

# Adaptive Mobility Management Scheme for Mobile IP using Ad Hoc Networks

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**Abstract:** *Mobile IP has been developed to handle global mobility of mobile hosts. Mobile IP suffers from a number of drawbacks such as frequent location update, high signaling overhead, high handover latency, high packet loss rate, and requirement of infrastructure change. To treat these problems, we propose a new mobility management scheme by constructing dynamic service regions of Ad Hoc networks for roaming mobile host without location update to reduce signaling overhead and packets loss. Analytical analysis and simulation results are shown in this paper to demonstrate that the proposed scheme performs better performance than other schemes.*

**Keywords:** *Mobile IP, Mobile Ad Hoc Networks, Mobile, Mobile Handover, Signaling Cost*

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## 1. Introduction

Mobile IP (MIP) [10] has been designed to handle mobility of Internet hosts at the network layer to manage mobile data communication. It allows a TCP connection to remain alive when a mobile host (MH) moves from one point of attachment to another. Several drawbacks exist when using MIP in a mobile computing environment, the most important ones identified to date are frequent location update, high handover latency, high packet loss rate [12], high signaling overhead, and requirement for change in infrastructure. MIP is based on the concept of home agent (HA) and foreign agent (FA) (which requires modification to existing routers in Internet) for routing packets from previous point of attachment to the new one. An MH needs to complete the following four steps before it can receive forwarded data from the previous point of attachment: (i) perform layer 2 (L2) handover, (ii) discover the new care-of address (CoA), (iii) registering the new CoA with the HA, and (iv) forwarding packets from the HA to the current CoA. During this period, the MH is unable to send or receive packets through its previous or new point of attachment.

IP version 6 (IPv6) is being designed within the IETF as a replacement for the current version of the IP protocol used in the Internet (IPv4) [2] and IPv6 networks have been deployed rapidly all over the world. Mobile IPv6 (MIPv6) [4] is a network protocol designed to enabling mobility in IPv6 networks. Mobile IPv6 allows nodes to move within the Internet topology while maintaining reachability and on-going connections between mobile and correspondent nodes. To do this a mobile node sends Binding Updates (BUs) to its Home Agent (HA) and all Correspondent Nodes

(CNs) that it communicates with, every time it moves. Binding updates requires approximately 1.5 round-trip times between the mobile node and each correspondent node and one round-trip time is needed to update the Home Agent. These round trip delays will disrupt active connections every time a handoff to a new AR is performed.

This concept gives rise to a large handover latency, high packet loss rate, and high signaling overhead, so our work investigates modeling of new scheme for minimizing these costs.

Our scheme depends on connecting an ad hoc network to the internet and using mobile IP in ad hoc network. There are many solutions developed for this purpose. In "MIPMANET - Mobile IP for Mobile Ad Hoc Networks" [5], a solution is presented for connecting an ad hoc network, in which on-demand routing protocol (AODV) is used, to the Internet. MIPMANET provides Internet access by using Mobile IP with foreign agent care-of addresses and reverse tunneling. This allows nodes to enjoy the mobility services of Mobile IP while at the same time the requirements on the ad hoc routing protocol are kept to a minimum. This solution shows that the ability to choose the closest access point to the Internet is worth extra work, as less traffic is generated in the network resulting in lower delays and fewer dropped packets. The solution uses Mobile IP foreign agents as access points to the Internet in order to keep track of in which ad hoc network a node is located in and to direct packets to the border of that ad hoc network. The ad hoc routing protocol is used to deliver packets between the foreign agent and the visiting node. A layered approach with tunneling is used for the outward data flow to separate the Mobile IP functionality from the ad hoc routing protocol. All this makes it possible for

MIPMANET to provide Internet access with the ability for nodes to select and perform seamless switching between multiple access points. In short, MIPMANET works as follows:

- Nodes in an ad hoc network that want Internet access use their home address for all communication and register with a foreign agent.
- To send a packet to a host on the Internet: Tunnel the packet to the foreign agent with whom you are registered.
- To receive packets from hosts on the Internet: The packets are routed to the foreign agent by ordinary Mobile IP mechanisms. The foreign agent will then deliver the packets to the node in the ad hoc network.
- Nodes that do not require Internet access will see the ad hoc network as a stand-alone network, i.e., they will not need any knowledge about routes to destinations outside of the ad hoc network.

The rest of the paper is organized as follows: Section 2 describes related work. Section 3 describes our proposed scheme. Section 4 develops a computational procedure and results and compares performance of our scheme with others. In Section 5 concludes the paper.

## 2. Related work

Many improvements to MIP have been proposed to reduce handover latency and packet loss, most of them solve the problem by using additional network node. In IPv4, GFA [3] describes a new kind of "regional registrations", i.e., registrations local to the visited domain. The regional registrations are performed via a new network entity called a Gateway Foreign Agent (GFA) and introduce a layer of hierarchy in the visited domain. Regional registrations reduce the number of signaling messages to the home network, and reduce the signaling delay when a mobile node moves from one foreign agent to another within the same visited domain.

In IPv6, MAP (Mobility Anchor Point) [7] is used to eliminate the additional delay element from the time-critical handover period and so will significantly improve the performance of Mobile IPv6. A mobile node entering a MAP domain will receive Router Advertisements containing information on one or more local MAPs. The MN can bind its current location (on-link CoA) with an address on the MAP's subnet (RCoA). Acting as a local HA, the MAP will receive all packets on behalf of the mobile node that it is serving and will encapsulate and forward them directly to the mobile node's current address. If the mobile node changes its current address within a local MAP domain (LCoA), it only needs to register the new address with the MAP. Hence, only the Regional CoA (RCoA) needs to be registered with

correspondent nodes and the HA. The RCoA does not change as long as the MN moves within a MAP domain. This makes the mobile node's mobility transparent to the correspondent nodes that it is communicating with. A MAP domain's boundaries are defined by the Access Routers (ARs) advertising the MAP information to the attached Mobile Nodes.

Recently I.R. Chen, W. He and B. Gu, propose a new design extends IETF work-in-progress Hierarchical Mobile IPv6 (HMIPv6) with the notion of dynamic mobility anchor points (DMAPs) [1] for each mobile node (MN) instead of static ones for all MNs. These DMAPs are access routers chosen by individual MNs to act as a regional router to reduce the signaling overhead for intra-regional movements. The DMAP domain size, i.e., the number of subnets covered by a DMAP, is based on the MN's mobility and service characteristics. Under DMAP protocol, a MN interacts with its home agent and application servers as in the MIPv6 protocol, but optimally determines when and where to launch a DMAP to minimize the network cost in serving the user's mobility and service management operations.

Another paper tries to make balance between using (MAP) or not depending on session to mobility ratio (SMR) [8]. MN informs a correspondent node (CN) of its on-link care-of address (LCoA) if the CN's SMR is greater than a predefined threshold. If the SMR is equal to or lower than the threshold, the CN is informed with the MN's regional CoA (RCoA).

In [11], Shaojian Fu, Mohammed Atiquzzaman, Liran Ma and Yong-Jin Lee describe and evaluate the performance of SIGMA, a Seamless IP diversity-based Generalized Mobility Architecture. SIGMA utilizes multi-homing to achieve seamless handover of mobile hosts, and is designed to solve many of the drawbacks of MIP, including requirement for changes in infrastructure. They evaluate the signaling cost of SIGMA and compare with that of hierarchical Mobile IPv6 (an enhancement of Mobile IP) by analytical modeling. The performance evaluation includes handover latency, packet loss, and throughput. Results indicate that in most cases SIGMA has a lower signaling cost than Hierarchical Mobile IPv6. Moreover, for a typical network configuration, SIGMA has a higher handover performance over Mobile IP.

A new location management scheme has been proposed in [6] for Mobile IP that reduces signaling burdens configuring regional network dynamically according to the characteristics of users and network. This paper proposes a cost model to calculate the total signaling cost for cost comparison. The proposed scheme performs better than other schemes when compared the total signaling cost and the regional network size. Also, this scheme enhances the system robustness and the load distribution.

All of these solutions treat some problems of Mobile IP and ignore the other, and in the same time

other problems are appeared when implementing these solutions in wireless networks like usage new network nodes (such as MAP in IPv6 or GFA in IPv4) which increase cost of the system. Our scheme treats many drawbacks of Mobile IP without modification in existing protocols and networks topology.

### 3. Proposed Scheme

We propose a new mobility management in mobile IP systems using Ad hoc networks to reduce network signaling and communication overhead.

The proposed solution determines service region dynamically by connecting subnet area with Ad hoc network. The Ad hoc network extends dynamically (in terms of the number of hobs) by considering mobility characteristics of mobile host and network

environments. The service regions reduce frequency of handoffs by let out mobile hosts roaming without advertising the home agent or correspondent nodes about its new location.

Figure 1 illustrates our scheme in Mobile IP environments. The mobile node (MN) roams between various subnets through service regions of Ad hoc networks. When the MN was resident in location A, it obtained a care-of address (CoA) from subnet 1 and connects directly to its foreign agent (FA). After that, the MN moved outside of subnet 1 (in location B) which is uncovered area and there is no service from any subnet. So the MN decided to continue its connection with subnet 1 throw Ad hoc network by using the nearest mobile connected with subnet 1.

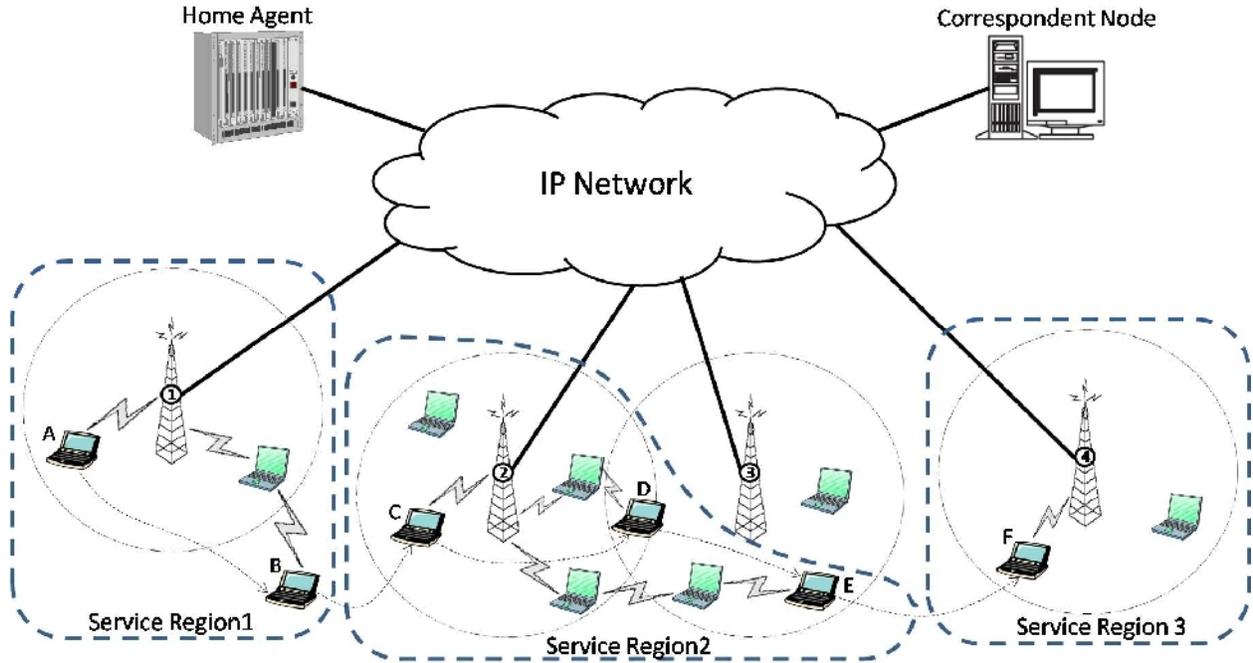


Figure 1. Adaptive mobility management of mobile IP by using Ad Hoc Networks.

If the MN moved to location C, it will receive service signal from subnet 2. So at this moment, the MN must decide if it will connect to this subnet or stay connected to subnet 1. This decision has been made by calculating two values. Based on [11] we expressed

$$C_{\text{home}} = \frac{2C_{LP}^f + C_{LP}^h + 2(\text{dist}(h, f) + 2\varphi)\delta}{T_s} + \lambda\eta + \varepsilon\rho P_c + \sigma(\text{dist}(h, f) + \varphi) \quad (1)$$

Where  $C_{LP}^f$  is the registration processing cost at FA,  $C_{LP}^h$  is the registration processing cost at HA,  $\text{dist}(h, f)$  is the hop distance between the HA and the FA,  $T_s$  is the average dwelling time that the MN resides in one subnet,  $\lambda$  is the packet arrival rate,  $\eta$  is processing cost of the HA,  $\rho$  is the traffic load,  $P_c$

equations for calculating these values. The first value  $C_{\text{home}}$  is the cost of the total signaling cost of the home registration and packet delivery, it is calculated by equation 1.

is the average processing cost of Ad hoc network.  $\varphi\delta$  is the transmission cost between the MN and the FA, and  $\varepsilon, \sigma$  are constants.

The second value  $C_{\text{regional}}$  which is calculated by MN is the total signaling cost of regional registration and packet delivery, it is calculated by equation 2.

$$C_{regional} = \frac{2(dist(h, f) + dist(f, m) + 2\varphi)\delta}{T_s} + \lambda\eta + \varepsilon\lambda P_c + \sigma(dist(h, f) + dist(f, m) + \varphi) \quad (2)$$

Where  $dist(f, m)$  is the hop distance between the FA and the MN. Finally the MN can make decision by calculating the difference between  $C_{regional}$  and  $C_{home}$ .

$$C_{diff} = C_{regional} - C_{home} \quad (3)$$

If  $C_{diff}$  is smaller than a predefined threshold, the MN continue communication with current FA through Ad hoc network and if not, it performs the home registration to the HA.

As shown in Figure 1, the MN decided to connect with subnet 2 at location C. So it obtained a new CoA and updated its location to home agent (HA) and correspondent node (CN). After that the MN moved to location D and received service signal from subnet 3, but it decided to continue connecting with subnet 2 through Ad hoc network because  $C_{diff}$  (equations 1-3) is smaller than the threshold value. The MN continued roaming in service region 2 until location E. After that it moved to location F and decided to register with new service region ( $C_{diff}$  is larger than the threshold value) and obtained a new CoA.

We can conclude processing of our scheme as follows. When MN enters certain service region it take a CoA and it won't change this address as long as it roams in this service region so the MN don't need to advertise the HA and CNs in its advertising list with its location if it make a hand off inside the service region. But if MN leaves a service region and enters another one it needs a new CoA. Next steps explain the idea when MN advertise its HA and CNs of its new address and when it doesn't need to do this:

- When mobile node enters a foreign subnet it receives a new CoA. This done when MN sends solicitation message to the new AR then the AR produce a new CoA and send it to MN.
- The CoA is the address of the first FA that MN enters and this address does not change as long as the MN moves within the service region which created by Ad hoc network. In this way, network-wide signaling (inform the HA and CNs in its advertising list of this new CoA) is only required when the MN roams outside of its current service region and, thus, signaling traffic and handoff latency can be reduced.
- When MN enters another subnet, it will receives an advertisement from the FA router, then MN will calculate the total signaling cost of registering with this subnet or continue connecting with the previous subnet through Ad hoc network.
- If MN decided that registration with the next subnet will give lower signaling cost and overhead communication than communication with the

previous subnet through Ad hoc network, then it obtains a new CoA and advertises CNs and the HA with it.

Next steps explain how FAs and MNs will route packets to and from the service region:

- When MN enters domain of service region, then the first FA address will be it's care-of address, so any CN try to send packets to this MN will send through using this FA.
- If the MN remains in this FA the packets will send directly to it. And there is no need to use ad hoc network because MN stays in the primary FA subnet.
- If the MN enters another FA region within current service region then an Ad hoc network path made from MN to nearest node which connected with the old FA. We name this node as access node. This path is used to route packets to the MN.
- An update message must be sent to the primary FA to advertise it to send any other packets to this access node.
- Access node will route packet to MN using Ad hoc routing protocol.

There are many ad hoc routing protocols can be used to implement our solution but we select AODV to reduce the delay of routing packets. AODV [9] is a distance vector routing protocol that operates on-demand. There are no periodic routing table exchanges; routes are only set up when a node wants to communicate with some other node. Only nodes that lie on the path between the two end nodes keep information about the route.

Whenever a node wishes to communicate with a destination for which it has no routing information, it initiates route discovery. The aim of route discovery is to set up a bidirectional route from the source to the destination. Route discovery works by flooding the network with route request (RREQ) packets. Each node that receives the RREQ looks in its routing table to see if it is the destination or if it has a fresh enough route to the destination. If it does, it unicasts a route reply (RREP) message back to the source, otherwise it rebroadcasts the RREQ. The RREP is routed back on a temporary reverse route that was created by the RREQ.

Each node keeps track of its local connectivity, i.e., its neighbors. This is performed either by using periodic exchange of so-called HELLO messages, or by using feedback from the link-layer upon unsuccessful transmission. If a route of the Ad hoc network has been broken, some nodes along that route will detect that the next hop router is unreachable based upon its local connectivity management. If this node has any active neighbors that depend on the

broken link, it will propagate route error (RERR) messages to all of them. A node that receives a RERR will do the same check and if necessary propagate the RERR further in order to inform all nodes concerned. AODV uses sequence numbers to determine freshness of routing information, thereby preventing routing loops.

Our solution treats many problems of Mobile IP and covers many advantages not included by other related schemes. First of all, it guarantees seamless handover of mobile nodes over uncovered areas (have no signaling service) and in overlapped area between two subnets (have service signals from two subnets) with minimizing latency and packet loss rates. Also, our solution rids the problem of ping pong mobility when mobile node roaming between two foreign agents in frequently manner which increases signaling cost and overhead on the network with traditional Mobile IP, because the mobile node will obtain a new care-of address and will register its location to the home agent every time when it enters and leaves each of the foreign agents. But with our approach the mobile node will stay connected with the first foreign agent through Ad hoc network because the mobile node has high mobility ratio in this case and needs to reduce the signaling cost.

Our scheme treats problems related to requirement of infrastructure change in Mobile IP network, so using Ad hoc network don't need a pre-existing infrastructure and we can build scalable Mobile IP networks without any additional resources, such as, MAP (as in IPv6) or GFA (as in IPv4), instead of that the ad hoc network will perform all required tasks with autonomous topology.

Another advantage of our approach that each mobile node can dynamically obtains the optimal size of its service area and makes decision for extending this area only at handoffs to reduce overhead of calculation processing and saves mobile resources. And in the same time, a group of mobile nodes can share the same ad hoc network if they are neighbors and have high mobility.

On the other hand, we know that our solution uses and wastes resources of mobile node when calculation signaling cost. But we believe that it's not an important problem with the advanced level of technology used for mobile manufacturing nowadays.

Our scheme minimizes the signaling cost which is caused by frequent location update and reduces handover latency and packet loss rates as described in the next section.

#### 4. Performance Evaluation

In this section, we describe the simulation topology and configurations that have been used to compare the performance of our scheme (MIPAD) with hierarchical Mobile IP (HMIP). We have used ns-2 simulator [13]

to illustrate the seamless handover, handover latency, throughput, and packet loss rate.

The network topology used in our simulations is shown in Figure 2. In the simulation, mobile host (MH) initially has an IP address of 2.0.1 when it is associated with Access Router 1 (AR1). After moving into the uncovered area MH will lose the connection in the case of HMIP and will continue communicating with AR1 through Ad hoc network in case of MIPAD. Once MH moves to the Access Router 2 (AR2), it will get new IP address 3.0.1 (IP2) in the case of HMIP and will save its address in case of MIPAD. The MH will roam between these accesses routers four times. FTP source and sink agents are attached to the CN and MH, respectively, to transfer bulk data from CN to MH. To stabilize the result, each simulation run lasted for 200 s of MH's linear back and forth movement between AR1 and AR2. IEEE 802.11 is used as the MAC layer, and each AR.

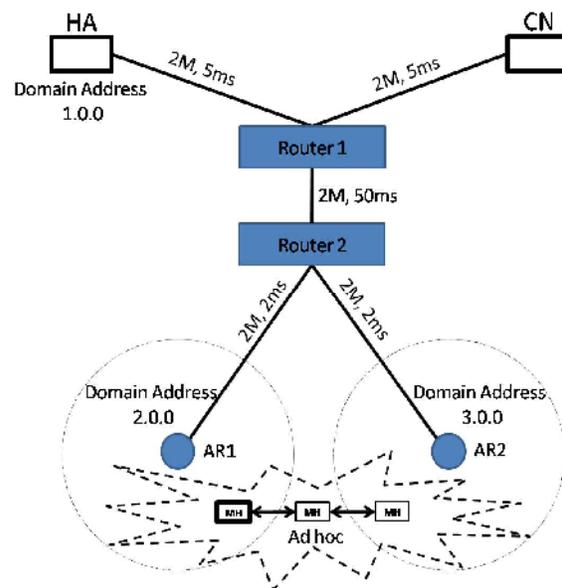


Figure 2. Simulation topology.

As shown in Figure 3, our approach reduced handover latency. We define handover latency as the time interval between the last data segment received through the old path and the first data segment received through the new path by the MH, such as, interval between 107 s and 138 s on HMIP curve compared with interval between 139 s and 155 s on MIPAD curve. Also we note that MIPAD received more packets than HMIP.

Handover latency increases with increasing moving speed of the MH, as shows in Figure 4.

We note that MIPAD has lower latency than HMIP. But after certain moving speed, MIPAD performs ineffective performance. So if moving speed exceeded threshold value, it will cause high signaling cost and then MH decide connecting to the next foreign agent.

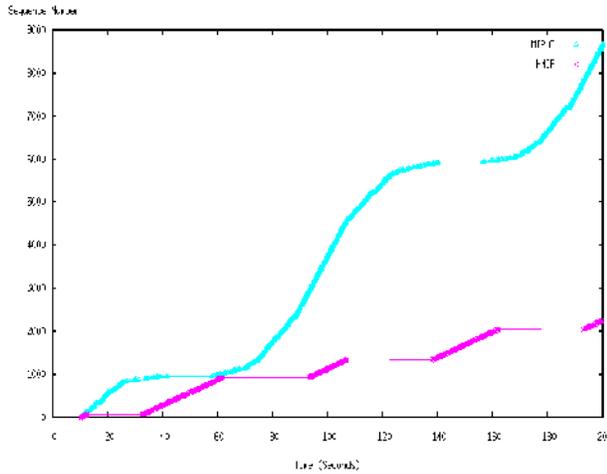


Figure 3. Received packets.

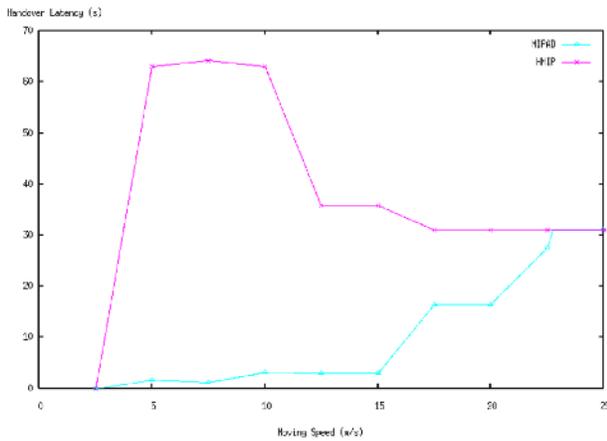


Figure 4. Handover latency.

Figure 5 shows packet loss rate of using MIPAD and HMIP. We observe that our scheme reduced losing of packets at handoffs. We note also that the MIPAD be inefficient for very high mobility speed.

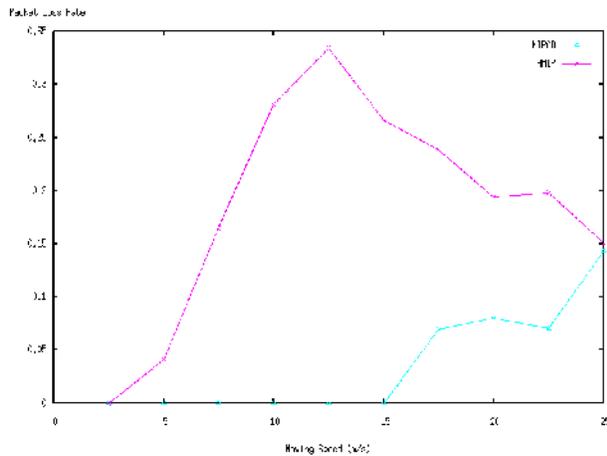


Figure 5. Packet loss rate.

Another advantage of our scheme, that it increases the throughput and performs better performance than HMIP as shown in Figure 6. We observe that throughput is decreased when mobility speed of MH

increased. This result is expected because latency increases when mobility speed increases as show in Figure 5.

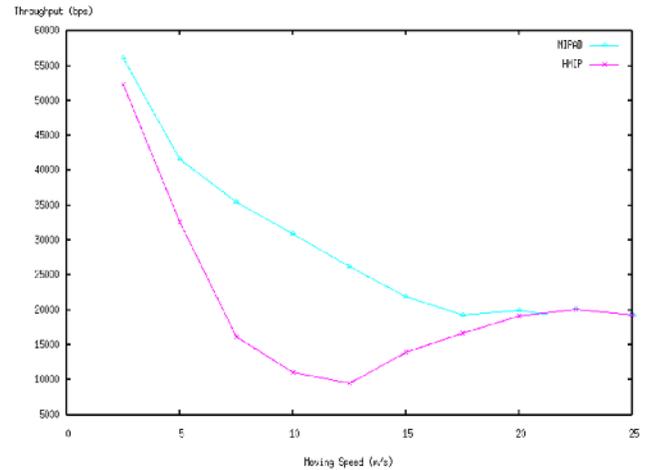


Figure 6. Throughput.

### 5. Conclusion and Future Work

We described and analyzed a new mobility management scheme by constructing dynamic service regions of Ad Hoc networks to reduce signaling overhead and packets loss. The experiment results show that our scheme performs better performance than other. Implementation of our scheme is compatible with Mobile IP networks used nowadays and no need to any modification of existing protocols.

As a future work, we are interested to research for analysis new routing protocols of Ad hoc network for reducing communication overhead and latency. Also we are interested to study the performance of using clustered Ad hoc network rather than flat for reducing signaling cost.

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