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ANALYSIS OF HANDOFF MECHANISMS IN MOBILE IP

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Abstract
One of the most important challenges in mobile Internet Protocol (IP) is to provide service for a mobile node to maintain its connectivity to network when it moves from one domain to another. IP is responsible for routing packets across network. The first major version of IP is the Internet Protocol version 4 (IPv4). It is one of the dominant protocols relevant to wireless network. Later a newer version of IP called the IPv6 was proposed. Mobile IPv6 is mainly introduced for the purpose of mobility. Mobility management enables network to locate roaming nodes in order to deliver packets and maintain connections with them when moving into new domains. Handoff occurs when a mobile node moves from one network to another. It is a key factor of mobility because a mobile node can trigger several handoffs during a session. This paper briefly explains on mobile IP and its handoff issues, along with the drawbacks of mobile IP.

Keywords: Mobile IP, Hierarchical model, Handoff method, Route optimization, Handoff latency

1. Introduction
The development of network technologies such as wireless local area network (WLAN) has made the users to benefit from Internet connectivity almost anywhere and at anytime. Mobility in wireless networks was made more possible after the establishment of mobile Internet Protocol version 4 (IPv4) which is a connectionless protocol. It allows users to roam across various networks and access links maintaining continuous communication [1]. In order to improve experience the Internet Engineering Task force (IETF) has defined a newer version of Internet Protocol called mobile IPv6. Mobile IPv6 is the next generation wireless internet protocol to support IP mobility. Handoff is the main aspect of mobility in IP networks. To support mobility, mobile IP has implemented some mechanism for handoff. But current mechanism is far from perfect as the handoff duration is more and it thus disconnects the mobile node [2]. So a good handoff mechanism should be implemented in order to support IP mobility. Some improvements to solve such problems are discussed in the following sections.

2. Internet Protocol
The Internet Protocol (IP) is the primary protocol used for relaying packets across an internetwork. It is used to identify the node and also the subnet in which the node is located. Access Router (AR) finds the path to send packets, with the help of IP address. This method works well for nodes in fixed location on the network, but if a node begins to move, its IP address becomes false, as the location in the network changes. That is why the established routing mechanism does not support mobility of nodes in network [1].

2.1 Internet Protocol version 4 (IPv4)
The IETF described IPv4 in RFC 791. IPv4 is the fourth revision but the first version of the protocol to be widely used. It is a connectionless protocol used for communication of nodes while roaming. The address size of IPv4 is 32 bits. As there is a rapid increase of end users, a shortage of IPv4 address shortage has been anticipated. This limitation led to the development of IPv6.

2.2 Internet Protocol version 6 (IPv6)
IPv6 is the next version of Internet Protocol designed to succeed IPv4. IETF proposed IPv6 in RFC 2460. The main reason to develop IPv6 was the exhaustion of IPv4 address space. The address size of IPv6 is 128 bits. It is also a connectionless protocol with some good improvements.

3. Mobile Internet Protocol (MIP)
To overcome the problem of mobility in Internet Protocol a standard was proposed, namely mobile IP. Mobile IP is a standard that allows users to move from one network to another without loosing connectivity. It was created to enable users to keep the same IP address while travelling to a different network. Thus ensuring that a roaming node could continue communication without connections being dropped [6].
The terms used in mobile IP are defined below:
Mobile Node (MN): It is an internet connected device whose location and point of attachment to the internet may be frequently changed.
Correspondent Node (CN): A node to which a MN is communicating.
Home Network (HN): A network within which the MN receives its identifying IP address.
Foreign Network (FN): A network in which a MN is operating when away from its HN.
Home Agent (HA): A router on a HN which tunnels the packet to the MN.
Foreign Agent (FA): A router on the FN which stores information about the MN when visiting its network.
Care-of-Address (CoA): A temporary IP address of MN when it is in FN.

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Binding Update (BU): The message sent by the MN to notify HA or CN about its changed location.

3.1 Mobile IPv4

The IETF defined mobile IPv4 to allow mobile nodes to maintain a permanent IP address while roaming from one network to another. Mobile IPv4 is the first revised version of mobile IP. The tunnelling of packets in mobile IPv4 is discussed below.

The MN sends the packet to the CN through the FA, but the packets from the CN are sent to the HA and then tunnelled to FA which then forwards it to the MN as shown in Fig.1. This way of communication is called as *triangular routing*. However, if MN moves to the FN which is the Home network of the CN, then this triangular routing would be a problem. Instead of directly sending packets from CN to MN, it goes through HA and FA which results in packet delay and packet loss [6].

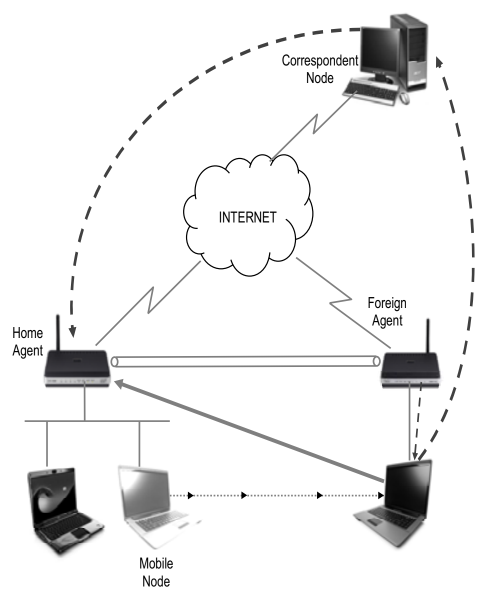

Fig.1: Mobile IP Tunnelling

3.2 Mobile IPv6

To overcome the problem of triangular routing, a newer version of mobile IP has been introduced, called the mobile IPv6. It is the next generation Internet Protocol. Mobile IPv6 eliminates the need for FA entity which then solves the triangular routing problem [3]. The packets sent from CN to MN will initially be sent to HA, it then forwards the packet to MN. Now, when MN sends a reply message to the CN, it will update the CN about its new location. From then onwards, the CN will communicate directly with the MN. This solves the triangular routing problem. But whenever a MN moves from one network to another network, handoff will occur which means that the protocol handles the movement of MN [4], [7]. More about handoffs will be discussed in further sections.

4. What is Handoff?

Handoff occurs when MN moves away from the area covered by one AR and enters the area covered by another AR. The first AR transfers the communication of MN to the second AR in order to avoid interruption in the connection. MN acquires the service of another AR during handoff. Generally, handoff consists of the following procedures when a MN moves from one AR to another:

- Check and confirm MN's authorization to be served by new AR.
- Register MN at new AR and de-register it at previous AR.
- Assign resources for MN at new AR and withdraw its resources at previous AR.
- Update the movement of MN and its new location to the other nodes i.e., the HA and CN.
- Route the packets destined to MN and ensure that all the services are assured during and after the relocation.

5. Mobile IP Handoffs

During the migration of a MN to a new FN, MN is not aware of the new network or the router. In due course, new CoA is assigned to the MN from the new AR. Then it registers and updates its new location with the HA by sending a registration request message. HA in turn, sends an acknowledgement responding to the registration message. When the reply is received, the handoff is complete [10].

Therefore, handoff is the process of network managing the MN's association with the new FN. Mobile IP has equipped some handoff mechanism to strengthen the mobility of nodes. Nevertheless, this mechanism is deficient and could also become a drawback in the functioning of entire protocol, especially in the case of frequently occurring handoffs [9].

6. Approaches to the Improvement of Mobile IP Handoffs

Most of the handoff methods are intended to reduce the overall handoff latency. This overall latency is calculated by the summation of various factors such as:

- The time taken to discover the movement of a MN
- The processing time of MN in each AR
- Registration time with new AR
- Registration time with old AR
- Time taken to send the BU message to the HA and CN

- Time taken to receive an acknowledgement from HA and CN

As these delays happen each and every time a MN moves from one location to another. The delay in the delivery of packets sometime leads to packet loss.
Many improvements have been made to reduce this handoff latency. The mechanisms for handoff in mobile IP and its improvements are given in the following subsections:

6.1 Hierarchical Mobile IP
Hierarchical Mobile IP is an extension to the actual mobile IP protocol in which some modification is made in the general architecture. In the hierarchical model, a new entity is added to the original architecture and it is set up in a hierarchical manner. Handoff in hierarchical mobile IPv4 and mobile IPv6 are discussed below.

6.1.1 Hierarchical Mobile IPv4
The new entity introduced for hierarchical mobile IPv4 (HMIPv4) model is the Domain Foreign Agent (DFA). DFA is connected to the routers of the foreign domain, whereas in original mobile IP, each sub network has a FA attached to its router. The usage of FA is eliminated in the case of HMIPv4 model, instead DFA is used. The location of CoA is now at the DFA.
Whenever the MN migrates from one network to another network within the same domain, the CoA does not change and the MN need not send a BU message to the HA, which helps in reducing the overall handoff latency [9]. This sort of movement by the MN is known as the intra-domain handoff.
Intra-Domain handoff takes place when the previous sub network and the next sub network are in the same domain. When the handoff takes place in situations where the previous and the next sub network are not in the same domain, it is called an inter-domain handoff. In an inter-domain handoff the MN moves to a new domain and updates the HA about its new location by registering its new CoA received from the new DFA. This follows the same procedure as in the actual mobile IP.
Hierarchical setup not only focuses on the reduction of handoff latency but also minimizes the amount of traffic sent over the network. Both effects occur only in the intra-domain handoff, because the inter-domain handoffs and handoffs in the original mobile IP are handled in a similar way.

6.1.2 Hierarchical Mobile IPv6
In Hierarchical Mobile IPv6 (HMIPv6), a new entity called the Mobility Anchor Point (MAP) is introduced, as shown in Fig.2. The MAP works the same way as the DFA seen in previous section; it can also be regarded as a local HA for the MN. When changing the location within the domain, the MN registers its new CoA with the MAP which keeps track of the MN. The MAP updates the HA about the MN's new location. When MN moves away from the domain, it registers its new address with the previous MAP and HA initially. Later on, the MN does not have to update its location to the HA until it moves away from the domain. Thus, by adding this MAP in MIPv6, the number of updating messages (BUs) sent by the MN to its HA is brought down to one. The packets destined to MN will be received by the MAP; it then encapsulates and forwards them to the MN [13].

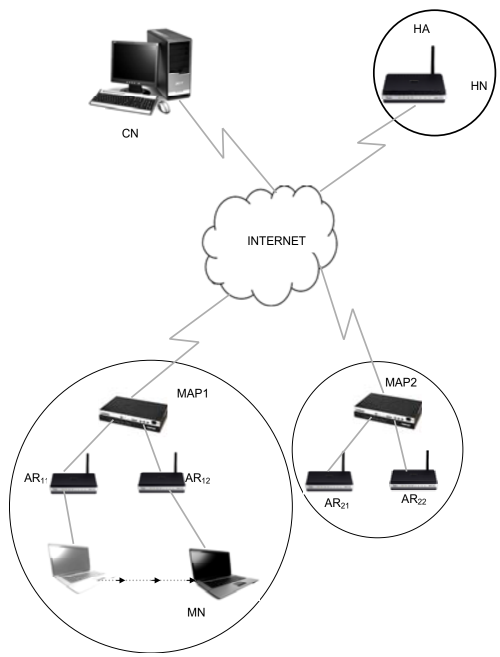

Fig.2: Hierarchical Mobile IP

6.2 Fast Handoff in Mobile IP
Another significant mechanism that assists in reducing the handoff latency is the Fast Handoff mechanism. Fast Handoffs in mobile IPv4 and mobile IPv6 are explained in following sections.

6.2.1 Fast Handoff in Mobile IPv4
The aim of this approach is to do all the necessary work for the handoff before the actual handoff takes place. Some warnings are given to the MN to indicate that there is a chance for handoff to take place. This indication will help MN to begin all the necessary work. Thus, it helps in reducing the overall handoff latency and also lessens the chances of packet loss resulting in an effective and smoother handoff.
As soon as the MN gets a warning, it starts requesting the neighbour networks for its arrival and also requests for a new CoA. After receiving a CoA, it will start scanning for new access routers

by utilizing the router advertisement messages. When the MN detects a new AR from the scan results, it gathers information about this new AR. It should be noted that while residing in the previous subnet, the MN can acquire a new CoA.
When actual handoff occurs, the MN can make use of the gathered information to create a Fast Binding Update (FBU) message. MN uses this FBU to register its next location with the previous AR, while it is still connected to it. After the actual handoff takes place, the previous AR can tunnel the packets to the next AR. The tunnel is created only after receiving the handover acknowledgement messages. This in turn results in minimizing the packet loss [5]. MN uses the FBU to update it's HA about its new location when handoff really occurs. The MN will use the gathered information when it is connected to the next AR.

6.2.2 Fast Handoff in Mobile IPv6

The mechanism of Fast Handoff in Mobile IPv6 is the same as that of in mobile IPv4 seen in previous section. But, Fast handoff in mobile IPv6 uses an update message called the Pre-Binding Update (PBU) message. It is a message that encloses the new CoA of the MN and composes a temporary binding at the CN. PBU is sent to the CN before the actual handoff. As stated above, the discovery of new CoA is done in the same method by using the Router advertisement messages [11].

6.3 Route Optimization Technique

Route optimization is one of the improvements in mobile IP protocol. The MN finds the shortest and optimal path to send messages to the CN. As mentioned in section 3.1. This does not happen in the case of CN sending packets to MN, the packets travel from CN to the MN via the HA. It is not a big issue if CN is away from the MN. The problem occurs when the MN and CN are closer to each other or may be in the same network and HA is somewhere away from the others. This problem is called as the triangular routing which leads to a long delay in arriving of packets to the destination, sometime it also results in packet loss.
Enabling the CN to have BU message from the MN, will help in solving this particular problem. CN can be updated about MN's new location in two ways; either HA can notify CN about the MN's current location when it receives packet from CN, or MN can send a BU message to the CN immediately after the happening of handoff [14].
This technique has got some security issues called message replaying where there are chances for someone to eavesdrop on the conversation between CN and the MN. That is why a CN should identify and authenticate the MN's BU message before sending any packets. Thus, enhancement in the overall performance and security for route optimization technique is more important.

6.4 Other General Solutions

There are also some solutions provided for handoff that do not fall into any major approaches discussed above. Some of these improvements are described in the following subsections.

6.4.1 Multicast Technique

In this technique, a MN is assigned a multicast address by the MAP. The HA of the MN informs its corresponding neighbours about this multicast address. So when the MAP receives a packet intended to the MN, it directs the packet to the MN's multicast address [8]. The MN as well as the neighbour routers receives the message from the MAP. The neighbour router stores this message for future use. Later, when the MN migrates to the neighbouring router, this router buffers the previous few messages designated for the MN. This can radically reduce the occurrence of packet loss during handoff.

6.4.2 Buffering Technique

In this method, buffers situated at the previous AR are used during handoffs. It is used to store packets designated for the MN. The previous AR will be notified about the new CoA when MN is connected to a new AR, so that it can pass on the buffered packets to the MN. This technique will also help in reducing the packet loss [15].

6.4.3 Combinational Strategy

A combination of two mechanisms will help in improving the handoff in mobile IP. Combining fast handover technique with hierarchical set up will improve the efficiency of mobile IP. Hierarchical model reduces the handoff latency when compared to original mobile IP. However micro mobility handoff occurs in intra domain which in turn has a delay in handoff that results in packet loss. To reduce this latency, fast handoff mechanism can be implemented where handoff is initiated before the real handoff takes place [15]. Hence combinational mechanism will reduce the handoff latency and packet loss in some way.

7. Factors determining handoff mechanisms

To determine the efficiency of a good handoff mechanism, some factors have to be considered while implementing that mechanism in Mobile IP networks. Each of these factors will be discussed in this section.

7.1 Ease of Implementation

This factor determines the effort to deploy the protocol in existing hardware and software. It is better if only certain part of the architecture is changed, rather than introducing entirely new implementation aspects.
The *Hierarchical model* would be a good choice because only DFA or MAP is added in the domain,

neither the routers nor the access points have to be updated or modified. In *Fast Handoff* mechanisms, there is a necessity for FAs to be altered so that they can adopt the new type of messages introduced by the protocol. These messages report the MN about the FA. So when considering the implementation aspect, fast handoff does not seem to be a better option [5]. In *Route Optimization,* FAs need not be changed, the MN, HA and CN should be modified. So, updating a CN is a complicated task. Thus, implementation of this mechanism is not very easy.

7.2 Accessibility

This criterion explains how easily a protocol can be handled and used. A protocol with excellent accessibility can handle a huge number of nodes simultaneously without affecting the overall performance. When managing the handoff, the amount of traffic caused by this protocol should be considered as an important factor. The accessibility of the protocol will be good, if the traffic generated is less. This criterion also comprises the factor of capability which determines the capacity of central database.

The *Hierarchical set up* lessens the amount of traffic generated over the Internet. This is possible because intra-domain handoffs do not produce any traffic outside the domain, since registration of MN with the HA is excluded in this model. However, there is also a drawback in this model; it uses the DFA (or MAP) to handle all the MNs within the domain. A domain has limited capacity and hence it cannot manage a large number of MNs. The *fast handoff* mechanism does not involve a central database but it generates more traffic for updating the new CoA with the HA of the MN. *Route Optimization* does not have any major issues [16] with accessibility because there is no usage of central database.

7.3 Delays in Handoff

This is the most reasonable factor to be considered when determining a handoff mechanism. This factor is the main reason for the implementation of new mechanisms or modification of the existing protocol. Generally, decreasing the handoff latency increases the smoothness of experience to the users. The total handoff latency is made up of several factors, as explained in section 6.

The *hierarchical model* reduces the registration time taken by the MN to update its new location with the HA and CN. Instead, it updates the CoA with the DFA (or MAP) which is closer to its location. Thus, the overall handoff latency will be reduced. The *Fast Handoff* mechanism helps in reducing the overall latency by doing all the necessary tasks before the actual handoff takes place. As the handoff happens very quickly, it reduces the duration of MN not capable of receiving any packets. *Route Optimization* does not help in decreasing the handoff latency. In fact, it increases the overall handoff latency by sending a BU message to CN.

7.4 Loss of Packet

Another important factor for the creation of new protocols and suggestions of new mechanisms is to reduce the occurrence of packet loss during handoff. There are chances of packets being lost during or after the movement of the MN from one point to another.

The *Hierarchical model* does not fully support the protocol in reducing the occurrence of packet loss. It eliminates the CoA registration time which helps in reducing the amount of time taken by packets to arrive at the correct address. This reduces the occurrence of packet loss. *Fast Handoff* helps to reduce packet loss by doing all the necessary work before actual handoff. The time taken for handoff is reduced. So the chances for packet loss occurring is also decreased. It also assists in forwarding packets to the MN by using a tunnel between FAs. Hence, the rate of packet loss is reduced. In *Route Optimization* technique, there will be an increase in the occurrence of packet loss because the CN should be updated about the MN's new location before it sends packets to the correct new location. So, the packets which are sent before updating the new CoA will be received by the previous AR. This leads to an increase in occurrence of packets being lost [14].

7.5 Packet Reordering

A factor which is less considered for the implementation of protocol is packet reordering. It does not affect every protocol but there is a possibility for packets being reordered sometime. Packet reordering may occur when the node is connected to a new AR and receives packets forwarded by the old AR.

The *Hierarchical model* does not use buffers. So there is no chance for packet reordering. The *Fast Handoff* can involve packet reordering. This occurs when packets from the previous AR are tunnelled to the new AR. As said above, *Route Optimization* increases the occurrence of packet loss. Packet reordering is not applicable in this technique.

8. Conclusion

In conclusion, the hierarchical model seems to be a better option in the improvement of handoff mechanism in mobile IP. Since the next generation internet protocol focuses on the improvement of global handoff, the intra-domain scenario in which handoffs occur frequently is not taken into consideration. Hierarchical model is a good improvement to the existing protocol, because it is more effective in a situation with lots of local movement of MNs. A combination of strategies would be a better option in reducing handoff latency and packet loss. Combining fast handover with hierarchical model would improve the micro mobility as well as macro mobility handoffs. The hierarchical model increases the efficiency of handoffs significantly. It appears to be the best adoption of mechanism for the current standard of protocol, especially with mobile IPv6, where only some amount of changes have to be made.

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