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Performance of Handover in Mobile IP Networks

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Abstract
Mobile IP Protocol (MIP) is an old protocol and it is a Standard Protocol that allows users to maintain non-stop connectivity with their home address regardless of physical movement. In this paper we study handoff in mobile IP networks and Mobile IP Protocol Extensions for Handoff Latency Minimization [9].
Keywords: Mobile IP, Fast Handoff, Roaming, Eager cell switching, Lazy cell switching.

I. Introduction

The IP is expected to become the main carrier of traffic to mobile and wireless nodes. This includes ordinary data traffic like HTTP, FTP, and e-mail, as well as voice, video, and other time-sensitive data. To support mobile users, the basic Internet protocols have been extended with protocols for intercepting and forwarding packets to a mobile and possibly roaming node. Seamless roaming requires that users and applications do not experience loss of connectivity or any noticeable hiccups in traffic. This is not only important for time-sensitive traffic, but also for TCP based traffic, as TCP performance is highly sensitive to packet loss and reordering.

It is therefore imperative that a handoff is initiated in such a way that network connectivity is maintained for the longest possible period of time, and that the handoff latency and packet loss is minimized [3].

However, little is known about the performance of the Mobile IP in an actual network. In particular, it is not understood how different handoff initiation algorithms influence essential performance metrics like the packet loss and the duration of a handoff.

II. Hand off Initiation

The Mobile IPv6 specification [6] contains only a weak specification of handoff initiation algorithms.
Two conceptually simple handoff initiation algorithms that have gained considerable interest are ECS1 andLCS2 [3]. Both operate at the network layer without requiring information from the lower (link) layers.
A handoff algorithm has three major responsibilities:

1. Detecting and quality assessing available networks
2. Deciding whether to perform a handoff, and
3. Executing the handoff.

Handoff initiation consists of the first two activities. A seamless handoff requires that no packets are lost as a consequence of the handoff. In general, it is also desirable that packets are not reordered, duplicated, or extraordinarily delayed.
First consider the scenarios depicted in Figure 1.

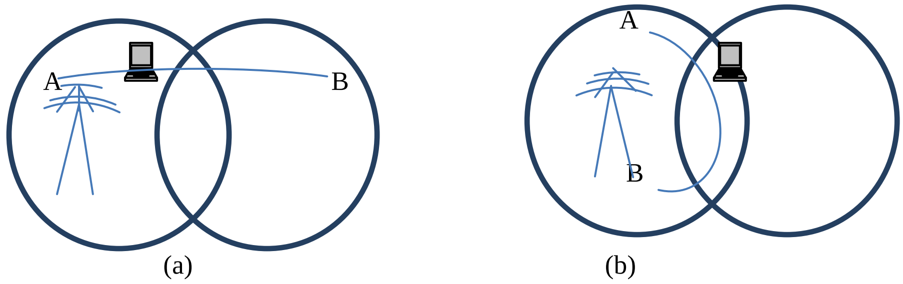

Figure1 A node moves from point A to B:
(a) Seamless hand off technologically possible,
(b) Seamless hand off possible, but not performed.

Here the ranges of two wireless networks (1 and 2) are depicted as circles. A mobile user moves from point A to point B. In the situation shown in Figure 1(a), where the networks do not overlap, no Mobile IP handoff initiation algorithm could avoid losing packets (one might imagine a very elaborate infrastructure where packets were multicast to all possible handoff targets and that packets could be stored there until the mobile node arrives, but even then a long period without network access would

most likely be noted by the user). In the situation shown in Figure 1(a), where the networks overlap sufficiently), seamless handoff is possible.
Figure 1(b) shows that there are situations where a handoff is possible, but not desirable. ECS proactively initiates a handoff every time a new network prefix is learned in a router advertisement. Conversely, LCS acts reactively by not initiating a handoff before the primary network is confirmed to be unreachable. When the lifetime of the primary network expires, LCS probes the current default router to see if it is still reachable. If not, a handoff to another network is initiated. Consider what happens when ECS and LCS are subjected to the movement in Figure 1(a).
Figure2 illustrates a timeline for LCS where significant events have been pointed out. The first event is that network 2 gets within range. However, the mobile node cannot, in general, observe this before it receives a router advertisement from network 2. This results in a network discovery delay. LCS does not yet per form a handoff. Next, network 1 gets out of range [6].

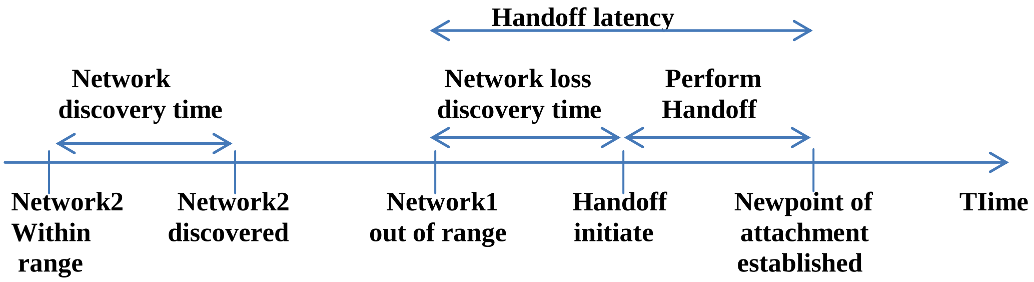

Figure2 LCS

This cannot, in general, be detected immediately, as this requires active communication with the base station, and it gives rise to a network loss discovery delay. LCS declares the network unreachable when the lifetime of the last received router advertisement has expired and the following probing is unsuccessful. LCS then hands off to one of the alternative networks known to it through router advertisements—in this case network 2—and thus establish a new point of attachment. Thus, LCS will lose packets in the handoff latency interval.
The behavior of ECS is illustrated in Figure3).

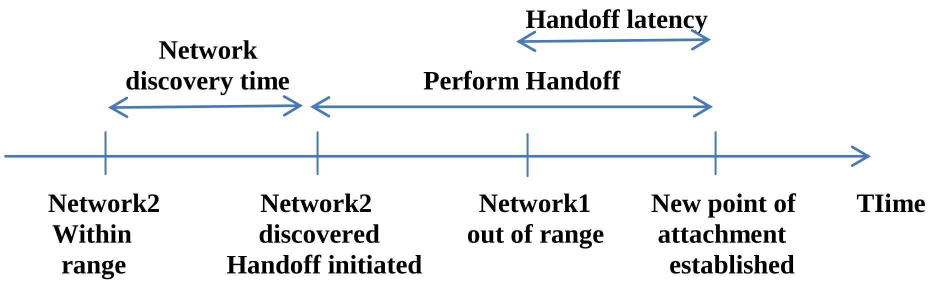

Figure3 ECS

ECS handoff immediately when a new network is discovered. If the mobile node has an interface that is capable of receiving from the old network while attaching to the new, a seamless handoff can be performed provided a sufficient network overlap.

The performance of ECS thus depends on the frequency with which access routers are broadcasting router advertisements. Similarly, LCS also depends on the frequency of broadcasted router advertisements, but additionally depends on the lifetime of network prefixes and probing time. The theory and data needed to decide what handoff initiation algorithms to use in what circumstances, how to tune protocol parameters, and where to put optimization efforts, are missing.

Both ECS and LCS are very simple-minded approaches. PCS is our proposal for a more intelligent handoff initiation algorithm that also considers measured signal-to-noise ratio and round-trip time to access routers [8].

Periodically (currently every 0.5 second) the algorithm sends an echo request to the default router a tall available networks. The default routers are expected to reply to the echo. These echo requests are sent for three reasons:
1. It is only possible to measure the SNR of a link to a network if there is traffic at the network.
2. It can be determined faster that a network has become unreachable than by monitoring the lifetime of network prefixes.
3. The round-trip time is an indication of the capacity of a network.

Parametric cell switching only performs handoff when a significantly better network is available .The cost of using the PCS algorithm is a slightly increased network load.

III. Mobile IP Protocol Extensions for Handoff Latency Minimization

When using Mobile IP, the movement of a MN away from its home link is transparent to transport and higher-layer protocols and applications, since the IP address of the communicating nodes remains the same at all times. Therefore, the MN (Mobile Node) may easily continue communication with other nodes after moving to a new link. At least in theory. There are cases in which it is not possible for the MN to keep its IP address after a handoff [11]. For example when the MN operates in private address networks which are separated from the public Internet by Network Address Translation (NAT) devices, which is not an uncommon case.

The basic idea is that the MN would use a specific source port for the communication with HA (Home Agent) from which the HA would "guess" the real IP address of the MN. Further, the MN would use a dedicated destination port to tell the HA that it is communicating from behind a NAT.

Handoffs between subnets served by different FAs1 (L3 handoffs) require a change of the CoA (Care of address) and a succeeding registration of the new CoA with the HA [6]. This process takes some nonzero time to complete as the Registration Request propagates through the network. During this period of time the MN is not able to send or receive IP packets. The latency involved in Layer 3 handoffs can be above the threshold required for the support of delay-sensitive or real-time services. IETF is working on several drafts, which propose methods to achieve low-latency Mobile IP handoffs. The methods are explained in the following.

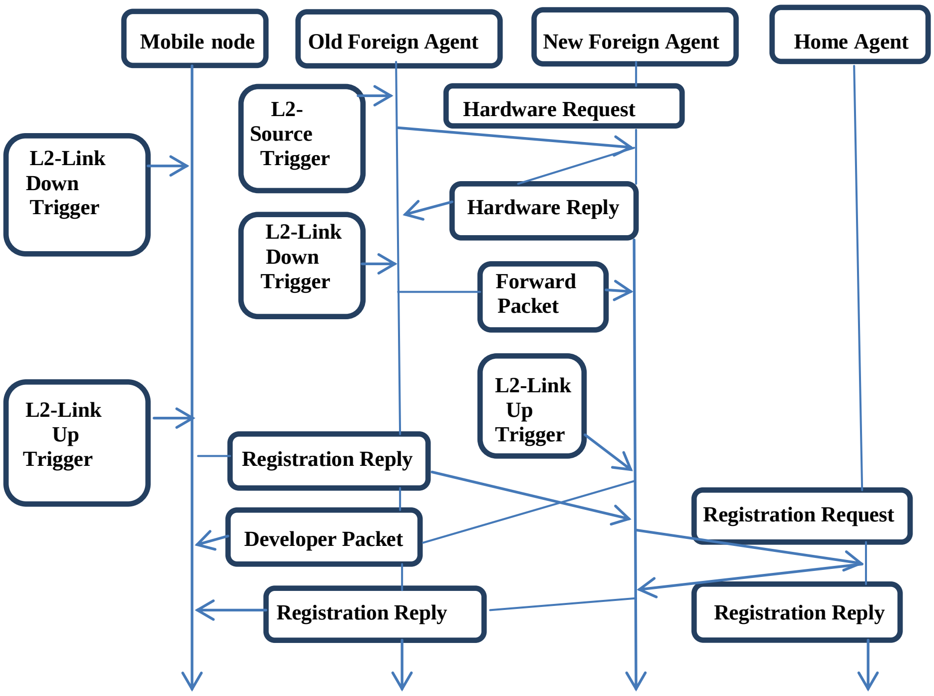

Figure4 Pre-Registration Handoff

IV. Low Latency Handoffs in Mobile IPv4

In described two techniques, which allow greater support for real-time services on a Mobile IPv4network by minimizing the period of time when a MN is unable to send or receive IPv4 packets due to the delay in the Mobile IPv4 registration process.

The L3 handoff can be either network-initiated or mobile-initiated. Accordingly, L2 triggers can be used both in the MN and in the FAs to trigger particular L3handoff events.

V. Pre-Registration handoff method

This handoff method allows the MN to communicate with the New Foreign Agent (nFA) while still connected to the Old Foreign Agent (oFA) [2].

This way, the MN is able to "pre-build" its registration state on the nFA prior to an underlying L2 handoff.

• Network-Initiated Handoff

A network initiated handoff can be source triggered (Figure3) or target triggered (Figure5), depending on whether oFA (source trigger case) or nFA (target trigger case) receives an L2 trigger informing it about a certain MN's upcoming movement from oFA to nFA. In both cases the mobile node receives a Proxy Router Advertisement message (PrRtAdv), which contains information about the nFA. Upon reception of an PrRtAdv message the MN starts registration with nFA by sending it a Registration Request message. This message has to be routed through oFA since the MN is not directly connected to nFA prior to the L2 handoff [1].

The nFA performs the registration of the MN with the HA and buffers the Registration Reply until the MN completes the L2 handoff and connects to nFA.

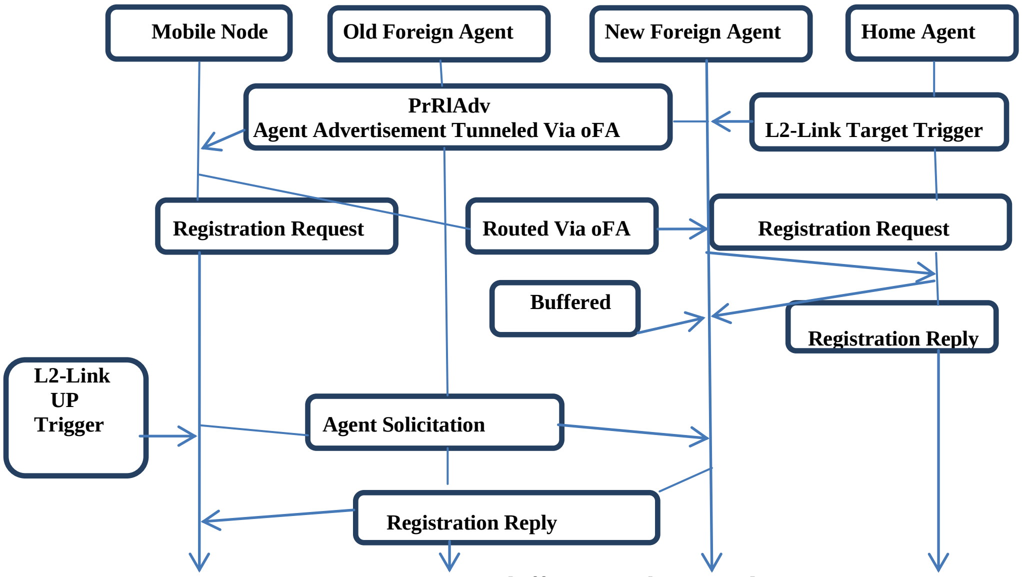

Figure5 Pre-Registration Handoff - Network Initiated, Target Trigger

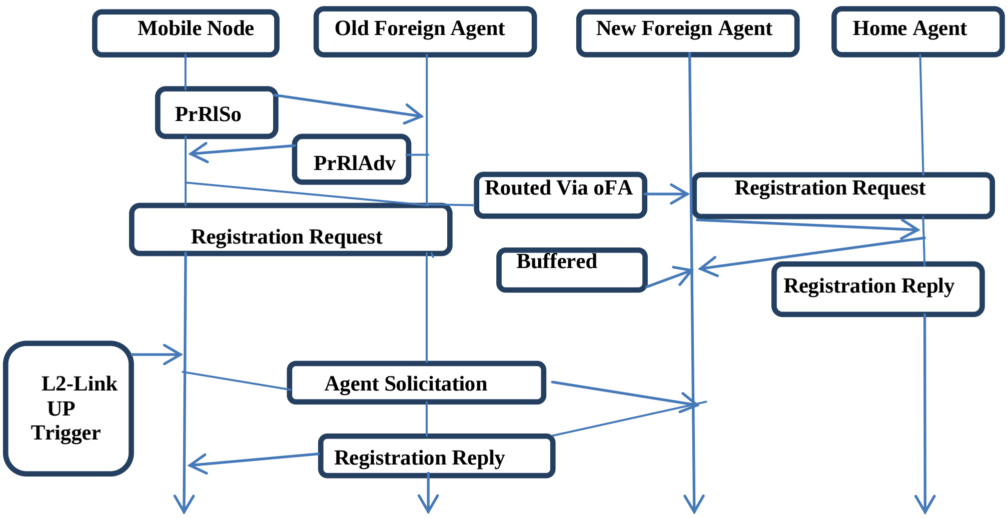

Figure6 Pre-Registration Handoff -Mobile Initiated

VI. Mobile-Initiated handover

A mobile-initiated handoff (Figure6) occurs when a trigger is received at the MN to inform that it will shortly move to nFA. The L2 trigger contains information such as the nFA's identifier (i.e. it's IPv4address).

As a consequence of the L2 trigger, the MN begins registration with nFA by sending the \Proxy Router Solicitation "(PrRtSol) message to oFA. The solicitation message must contain an Id entire of nFA (i.e. nFA's IPv4 address). oFA replies to the MN with aPrRtAdv message containing the agent advertisement for the requested nFA. In order to expedite the handoff, the actual nFA advertisement can be cached by oFA, following a previous communication between the two [5].

Such caching can be done in a pre-soliciting process of known FAs to avoid performing the solicitation during an actual handoff procedure. In case that oFA does not have cached information about nFA it has to make an PrRtSol-PrRtAdv exchange with nFA in order to obtain the information. The rest of the registration process is similar to the network-initiated cases [10].

VII. Post-Registration handoff method

This extension proposes the setup of a tunnel between nFA and oFA, thus it allows the MN to continue using its oFA while on nFA's subnet. This enables a rapid establishment of service at the new point of attachment which minimizes the impact on real-time applications. The MN must eventually perform a registration, but it can do this after communication with the nFA is established.

The handoff process starts with either oFA or nFA receiving an L2 trigger informing it that a certain MN is about to move from oFA to nFA. In the former case the trigger is called Layer 2 Source Trigger (L2ST) and in the latter case Layer 2 Target Trigger (L2TT) to indicate whether the trigger is made in the previous network (source) or the destination network (target) of the MN. The trigger contains the MN's L2 address and an identifier for the other FA (i.e., the other FA's IPv4address). The two FAs make a Handoff Request (HRqst) - Handoff Reply (HRply) exchange. The exchange triggers the initialization of a bi-directional tunnel between the two [4].

The point during the L2 handoff in which the MN is no longer connected on a given link is signaled by an Layer 2 Link Down Trigger (L2-LD) trigger at oFA and MN. The completion of the L2 handoff is signaled by an Layer 2 Link Up Trigger (L2-LU) trigger at nFA and MN. The trigger is handled as follows:

a.) When oFA receives the L2LD trigger, it begins forwarding packets to MN through the forward tunnel to nFA.

b.) When the nFA receives the L2LU trigger, delivering packets tunneled from oFA to MN and forwards outstanding packets from MN using normal routing mechanisms or through a reverse tunnel to oFA or the HA.

c.) When the MN receives the L2LU, it initiates the registration process with nFA by soliciting an agent advertisement. After registration, the nFA takes over the role of default foreign agent for the MN.

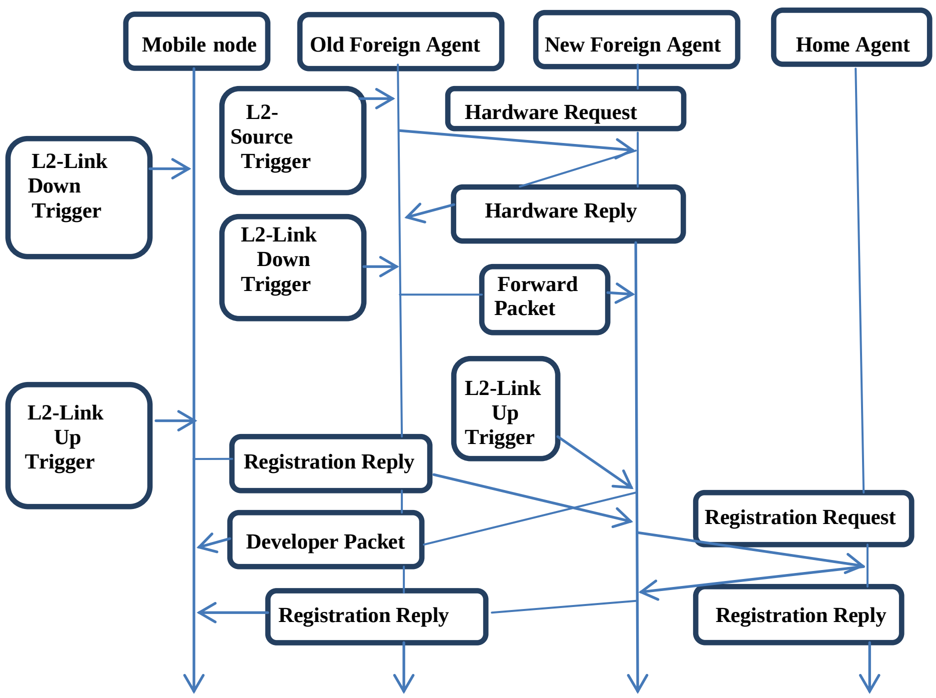

Figure7 Post-Registration Handoff -Source Trigger

Figure7 shows the Post-Registration process after a source trigger. The only difference in the target trigger case is that nFA initializes the handoff [3].

VIII. Conclusions

There are a number of important metrics that should be considered when evaluating the performance of a handoff initiation strategy as experienced by a mobile node:

- Handoff latency: The handoff latency is the time where the mobile node is potentially unreachable. In general, it is caused by the time used to discover a new network, obtain and validate a new COA(identifies the current location of the mobile node), obtain authorization to access the new network, make the decision that a handoff should be initiated, and ,finally, execute the handoff, which involves notifying the home agent of the new COA and awaiting the acknowledgment from the HA.
- Number of performed handoffs: The more handoffs a given strategy will perform in a given scenario, the more likely it is that the user will observe them, and the more the network is loaded by signaling messages.
- User value: When several networks are candidates as target for a handoff, the one most optimal from the user's perspective should be chosen. This may be the network that offers the most bandwidth, cheapest price, the most stable connection, and so on.

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