An Improved Framework for Enhancing QoS in MIPv6

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Abstract— With the advent of technology, a large number of wireless and mobile devices are being connected to the internet increasingly giving the users access to the internet while on move. This mobility has been supported through the Internet Protocol known as Mobile IP, allowing the users with mobile devices to have continuous network connectivity to the internet without changing their IP addresses when moving from one network to another. Mobility is supported in both versions of IP, using MIPv4 in IPv4 network, and MIPv6 in IPv6 network. The framework of MIP moves around the core concepts like throughput, delay (handover latency) and packet loss. These concepts are the metrics of the quality of service (QoS) that must be efficient in providing consistent, predictable data delivery service over the networks. While on move, the Mobile Node (MN) undergoes a handover process, in which a MN is disconnected from one network and connected to another. The time period of disconnection during the handover process is known as the handover latency and it may cause a major problem of real–time packet loss, i.e., a number of packets may not reach their destination. The major delay in handover is due to the duplicate-address detection (DAD) process. Several solutions have been proposed to overcome these problems in MIPv6. However, no solution seems to be the optimum. The framework in this paper suggests the removal of DAD procedure and configuration of a new Care of Address for the MN by the NAR (New Access Router) and the use of efficient buffer management mechanism for improving the two metrics of, and enhancing the QoS in MIPv6.

Keywords- MIPv6; Handover; Packet Loss; Buffering; Signal Strength

I. INTRODUCTION

The interest in mobile communication over internet, increasing day by day, requires that the IP protocol, originally designed for stationary devices, must be enhanced to allow the use of mobile devices [1]. The basic problem with supporting mobile nodes in IP internetworks is that if a device changes networks, data sent to its old address cannot be delivered by conventional means. Traditional workarounds such as routing by the full IP address or changing IP addresses manually often create more problems [2]. The solution to these difficulties was to define a protocol especially to support mobile nodes, which adds to the original Internet Protocol. The protocol is called as Mobile IP. The Mobile IP is supported by both versions of Internet Protocols, i.e., MIPv4 for IPv4 networks and MIPv6 for IPv6 networks. Mobile IPv4 allows transparent routing of IP datagrams to mobile nodes in the Internet. Each mobile node is always identified by its home address, regardless of its current point of attachment to the Internet [3]. Mobile IPv4 has so many issues that needed to be worked on and enhanced such as the security and routing issues. The problems may include: Triangle Routing, Duplicating fields in IP-within-IP, and Routing efficiencies [4]. The mobile internet protocol version 6, i.e., MIPv6 for the IPv6 network overcomes the problems existing in MIPv4. MIPv6 is the next generation protocol that allows an IPv6 node to be mobile—to arbitrarily change its location on an IPv6 network—and still maintain reachability. Connection maintenance for mobile nodes is done by handling the change of addresses at the Internet layer using Mobile IPv6 messages, options, and processes that ensure the correct delivery of data regardless of the mobile node's location [4].

With the growth in networking, many enhancements are done over the MIPv6 to improve its performance. All the architectures of MIPv6 move around the core concepts of Quality of Service (QoS) of MIPv6. “Quality of Service” is a measurement of the network behavior with respect to certain characteristics of defined services. Providing QoS means providing real-time as well as non-real-time services [5]. The QoS metrics may include various factors like throughput, delay (handover latency) and packet loss. These concepts must be efficient in providing consistent, predictable data delivery service over the networks. The major concern is the problem of handover latency and the real-time packet loss that leads to the deterioration in the communication service. In Mobile IP, when a node moves away from one network and attaches to another, it needs to obtain a new IP address. This procedure is known as the handover [6]. The handover process can be defined as a sequence of steps that are performed when a MN gets disconnected from one network and tries to connect to another network. Handover mechanism is the important part of Mobile IP. The handover process involves various steps, viz, discovery of routers, movement detection, care-of-address configuration, duplicate-address-detection and binding registration. The handover in basic MIPv6 is shown in Fig. 1.

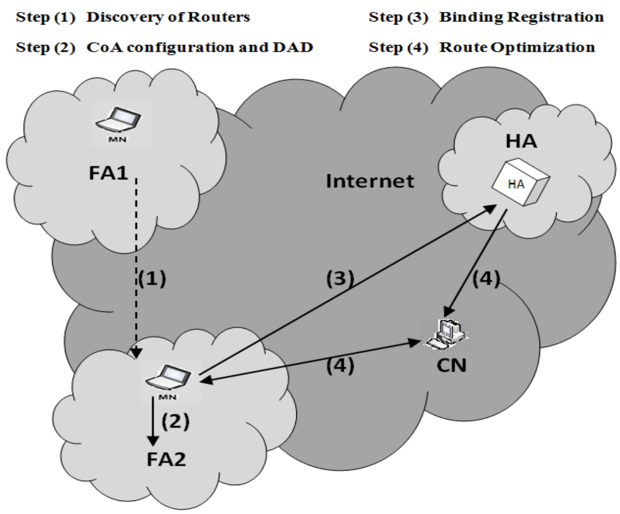

Figure 1. Basic MIPv6 Architecture

When an IPv6 node changes its location, it might also change its link; consequently, its IPv6 address might also change in order to maintain connectivity. There are mechanisms to allow for the change in addresses when moving to a different link, such as stateful and stateless address auto configuration for IPv6. However, when the address changes, the existing connections of the mobile node, which are using the address assigned from the previously connected link, cannot be maintained and are ungracefully terminated [7]. The major problem that occur in MIPv6 is that of handover latency, the time interval during which a MN cannot send or receive any packets during handover [8] thus causing the packet loss as well. Packet loss may be defined as the amount of packet dropped, lost or corrupted during transfer. The higher the packet loss, the poorer is the performance [9]. These problems will be huge during real-time sessions between the MN and the CN. Numerous efforts have been attempted to develop efficient handover schemes.

To minimize the handover latency and real-time packet loss, and enhancing the QoS of MIPv6, an improved framework is proposed in this paper. The paper is organized as follows: The basic framework for MIPv6 is reviewed in Section II. Section III provides the details of the improved framework. Then, Section IV evaluates the improved framework on the basis of numerical analysis followed by the comparison of the basic and the improved frameworks for MIPv6 in Section V. At last, conclusion is derived in Section VI.

II. BASIC FRAMEWORK FOR MIPv6

The MIPv6-handover is composed of L2-handover and L3-handover where **L2 handover** is the process by which the MN changes from one link-layer connection to another. **L3 handover** is the process in which a MN detects a change in an on-link network prefix that would require a change in the primary CoA [7]. The L2-handover latency is negligible as compared to the L3-handover latency. Thus L3-handover latency is the major problem that is of greater concern. This L3-handover process is illustrated in Fig. 2 [10].

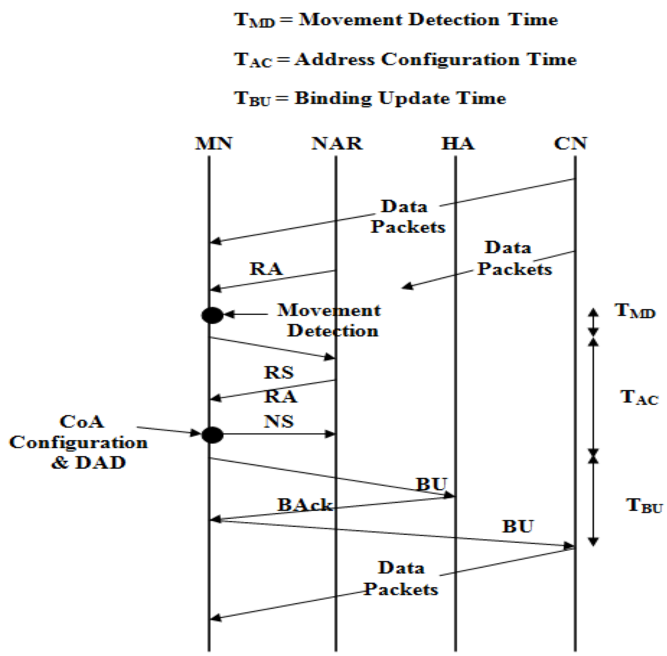

Figure 2. Basic Framework for MIPv6

The l3-handover process consists of five phases:

A. Discovery of Routers

The mobile uses the “Neighbor Discovery” protocol mechanisms to detect the available neighboring routers. For the purpose, the routers send out Router Advertisement (RA) messages periodically, or in response to Router Solicitation (RS) message from MN [11].

B. Movement Detection

This detection is based upon the reception of RA messages emitted by the current routers present on the networks. MN maintains the list of prefixes and of default routers using the received RAs [6].

C. Care-of-Address Configuration

When the MN detects that it has no more contact with its current router, it chooses another one in its default router list and creates its IP address starting from the corresponding prefix, using stateless address autoconfiguration [6].

D. Duplicate-Address-Detection

Once an IPv6 MN has configured its CoA, it must perform DAD to ensure that its configured address is unique on the link. To perform DAD, the MN sends out a Neighbor Solicitation (NS) message with its own address as the target address of the solicitation message [6]. If there is another node on the link that is using the same address, that node will acknowledge the message by sending the Neighbor Advertisement (NA) message to the MN. If the MN receives the NA message, the configured CoA is not unique. Then, the MN re-configures the CoA and repeats the process until it gets a unique CoA. When it detects a CoA that is unique, the address is assigned to the MN [12].

E. Binding Registration

After configuring a unique CoA, the MN has to inform the HA about of its current address by sending the Binding Update (BU) message. On receiving the BU message, the HA establishes a tunnel between the MN and its Correspondent Nodes (CNs) for data transmission. The HA then confirms the registration by sending the Binding Acknowledgement (BAck) message to the MN. When the MN receives the BAck message from the HA, it sends the BU message to the correspondent node (CN) to inform about the handover. After the completion of the binding registration, communication is re-established between the MN and the CN [13].

The time interval required for the handover process, called handover latency may lead to many problems like:

- delay in communication

- lesser throughput (average rate of successful data delivery over a communication channel) [14]
- Packet loss (number of packets that doesn't reach their destination).

Packet loss is the number of packets that are lost during handover process, when MN is disconnected from PAR but not connected to the NAR. It directly affects the perceived quality of the application. It compromises the integrity of the data or disrupts the services. Factors may cause packet loss are as follows:

- At the network level, packet loss can be caused by network congestion, which results in dropped packets.
- Another cause of loss is caused by bit error that occurs due to noisy communication channel.

Such loss will most likely occur in a wireless channel. In addition to this, packet loss probability is also affected by Signal-to-noise ratio and distance between the transmitter and receiver. When caused by network problems, lost or dropped packets can result in highly noticeable performance issues or jitter with streaming technologies, voice over IP, online gaming, and videoconferencing, and will affect all other network applications to a degree [15]. It is observed that there is a great problem of handover latency and the packet loss in mobile communication using basic framework of MIPv6 [16]. This problem becomes worse in case of real-time communication. Thus an improved framework for minimizing the handover latency and the real-time packet loss in MIPv6 is required to be designed for providing efficient mobile communication, as explained in next section.

III. IMPROVED FRAMEWORK FOR MIPv6

The improved framework for enhancing the QoS in MIPv6 suggests few measures to solve the problems occurring in conventional approach in MIPv6. The l3-handover process consists of five phases:

A. Minimizing Handover Latency

The major handover latency occurring in conventional approach in MIPv6 is due to the DAD process. In the improved framework, the DAD process is removed and the CoA configuration is done by the neighboring router itself and not by the MN, taking care of its uniqueness. For the purpose, the routers maintains two address pools, one is the **"Free Address Pool"** for storing addresses that are freely available to be assigned to the new connecting node, and the other, **"Assigned Address Pool"**, storing the already assigned addresses that are being used by other connected nodes. Thus the handover process in the improved framework involves various steps as shown in Fig. 3.

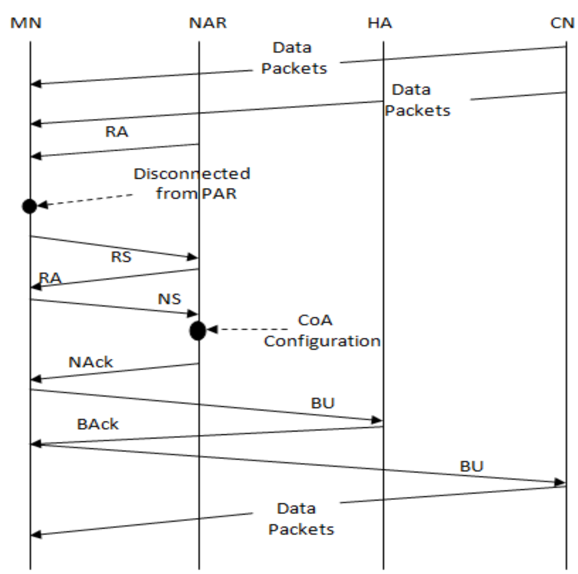

Figure 3. Improved Framework for MIPv6

These steps are explained as follows:

- As soon as a MN detects the movement from one network to another, it sends an FBU to the Previous Access Router (PAR) and RS message to the neighboring routers;
- After receiving the RA message, a MN sends the Neighbor Solicitation (NS) message to the NAR requesting for the configuration of new CoA to be assigned;

- The NAR, considering the link – layer address of the MN from the NS message, configures the unique new CoA for the MN from the Free Address Pool;
- NAR then sends the new CoA to the MN by encapsulating it in the Neighbor Advertisement (NA) message;
- When the MN gets assigned the new CoA, it sends the BU message to the HA for its new CoA registration;
- On receiving the BU from MN, the HA make its entry in its binding cache, establishes the tunnel between the MN (with its new CoA) and its CNs and confirms the update by sending the BAck message to the MN;
- The MN after receiving the BAck message from the HA, sends the BU to the CNs to inform them about its new CoA for direct communication.

When the process is completed, the communication re-establishes.

B. Minimizing Packet Loss

Whenever a MN detects its movement away from the present point of attachment, it sends a Fast Binding Update (FBU) message to the PAR and also the Neighbor Solicitation (NS) message to the NAR. The FBU message includes a group of addresses that are considered to be the possible NAR to which the MN may connect. Then during handover, the packets sent by CN towards the MN, are multicast from the PAR to the NARs where these packets will be buffered. After the completion of the handover process, these packets will be forwarded to the intended MN. This solution minimizes the packet loss. This solution is explained as follows:

The possible NARs would be selected from the available routers neighboring the PAR as shown in Fig. 4.

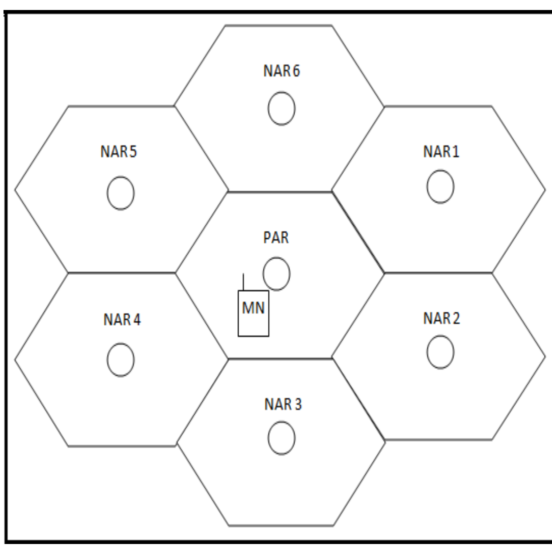

Figure 4. Neighboring Routers

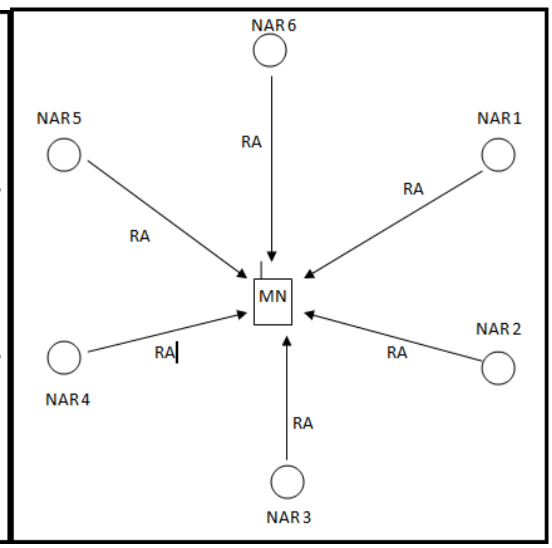

Figure 5. Position of the MN when receiving the RAs

When the MN receives the RA messages from the neighboring routers periodically as shown in Fig. 5, it checks for the signal strength and maintains its information in a table as shown in TABLE I.

TABLE I. DATA STRUCTURE STORING INFORMATION ABOUT THE SIGNALS

NAR	IP ADDRESS	S_P (DB)	S_N (DB)	S_N - S_P

where S_P would be the previous signal strength,

S_N be the New signal strength, and

$S_N - S_P$ gives the change in signal strength.

This table is maintained at the MN itself consuming the cache memory for storing the address of the 6 neighboring Routers and their previous and new signal strengths. The memory size depends on the size of NAR's address, and the size required storing the values of signal strengths for six neighboring routers.

When a message or signal is received from the nearby device, the signal strength is more than that received from the far away device. So if the signal strength of the received RAs is increasing, this means that the MN is moving towards the source router and if the signal strength of the received RAs is decreasing, this means that the MN is moving away from the source router. The neighboring routers, whose RA message's signal strength is increasing, are considered to be the possible NARs to which the MN can precede the handover process. So these will be selected, and their addresses are grouped as the multicast group addresses. On predicting a handover to a Next Access Router (NAR), the Mobile Node submits this multicast group addresses to the Previous Access Router (PAR) by encapsulating as Mobility Options in Fast Binding Update (FBU) message. Then the PAR retrieves this multicast group of addresses from the FBU, and performs the multicasting of the packets sent by the CN during handover, to the multicast group addresses. Considering the Routers NAR 2, NAR 3 and NAR 4 is the possible NARs to which MN can precede the handover, this forwarding of packets can be done as shown in Fig. 6.

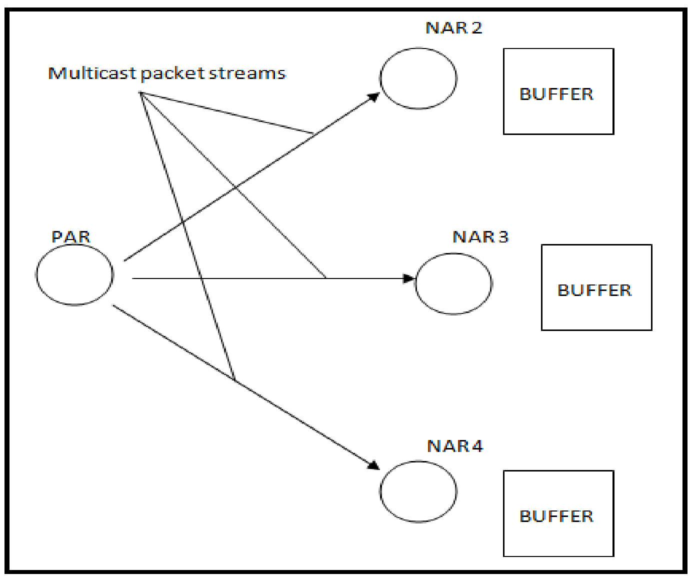

Figure 6. Buffering of multicast packet streams

These packets are then buffered at all these NARs for t seconds, where t would be selected as:

$$t > T_{Handover} \qquad (1)$$

Thus $T_{Handover}$ would act as the threshold value for buffering, before which the packets would be lost. When the MN completes its handover with any of these routers, that NAR will forward these buffered packets to the MN. After forwarding the packets, these will be discarded at the NAR.

The improved framework is evaluated on the basis of numerical analysis as explained in Section IV.

IV. NUMERICAL ANALYSIS

Both, the general as well as the improved framework would be analyzed on the basis of numerical analysis.

A. *Analysis for Handover Latency*

The handover latency in a basic framework for MIPv6 is shown in the Fig. 7 [17].

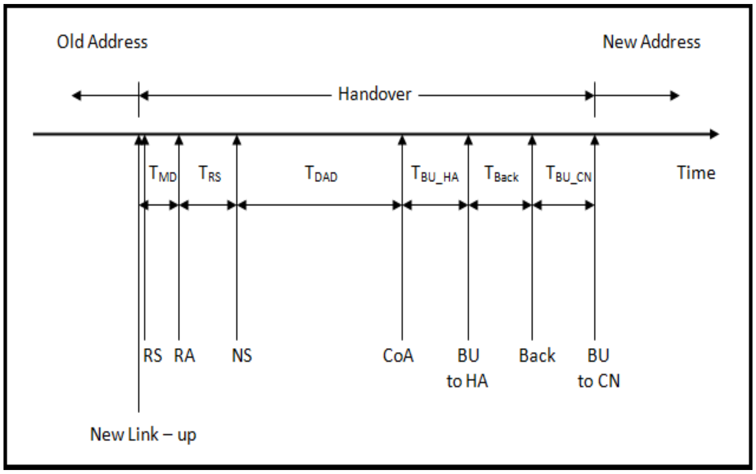

Figure. 7. Handover Latency in Basic Framework for MIPv6

Here, the handover latency is found to be calculated (in seconds) as below:

$$T_{HANDOVER\_MIPv6} = T_{MD}+T_{RS}+T_{CoA}+T_{DAD}+T_{NA}+T_{BU\_HA}+T_{BAck}+T_{BU\_CN} \quad (2)$$

where all the parameters are explained in the TABLE II.

TABLE II. HANDOVER LATENCY PARAMETERS

T_{MD}	Movement Detection delay
T_{RS}	Time taken for random waiting delay of an NS message
T_{CoA}	Care of Address configuration delay
T_{DAD}	Duplicate Address Detection delay
T_{NA}	Neighbor Advertisement delay
T_{BU_HA}	Time taken for sending BU to HA
T_{BAck}	Time taken by HA for sending Binding Acknowledgement
T_{BU_CN}	Time taken for sending BU to CN

Here DAD is performed repeatedly with CoA configuration and NA thus increasing the time, T_{DAD}. In the improved framework, the process of DAD is removed, thus minimizing the handover latency. Hence the handover latency can be calculated (in seconds) as shown in Fig. 8:

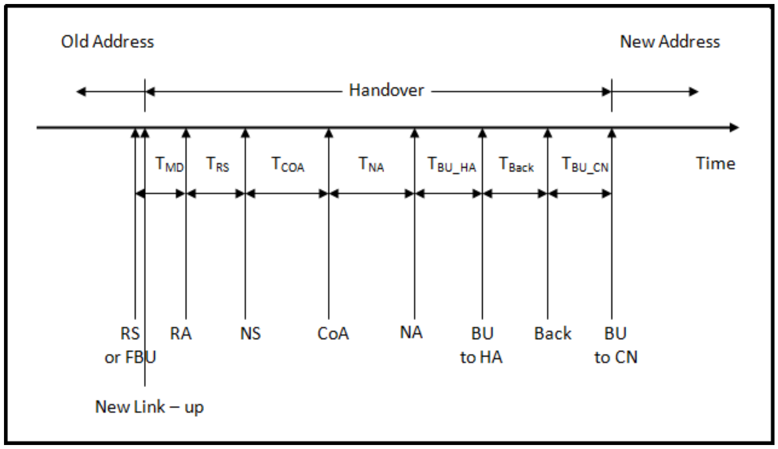

Figure 8. Handover Latency in Improved Framework for MIPv6

Here the handover latency is calculated as:

$$T_{\text{HANDOVER\_Improved}} = T_{\text{MD}}+T_{\text{RS}}+T_{\text{CoA}}+T_{\text{NA}}+T_{\text{BU\_HA}}+T_{\text{BAck}}+T_{\text{BU\_CN}} \quad (3)$$

From equation (3), handover latency in basic framework will be directly proportional to the DAD delay:

$$T_{\text{HANDOVER\_MIPv6}}\ \alpha\ T_{\text{CoA}} + T_{\text{DAD}} + T_{\text{NA}} \quad (4)$$

Similarly, from equation (3), the handover latency in Improved framework will be directly proportional to the sum of Care of Address configuration delay and Neighbor Advertisement delay:

$$T_{\text{HANDOVER\_ImprovedMIPv6}}\ \alpha\ T_{\text{CoA}} + T_{\text{NA}} \quad (5)$$

Now comparing equations (4) and (5), we conclude that

$$T_{\text{HANDOVER\_ImprovedMIPv6}} < T_{\text{HANDOVER\_MIPv6}} \quad (6)$$

i.e. the handover latency is lesser in Improved framework as compared to that in basic framework.

B. *Analysis for Packet Loss*

Now, the packet loss is the number of packets that are lost during the handover process. In general, in wireless and mobile networks, packet loss is mostly caused by bit errors in an error-prone wireless channel, congestion in the network, or due to handover. But the major loss is occurred due to the handover latency. All other factors are occasionally responsible. The main reason for packet loss caused by handover is the fact that packets are routed to the previous access router for buffering while the link to the previous access router is already broken. These packets might be dropped by the previous access router. Thus in the basic framework for MIPv6, there is a great possibility of packet loss during the process of handover after the disconnection of the MN from the previous network. While in the proposed framework, as we suggest the buffering of packets for the time interval greater than the threshold value which is equal to the value of handover latency, the problem of real-time packet loss due to handover latency will be resolved completely. Thus,

$$\text{Buffering time, } T_{\text{BUFFERING}} > T_{\text{THRESHOLD}} \quad (7)$$

$$\text{where } T_{\text{THRESHOLD}} = T_{\text{HANDOVER\_ImprovedMIPv6}} \quad (8)$$

Still the packet loss is possible, that may occur occasionally and that too is very less as compared to that in the basic framework, due to following reasons:

- bit errors in an error-prone wireless channel,
- Congestion in the network.

In case the MN moves towards the black hole region or gets disconnected for more than the packet buffering time, due to any of the reasons mentioned above or some other reason, there is a possibility of packet loss.

V. COMPARISON OF GENERAL MIPv6 AND IMPROVED MIPv6

Let us assume a handover with following delays (in seconds) as in TABLE III:

TABLE III. DELAYS IN MIPv6 HANDOVER

T_{MD}	T_{RS}	T_{CoA}	T_{DAD}	T_{NA}	T_{BU_HA}	T_{BAck}	T_{BU_CN}
.075	.083	.091	1.245	.082	.909	.819	.884

Here Handover latency in basic framework from equation (2) comes to be:

$$T_{HANDOVER\_MIPv6} = 4.188 \text{ seconds} \quad (9)$$

Handover latency in improved framework comes to be:

$$T_{HANDOVER\_ImprovedMIPv6} = 2.943 \text{ seconds} \quad (10)$$

From the above analysis and the equations (VI) and (VII), the comparison of the existing MIPv6 and the improved frameworks is illustrated in TABLE IV.

TABLE IV. COMPARISON BETWEEN IMPROVED MIPv6 and GENERAL MIPv6

QoS	General MIPv6	Improved MIPv6
Handover Latency (Average)	More	30% lesser than MIPv6
Packet Loss	More	Only Under Exceptional Conditions

The table illustrates that the proposed framework reduced the handover latency by 30% as compared to the existing MIPv6. Also the packet loss is also reduced to a great extent. The packet loss remains to occur only under certain exceptional conditions like network congestion, errors in bits, etc.

VI. CONCLUSION

In this paper, we have compared the handover latency of basic framework and that of improved framework. We first analyzed both the frameworks for handover process and then we compare their performance on the basis of numerical analysis. From the numerical analysis and comparison, it is concluded that the removal of DAD process in the improved framework had reduced the handover latency by about 30%. Also the use of buffer management and forwarding of packets provided a substantial reduction of real-time packet loss in improved framework. Thus makes the mobility in IPv6 network more reliable and efficient.

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