A Cross-Layer Decision for Mobile IP Handover

Mohamed Alnas, Abdalla M. Hanashi, and Irfan Awan

***Abstract*—Network layer indications are not readily available upon a link change; therefore, general dependence on the network layer may introduce unnecessary delays due to network layer signaling for a simple link layer handover. If information could be gathered at link layer to determine the need for network layer signaling, then both the delay and signaling load could be really improved over the current standards of Mobile IP.**

This paper presents a Cross-layer decision on two layer network and link layers to improve the performance of Enhanced Mobile IP (E-Mobile IP) handover in which reducing packet loss and latency during handover process.

***Index Terms*—Mobile IP handover, fast handover, packet loss, handover latency.**

I. Introduction

Increasingly the access networks will be heterogeneous, and the IP layer, which will be the integrating common layer across the networks, will need to deal with different access topologies, from full mesh to point-to-point, from dedicated bandwidth to shared bandwidth, and from best effort service to guaranteed Quality-of-Service (QoS), across different link layer technologies. Different access technologies have different characteristics also related to QoS, coverage area, and power consumption, etc. [1]. These access networks overlapped and constitute a wireless overlay, as heterogeneous network.

The access technologies might also provide their specific link layer handover mechanisms, but, for the Mobile Node (MN) to be always globally accessible, some upper layer mobility management technique is necessary, such as Mobile IP [2], [3].

Mobile IP is a standard protocol proposed by the Internet Engineering Task Force (IETF) that allows users to keep connectivity with their home IP addresses regardless of physical movement.

Mobile IP handover defined as the process for redirecting IP packet flow destined to the MN's old location to the MN's current attachment point. In the basic Mobile IP, when MN moves to a new subnetwork, packets are not delivered to the MN at the new location until the Care-of-Address (CoA) registration to Home Agent (HA) is complete. Mobile IP doesn't buffer packets sent to the MN during handovers. Therefore, these packets may be lost and need to be retransmitted [4], [5].

Link layer information can be used as hints when a handover has to be performed [6]. Mobile IP use link layer information to force a handover to a new access network before any mobility at the network layer can be detected [6].

The foremost importance of any such decision is network availability. Second important information set comprises of the application specific preferences that help in short-listing the available networks to those which provide near application specific requirements.

In this paper we propose and evaluate the use of cross layer by means of Link Layer Information to improve the performance of Mobile IP handover with the aim of reducing packet loss and handover latency.

II. Related Works

Low Latency Handover [7] is a scheme to counter the effects caused by the gap in link layer communication. This scheme describes methods for a MN to conduct its registration with the new Foreign Agent (nFA) while still being connected to the old FA (oFA) or a way for MN to postpone this registration after link layer handovers, and still receive traffic sent to the oFA.

The first is called Pre-Registration while the latter is called Post-Registration. Both of these techniques rely on link layer triggers to be present in the system. If the underlying layer provides these triggers and manages to deliver them in a time, the network layer handover can proceed with very low latency. But this requirement proves to be unachievable for many link layers.

Mobile Wi-Max as defined in [8] can perform handover on either Break-Before Make (BBM) or Make-Before Break (MBB) configuration. Mobile Wi- MAX by default incorporates a BBM approach of Hard Handover. This approach may introduce long delays unacceptable for real time applications. Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS) are alternatives for MBB approach. In MDHO Mobile Station (MS) can communicate with all neighboring Base Stations (BSs) in a pre-handover negotiation through scanning process.

In FBSS all neighboring BSs should be using same frequency and user contexts, when an MS needs to change its current BS, it needs to choose an anchor BS from the set and continue communication.

The link layer hints are used as an input to a handover decision process in [9]. An algorithm for handover initiation and decision is developed based on the policy-based handover framework introduced by the IETF. A cost function is designed to allow networks to judge handover targets based on a variety of user and network valued

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metrics. These metrics include link layer hint parameters, as well as other QoS metrics. The evaluation of this methods consider only the network controlled side while mobile control was not mention, which in fact make a different between both of them.

An IETF draft in [10], presented a mechanism that extends Mobile IPv6 by including link events information to optimize network layer movement detection. The work considers smooth handovers for MNs that are equipped with multiple interfaces moving across different and heterogeneous links. In particular, the use of link-up, link-down, and link-type hints were recommended for Mobile IP nodes moving between 802.11 and GPRS.

Fast Mobile IPv6 tries to reduce handover delay by providing fast IP connectivity as soon as MN attaches to a new subnet. To realize this, MN must launch the passive or active scanning process to discover the available Access Point (AP) [11]. According to the probe results, Access Router (AR) provides MN with the corresponding subnet prefix information, and then MN could generate a new (nCoA) when it is still connected to its current subnet. To minimize packets loss, a bi-directional tunnel is set up between old AR and new AR.

Utilizing this tunnel, oAR forwards packets destined to MN's old CoA to its nCoA, MN could also continue to send packets to Corresponding Node (CN) through oAR. Such tunnel remains active until MN completes a Binding Update (BU) with its CNs. However, there are two mains shortcomings in the Fast Mobile IPv6 protocol.

First; MN couldn't receive or send the data during the probe phase, while it lasts minimum 350 ms [11] furthermore, MN must spend time to re-switch the channel and re-associate with its oAP to exchange the messages with oAR;

Second; Duplicate Address Detection (DAD) process could not be completely avoided if MN's nCoA is not validated by the nAR before MN disconnects with its oAR.

III. Network Layer Approach

Mobile IP is a network layer mobility solution for IP networks. Mobile IP defines three basic components: a MN that move within Mobile IP network, an HA which is a special agent sitting on a router located in MN's home link and a FA, which is yet another special agent built in a router residing in foreign links [1]. These three components cooperate to locate and register the current IP address of an MN as it moves across different IP subnets.

Mobile IP is also designed to provide mobility transparent packet transmission service, called *tunnelling*, to upper layer protocols [12].

Mobile IP handover consists of two phases: *agent discovery* and *registration*. Agent discovery is a period in which an MN detects its movement from one subnet to another and obtains a new IP address, called CoA [7].

Registration is a procedure in which an MN informs the HA of its CoA, and the HA updates the binding information according to the registration request. Mobile IP is designed to provide mobility transparent packet forwarding to MN regardless of its location in foreign links.

From the information given by agent discovery, an HA sets up a virtual tunnel, which is a particular route, to the CoA of MN (either an FA's CoA or a collocated CoA), the HA forwards packets originally destined to the home address of the MN to the CoA of the MN [8].

IV. Link Layer Information

Link-layer information allows a MN to predict the loss of connectivity more quickly than layer 3 advertisement based algorithms. It is used to predict a breakdown wireless link before the link is broken. This facilitates the execution of the handover, and the elimination of the time to detect handover.

MN monitors any advertisements, records the lifetime and updates the expiration time when a new advertisement is received from new network. When the advertisement lifetime of the current Mobile IP's FA expires, the MN assumes that it has lost connectivity and attempts to execute a new registration with another FA. Although the MN might already be informed about the availability of nFA, the mobile agent defers switching until the advertisement lifetime of the oFA is expired [7].

The fact that a MN receives an advertisement does not necessarily mean that the link to the current FA is broken.

V. Anticipated Handover

In anticipated handover, a handover is initiated when either the MN or the oAR have predictive information about the next point of attachment to which the MN will move to. If the MN has such information, or it chooses to force a handover to a new subnet, it sends a Router Solicitation for Proxy (RtSoIPr) to the oAR, and receives a Proxy Router Advertisement (PRtAdv) in response, providing the MN with link layer (L2) information, such as the subnet prefix, link quality, measured bandwidth and available attachments status required for the MN to establish a new CoA on the new subnet [13].

When oAR receives an indication from L2 that the MN will be moving or RtSP indicating that the MN wants to move, the oAR exchanges messages with nAR in order to obtain or validate the new CoA for the MN. The oAR sends a Handover Initiate (HI) message to the nAR. The HI message contains the requested new CoA on the new subnet [1].

When the nAR receives HI, it does the following:

- If the HI message does not have a new CoA, it allocates a new CoA.
- If the HI message contains a proposed new CoA, the new AR validates the new CoA.

The nAR replies to the oAR with a Handover Acknowledgement (H-ACK) message containing either the new CoA that allocated with nAR or an indication whether the new CoA proposed by the oAR is valid.

VI. Proposed Algorithm

The Enhanced Mobile IP (E-Mobile IP) protocol enables a MN to quickly detect at IP layer that it has moved to a new subnet by receiving link related information from the link layer. In other words it gathers anticipation information about the new AP, and the associated subnet prefix when the MN is still connected to the previous subnet [7], [12]. The overall messages exchange described bellow:

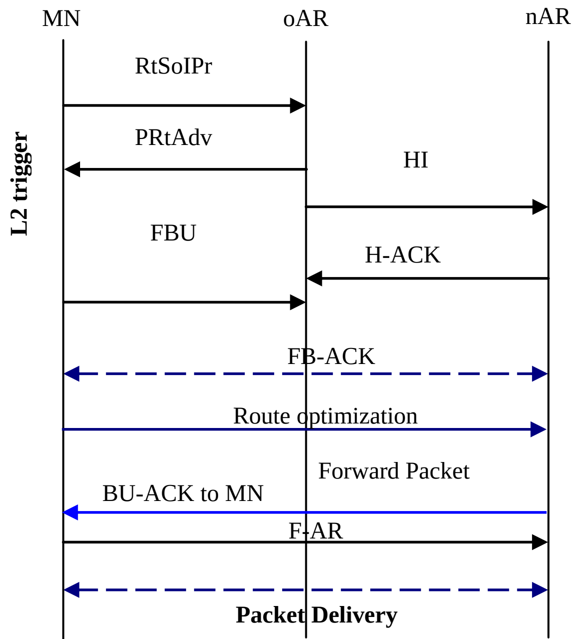

Fig. 1. Message exchange during handover.

- MN will initiate L3 handover by sending *RtSoIPr* message to the oAR, if L2 trigger is received at the mobile-initiated handover, on the contrary, the oAR will send *PRtAdv* to the MN, if the L2 trigger received at the network-controlled handover [12].
- MN checks the neighbour cache to determine the link layer address of the next hop node. The neighbour cache also has an associated state with each neighbour entry.
- A neighbour considered reachable if it has recently received confirmation that packets sent to the neighbour have been received.

This is achieved in different ways, either the receipt of a neighbour advertisement from the neighbour in response to a neighbour solicitation sent by the MN or a hint from upper layer protocols.

- The MN obtains a new CoA in time that still connected to the oAR, it perform that by receiving router advertisement (*RA*) included the visited network information from the nAR.

The oAR will validate the new CoA and sends a HI message to the *nAR* to establish bidirectional tunnel process between *oAR* and *nAR* [13].

- The new AR will respond with H-ACK message.
- MN sends a fast binding update (*FBU*) to the *oAR* to update its binding cache with the MN's new CoA.
- When MN receives a *PRtAdv*, it has to send *FBU* message prior to disconnect its link.
- After the oAR receives *FBU*, it must verify that the requested handover is accepted as it was indicate in H-ACK message.
- The *oAR* starts forwarding packets addressed for the old CoA to the *nAR* and sending *BU-ACK* with fast access router *F-AR* to the MN.

VII. Procedure

When an MN is aware of its movement towards nAR through L2 trigger, the MN must perform a fast handover procedure. After connecting to nAR, a MN immediately sends Fast Neighbour Advertisement (*F-NA*) message without the need for route discovery in order to inform its presence, so that arriving and buffered packets can be forwarded to the MN.

In order to complete the handover, MN must perform home registration with HA and correspondent registration, including a return routability procedure and BU with the CN.

A fast handover procedure starts with the MN sending an *RtSolPr* message, and ends with MN receiving Fast Binding Acknowledgement (*FB-ACK*) message on the previous link. In this proposal we use Pi-Calculus to describe the system of E-Mobile IP handover as following:

A. Handover System

The handover system made up of access routers and the HA as following

$$System \overset{def}{\equiv} new\ connect\ \ MN \mid oAR \mid nAR \mid HA \langle give\ \ i, talk\ \ i, switch\ \ i, alrert\ \ i \rangle$$

B. Mobile Node (MN)

The MN will receive a link from the nAR which is used to communicate with it. Then, the MN sends *RtSolPr* to inform the oAR that it is going to handover to the nAR.

$$MN \overset{def}{\equiv} \overline{RtSolPr} \langle oCoA \rangle . PRtAdv\,(nCoA, Link\ \ Information, LinkIdentifier)\ \overline{\mathrm{FBU}} \langle new \rangle . FB\text{-}AcK . MN$$

MN will send a disassociation request including all of other requirements to the oAR to let it knows that MN will make a handover to the nAR.

C. Old Access Router (oAR)

The oAR is made up of components:

Router solicitation for proxy (*RtSolPr*): is a process utilized by the MN sent to its current AR to request information about likely candidate APs, and handle the MN initial request for the handover.

Forward: a process in which passes both new and old CoA.

Handover Initiation (HI): A request message sent to the nAR to make the handover process.

The oAR first receives the handover request from the MN, and then sends it directly to the nAR

$$OAR \overset{def}{\equiv} \mathrm{RtSolPr\,(oCoA)} . \overline{Forward} \langle \mathrm{oCoA} \rangle . \mathrm{Forward}\ (\ \mathrm{nCoA}\ )\ \overline{PRtAdv} \langle nCoA, Link\ \ Information, LinkIdentifier \rangle . \overline{\mathrm{HI}} . \mathrm{HAcK} . \mathrm{oAR}$$

D. New Access Router (nAR)

The nAR is made up of components:

Forward: a process in which passes both new and old CoA

Proxy Router Advertisement (*PRtAdv*): is the response by the present AR, containing the neighbouring router's advertisement the link information and network prefix.

Handover Acknowledgement: a confirmation sent back to the oAR to make the handover to the nAR

$$nAR \overset{def}{\equiv} Forward(oCoA)\,.\,\overline{Forward}\,\langle nCoA\rangle\,.\,HI\,.\overline{HAcK}$$

$$PRtAdv\,\langle nCoA, Link\ Information, LinkIdentifier\rangle$$

$$\overline{\text{BU-Ack}}\,.\,\langle\text{Forward Packets}\rangle\,.\,nAR$$

Upon the verification of the variables, nAR will send the Acknowledgment (*ACK*) to confirm it's acceptance, then oAR will start sending buffered packet to nAR distend to the MN.

E. Home Agent (HA)

The HA always communicate with both entity MN and (oAR, nAR).

Give: an exchange process sent one router at time either oAR or nAR.

Talk: a process sent to the MN when it returns to its home network.

Switch: a process sent to a specific router to let it know that the MN is going to communicate with it.

Alert: is a plant level messaging application that links process automation to the current AR.

$$HA \overset{def}{\equiv} give1\ \langle \text{talk2}, \text{switch2}\rangle\,.\,\text{alert2}\,.\,\text{HA}$$

$$HA \overset{def}{\equiv} give2\ \langle \text{talk1}, \text{switch1}\rangle\,.\,\text{alert1}\,.\,\text{HA}$$

In this stage HA will get multi input from both, MN and oAR, before the handover executed to the nAR:

$$\overline{x}a \mid xu\,.\,\overline{y}u \mid xu\,.\,\overline{z}u \;\rightarrow\; \overline{y}a \mid xu\,.\,\overline{z}u$$

$$(and\ ,or)$$

$$\rightarrow\; xu\,.\,\overline{y}u \mid \overline{z}a$$

MN will send and receive packets (from/to) nCN and HA:

$$\overline{x}a \mid xu\,.\,\overline{y}u \;\rightarrow\; \{a/u\}\left(\overline{y}u\right) = \overline{y}a$$

Value a being sent for the communication between the input and output:

$$a\left(\overline{x}\right)\,.\,\overline{c}(x) \mid (ub)\,.\,\overline{a}b$$

$$(ub)\,.\,\left(a(x)\,.\,\overline{c}x \mid \overline{a}b\right)$$

We can see that *b* has transition between the components, because of:

$$a(x).\overline{c}x \mid \overline{a}b \;\rightarrow\; \overline{a}b$$

Then; we get

$$(ub).\left(a(x).\overline{c}x \mid \overline{a}b \;\rightarrow\; (ub).\overline{a}(b)\right)$$

$$In\ \ general\ \ b \notin fn(P)$$

Finally; MN handover is:

$$a\left(\overline{x}\right).P \mid (ub).\overline{a}b.Q \;\rightarrow\; (ub).P\{\,b/x\,\}Q$$

$$P = a(x)\left(if\ \ x = Y\ ,then\, T + if\ \ x = Z\ then\ S\right)$$

This is the actual communication of the E-Mobile IP handover, when the MN used channel $\overline{a}$ to passing values *b* between oCN, nCN and its local HA

VIII. Handover Scenario

For simplicity we assume that there is no change in direction while the MN moves inside the overlapping area. The best possible handover point occurs at position A. The coverage area can be defined in terms of signal strength; the effective coverage is the area in which MNs can establish a link with acceptable signal quality with the AP. The coverage radius defined as the distance from an AP to its coverage boundary. The cell radius is the distance from an AP to its cell boundary.

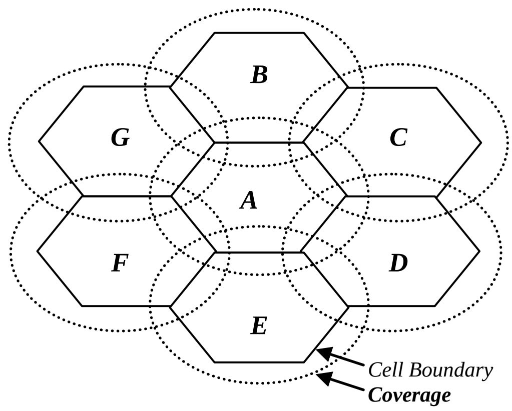

Fig. 2. Overlapping coverage area.

IX. Performance Evaluation

We use network simulator CIMS NS-2 version ns2-allinone-2.31 as a simulation tool in order to simulate FMIPv6 handover [14]. It supports for routers set in order to reduce unsolicited RA intervals and the addition of the RA interval option as defined in the MIPv6 draft. This will enable CN support for route optimization.

A MN connects to the CN using ns-2 IEEE 802.11 wireless LAN model. The results were obtained using a 7 MNs moving between different neighbouring at speed of 20metre/s, and the overlap area is 25m.

As Fig. 3 shows, when the number of handovers per minute increases the throughput received at the MN decreases. E-Mobile IP and standard Mobile IP (S-Mobile IP) handover throughput curves stay close together for the handover rates lower than 10 handover/mins, where the experiment Mobile IP has higher throughput.

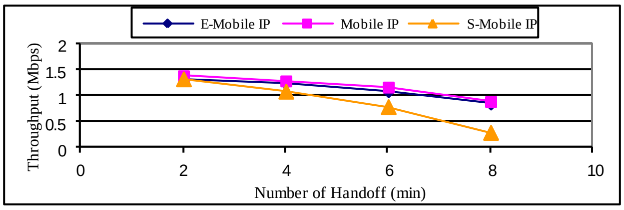

Fig. 3. Handover and throughput.

This can be explained by the concurrent reception in the MN from more than one CN, so the MN receives more packets.

But, when mobility speed increases, the E-Mobile IP handover curve gets closer to Mobile IP curve. This is mean that E-Mobile IP works better, because Mobile IP is not able to use its advantage of concurrent listening.

Fig. 4 shows an example of the uplink MN to CN transmission behavior with sixe handovers in the unit time of all three schemes S-Mobile IP, Mobile IP and E-Mobile IP.

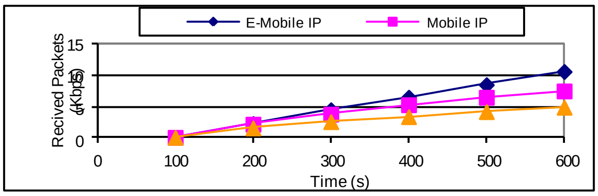

Fig. 4. Handover behavior.

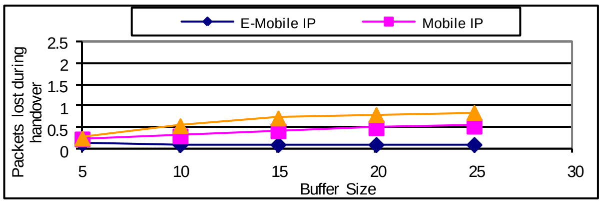

Fig. 5. Packet loss vs buffer size.

The result graph shows the transmission bit rate of each handover protocol. Handover delay periods are known in both S-Mobile IP and Mobile IP, although Mobile IP received more data than that of S-Mobile IP, but both of them show inherent handover delay, this is because of their registration period. On the other hand, E-Mobile IP handover shows the highest transmission rate without any delayed period.

This is because E-Mobile IP uses multi-homing and buffer procedure, which provides fast and accurate data transmission.

The number of packets lost depends both on the size of buffer used to store packets for potential handovers and the sending rate as seen in Fig. 5. The number of packets lost is constant for S-Mobile IP since no buffer is used and increases as the sending rate increases since more packets are sent while MN is unable to receive them during handover.

On the other hand, the number of packets sent decreases as buffer size increases for E-Mobile IP

This means that the packet loss can be totally eliminated if the buffer size is chosen large enough. Furthermore, this buffer size can be adjustable to the sending rate since the number of packets lost increases as sending rate increases for constant buffer size.

Fig. 6 shows the uplink MN to CN handover delay of S-Mobile IP, Mobile IP and E-Mobile IP over handover rate.

Total handover delays versus handover rate shows how the handover delay of each handover protocol reacts when scale of mobility varies, the total handover delays of S-Mobile IP and Mobile IP increase as expected, in contrast, E-Mobile IP handover does not incur any delay irrespective of the handover rate. This is due to the fundamental difference between E-Mobile IP handover registration procedure and other schemes procedures.

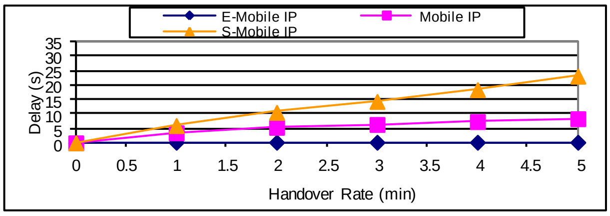

Fig. 6. Total handover delay.

Handover delay of S-Mobile IP and Mobile IP becomes more significant as handover rate increases. As we can see handover delay and handover rate product directly affects the end-to-end throughput and packet loss. Thus, S-Mobile IP and Mobile IP can't be a proper handover approach in large scale mobility environments. On the other hand, E-Mobile IP does not affect any significant throughput decrease nor packet loss by keeping handover delay zero regardless of handover rate.

The partially better behavior for Mobile IP is a consequence of the higher wireless load of the fast handover approach. A higher number of signaling messages sent via the wireless medium yields to a higher channel access delay and higher collision rate, resulting in a lower bandwidth achieved.

X. CONCLUSION

The usage of link-layer information at the IP layer is an open question and is still in progress in the IETF community, while it is commonly accepted that the usage of link-layer information can result in a more efficient IP packet transport.

In this paper, we have presented Pi-Calculus algorithm for E-Mobile IP handovers with less control traffic compared to previous algorithms in wireless networks. Our scheme uses Link Layer Information and location information of the neighbour inside every domain of the network.

We have shown the necessary changes in registration messages and the format of location advertisement messages.

The result in this proposal shows that the Mobile IP handover use of link layer information gives better performance in term of handover latency and packet loss, but this can be enhancement for other application services.

There are however requirements affecting the deployment of Mobile IP in today's different type of networks. The result in this proposal shows that the Mobile IP handover use of link layer information gives better performance in term of handover latency and packet loss.

Future work will address the deployment of Mobile IPv6 using network layer for movement detection, in evaluation of Mobile IPv6 fast handover, and handover delay

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