IMPROVEMENT IN THE MOBILITY OF MOBILE IPV6 BASED MOBILE NETWORKS USING REVERSE ROUTING HEADER PROTOCOL AND FAST HANDOFF

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ABSTRACT

Mobile IPv6 based Mobile Networks are becoming increasingly important with the widespread popularity of wireless internet connectivity. For large networks, an extension, namely, the Hierarchical Mobile IPv6 is used, which suffers from overloading of the Home Agent as every packet sent has to pass through it and this produces a significant loss in performance. In this paper, a method to improve the mobility using the fast handover of Mobile IPv6 (FMIPv6) and the Reverse Routing Header Protocol is proposed. Simulation results at different packet intervals show that, the proposed scheme is able to reduce the average delay and achieve an optimum level of throughput.

KEYWORDS

Fast handoff; Reverse Routing Header Protocol; Hierarchical Mobile IPv6; Wired-wireless networks; Network Mobility; Home Agent; Mobile Networks.

1. INTRODUCTION

With the advent of information technology, the Internet has grown by leaps and bounds, and there is widespread speculation that there may come a time when all the IP addresses are used up. This would create several problems, including but not limited to, browsing the web, online banking, videoconferencing and every other service the Internet provides. Although it seems implausible that 4.3 billion addresses would become depleted, most Regional Internet Registries have become exhausted. This was the sole motivation behind the IPv6 protocol that can support 3.4×1038 addresses and is the Internet Engineering Task Force (IETF) successor technology. The IPv6 allows for stateless address auto configuration and has network security (IPsec) as a design requirement. Additionally, the IPv6 avoids triangular routing thereby improving mobility.

The Mobile IPv6(MIPv6) is an IETF standard that allows mobile device users to move from their Home Network to another while maintaining a permanent IP address, thereby ensuring location transparency (similar to a Distributed System Environment). This facility allows for seamless and continuous internet connectivity. However, the reason for the lack of popularity in deploying Mobile IPv6 is due to poor handoff latency and other drawbacks leading to packet loss and poor performance for live audio and video streaming-based applications. MIPv6 has not seen commercial interest because it requires the mobile equipment itself to participate in the mobility process and this reduces the battery life of the mobile equipment. While MIPv6 manages mobility for a single host, the Network Mobility Basic Support Protocol (NEMO BSP)

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Although host-based Mobile IPv6 protocols have been studied extensively, a different approach where the entire network moves, known as Network Mobility (NEMO) is of great interest in the

manages mobility for an entire network. NEMO exhibits several features such as bandwidth conservation, reduced signalling and improved manageability, etc., though it also has a few drawbacks, like fragmentation, jitter, packet delay and severe bottleneck in the home link etc. An extension of the Mobile IPv6, the Hierarchical Mobile IPv6 based mobile networks have issues, such as the rapidly changing point of attachment of the mobile router, which in turn leads to binding update storm, double registration etc. Due to the rapidly changing topology of the mobile network, location updates must be performed at the Home Agent (HA) and every packet sent has to pass through the HA. This simply, overloads the Home Agent and in turn, leads to the dropping of packets at the HA, which eventually, leads to delay in the handover and degrades the overall network performance.

In this paper, by using the fast handover of Mobile IPv6, a reduction in the delay incurred during handover is proposed in the form of a soft handover scenario using improved router advertisements. To eliminate the route discovery for acknowledgements, the Reverse Routing Header Protocol (RRH) is employed. The purpose of this protocol is to record the route through which the packet travels from the Correspondent Node to the Mobile Node.

The rest of this paper is organized as follows: Section 2 explains the related works. In Section 3, the background of fast handover of Mobile IPv6 and the packet loss scenario are explained along with the proposed system. In Section 4, the system setup and transfer of data is explained. Section 5, explains the simulation and testing of the proposed system. The concluding remarks are given in Section 6.

2. RELATED WORKS

One of the most interesting and recent research challenges in the world of wireless networks is to design and enable a seamless handover, while reducing latency and simultaneously maintaining an optimized routing mechanism. In [1] the existing IPv6 mobility management protocols such as the Proxy Mobile IPv6, Fast MIPv6 and Hierarchical MIPv6, and their characteristics, and their findings on handover performance have been compared and analyzed. The analysis serves to highlight the differences among the various protocols, but discusses the MIPv6 protocols which were initially developed to support mobility in individual hosts, rather than the network in its entirety. Addressing this issue, solutions have been proposed [2] to support Network Mobility (NEMO) based on a Mobile Router concept. The main focus is on various Route Optimization (RO) techniques in mobile ad-hoc networks (MANETs), to compensate for the inefficient routing and delay owing to the usage of Bi-Directional Tunnel (BDT) which helps to solve the Pinball routing problem. Although the paper highlights the reduction in traffic congestion, it lacks any testing done in real-time to support it.

Even though the two extensions to MIPv6, Fast MIPv6 (FMIPv6) and Hierarchical MIPv6 (HMIPv6) provide significantly better throughput in terms of performance and signalling overhead, a third scheme fast handover over Hierarchical MIPv6 (FHMIPv6) provides the best of both schemes. HMIPv6 which depends primarily on the concept of the Mobility Anchor Point (MAP) and FMIPv6 which depends on Access Routers (AR), have their implementation applied in the most straightforward way. The paper [3] proposes an improved version of FHMIPv6 as the MAP tries to prevent any redundant binding updates (during fast handover) to take place. It reuses some of the handover information obtained by analysing the pattern in which the Mobile Node (MN) moves and improves the handover process. Key features of this paper are that the rate of packet loss and handover latency are shown to reduce and the throughput and network performance is improved, especially in networks in which mobile nodes have a zigzag pattern of movement. Simulations are performed by means of Network Simulation-2 (NS-2) and the results are tabulated.

field of Next-Generation Wireless Networks (NGWNs). An unrelated but equally interesting protocol is the Optimized Route Cache (ORC) protocol, which is used to provide a sense of mobile transparency by maintaining the route that the entire network takes. A hybrid scheme called OwR that combines the ORC protocol with the Reverse Routing Header protocol (RRH) is proposed in [4]. With a few modifications, the OwR is shown to be stable and at least as effective as the RRH alone. Moreover, ORC works on a best effort basis thereby limiting the number of sessions that the routing can be optimized for. Nevertheless, simulation results have shown that, the performance of OwR can be improved and the cost of RO in a nested network can be decreased.

NEMO allows users on the move, to stay connected to the internet and this emphasizes the significance of the mobility management of a mobile network in heterogeneous networks like 802.11 WLAN or UMTS. Mobile nodes in such networks are restricted by the bandwidth associated with that network's configuration. The problem of controlling the traffic flows due to the varying bandwidth, of each application further increases complexity of the management scheme. Thus, it is essential to prioritize traffic flow and allocate a minimum bandwidth guarantee. A comprehensive study of the performances of the mobility protocols namely, Mobile IPv6 and NEMO-BSP (NBS) has been made in [5]. The study revolves around a dynamic Quality of Service (QoS) provisioning mechanism which compares factors like packet delay, packet forwarding and packet loss rates and integrates this mechanism into the mobility protocols to provide QoS in the aforementioned heterogeneous networks.

The MIPv6 served only as a global solution to manage mobility in networks however, the Hierarchical MIPv6 (HMIPv6) was later designed to improve the performance, both in micro and macro networks by introducing a hierarchy. An Optimal Choice of Mobility Management (OCMM) is proposed in [6] that focuses not on the performance, but rather on the application scopes of these two protocols, and chooses the better one among them depending on user criteria and specifications. It is also shown that, the OCMM outperforms both MIPv6 and HMIPv6 in terms of the total cost including average registration and packet delivery costs; yet the authors do not address the issue of RO, and the packet overhead remains largely inefficient.

An alternative solution to the problem of devising a framework of the mobility management scheme is explained in [7], which is based on the movement pattern of the user. The seamless handover is the main factor that provides a measure of performance and the main idea in this paper is the enhancement of a pre-existing model, called Seamless Handoff Architecture for Mobile IPv6 (S-MIPv6) by simplifying the existing architecture and perfecting the prediction algorithms that are being used.

To combat the large overhead incurred in Mobile IPv6, the two existing mechanisms of RO and BDT have been studied and an improved tunnelling based routing method with a better performance is shown to have lesser overhead, allowing for larger payloads to be sent with lesser delay [8]. Regarding the issue of smooth handovers, the FMIPv6, which is a cross layer handover scheme, makes use of a Link Layer (L2) trigger to invoke handovers and by further analyzing the MN, a predictive algorithm is developed that supports an adaptive handover trigger scheme (IMP-AHT). The premature L2 trigger causes serious performance loss, and measures to compensate the same are addressed in [9].

Seamless and smooth handovers have been a huge technical challenge in mobile wireless networks, and the providing for continuous services while moving through heterogeneous wireless networks, is the main issue in the fourth generation wireless Networks. An intelligent context-aware solution that points out the importance of multi-homing is proposed in [10]. It is based on advanced decision approaches like fuzzy logic and analytical hierarchy processes.

In order to further delve into the problem of what constitutes a seamless and smooth handover, it is essential to understand the various problems that are associated with a MN that actually does the handover. Radio interference and a reduction in the signal strength as the MN moves

from network are quite common. It is proved in [11] that trend-based handover triggering schemes are better indicators of link failure than their threshold-based counterparts and also by comparing existing handover triggering schemes, it is proposed that the use of frame retransmission improves the quality of communication.

There are a number of delays that occur in Mobile IPv6 and these can be broadly classified into Layer 2 (L2) and Layer 3 (L3) delays. Among them, Movement detection delay (in L2) and Duplicate Address Detection (DAD in L3) are the most time-consuming of the delays. Two solutions are proposed in [12], one for each layer. The first solution utilises fuzzy logic for L2 while the second solution implements Parallel DAD in L3. The researchers support their claims with simulations showing a significant reduction in both the handover latency and a substantial improvement in the rate of packet loss in both those layers.

Another trend of the wireless internet is the concept of a flatter architecture. There are many challenges like reachability and scalability in the centralized management scheme. Some important network entities and signalling procedures have been proposed and defined. In [13], fast handoffs have been simulated in intra-domain as well as inter-domain networks. The Signal-to-Noise Ratio (SNR) and the Signal-to-Interference Ratio (SIR) are link layer triggers which are used to achieve fast handoff in a hierarchical domain, by enabling the handoff before the MN reaches the destination routers.

Proxy Mobile IPv6 (PMIPv6) is a mobility management scheme that was primarily introduce to reduce the handoff latency that occurs in normal Mobile IPv6. PMIPv6 serves to reduce the large signalling overhead that occurs in Mobile IPv6, and ensures that the functionalities are carried out by the mobile network itself. Although it is not known whether next generation networks will make use of MIPv6, the use of IPv6 and PMIPv6 in real-time services have been tested in Android and their respective challenges have been analysed [14]. They also go on to infer that, with a few changes to the existing schemes, it is highly probable that they may provide support for, not only the mobility management but also, the seamless handovers.

It might seem that PMIPv6 does offer some solution to the handoff latency issues of Mobile IPv6 but PMIPv6 has its own share of drawbacks. Solutions to some of the problems such as the disruption latency and data loss due to traffic faced by PMIPv6 in localized domains are offered in [15]. In theory, at least, PMIPv6 is shown to possess lower handoff latency as compared to host-based mobility management protocols like MIPv6 or Hierarchical MIPv6. A Mobile Host (MH) works in a reactive mode, and has some loss in communication performance; however, the article proposes a proactive latency low handover mechanism, which utilises a make-before-break technique, in order to support the mobile host's seamless and fast roaming in PMIPv6. This would enable the mobile host to re-configure its interface more quickly after a handover.

A cross-layer integrated mobility and service management scheme, called Dynamic Mobile Anchor Point with Smart Router (DMAPwSR) in Mobile IPv6 environments is proposed and analyzed in [16]. The goal of DMAPwSR is to minimize the overall mobility and service management cost for serving mobile users with diverse mobility and service characteristics. The basic idea of DMAPwSR is that, each MN can utilize its cross-layer knowledge to choose smart routers to be its dynamic mobility anchor points (DMAPs), to balance the cost associated with mobility services versus packet delivery services. An analytical model based on stochastic Petri nets to analyze the DMAPwSR and compare its performance against Mobile IPv6 and HMIPv6, was also developed.

3. THE PROPOSED SYSTEM

The system architecture for the proposed system is given in Figure 1. The solid lines indicate a wired connection, whereas the dashed lines indicate a wireless connection. Here there is one MAP indicating only one domain. A MAP marks the boundary of a sub network. All the routers connected with it belong to one sub network. The handoff occurs when the mobile router changes its point of attachment from one access router to another.

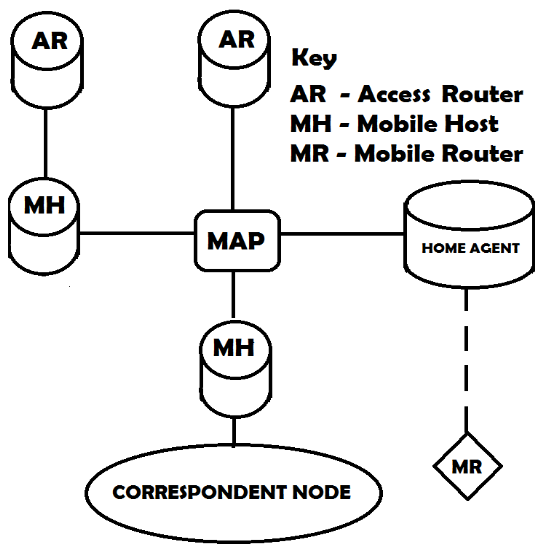

Figure 1. The proposed architecture

The AODV protocol is used, as it significantly reduces the control overhead, because the nodes are informed in case of link failure (unlike what is seen in DSDV). The packets sent by the Correspondent Node (CN) are intercepted by the Home Agent (HA), and the HA forwards these packets to the respective Access Router (AR). The HA binding cache lookup is done on a per packet basis. The return path for the acknowledgements is determined with the help of the reverse routing header, as shown in Figure 2. A multi-hop wireless routing is simulated.

3.1 FAST HANDOVER

In the simplest terms, Handover can be thought of as terminating existing connectivity and obtaining new IP connectivity. This switch in connectivity is performed by sending a successful binding update to the Home Agent so that the Mobile Node can receive packets directly at the new care of address (CoA). Therefore, it is necessary to reduce the latency due to the binding updates and the IP connectivity. Moreover, there are problems of overloading brought about by the location updates at the HA, when the Mobile Router (MR) rapidly changes its point of attachment. The MAP marks the boundary of a sub-domain, and is a router based on which a mobile node's regional CoA is assigned. Proactive handoffs between the current and the next access router, bypass the HA and reduce the congestion due to excessive binding updates at the HA. Figure 3 traces the steps involved in performing the handoff and how the RRH is used to get the latest address of the MR via the Next access Router (NAR). Fast handover introduces four new message types to be used along with MIPv6, which allows the anticipation of the Layer 3 handoff such that data traffic can be forwarded to the MR's new location before it moves there. The Router Solicitation for Proxy Advertisement (PrRtSol) and Proxy Router Advertisement (PrRtAdv) messages are used for aiding movement detection. This results in reduced packet loss due to layer 3 handoff latency.

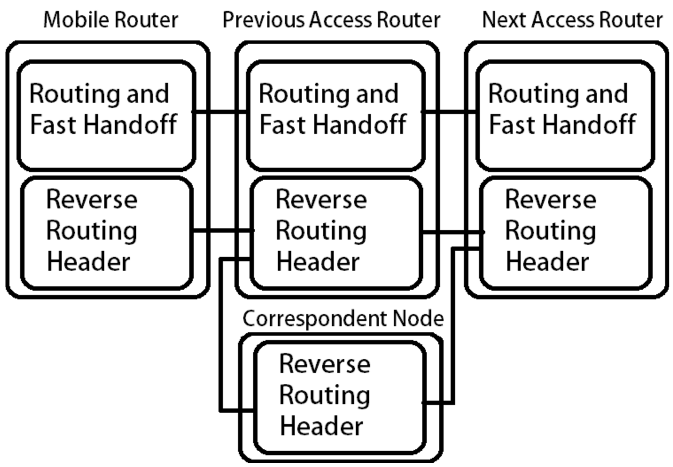

Figure 2. Functioning of the proposed system

These messages are used between the MR and AR and between the Previous Access Router (PAR, the access router to which mobile router is attached before handing off) and NAR (the access router to which the MR handoffs to). Through the two PrRtSol and PrRtAdv messages, the MN also devises a potential new care of address (NCoA) when it is still present on the PAR's link. Hence, the latency due to the new prefix discovery subsequent to handover is eliminated. MR initiates the procedure by sending the PrRtSol to the PAR which contains the link layer address. MR will receive the PrRtAdv in response and forms the CoA according to the IPv6 address auto-configuration. In order to reduce the binding update latency, the protocol specifies a binding between the Previous CoA (PCoA) and NCoA. The MR sends a Fast Binding Update (FBU) message to its PAR to establish this tunnel.

Finally, the routers could transfer network-resident contexts, such as access control, Quality of Service (QoS), and header compression, in conjunction with handover. For these operations, the protocol provides Handover Initiate and Handover Acknowledge messages, all of whose definitions have been described in [17].

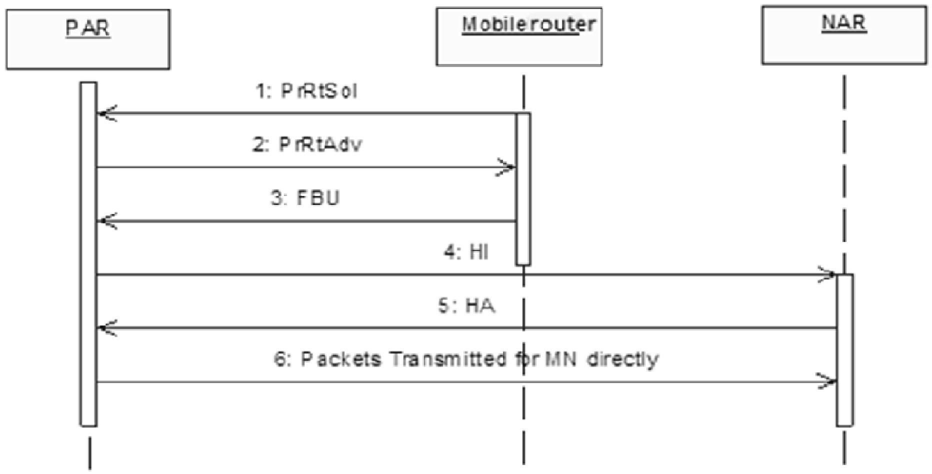

Figure 3. Sequence diagram depicting fast handover in Mobile IPv6

3.2 REVERSE ROUTING HEADER

A nested mobile network may consist of a number of Bi-Directional Tunnels (BDTs) with a tunnel between an MR and the HA associated with the MR. This results in the usage of many network resources. To avoid this, a new routing header protocol called the Reverse Routing header protocol (RRH) is proposed. According to the RRH, only a single bidirectional tunnel is enough between the first MR and the HA, in order to forward the packets. The RRH records the route out of the nested mobile network and is converted into a routing header for packets destined to the mobile network. The Local Fixed Node (LFN) and a CN operation are left unchanged from the Mobile IPv6. A CN can also be an LFN. An RRH is inserted by the first MR on the mobile network's outbound path, as part of the reverse tunnel encapsulation. It is removed by the associated HA when the tunnel packet is decapsulated.

When applied to the NEMO problem, the RRH can be used to update the HA on the actual location of the MR. Only the egress MRs which are not at the home network, and are forwarding packets, update the HA on the move. The first hop for the return path is the last hop on the path of the incoming packets that is between the HA and the MR of the mobile network. The agent saves the IP address of the MR from the source field in the IP header. The full path to and within the mobile network is piggy backed with the traffic on a per packet basis to cope with the rapid movement. This makes the packet construction different from the Mobile IPv6. Subsequently the MR sends an FBU to bind its newly formed CoA as the last message before the handover is executed. After receiving the FBU from the MR, the PAR starts forwarding packets destined for the MR to its new CoA.

3.3. SYSTEM SETUP AND DATA TRANSFER

The initial system setup is shown in Figure 4. The proposed system has been configured using the TCL script languages in a wired-wireless scenario. There are 8 nodes in the scenario, out of which 7 nodes belong to the wired network, and only one is a mobile router which has mobility. The data transfer from the correspondent node and the mobile router is shown in Figure 5. The simulation time is setup to 80s. The CN communicates with the MN inside the mobile network through the HA, which indicates that the MN is within the home network. The MN is registered with the HA, which keeps track of the location updates of the mobile network and its entities (MNs and/or sub routers).

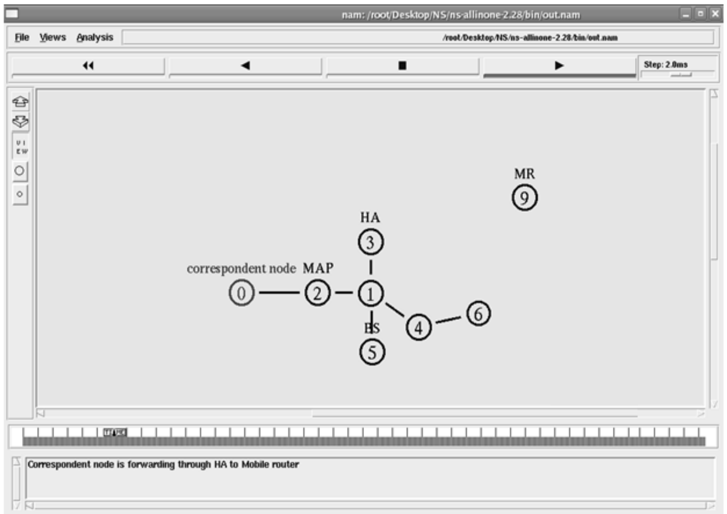

Figure 4. The initial system setup

The MAP divides the entire network into sub domains, i.e., all the entities under a MAP is administrated by the MAP itself rather than the HA directly. This distributes the load on the HA. The default access router for the mobile network is the HA but it has the capability to accept the other base stations as the access routers, when the MR is away from the transmission range of the HA. The packet transfer before handoff is through the HA to the MR, behind which the destined node is available. All the intermediate routers add their own IP addresses to the data packet.

When the packet reaches the HA, the entire path through which the packet had travelled is recorded as the header. The HA strips the header and encapsulates the packet, and establishes a BDT to the MR. The MR then decapsulates the packet and reverses the header, i.e., the source now becomes the destination and the destination in the RRH becomes the source of the packet.

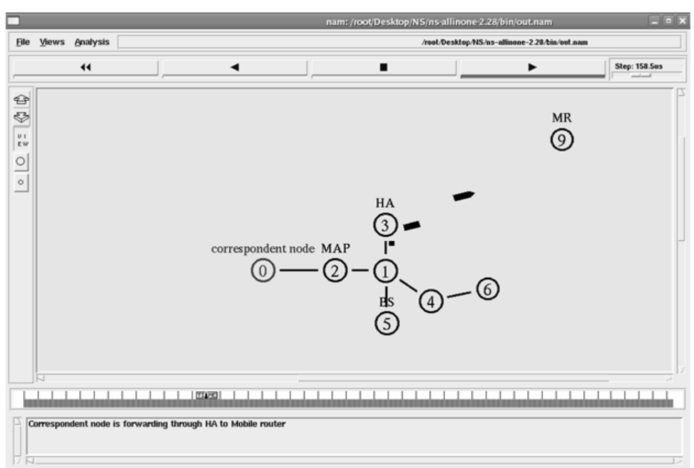

Figure 5. Packet transfer before handoff

Figure 6 shows the packet transfer after the handoff has occurred. When the MR moves out of the transmission range of the HA, it broadcasts the router solicitation message. The receipt of this by the current AR (HA in this case) indicates that the transmission of the packets intended for the mobile network cannot be forwarded through it; so, it broadcasts a handoff initiation (HI) message to the nearby routers. One of the routers accepts this request, and sends back the Handoff Acknowledgement (HAck). The HA sends the acknowledgement back and the handoff is completed.

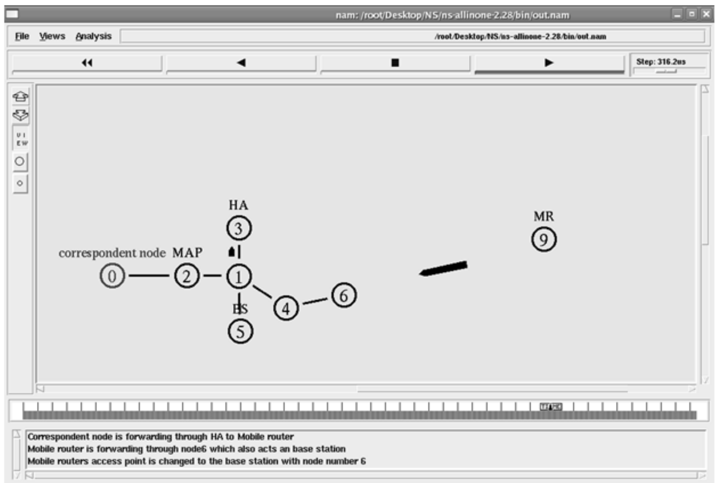

Figure 6. Packet transfer after handoff

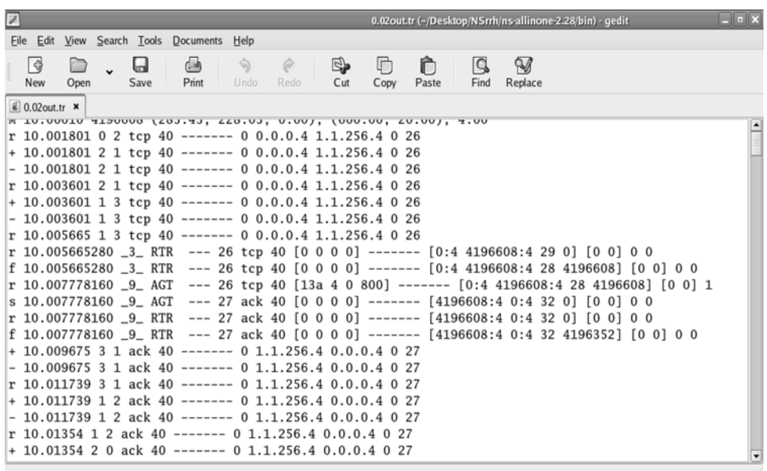

Figure 7. Screen shot of the Trace file

During fast handover, the change in the point of attachment of the mobile router should be carried out without the loss of the communication data. The observation from the simulation is that initially the router number 3 acts as the AR for the communication with the mobile router. When the MR moves out of the range of router 3, router 6 acts as the new access router. It can be said that data is being transferred from the PAR to the MN and also the transfer point is handed over to the NAR indicating the packet transfer and handoff is taking place. Due to the bypassing of the HA, the number of packets being dropped is very minimal.

On employing RRH, it is expected that the acknowledgements should take the same route through which the data packets had reached the destination node. Moreover, it is observed that, the HA decapsulates the packet header and reverses the header.As the packets pass through the intermediate router their address is added in the header. When the packet reaches the HA, the entire path is known and the header is reversed to determine the path for the acknowledgements.

The QoS metrics, the throughput and the delay are used for the purpose of analysis. The packet interval has been varied from 0.02 ms to 0.06 ms, and the average delay observed at the MR has been plotted in Figure 8. The graph clearly indicates that when the packet interval reaches 0.04 ms, the delay is reduced considerably. The delay is further reduced by 0.0001 when the packet interval is 0.05 ms, after which there is again increase in the delay. The average delay is optimum when the packet interval is at 0.04ms and is found to increase upwards from 0.05ms.

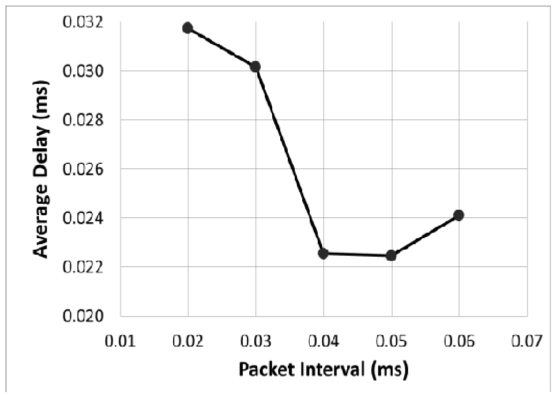

Figure 8. Packet Intervals versus Average Delay

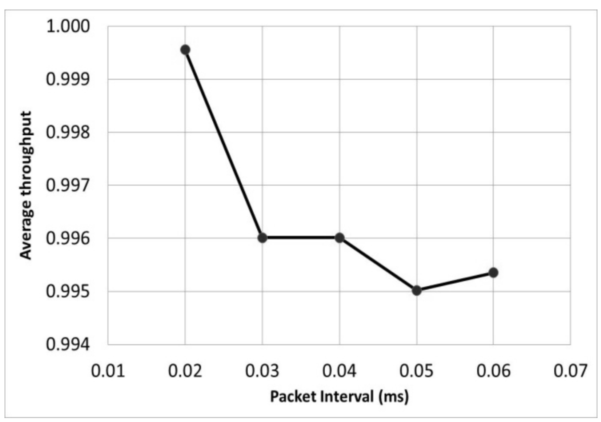

Figure 9. Packet Intervals versus Average Throughput

Figure 9 shows the average throughput for various packet intervals. The graph indicates good throughput at the beginning of the simulation after which there is a sudden decrease in the average throughput. The average throughput is optimum when the packet interval is 0.03 ms and 0.04 ms. The scenario been considered for the analysis purpose is the one where the data packets are generated by the CN and are received by the MR which acts as the destination node. The MR sends the acknowledgement back to CN on a per packet basis.

Table 1. Analysis of Average Throughput and Average Delay Product (AT x AD)

Packet Interval	Average CW Size	Range	ATxAD
0.02	47.026744	69.8	0.0319
0.03	39.212015	57.8	0.0298
0.04	34.626122	50.9	0.0224
0.05	31.533755	46.2	0.0224
0.05	29.275673	42.8	0.0239

As per the simulation results, the optimum average throughput is observed at the packet interval 0.04 ms. The number of bytes sent is 2348320 bytes and that received is 2338960 bytes. A trade off is achieved between the delay and throughput at 0.04 ms as observed in Table 1 such that the product of average throughput and average delay is 0.0224 at 0.04 ms and on increasing the packet interval further, the product is found to increase, suggesting the possibility of an increase in the delay. Thus, the throughput of 0.996014 is found to be optimum for the minimum delay at an interval of 0.04 ms.

5. CONCLUSION

A wired-wireless scenario that uses the TCP to implement a fast handover, incorporated with NEMO to improve the mobility of the network, is proposed. To overcome the reverse tunnelling and high data loss drawbacks of NEMO, the RRH protocol has been proposed as an extension, which allows for acknowledgments to be sent until the session completes. The performance of the proposed system is analysed in terms of throughput and average delay. It is concluded that, the FHMIPv6 along with the RRH improves the performance in scenarios with CBR traffic. There is a need to conduct further testing with various types of application traffic to observe the performance of the proposed system. This proposal can be further applied to real world architectures in both wired networks and mobile environments to test the efficacy for further validation.

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