Performance of intelligent Mobile IPv6

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Received 22 February 2005; received in revised form 18 October 2005; accepted 19 October 2005

Abstract

Mobile IP is the current standard proposed by IETF for mobility management in IP networks. Mobile node communicating with static correspondent node (CN) has been considered in previous performance studies. We propose the mobility of CN and two additional mobility combinations for Mobile IP in this paper. CN mobility causes performance degradation in an environment with frequent handoffs. A new scheme for Mobile IPv6 called Intelligent Mobile IPv6 is proposed. It is observed through simulation results that the performance of Intelligent Mobile IPv6 is better than Mobile IPv6.

Published by Elsevier B.V.

Keywords: Mobile IP; Correspondent node; Fast handovers; Hierarchical mobility

1. Introduction

With the increasing demand for wireless mobile devices and advances in wireless broadband communication, cellular and Internet service providers along with relevant standardization bodies are looking at the possibility of creating an all IP (Internet Protocol) mobile architecture. Mobile IP is the current mobility protocol for Internet that is standardized by Internet Engineering Task Force (IETF). Mobile IP allows a mobile node (MN) to change its point of attachment while maintaining connection across media of dissimilar types. Mobile IP has two different versions based on version 4 and version 6 of IP. Mobile IPv4 [4] uses separate UDP (User Datagram Protocol) based protocol for registration. In IPv6, mobility signaling and security features have been integrated as header extensions. It has been observed in current literature that MN in Mobile IPv6 (MIPv6) has been communicating with static CN. In this paper, an effort is made to simulate and evaluate the performance of MIPv6 in view of mobility of CN. Basic work for MIPv6 has been done in Ref. [7]. In order to be a true mobility protocol, Mobile IP should also support the mobility of CN. The model presented in Ref. [14] has been taken to simulate the mobility of CN. This includes the use of mobility header, type 2 routing header, reverse routability procedure and data transfer using tunnels and route optimization. Mobility of CN when taken into account with reference to an

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environment where there are frequent handoffs, may lead to more packet delays, packet losses and signaling overheads. We propose a new intelligent mobility model in MIPv6 called Intelligent Mobile IPv6 (IMIPv6) that minimizes the handoff delay caused due to network layer handoff with the movement of MN and CN. In this paper, we analyze and evaluate the performance in different cases of mobility of CN. We present a simulation study that allows detailed analysis of delay characteristics, packet loss for MN and CN involved in handoffs. Simulation results indicate that the performance of IMIPv6 is better than original MIPv6.

The rest of the paper is structured as follows. In Section 2, we explain four possible mobility combinations. Two of these mobility combinations have been proposed by us. In Section 3, extensions to Mobile IPv6 with Fast handovers for Mobile IPv6 and Hierarchical Mobile IPv6 are discussed. The proposed Intelligent MIPv6 is also elaborated in this section. In Section 4, we describe simulation architecture using mobility of CN. Simulation results are discussed in Section 5. Finally, Section 6 summarizes the conclusions.

2. Mobility options

While considering the mobility support to IPv6, only the mobility of mobile node has been discussed. Other possible combinations of mobility mentioned in Ref. [14] can be obtained by adding the mobility of correspondent node in order to get the complete mobility. There are four different cases, in which mobility of the mobile node and the correspondent node is possible. These are given below.

1. When mobile node and correspondent node are stationary.
2. When mobile node is mobile and correspondent node is stationary.
3. When mobile node is stationary (restricted to its home network) and CN is mobile.
4. When mobile node and correspondent node are mobile.

First two combinations are already existing and being widely discussed in literature. In this section, we are defining first two cases and then explaining the remaining two cases that have been proposed in Ref. [14].

2.1. Case I — when mobile node and correspondent node are stationary

This is the most prevalent case, in which the mobile node (with the inherent capability of being mobile) is restricted to its home network or not mobile at all i.e. stationary. Similarly, the correspondent node is stationed at one place. In this case, neither of the nodes use any form of mobility and thus packets are routed from source to destination using conventional TCP/IP protocols without using any mobility support. In TCP/IP based network like Internet, routing is based on a stationary IP address. It is similar to delivering a postal letter based on the fixed address written on the envelope. Use of TCP/IP in Internet requires a user to get an IP address to access Internet. With this IP address, different layers above network layer create sessions and allow user to transfer data [18].

2.2. Case II—when mobile node is mobile and correspondent node is stationary

This is another case, which is being considered in all the literature to develop mobility support for IP. In this case, mobility of MN is most important. The TCP/IP protocol was designed 30 years back before the age of mobile computing so it is not having efficient mechanism for mobility. It is therefore required to add new functionalities, like mobility of devices to TCP/IP protocol [15,16]. In recent past there have been proliferation of devices that supported mobility. Technology has made it possible to send data and pictures through cellular phones [13,21]. Similarly, computing devices and their variants have reduced in size and now these are easy to carry from one place to another. Mobile IP [4] eliminates the stop and start approach to IP connectivity that is required with network location change. It enables users to maintain the same IP address regardless of their point of attachment to the network. Since mobility functions of Mobile IP are performed at network layer rather than physical
layer, mobile devices can span different types of wireless and wire line networks while maintaining connections and applications. Mobile IP was developed to enable mobility in IPv4 networks. Number of enhancements has been made to Mobile IPv4 to overcome some of the identified problems like triangular routing, ingress filtering, authentication and authorization [5,6,19]. Mobile IPv6 [7] has been proposed for IPv6 and mobility has been integrated in IPv6 as header extensions.

2.3. Case III — when correspondent node is mobile and mobile node is stationary

In the above two cases, the correspondent node was stationary. In this case, the CN is mobile and continues communicating with a MN which is stationary or restricted to its home network as shown in Fig. 1. The CN has gone beyond its home network and it is moving in IPv6 network. We will call it mobile correspondent node (MCN). MCN will maintain all the information related to bindings in a list called binding update list (BUL).

MCN needs to register its care of address (CoACN) with its home agent (HACN). Whenever MCN crosses its network boundary, it must send binding updates (BU) to HACN and home agent of MN (HAMN) so that MCN can continue sending or receiving packets to and from mobile node (stationary or restricted to its home network). Reverse return routability procedure (3RP) [14] is performed in this case and it ensures that MCN is present at its claimed position.

Now we consider the scenario which has been shown in Fig. 2. It represents how mobile node and CN interact when these are stationed at their home and later on CN starts moving. The sequence of interactions among different entities is shown in Fig. 2 and the steps are given below.

1. Mobile node (located in its home) starts sending packets to CN at its home address as it is connected to its home only. CN has not yet started moving so all packets are delivered to CN through its HA.
2. CN starts moving and losing connection to its current HACN or otherwise determines that it should switch over to another access router (AR).
3. It reaches in foreign area and uses IPv6 neighbors discovery protocol. The mobile CN listens to router advertisements and uses this information to determine that it has reached to a new link.
4. Now MCN needs to acquire a CoA so that it can communicate with mobile node. Stateless address configuration protocol or stateful pro-
tocol such as dynamic host configuration protocol version 6 (DHCPv6) can be used by MCN depending on the availability.

a. In case of stateless address auto-configuration protocol, address prefix of router advertisement message is combined with a locally generated interface identifier to generate tentative global address by MCN. This address is sent to link local multicast group, to verify the uniqueness of this address.

b. DHCPv6—if used immediately responds with an address.

5. MCN should update its home agent ($HA_{CN}$) with new address using binding update (BU) message. Now it is expecting a binding acknowledgement (BA) from $HA_{CN}$.

6. Mobile registration is used by MCN to provide information about its current location to mobile node. Reverse return routability procedure (3RP) is performed as a part of this registration which enables MN to obtain some reasonable assurance that MCN is in fact addressable as its claimed CoA as well as at its home address.
7. **MCN initiates 3RP by sending two messages to MN simultaneously.**
   a. One of the messages home test init (HOTiCN) of 3RP is tunneled through HACN. It is sent through normal routing to HAMN which will deliver this HOTiCN to MN in its home network.
   b. Care-of test init (COTiCN) message is sent directly to MN.

8. One of responses home test (HOTCN) is received from MN through tunnel from HACN and other response i.e. care-of test (COTCN) is received directly from MN.

9. Once 3RP completes, CN can send actual binding update message to the MN.

10. MN will accept binding updates from MCN only after the above assurance and then the MN sends its packets to CoA_CN.

11. MN should now update its BUL.

12. Mobile node can now send packets directly to MCN at its CoA. MCN can also send packets directly to MN using type 2 routing header.

It is possible that a node can take two different roles i.e. of a MN and a CN. At one time, it is acting as a mobile node, when it is mobile and initiates communication with its CN. Other time its role changes in the sense that some other node is communicating with it and its role is that of a correspondent node. When a node is acting as a CN, it should be able to process mobile registration.

### 2.4. Case IV — when mobile node and correspondent node are mobile

This is the most complicated case when mobile node and correspondent node are mobile and have gone beyond their home networks. The MN has crossed its home area and the CN has also moved to IPv6 subnet. This scenario has been shown in **Fig. 3**. Both of these moving nodes are required to register their CoAs with their respective home agents and to each other. 3RP is also used in this case but HOTiCN and HOTCN are doubly tunneled from home agents of MCN and MN. When MN is mobile, it will have correspondent registration and when CN is mobile, mobile registration is done [14].

Now consider the case when MN has started moving and communicates initially with a stationary CN. While communication is going on, later on CN also starts moving. Now MN and CN are mobile and communicating with each other. The sequence of

![Fig. 3. General scenario of MIPv6 when correspondent node and mobile node are mobile.](image-url)
interactions among different entities is shown in Fig. 4 and the steps are given below:

1. MN starts moving and losing connection to its current HA and gets a new address. Binding updates and acknowledgements are exchanged to update home agent of MN. Correspondent registration is used by MN to provide information about its current location to CN. Return rout-
router advertisements and uses this information to determine that it has reached to a new link.

4. MCN needs to acquire a CoA so that it can communicate with mobile node. Stateless address configuration protocol or stateful protocol such as DHCPv6 can be used by MCN depending on the availability.

5. Now MCN should update its home agent with new address using BU message. It now expects a BA from HACN.

6. Mobile registration is used by MCN to provide information about its current location to mobile node.

7. 3RP is performed as a part of this registration. 3RP in this case works differently from the earlier case. In this case, HOTiCN and HOT-CN are doubly tunneled through HA of MN and MCN.

8. MCN sends two messages to MN simultaneously.

9. One of the messages HOTiCN of 3RP is double tunneled through home agents of MN and MCN. Initially it is tunneled from MCN to HACN, from where it is sent through normal routing to HAMN which will tunnel this HOTiCN to MN at its CoA.

10. COTiCN is sent directly to MN.

11. One of responses HOT-CN is received from MN through double tunnel. From CoAMN, HOT-CN is tunneled to HAMN from where it is sent through normal routing to HACN which will tunnel this HOT-CN to MCN at its CoA.

12. Other response COT-CN is received directly from MN.

13. Once 3RP completes, CN can send actual binding update message to mobile node.

14. MN will accept binding updates from MCN only after above assurance and then sends its packets to CoACN. MN should now update its BUL.

15. Mobile correspondent node and mobile node can now communicate and transfer data.

All messages related to bindings are sent through modified mobility header, which is an extension header. This header is used by any node which is mobile and it is also used by home agents [14].

3. Extensions to Mobile IPv6

In this section, we give an overview of Fast handovers for Mobile IPv6 and Hierarchical Mobile IPv6. The features of proposed Intelligent MIPv6 have been elaborated in this section.

3.1. Fast handovers for Mobile IPv6

Any change from one point of attachment to another of a node because of its mobility is called handover or handoff. Packet loss or delay due to mobile IP handover delay has been discussed in IETF and several mechanisms have been proposed and standardized [1–3,10,12,20]. Fast handover mechanism for Mobile IPv6 [17] focuses on reducing lengthy address resolution time when mobile node enters a foreign domain. It describes two different types of handover mechanisms. These are tunnel based and anticipated handover. Tunnel based handover relies on L2 trigger and anticipated handover is solely based on L3 information. There are four messages which have been added in fast handover proposal. These are router solicitation for proxy (RsolPr), proxy router advertisement (PrRtAdv), handover initiation (HI) and handover acknowledgement (HaCk). Indication mechanism based on link-layer (L2) trigger anticipates the movement of mobile node after receiving a router advertisement from a new AR (NAR). MN sends a RtSolPr to the previous AR (PAR) with an identifier of the attachment point to which it will move. MN will receive a PrRtAdv in response from PAR containing the proposed new care of address (nCoA), IP address of NAR and link-layer address. The PAR sends a HI message to NAR to facilitate forwarding of packets and to reduce latency during handoff. After receiving HI message, NAR first checks whether nCoA is a valid address of its subnet. If nCoA is accepted, NAR adds the nCoA to neighbor cache and responds with a HaCk message indicating either accepting or rejecting the nCoA. If HaCk indicates that nCoA is valid, the PAR prepares to forward packets for MN to nCoA. Otherwise PAR prepares to tunnel packets from MN to the previous care of address (pCoA) at NAR. Immediately after getting confirmation of a pending layer 3 handover through PrRtAdv, MN sends a fast binding update.
to PAR as the last message before handover is executed. MN then receives a fast binding acknowledgment (F-BAck) either through PAR or the NAR indicating that binding was successful. When MN arrives at NAR, it sends fast neighbor advertisement (FNA) to initiate flow of packets. The NAR responds to the FNA with the neighbor advertisement acknowledgement (NAAck) to notify the MN to use a different nCoA if there is address collision. The NAR will start delivering packets immediately after getting an indication that MN is already attached to it. PAR will be forwarding all the packets, which arrive for MN under its pCoA after MN has moved. The details of Fast handovers for Mobile IPv6 are at Ref. [17].

3.2. Hierarchical Mobile IPv6

In Mobile IPv6, every movement of MN introduces rather long registration latency. Hierarchical schemes separate mobility management into micro and macro mobility. Handoff operations regarding latency and signaling overheads can be optimized in micro mobility. The HMIPv6 [8] introduces a new entity called mobility anchor point (MAP). The MAP is a router, which is hierarchically placed above ARs at the edge of network. HMIPv6 allows the MN to register locally in a domain and then minimizes the amount of signaling to HA and MN. When a MN moves into a new domain, it is assigned two CoAs i.e. a regional address (RCoA) and an on link address (LCoA). RCoA is an address on sub-network of MAP and it is used by MN as CoA during registration. LCoA is same as CoA in MIPv6. While moving between subnets inside domain of MAP mobile host only changes its LCoA. This hides movement from its home agent. When moving outside the domain of one MAP into another MAP domain, MN sends a BU to MAP which will bind RCoA of MN to its LCoA. Binding acknowledgement (B Ack) will be returned by MAP to MN on successful registration. MN must also register the new RCoA with its HA by sending another BU. Finally similar BUs should be sent to the active corresponding nodes by the MN. Hierarchical MIPv6 has been described in Ref. [8].

3.3. Intelligent Mobile IPv6

In this section, we are proposing Intelligent Mobile IPv6 which uses the features of fast handover and hierarchical mobility along with the mobility of correspondent node. The frequent movement of mobile nodes between ARs causes the services disruption. MN cannot continue its communication during service disruption time period as MN requires time to update its HA using binding updates. This time period can be minimized by anticipating the handover as done in fast handover. MN obtains a new CoA before breaking the connection with existing PAR. Once a MN attaches itself to NAR it can resume communication. In MIPv6, each time a MN changes its location, it informs HA and CN using binding updates. This signaling among MN, CN and HA can be reduced by using MAP. The use of MAP allows a MN to send only one binding update to the MAP to register its new CoA after movement within MAP domain. The use of MAP would improve the efficiency of IMIPv6 by redirecting the traffic, thus saving delay and bandwidth between PAR and MAP. The general scenario for IMIPv6 is given in Fig. 5. The MN and the CN are mobile and they are visiting a subnet based on IPv6. In this subnet, the hierarchy of the ARs is maintained through MAP. The same AR may act as a PAR at one time and a NAR at other times depending on the movement of...
MN and CN. A MN may move within the domain of a MAP or between MAPs. When MN is expected to move from AR1 to AR2 within MAP domain, AR1 is PAR and AR2 will be NAR. Similarly, CN moves within one MAP domain from one AR to other. The sequence of operations for the general scenario of Intelligent MIPv6 is given below. These operations are also represented in Fig. 6.

1. MN and MCN are mobile and communicating with each other. MCN is connected to its PAR while communicating and MN is about to change its location.
2. The handover process may be initiated by the MN or PAR by using wireless link-layer information or triggers. These triggers inform that MN will soon be handed off between two ARs. If trigger is received by the MN, it sends PrRtSol message to PAR. When the trigger is received by PAR, it directly transmits PrRtAdv with a MAP option.
3. PrRtAdv message contains information from NAR which is used by MN to obtain new CoA while connected to PAR.
4. MN will update the MAP about this new CoA through a modified fast binding update (MF-BU) as the last message before handover is executed. The only difference in original F-BU and MF-BU is that of the destination address. In MF-BU message, destination address points to

Fig. 6. Operations in Intelligent Mobile IPv6.
The purpose of MF-BU is to authorized MAP to bind old CoA with new CoA so that arriving packets can be tunneled to NAR.

5. HI and HAck messages are exchanged between MAP and NAR. These are used to check the validity of new CoA and to establish a tunnel if new CoA is not valid. This exchange facilitates the forwarding of packets between them and also to reduce the latency perceived by MN during handover.

6. The MN receives a modified F-BAck (MF-BAck) either through MAP or NAR indicating that binding was successful. In MF-BAck message, the source address represents the address of MAP instead of PAR which was the case in F-BAck.

7. The MAP will now be forwarding the packets to NAR.

8. The FNA message is sent from MN to the NAR to announce its attachment with NAR. This message will also be used to confirm the use of new CoA when the MN has not received MF-BAck because of handover.

9. NAR responds to MN, by sending a new router advertisement with NAAck option. It is used to notify the MN to use a different new CoA if there is an address collision.

10. The packets can now be sent and received between MN and NAR.

11. The MN has reached to a new area covered by NAR and MCN is still connected to its PAR. The MN and MCN are communicating through NAR_{MN} and PAR_{CN}.

The same process will be repeated for mobile CN, which is about to handover from one AR area into another AR area. As the MN had already changed its location and after the handover of MCN, MN and MCN are connected to their NARs. The data transfer will now take place between NAR_{MN} and NAR_{CN}.

Simulation architecture is required to be designed so that the mobility of correspondent node of case 3 and case 4 of Section 2 along with the features of Intelligent MIPv6 can be simulated. This will help in generating results and analyzing the performance of IMIPv6 protocol. This has been discussed in next section.

4. Simulation architecture

The OMNet ++, an object-oriented module discrete event simulator [9] has been used to simulate mobility of correspondent node in MIPv6. The goal of our simulation is to examine the effect of mobility of correspondent node on end to end UDP communication session by considering packet latency, successful packet rate and signaling overhead. The designed simulation architecture of Fig. 7 is composed of home agents of MN and MCN that are connected to Internet. We have considered the case of highway for simulating the movement of nodes. The access routers are placed equally distant all across the highway. The distance between ARs is assumed to be varying from 200 to 800 m. The MAPs are separated by a distance of 1000 m from each other. In the simulation scenario, we assumed a well behaved MN and MCN movement pattern where nodes moved linearly from one AR to another at varying average speed of 10, 15, 25 and 40 m/s. We are assuming that MN and MCN are moving with the same speed. With this simulation architecture, it is possible to simulate four different types of traffic that are explained below.

In the first type of traffic, a static CN is communicating with a MN, which is initially positioned near its HA. Later on, the MN starts to move in a different network. This is a typical MIPv6 scenario. We will call it baseline MIPv6 (BMIPv6). The second type of traffic is characterized by the communication between a static MN and a mobile CN. The CN, which is initially attached to its home area, moves in a different network. While roaming, the CN maintains its communication with static MN. We will call this case as correspondent node MIPv6 (NMIPv6). The difference in BMIPv6 and NMIPv6 is that in BMIPv6, MN is mobile whereas in NMIPv6 CN is mobile. In both the cases, moving nodes are communicating with their static counterparts. In the third case, MN and CN are mobile and both send packets to each other. Initially MN and CN are attached to their home networks. MN then starts moving and communicates with static CN, which later on also starts moving and continues communication. This is an example of complete mobility using MIPv6 and we will call it complete MIPv6 (CMIPv6). The above three cases use the features of MIPv6 with the added functionality for mobility.
of CN. These cases are elaborated in Section 2, at Sub-section 2.2, Sub-section 2.3 and Sub-section 2.4. In all of these cases, when a MN crosses the boundary of an AR to other AR area, handover occurs. The MN is required to inform its HA of this handover so that HA can send packets, which are intercepted by it when MN was performing handover, to MN at its new location. In the fourth case, MN and MCN are mobile and communicating with each other. While moving, these nodes are using the features of Intelligent MIPv6 (IMIPv6), which have been explained in Section 3.3. It requires a new entity called MAP to be added. The inclusion of MAP will require the binding updates by the node to be sent to home agent only when it is moving to other MAP. When a node crosses the cell limits of one AR to another within MAP domain, it will inform only MAP. The inclusion of fast handoff in IMIPv6 will reduce the address resolution time, when a node enters from one AR area into other AR area. The IMIPv6 ensures that a new temporary address is preconfigured on the mobile node before breaking its connection with previous AR. Once the mobile node is attached to the new AR, it can resume its communication through new AR.

The features implemented for the simulation in above four scenarios are given below. Standard OMNet ++ version 2.3p1 was patched with the freely available OMNet ++ wireless extension module. A card running 802.11 protocol was simulated under OMNet ++. This was further extended with the implementation of different messages and protocols to include the mobility of correspondent node. In simulation, an access network has been assumed that allows mobile nodes and mobile correspondent nodes to have access via radio interfaces only. The binding cache and binding update mechanism are added to original OMNet ++ node model as an IPv6 destination option, allowing MN to bind home address with CoA. This provided all nodes with the binding update functionality, satisfying the requirement for all MIPv6 qualified nodes. Security mechanism has been implemented into the binding updates using RR procedure. The changes in the mobility header are made to incorporate mobility of correspondent node bit. A new mechanism for 3RP was built to get assurance that MCN is addressable at its claimed CoA and home address in OMNet ++. New tunneling mechanism has been added for one sided and double sided correspondent tunneling. MAP has been implemented to provide hierarchical registration functionality. RtSolPr, PrRtAdv, HI and HAck messages have been added to provide fast handoffs features with previous access router and new access router functionality in MAP along with MF-BU and MF-BAck messages.
In the first three cases, we assume that no link-layer specific optimizations are used and wireless networking interface in MN and MCN can connect to at most one link at any one time. It implies that the MN or MCN are using a link technology, which cannot receive data from other access routers before it has terminated link-layer connection to its previous access router. We also assume that each MN and MCN has only one wireless interface, so it cannot use one interface to continue communicating with its current access router while it is searching for new access points using its other interface. The case of IMIPv6 is an exception to above assumption. The performance of mobility of correspondent node was evaluated by simulating the necessary exchange of signaling messages among MN, HAs and MCN for Fig. 7. For movement detection, the MNs use periodic router advertisement sent from ARs. This reduces complexity in result analysis, as there exist only signal interference. In order to simulate a realistic case where a MN will receive packets from the shared AR queue and where a MN will also compete with other MN and with an AR to access the channel, half of MNs receive data from CNs and the other half send data to CN. CN sending to MNs introduce delay in AR queue and MNs sending to CNs introduce delay in wireless link. Traffic from MN to CN or all other is 512 kbps (kilobits per second) exponentially distributed flow with constant packet size. The bandwidth of wireless link is 11 Mbps (million bits per second) and the links between AR and MAP have 10 Mbps. All other links have a bandwidth of 100 Mbps. Background traffic consists of 8, 64 kbps streams generated from static correspondent nodes to access routers. All simulations have duration of 300 s with a 5 s warm up phase.

5. Simulation results analysis

Series of simulation results have been performed in measuring the signaling overheads, rate of successful
packet delivery and packet delay in above mentioned 
four types of traffic. Each point in the following 
graphs represents the average of at least 100 
simulations. Sample size necessary to achieve a 
confidence interval of 95% with respect to average 
value has been selected as indicated in Ref. [11]. 
Signaling overhead is defined as the number of bits 
required in establishing a connection or data transfer 
during mobility. When MN changes its point of 
attachment frequently due to its mobility, there are 
several handoffs. These handoffs will cause exchange 
of several messages among different entities. In Fig. 8, 
the effect of interleaving distance of ARs on signaling 
overhead with the speed of mobile node at 10 m/s is 
shown through a graph. Figs. 9, 10 and 11 describe 
similar situations where the speed of mobile node is 
changing to 15, 25 and 40 m/s, respectively. The 
number of handoffs are directly proportional to the 
number of bits required for signaling. Signaling 
overhead is compared for above four types of traffic 
in the four graphs of Figs. 8–11.

In case of BMIPv6, CN initiates communication 
with MN, which has started moving and crossed 
several access routers causing handoffs. When the 
distance between ARs is less and nodes are moving, it 
indicates that there will be more handoffs for a 
specified time duration. As the distance between 
ARs increases, the number of handoffs are reduced. 
It can be seen from the graphs of the Figs. 8–11 that 
number of bits required for signaling decrease with 
the increase in the distance between ARs. With the 
increase in distance between ARs, the number of bits 
required for signaling are less. Performance of 
NMIPv6 is almost similar to that of BMIPv6 as 
evident from all the graphs of Figs. 8–11. Here static 
MN is communicating with a CN, which is moving
and thus causing signaling overhead. As the number of bits required for signaling are the same, result is the same for these two cases. In case of CMIPv6, it can be seen in the graphs that signaling overhead increase tremendously because of movement of MN and CN. Signaling overhead in case of IMIPv6 reduce drastically due to the use of mobility anchor point. Fig. 8 clearly indicates that the number of signaling bits in IMIPv6 are less in comparison to other cases even with the movement of MN and CN. The signaling overhead increase with the increase in the speed of mobile nodes for the same distance between ARs as observed from graphs of Figs. 8–11.

Packets which are sent from the source should reach destination. Rate of successful packets defines the percentage of packets, which are received successfully at destination. Graphs of the rate of successful packets delivered with the distance between ARs for varying speed of mobile node are drawn in Figs. 12–15. For all the four cases, the success rate of packet delivery increases with the increase in distance between ARs. When the distance between ARs is less, mobile node will be crossing the boundaries of ARs more frequently and causing packet loss. In case of BMIPv6 and NMIPv6, only one node is mobile so the rate of successful packets is higher in comparison to CMIPv6 where both nodes (MN and CN) are mobile. This is evident from the graphs of Figs. 12–15 which are drawn for the different speeds of mobile nodes. The increase in the speed of mobile nodes will cause more frequent crossing of AR area. This will decrease the rate of successful packets as evident from the graphs of Figs. 12–15. The performance of IMIPv6 is superior to other cases as the IMIPv6 allows the anticipation of crossing the boundary of AR before MN actually moves there and forwarding the packets from MAP to the new location of mobile node.

Packet delay is the difference of time when the packets are sent by correspondent node and received by a mobile node or vice versa. This delay when taken into consideration with the varying speed of mobile node can be caused as a result of movement detection and signaling for registration. Fig. 16 represents a graph which has been plotted for packet delay versus varying speed of mobile nodes with the distance between ARs limited to 400 m. Nodes experience packet delay in BMIPv6 and NMIPv6 because tunnel is created when handoff occurs and packets are sent through this tunnel. In case of CMIPv6, MN and CN are mobile and they send packets through double sided tunnels, so the packet delay is more. The graph of Fig. 16 indicates that the packet delay in case of IMIPv6 is less despite the movement of nodes, because the hierarchical approach used in IMIPv6 is particularly suitable for minimizing registration signaling delays and fast handover is well suited for reducing movement detection delays.

6. Conclusion

In this paper, we proposed the mobility of correspondent node in MIPv6. Different cases of mobility of mobile node and correspondent node have been discussed. We proposed IMIPv6 by combining the features of fast handoffs and hierarchical MIPv6 with the mobility of CN in MIPv6. We compared the existing MIPv6 with our proposed mobility of CN and IMIPv6 through simulation. The results show that Intelligent MIPv6 can greatly reduce signaling overheads and packet loss during handover.

Acknowledgements

The authors are thankful to the anonymous referees for their valuable comments.

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