Rule C:
if $(Load\_MAG = Normal)$ ***AND*** $(Load\_LMA = High)$ ***then***
adopt MAG *based* $PMIPv6$ *strategy*
{
// *The resultant decision is based on the following three parameters*
Overall signaling cost;
Overall handover latency;
Overall buffering cost;
}
}

3.2.1 Monitoring Load Status

First of all, the load status of the involved entities is checked. If there is no load on any of the entities then the proposed scheme will work on the strategy of a location-based extension protocol that provides better handover latency, buffering cost, and optimal signaling cost. If the load is high on MAG, or LMA then the scheme will operate on the optimal resource-efficient PMIPv6 extension. Furthermore, the term load status "normal" means that the entity responsible for the handover MNs request is not overloaded. In case any of the entities is overloaded, then the procedure to improve services' efficiency. The same is discussed in the subsequent section.

3.2.2 Communication of Status Information

For achieving such an objective, the scheme uses two additional variables maintained by LMA and MAG. At the start, these variables are set to normal for LMA and MAG. Over time, the LMA or MAG can modify such variables based on the load that the entity is capable of. The scheme will monitor the load of the LMA and MAG and if the load reaches a defined threshold then LMA and MAG will communicate with each other for making necessary arrangements. If LMA is overloaded, then the status is modified and communicated to MAG. Similarly, if the load on MAG becomes high, then MAG will communicate the load status with LMA. Such information sharing will help in providing a better quality of services to the MNs.

During mobility, if the number of connected MNs becomes high then these MNs will request handover if they are about to leave the pMAG domain. In this case, the MAG or LMA can be overloaded. For solving such an issue, the proposed scheme will transfer control from the overloaded entity to the non-overloaded entity to provide services. Such a situation is handled by adopting the following procedure.

3.2.3 Decision-based Procedure

If the load is normal and no entity such as LMA or MAG is overloaded, then we have several options to select a default strategy to be based on the PMIPv6 extension. Among the alternatives where any protocol extension that is based on either MAG or LMA, the adaptation can be based on various aspects such as achieving signaling efficiency, buffering required, and handover performance. By analyzing the cost required for handover latency, signaling, and buffering, the presented approach adopts a procedure that is cost-effective in the aforementioned analysis for cost measurement. If MAG and LMA are performing normally, and there is no load on either entity, then the scheme will operate on the procedure of LH-PMIPv6 (v2) because such procedure has overall better handover performance, and buffering efficiency, and optimal signaling cost. Among the location-based schemes, LH-PMIPv6 (v2) is an efficient scheme compared to location-aware, low latency, and LH-PMIPv6 (v1). Such setup will provide optimal resource utilization efficiency in normal operations i.e., when there is no load on the network entities.

Similarly, if the MAG is overloaded then the procedure will adapt its functionality based on the LH-PMIPv6 (v1) as it has better performance efficiency among the LMA-based extension protocols. Among the LMA-based extension protocols, LH-PMIPv6 (v1) is efficient compared to the low-latency scheme. Therefore, the LH-PMIPv6 (v1) will result in better resource utilization efficiency, and mobility management. Furthermore, if the load on MAG is high, then the proposed scheme will operate using the procedure of LH-PMIPv6 (v2) as it provides optimal signaling efficiency, less buffering, and handover latency. In such a case, the MAG will be responsible for performing mobility operations. Among location-aware PMIPv6 and LH-PMIPv6 (v2) schemes, the performance efficiency of LH-PMIPv6 (v2) is comparatively better. As a result, the procedure will be adopted to involve MAG in addition to achieving resource utilization efficiency.

3.3 Signaling Cost Measuring

In location-based LH-PMIPv6 (v1), the LMA is involved in the handover process. The required signaling includes the sharing of MAG's information with MNs δ, multicasting of IHR with neighboring MAGs C_{loc_MAG}, number of hopes between LMA and MAG C_{LMA_MAG} in addition to cell crossing rate μ_c, measuring time T, and cost of L2 report $C_{L2report}$. The overall signaling cost of LH-PMIPv6 (v1) is shown in Eq. (1).

$$C_{LH-PMIPv6} = \delta . \ C_{loc\_MAG} + \mu_c \ . \ T \ . \ \delta . \ \left\{ C_{L2report} + \left(C_{IHR} \ . \ C_{LMA\_MAG} \right) \right\} \tag{1}$$

In LH-PMIPv6 (v2), the signaling cost includes the sharing of MAG information with MNs C_{Loc_MAG}, cost of L2 report $C_{L2report}$, cost of a handover initiation C_{HI}, handover acknowledgment C_{HACK}, as well as the other associated parameters such as cell crossing rate μ_c, and measuring time T. The signaling cost for LH-PMIPv6 (v2) is shown in Eq. (2).

$$C_{LH-PMIPv6\ (v2)} = \delta \ . \ C_{Loc\_MAG} + \mu_c \ . \ T \ . \ \delta . \ \left\{ C_{L2report} + \left(C_{HI} + C_{HACK} \right) . \ H_{MAGs} \right\} \tag{2}$$

The signaling required in a low latency scheme includes the IHR messages from LMA towards surrounding (C_{IHR}) MAGs, number of hope between LMA and MAGs H_{LMA_MAG}, and other associated parameters such as cell crossing rate μ_c, and measuring time .T. The same is shown in Eq. (3).

$$C_{LL} = \mu_c \ . \ T \ . \ \delta . \ \left\{ \left(N^{*} \ C_{IHR} \right)^{*} \ H_{LMA\_MAG} \right\} \tag{3}$$

Furthermore, signaling costs for location-aware PMIPv6 include the cost of L2 report, cost of HI messages, HAck messages, and the number of hope between two MAGs. Using the fluid flow model, the overall signaling cost of location-aware PMIPv6 extension is shown in Eq. (4).

$$C_{Location-aware} = \mu_c \ . \ T \ . \ \delta . \ \left\{ C_{L2report} + \left(C_{HI} + C_{HACK} \right)^{*} \ H_{MAGs} \right\} \tag{4}$$

3.4 Handover Latency Measuring

Handover latency in a low-latency scheme is initiated when LMA sends an IHR message to the surrounding MAGs. The handover is started when the LMA receives the DeReg PBU message and is ended when nMAG received the RS message. in addition, the low latency scheme is affected by RSS error because the scheme is not based on location information and the prediction may be wrong. The overall handover latency is measured using Eq. (5).

$$t_{Low-latency} = t_{error} + \emptyset + t_{RS} + t_{PBA} + t_{WRS} + t_{L2} + t_{RA} \tag{5}$$

Location-aware PMIPv6 is based on location information and the handover latency is not affected by the RSS error. The starting point of handover in his scheme is when MN detaches from the pMAG domain and the endpoint is when the MN is connected with nMAG. Overall handover latency is calculated by Eq. (6).

$$t_{Location-aware} = t_{WRS} + t_{w-data} + t_{L2} + t_{RS} \tag{6}$$

LH-PMIPv6 (v1) is based on the working of a low latency scheme in addition to the location information parameter that affectively reduces the handover latency by eliminating RSS error. The starting point of handover is when MN is detached from pMAG and the endpoint is when the PBU message is sent by LMA to the nMAG. Based on the procedure, the handover latency for LH-PMIPv6 (v1) is obtained from Eq. (7).

$$t_{LH-PMIPv6\,(v1)} = t_{RA} + t_{WRS} + t_{RS} + t_{L2} + t_{PBA} \tag{7}$$

Furthermore, the LH-PMIPv6 (v2) is based on the location-aware PMIPv6 extension to achieve maximum efficiency in handover in addition to better signaling efficiency. The handover latency starts when the MN is detached from pMAG and the endpoint of handover is when the MN's attachment is detected by the nMAG. Upon attachment to nMAG, the buffered packets are forwarded without any delay. Handover latency for LH-PMIPv6 (v2) is calculated through Eq. (8).

$$t_{LH-PMIPv6\,(v2)} = t_{WRS} + t_{L2} + t_{RS} + t_{w-data} \tag{8}$$

3.5 Buffering Cost Measuring

During the handover process, the packets may be stored to solve the packet loss problem. Till now, various protocol extensions are devised from time to time. For solving the packet loss problem, various buffering mechanisms have been proposed to reduce the required buffering. In the low latency scheme, the buffering starts when DeReg PBU is received from the pMAG by LMA. Packets are stored in LMA and when MN is attached to nMAG the nMAG informs LMA regarding MN's attachment using the PBU message. LMA reply the PBU message with PBA and send the stored packets to nMAG. Based on the procedure, the buffering cost for the low latency scheme is measured using Eq. (9).

$$B_{Low-latency} = \lambda s\ .\ E(s)\{\ t_{error} + \emptyset + t_{RS} + t_{L2} + t_{WRS}) \tag{9}$$

Location-aware PMIPv6 is using location information therefore, the buffering cost is not affected by RSS error. Furthermore, the buffering starts when the pMAG detects that the location for handover is proper. The endpoint of the handover is when the MN's attachment is detected by the nMAG after receiving the RA message from MN. The overall buffering required for location-aware PMIPv6 extension is provided by Eq. (10).

$$B_{Location-aware} = \lambda s\ .\ E(s)\{\ \emptyset - t_{report} + t_{L2} - t_{mag} + t_{RS} + t_{WRS}\ ) \tag{10}$$

Location-based LH-PMIPv6 (v1) uses the location information in a more effective way to reduce the additional signaling cost. Packet loss in this scheme is prevented by buffering the packets in LMA and then the packets are forwarded to nMAG once the MN is attached to nMAG. Buffering in this scheme starts when the LMA receives DeReg PBU until the MN is detected by nMAG. The buffered packets are forwarded to nMAG that is destined to MN. The overall buffering required for LH-PMIPv6 (v1) is provided by Eq. (11).

$$B_{LH-PMIPv6\,(v1)} = \lambda s\ .\ E(s)\{\ \emptyset - t_{report} + t_{L2} - t_{mag} + t_{RS} + t_{WRS} + t_{PBA}) \tag{11}$$

In LH-PMIPv6 (v2) which is based on the working of MAG achieves the handover latency with optimal signaling required compared to the location-aware PMIPv6. In this scheme, the buffering starts when the MN is detected properly for handover by communicating HI and HAck messages. The buffering continues until the MN is detached from pMAG. As long as the MN is about to connect to its new nMAG, the buffered packets are forwarded to nMAG. The buffering ends when the MN is detected by nMAG and buffered packets are delivered to MN. Based on the procedure above, the buffering is measured using Eq. (12).

$$B_{LH-PMIPv6\,(v2)} = \lambda s\ .\ E(s)\{\ \emptyset - t_{report} + t_{L2} - t_{mag} + t_{RS} + t_{WRS}) \tag{12}$$

4 Evaluations Measures

The evaluation of the proposed solution is based on the performance of LMA and MAG-based PMIPv6 extension protocols. Among the LMA-based approaches, the low latency and LH-PMIPv6 (v1) are compared based on the required signaling, handover performance, and buffering required. Both schemes involve LMA during the handover process and when a request is made by MN, the LMA performs communication among network resources and initiates the handover process. Similarly, the performance of MAG-based approaches that involve MAG during mobility management and handover process initiation are compared. Among MAG-based schemes, location-aware and LH-PMIPv6 (v2) are compared based on the signaling required, handover latency, and buffering required for packet loss problem solution. In addition, various factors that affect the performance of considered for the performance difference. These factors are the number of MNs connected to MAG, probability of RSS error, and velocity of MNs.

The LMA and MAG-based schemes are compared based on their performance in the context of signaling cost, buffering required, and handover latency. Signaling cost is compared for variations in the velocity of MNs, number of MNs, and the probability of RSS error. Other measures such as handover latency and required buffering are measured in the context of variations in RSS errors. Such a task is achieved by developing an application in JAVA by implementing the equations defined in section III. The application is maily based on three modules. Such modules are the interface module, process module, and output module. The interface module is used for taking the input from the user. A user sets the parameters such as the number of MNs, cell perimeter, and so on. The processing module implements the equations of the existing and proposed schemes. The output module presents the results obtained after comparisons. The working procedure of the application starts by enabling the user to provide the input such as parameter settings. The processing module provides options to the user to compare the schemes based on the aforementioned criteria. In the end, the results are presented to the user for meaningful interpretations.

5 Results and Analysis

The proposed decision-based PMIPv6 solution is analyzed in the context of existing MAG-based and LMA-based PMIPv6 extension protocols. For effective comparison, the non-location-based schemes are not taken into account such as smart buffering, and FPMIPv6. However, to compare the effective performance among LMA-based PMIPv6 extensions, the comparison includes LMA based low latency scheme. Furthermore, among MAG-based schemes, the location-aware FPMIPv6 extension provides promising efficiency in existing approaches in the domain. Importance factors considered for comparisons are the probability of RSS error, the number of MNs, and its effect on the required signaling cost, required buffering, and handover latency. Furthermore, the velocity of the MN is directly proportional to the signaling cost as the MN is expected to move faster and the value of the cell crossing rate becomes high. Signaling cost for MN moving with higher velocity becomes high in the context of RSS error probability.

In the situation when the load on LMA is high, the scheme will operate by involving MAG in the mobility process. Involvement will handle the handover signaling and will provide services to the requesting MNs. For achieving the signaling efficiency, the MAG-based schemes are compared. These include the comparison of location-aware and the LB-Hybrid schemes as provided in Fig. 2, where RSS error has variations. Among these schemes, the location-aware scheme is affected significantly as compared to the LH-PMIPv6 (v1) and LH-PMIPv6 (v2). However, it is important to mention that location-aware PMIPv6 and LH-PMIPv6 (v1) is an LMA-based schemes. As a result, when

LMA is overloaded, the scheme will follow the procedure defined in LH-PMIPv6 (v2) for mobility management.

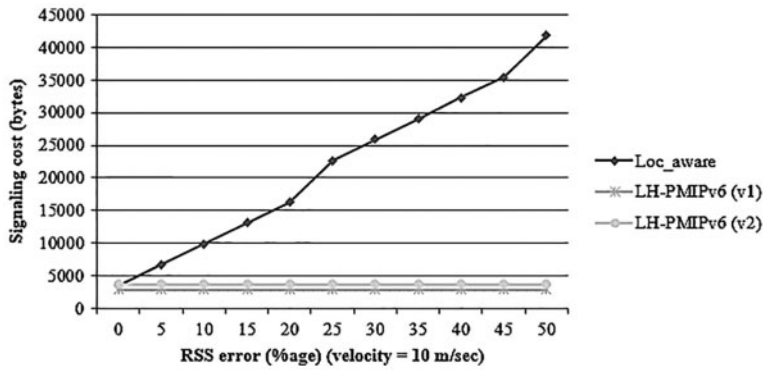

Figure 2: MAG based schemes analysis for RSS error

Similarly, when the load on MAG is high due to a large number of MNs requesting handover, then the control will be transferred to LMA for distributing the load. Among LMA-based schemes, the performance efficiency of location-based LMA-based and the existing low-latency scheme is compared. The comparison is depicted in Fig. 3, where the low latency scheme is significantly performing worst because it is not using location information. On the other hand, the LMA-based PMIPv6 (v1) is more efficient in terms of required signaling. For achieving better signaling efficiency, the proposed solution will operate the handover signaling based on the PMIPv6 (v1) procedure. Moreover, the signaling cost varies for Low latency schemes because the low latency scheme is not based on the location information. As a result, the RSS error affects the low latency scheme and incurs additional signaling. On the other hand, the LH-PMIPv6 scheme is based on the location information and it avoids any additional signaling due to RSS error.

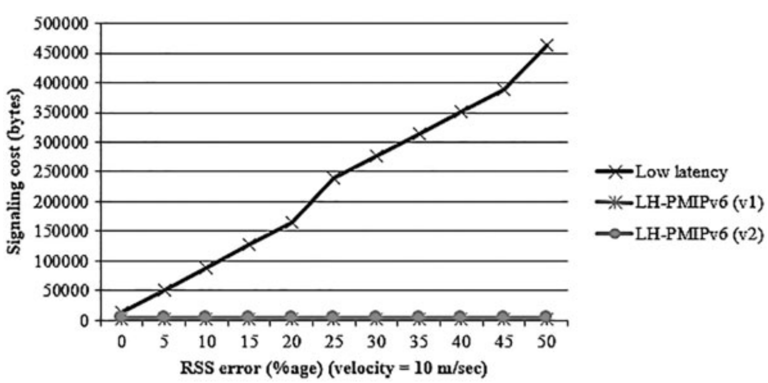

Figure 3: LMA based schemes analysis for RSS error

Furthermore, compared to the existing extensions, the LH-PMIPv6 extension protocols are more efficient. For better interpretation, the performance difference between LH-PMIPv6 (v1) and LH-PMIPv6 (v2) is shown in Fig. 4. Among these extensions, LH-Hybrid (v1) is more optimized for required signaling. So if neither LMA nor MAG is overloaded then the default procedure for handover will be followed based on LH-Hybrid (v1). Overall summary of the schemes' comparison is shown in Tab. 2.

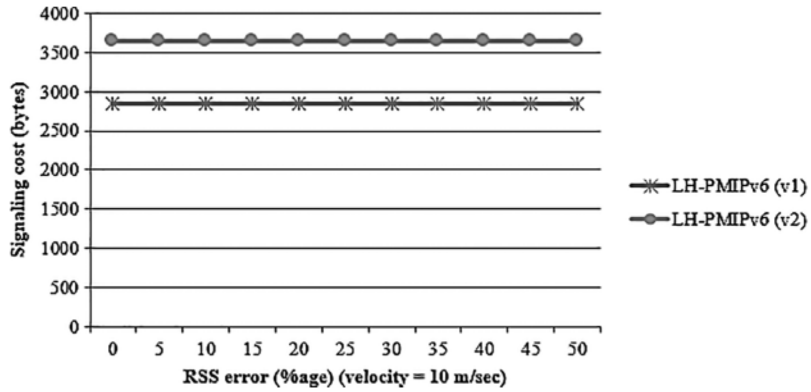

Figure 4: Signaling efficiency for LH-PMIPv6 (v1 & v2)

Table 2: Overall summary of the schemes' comparisons

S. no	Scheme	Handover	Buffering	Signaling
1	FPMIPv6	Medium	Low	Low
2	Low latency	High	High	High
3	LH-PMIPv6 (v1)	Low	Medium	Medium
4	LH-PMIPv6 (v2)	Medium	Low	Low

The number of MNs requesting handover has a direct influence over the signaling required. For representing the relationship of a number of MNs over location-based LB-Hybrid (v1 & v2) and LMA-based low latency scheme is shown in Fig. 5. Among these schemes, LMA-based LH-PMIPv6 (v1) is more efficient for a large number of MNs. Furthermore, MAG-based location-aware PMIPv6 is compared with LB-Hybrid schemes and the MAG-based LH-Hybrid (v2) is more efficient in terms of the number of MNs as shown in Fig. 6. In addition, the difference between the LH-PMIPv6 protocol extensions is shown in Fig. 7 which shows that LMA-based LH-PMIPv6 (v1) is better for achieving signaling efficiency. Therefore, in normal circumstances, the default selected protocol for achieving better signaling efficiency is LB-Hybrid (v1).

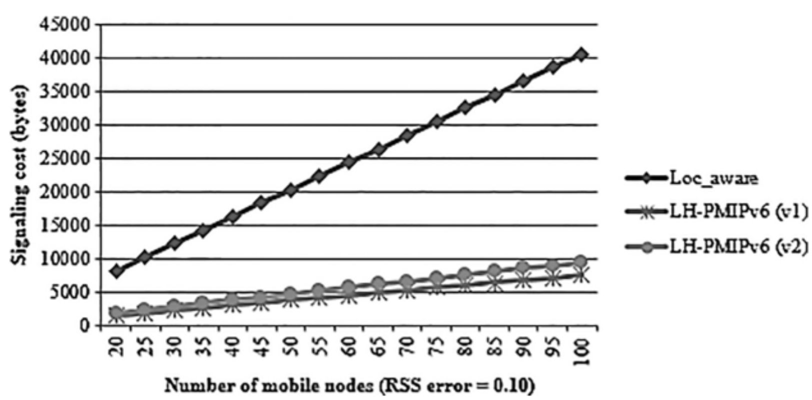

Figure 5: Signaling for number of MNs (MAG schemes)

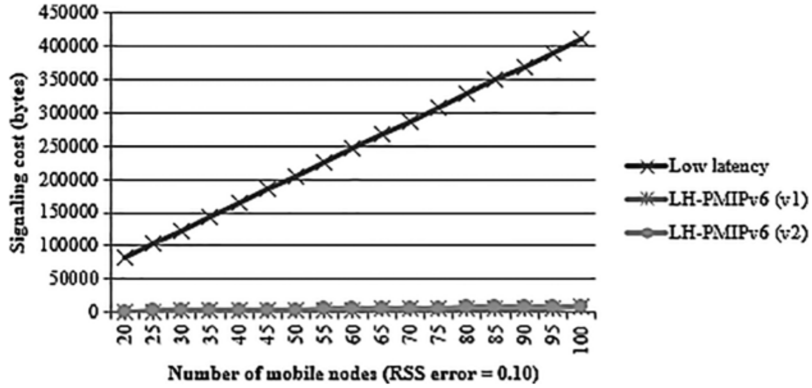

Figure 6: Signaling for number of MNs (LMA schemes)

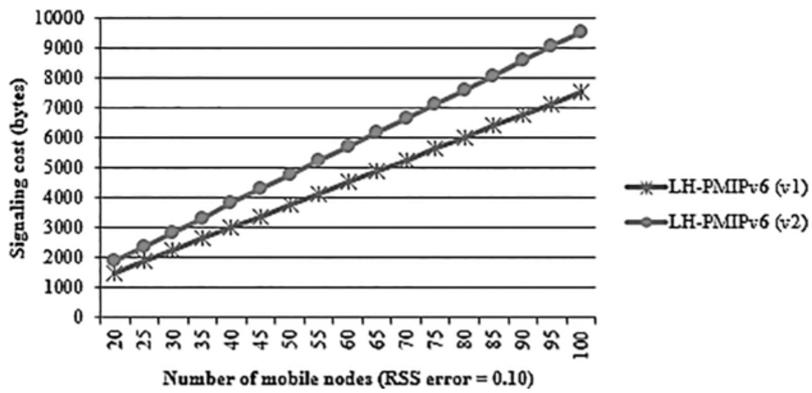

Figure 7: Signaling difference for LH-PMIPv6 (v1 & v2)

Handover latency is directly proportional to RSS error because, in case of wrong RSS measurement, LMA-based low latency schemes may result in additional handover latency. On the other hand, location-based schemes are significantly less affected by RSS error as the prediction of handover moment is much more accurate. Such comparison is shown in Fig. 8 and the low latency scheme has significantly higher handover latency while the location-based LH-PMIPv6 (v1), and LH-PMIPv6 (v2) are much more efficient in terms of handover latency.

One of the reasons behind the longer handover latency is, that the low latency scheme is not based on location information. In addition, the LH-PMIPv6 (v1) is LMA based extension and performs significantly better in terms of handover latency. Statistics of the same are represented in Fig. 8, where handover latency increases with the probability of error for the low latency scheme. However, the handover latency is not affected by RSS error in LH-PMIPv6 (v1), and LH-PMIPv6 (v2). Therefore, when the load on MAG is high, then the scheme will adopt the strategy based on LH-PMIPv6 (v2).

Similarly, the handover latency is not affected in location-aware PMIPv6 extension as location-based schemes provide accurate predictions regarding handover moment. Based on the comparison as depicted in Fig. 9, where the performance of LH-PMIPv6 (v2) is almost the same as for the location-aware scheme. However, the handover latency of LMA-based LH-PMIPv6 (v1) is comparatively longer comparatively. Therefore, when the load on LMA is high, the procedure adopted by LH-PMIPv6 (v2) will be adopted for achieving low handover latency.

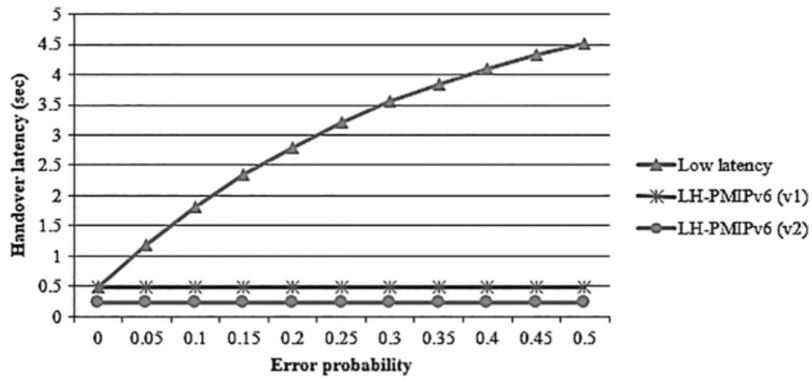

Figure 8: Handover latency (LMA based schemes)

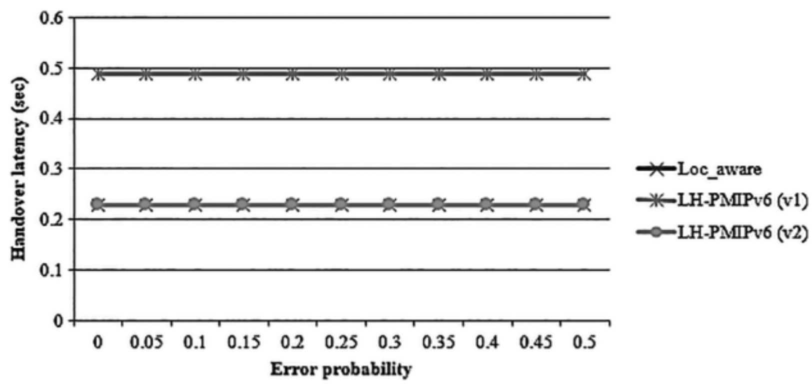

Figure 9: Handover latency (MAG based schemes)

Similarly, the accuracy of handover moment prediction directly influences the buffering required to address the packet loss problem. When MN is disconnected from pMAG then packets are stored so that such packets are delivered to MN. Required buffering is analyzed in the context of RSS error probability as shown in Fig. 10, where the vertical axis represents the buffering required. From the analysis, it is evident that the existing low latency scheme is affected by the RSS error while location-based schemes are not affected. As the LH-PMIPv6 (v1) and low latency schemes are based on LMA, therefore, when the load on MAG is high, the scheme will adopt the procedure of LH-PMIPv6 (v1) for better buffering efficiency.

Similarly, the MAG-based scheme such as location-aware PMIPv6 is compared in the presence of RSS error as depicted in Fig. 11. The buffering required for location-aware and LH-PMIPv6 (v2) are almost the same. When the load on LMA is high, then the proposed solution will adopt the procedure of LH-PMIPv6 (v2) as it is based on MAG in addition to the efficient signaling cost.

Based on the results obtained, the various scheme provides different performance difference in different situations. The proposed solution provides and adapts itself to enhance the performance when the network entities are overloaded due to a large number of MNs and mobility. The situation-based mobility management provides potentially better performance for reducing signaling cost, handover latency, and buffering.

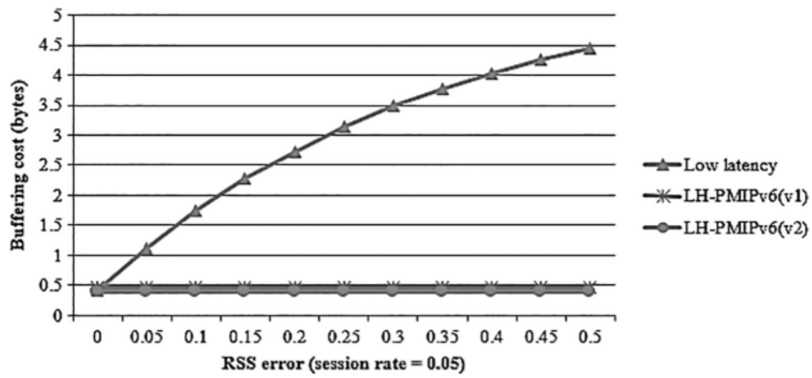

Figure 10: Buffering cost (MAG based schemes)

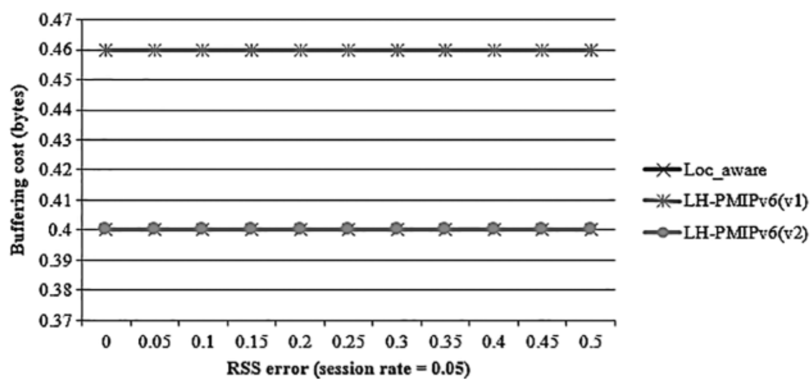

Figure 11: Buffering cost (LMA based schemes)

6 Conclusions and Future Work

Load on network entities in the PMIPv6 extension is one of the major problems in the domain. Ongoing efforts are trying to optimize the performance of the PMIPv6 protocol to pave the way for its adoption in future generation technology and resource utilization efficiency. In this paper, a decision-based resource-efficient PMIPv6 scheme is provided that considers the dynamic aspects of mobility management. The proposed solution considers multiple aspects of the mobility during MNs' roaming to efficiently use network resources. The provided solution works by monitoring the mobility load on network entities and based on the mobility, various strategies are adopted for quality of services and resource utilization efficiency. For achieving such an objective, the decision regarding mobility management is based on various aspects in addition to load on LMA or MAG. Based on the load status of network resources, the proposed scheme provides adaptive strategies for achieving performance efficiency in terms of signaling cost, required buffering, and handover latency. Based on the analysis of the proposed solution and existing extensions, the analysis shows potential improvements to reduce signaling cost, handover latency, service efficiency, and buffering required.

Modern communication technologies such as 5G required energy-efficient solutions for enhancing their performance [19]. The proposed work can be extended to integrate various aspects of future generation communication technologies to achieve energy efficiency and better mobility. In the future, mobility can be enhanced by exploiting various aspects such as node history, velocity, and direction.

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