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# Location Update Cost Improvement Over Incorporated Domains in Hierarchical Mobile IPv6

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**Abstract**

***Hierarchical MIPv6 (HMIPv6 adopts the Mobility Anchor Point (MAP) which acts as Mobile Node's Home Agent by intercepting the packets and tunneling them to the MN once it is under its domain. In the case of many MNs moving in adjacent domains such as a university and its campus; a lot of Location Update (LU) signals will occur due to normal frequent movement for MN's users. In this paper an incorporated domains is introduced that allows adjacent domains to be incorporated together while keeping their MAPs sharing the same RCoA, the objective of incorporated domains is to reduce the LU signals if the MN moves through adjacent domains. Moreover, in the incorporated domains the cost reductions were measured by the development of new simulation software code which showed 30% - 60% reduction in the cost of LU.***

**Keywords:** ***HMIPv6, Location Update, incorporated domains, RCoA and MAP.***

## 1 Introduction

There are various theoretical analyses performed by researchers, especially in presenting its benefits through high level simulations. Hierarchical routing is defined as promising approach for point to point routing with a routing state that is very small [1].
Hierarchical MIPv6, which is an enhanced version of MIPv6 introduced by [2], separates mobility management into micro mobility and macro mobility. The essential element of this structure is the Mobility Anchor Point (MAP). It is a

router or a set of routers that maintains a binding with MNs presently visiting its domain. It is usually located at the boundaries of a network, on top of the Access Routers (AR), to receive packets for MNs attached to that network.

The MAP acts as the local HA for the MN. It intercepts all packets addressed to the out-of-towners mobile node it hands out and tunnels them to the corresponding on-link Care of Address (LCoA) of the MN. If the mobile node travels to another address within a MAP domain, it only needs to register the new on-link address with the MAP since the universal CoA does not change. If a MN travels into a new MAP Area, it needs to get a Regional Care of Address (RCoA) and an (LCoA)as shown in Figure 1. The mobile node then uses the new MAP's address as the RCoA, while the LCoA address can be produced as stated in [3]. Subsequent to forming these addresses, the mobile node sends an ordinary MIPv6 Binding Update (BU) to the MAP, which will bind the mobile node's RCoA to its LCoA. Then the MAP will return a binding acknowledgement (BAck) to the mobile node indicating a successful registration. The mobile node must also register its new RCoA with its home agent by sending another BU that indicates the binding between its home address and the RCoA. Finally, it may send similar BU to its current Corresponding Nodes (CN), specifying the binding between its home address and the RCoA.

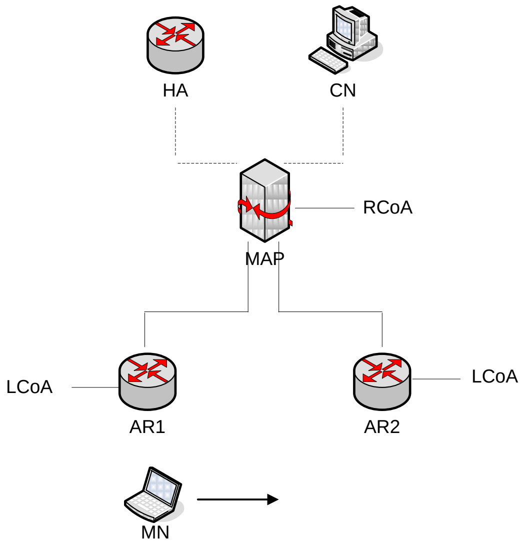


**Figure 1 HMIPv6 domain**

If we combine more than one domain together using the same RCoA as an application of the concept of Smart HMIPv6 [4] we can achieve better performance since the frequency of location updates on the MAP level will be minimized thus resulting in a better cost of location update. In order to reduce and balance the cost of location update, some researchers have made use of Gateway Location Register (GLR) which is made of three database structure levels by designing a dynamic location management method that is movement area based.

The GLR method can be used in optimizing the size of the movement-are based on the speed which leads to reduction in the location management [5].
The objective of this study is to introduce the concept of incorporated domains as an application of SSHMIPv6. This is done by introducing the concept, developing the conceptual and mathematical model and analyzing the improvement in terms of cost reduction through simulation.
The scope will be limited to the introduction and simulation of the newly proposed concept of incorporated domains through the development of a computer application that will be used to test and simulate the improvement in the reduction of cost of location updates in the system.
In this discussion we will ignore the effect of hand-off latency since it's beyond the scope of this study.

# Frequency of Location Updates

In HMIPv6, When a Mobile Node MN moves between different Access Routers ARs under the same domain in Micro-Mobility movement, only the on-link Care of Address LCoA changes while the Regional Care of Address RCoA remains the same and only the corresponding MAP will be informed about the change. However, when the movement occurs between ARs which are located under different Mobility Anchor Points MAPs both the LCoA and the RCoA need to be changed thus more cost will incurred due to the fact that both the Home Agent HA and all the Correspondent Nodes CNs need to be informed of the new location address.
To study the frequency of location updates, it is assumed that the frequency of location updates follows Poission distribution which is described by the following mathematical models according to [5]:
Mathematical model for location update between Access Routers

$$P_{AR} = \frac{(\mu t)^k e^{-\mu t}}{k!} \quad \textbf{Equation 1}$$

μ : Sub-net crossing rate
k : Number of changes of AR in t second
Mathematical Model for location update between MAPs

$$P_{MAP} = \frac{(\mu t)^k e^{-\mu l t}}{k!} \quad \textbf{Equation 2}$$

l : The map level
μ : Sub-net crossing rate
k : Number of changes of MAP in t second

# Incorporated Domains as an Application of SSHMIPv6

Previously Smart-Selection HMIPv6 was introduced which allowed for providing a way to deal with the issue of scalability in current HMIPv6 implementations through clustering more than one MAP to cater for the increased number of

Mobile Nodes in today's highly demanding market. This method reduced the delay encountered by packets in the previous implementations of HMIPv6.

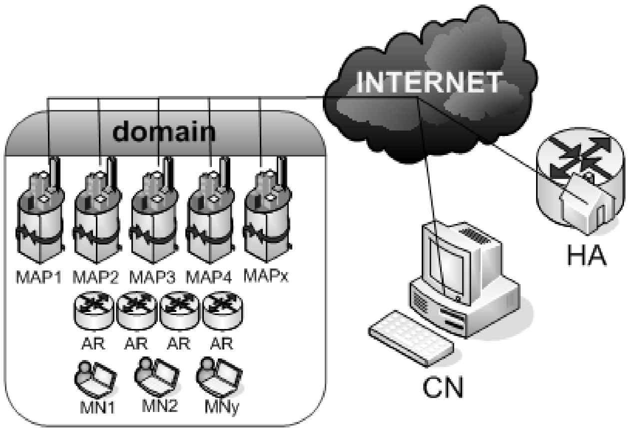


**Figure 2 Smart Hierarchical Mobile IPv6 architecture**

This study introduces a new concept that benefits from this newly developed SSHMIPv6 and is presented as an application of it. The idea is that there is usually more than one domain which shares a high number of traffic among them. For instance, the domain that covers a university campus and a domain that covers the hostel of that camps share a huge number of Mobile Nodes moving between the two domains on daily basis. The same concept can be applied to a domain covering a business district and the condominiums that accommodate those who work in this district are likely to have a high number of Mobile Nodes moving from one domain to the other.

If such relationships can be established, then combining these domains that share large numbers of Mobile Nodes moving between them under one SSHMIPv6 incorporated domain can provide huge savings in terms of cost of location update reduction and performance improvement since the movement between domains under the same incorporated domain involve cost of location updates only due to change of Access Routers ARs and not due to change of Mobility Access Points MAPs.

Moreover, if such a relationship cannot be identified easily then merely combining several adjacent domains under one incorporated domain can achieve the same effect stated above since mobile nodes are more likely to move to adjacent domains that they are to move to far away domain. This concept of incorporated domains if implemented can provide cost of location update reduction and improve the performance since the load on the Home Agent HA and Mobility Access Points MAPs will be significantly reduced thus allowing faster processing of the remaining location update requests in the queue.

# Mathematical Model Analysis

When the concept of incorporated domains is applied to the previously stated mathematical model devised by Dutta [6] in Equation 2 which will be affected as follows:
the mathematical model describing the frequency of location update due to change of MAPs shown in Equation 2 will be modified due to the change in the Sub-net crossing rate (μ) which can be calculated using the following equation:

$$\mu = \frac{\pi V}{4R_m} \quad \textbf{Equation 1}$$

Where $R_m$: is the radius of the MAP domain. This radius will be increasing as a result of combining several domains together. Subsequently, the Sub-net crossing rate (μ) will decrease resulting in a decrease in the frequency of location updates due to change of MAPs ($P_{MAP}$).
Nevertheless, the frequency of location update due to change of AR will remain the same and Equation 6-1 will not be affected. However, this will not affect the reduction in total cost since the frequency of location updates due to change of MAP will reduce significantly as shown previously.
The above analysis based on mathematical models showed that the implementation of the concept of incorporated domains will result in an increase in the frequency of location updates due to change of Access Routers (AR) and a decrease in location updates due to a change of MAP. This supports the proposed concept of incorporated domains since it has a positive change compared with the original HMIPv6 mathematical model. This improvement will be further verified using a computer based simulation to test the validity of the mathematical analysis.

# Simulation Environment

This section verifies the performance improvement by performing a simulation analysis of the implementation of incorporated domains. The simulation was carried out using Visual Basic programming language due to its general-purposes nature which allows the implementation of the mathematical model in order to evaluate the validity and soundness of the proposed conceptual model. The choice of Microsoft Visual Basic Version 6 was mainly due to the familiarity of the programming language. The simulation program will allow the end-user to specify the number of domains out of possible 25 domains. Any number of theses domains can be combined under incorporated domains. It is assumed that every Mobile Node MN belongs to a single Access Router AR and a single MAP inside each domain. Theses Domains, MAPs, ARs and MN are assumed to be identical for the purpose of this simulation.
For the purpose of this simulation the cost will be calculated using the following formulas outlined by [5]:

## 5.1 Cost due to change in AR

$C_{AR-U} = m \times P_{AR} \times [Q_d + d_{LA} \times E(z) + C_{MAP-U}]$

**Equation 1**

m: Number of mobile nodes

$P_{AR}$: Frequency of location update due to a change in AR as defined in 0

$Q_d$: Cost of packet processing in the queue

$d_{LA}$: The distance in terms of number of hops from AR to MAP

E(z): the unit cost per distance

$C_{MAP-U}$: The cost of MAP update.

## 5.2 Cost due to change of MAP

$C_{MAP-U} = C_{AR-U} + m \times P_{MAP} \times [Q_d + (d_l \times E(z)) + C_{MAP-U}] + \{ d_{HG} \times E(w)\}$

**Equation 2**

$C_{AR-U}$: cost due to change of an AR as defined in 0

m: Number of mobile nodes

$P_{AR}$: Frequency of location update due to a change in AR as defined in 0

$Q_d$: Cost of packet processing in the queue

$d_l$: The distance in terms of number of hops from MAP to MAP

E(z): the unit cost per distance

$C_{MAP-U}$: The cost of MAP update.

$d_{HG}$: The distance between HA and MAP

E(w): the unit cost

# The Simulation Software

The software was designed in a way that allows the test to be carried out on different situations by allowing changes in any of the variables used in the mathematical model. The simulation also tests several configurations that might benefit from the implementation of the concept of incorporated domains. The next parameter that should be entered to the simulation software is the path that the mobile node will follow. A proposed traveling path is shown in Figure33 below.
The path and domains distribution shown below are of the ideal case where the majority of location updates are due to a change in ARs. However, the software was designed to test all types of configurations including the worst case scenario when every move in the path requires the location update to occur in the MAP level. Nevertheless, the real situations are not represented by these two extremes and thus we will consider cases where a mixture of both scenarios is applied.

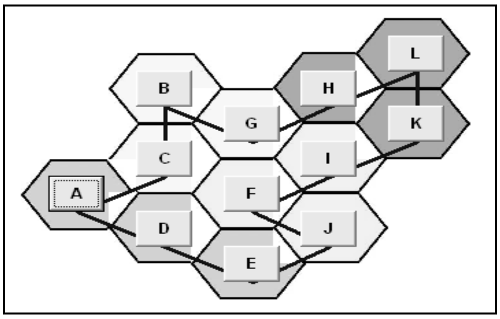


**Figure3 Entering the traveling path of the Mobile Node**

For the path shown in Figure3 the total cost for the current implementation is 1284 bytes while the incorporated domains implementation of HMIPv6 is calculated to be 728 bytes which show an improvement of 43.3%.

## Results

To test that the improvement is persistent over a wider range of scenarios starting by varying the number of mobile nodes since an increase of the number of mobile nodes can lead to an increase in the cost which might affect the improvement percentage of the proposed system. The results showed that the percentage of improvement of the results of the newly proposed system that implements incorporated domains did not show much decrease in the percentage of improvement when the number of mobile nodes increased. This is to be expected since the concept of incorporated domains is one of the possible applications of Smart-Selection Hierarchical Mobile Internet Protocol SSHMIPv6 which was designed in the first place to deal with the issue of scalability of the HMIPv6. The improvement trend can be noticed in the total costs shown in Figure44. Furthermore, the improvement percentage and its relationship with the number of mobile nodes can be seen in Figure55. This results show that the system showed significant cost reductions even with the increase of number of mobile nodes.

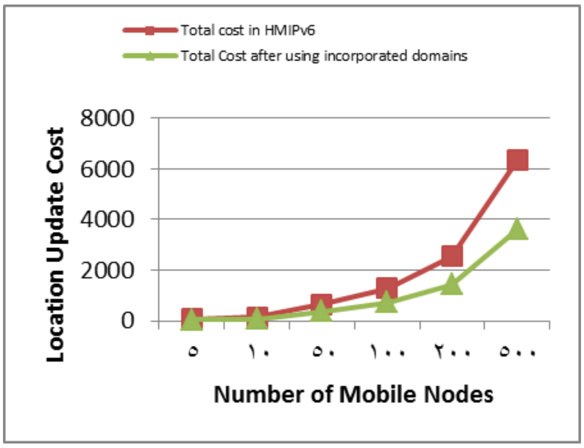


**Figure4 LU Cost vs. Number of Mobile Nodes**

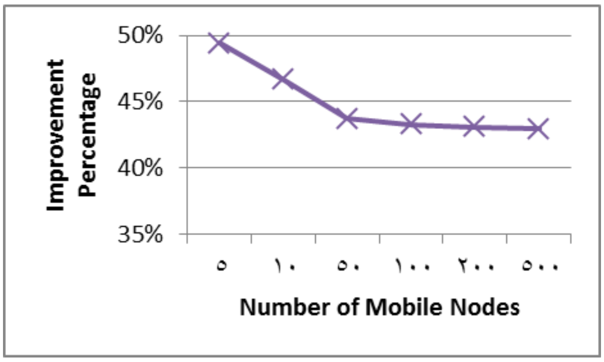


**Figure5 Improvement Percentage vs. Number of Mobile Nodes**

When the analysis is geared towards the relationship between the number of domains inside each incorporated domain and the location update cost reduction as a result of implementing incorporated domains as an application of SSHMIPv6, the results showed that a higher number of domains inside each incorporated domain is preferred and yields better results in terms of cost reduction.

Figure66 shows the relationship between the number of domains inside each incorporated domain and the total cost incurred as a result of location updates. It can be seen that the total cost starts to increase as the number of domains inside each incorporated domain decreases. This is to be expected since reducing the number of domains inside each incorporated domain increases the probability of the location update to be due to a change in the MAPs.

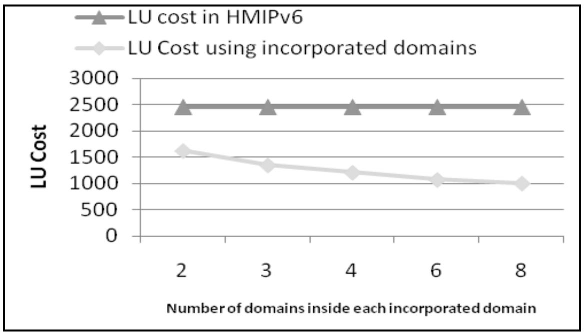


**Figure6 Number of domains inside each incorporated domain vs. Cost reduction**

The same is illustrated in Figure77 in terms of percentage of cost reduction in the cost of location updates. It can be notices that better cost reductions were achieved at higher numbers of domains per each incorporated domain.

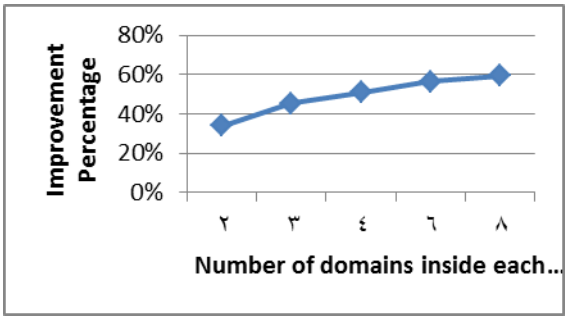


**Figure7 Percentage of Cost Reduction vs. Number of Domains inside each incorporated domains**

In the worst case scenario of a path that moves from one incorporated domain to the next in every step of the movement path an example of which is provided in Figure 88, the incorporated domain implementation will provide no improvement in terms of cost reduction. However, this scenario is highly unlikely since the concept of incorporated domains revolves around assigning domains that statistically have showed rapid movement among themselves and assigning one incorporated domain to cater for theses domains. Nevertheless, even in this worst case scenario the cost performance of the incorporated domain implementation didn't show any degradation in the cost incurred by the location update.

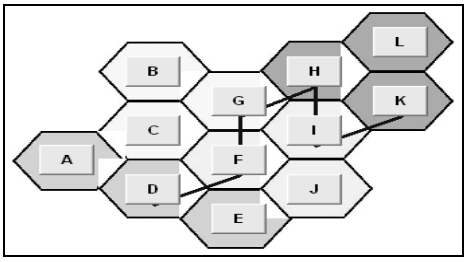


**Figure 8 Worst Case Scenario for MN path**

However, another possible scenario is one where the path is entirely inside one incorporated domain; in this case the savings encored as a result of the implementation of incorporated domains are much lesser than the normal HMIPv6. The case can be seen in Figure9. A huge cost reduction of 65.91% was achieved be using the incorporated domains implementation of HMIPv6.

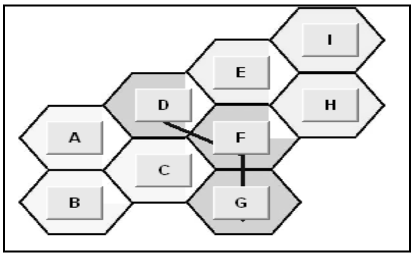


**Figure9 Best case scenario**

The actual scenario however, is not one of these two extremes previously mentioned but instead it's a mixture of both. One where some of the steps involve movement of the Mobile Node between domains under different incorporated domains while others involve movement among domains under the same incorporated domain. In this case the improvement can be somewhere in between the improvement of the two extremes and is expected to be in the range of 30% to 66%.

## Conclusion

In this paper the concept of incorporated domains was introduced, which is an application of SSHMIPv6 that provides reductions in the cost of location update and provide better performance for the overall system. The mathematical model was referenced and the effects of implementing the proposed conceptual model on the mathematical model were analyzed. The cost reductions were measured by the development of new simulation software that relied on the mathematical models for the calculation of cost of location updates incurred by the system before and after the implementation of the concept of incorporated domains. The collected data were further analyzed and the relationship was established between the different parameters like number of Mobile Nodes and the nature of the path that the mobile node is following.

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