An Enhanced Media Independent Handover Framework for Heterogeneous Wireless Networks

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***Abstract*—IEEE has introduced a standard on vertical handover known as Media Independent Handover (IEEE 802.21 MIH) which aims to achieve end user mobility by assisting the vertical handover across heterogeneous wireless technologies thus improving end user experience. However, the current MIH standard lacks context-aware architecture which is needed to adapt to the changing network dynamics and mechanisms to distribute load uniformly in the network.**

In this paper, we propose an enhanced architecture to IEEE 802.21 Media Independent Handover (MIH) framework in heterogeneous wireless networks. In the enhanced MIH framework, we add in a new network element known as Handover Agent(HA) for simplifying handover overhead at mobile nodes and offering more seamless vertical handover to mobile nodes. The proposed architecture addresses several challenges involved in unified heterogeneous network system such as context-aware handover, load balancing and signaling overhead. We also present comparative mathematical analysis of our proposed architecture with respect to the current MIH standard.

***Keywords*-MIH, Handover, Context aware, MADM, Heterogeneous wireless networks, network initiated;**

I. Introduction

IEEE has proposed Media Independent Handover (MIH) standard (IEEE 802.21) to facilitate vertical handover among heterogeneous wireless access technologies such as 3/4G cellular technologies (UMTS, W-CDMA, LTE, and LTE-Advanced) and Wireless LAN technologies (IEEE 802.11 a/b/g/n). The MIH interfaces between link layer and upper layer abstracting the need to communicate with each and every specific lower layers to perform a handover. The handover criteria can be based on QoS requirements of the users and factors such as RSSI (Received Signal Strength Indicator) and remaining batter power but this kind of handover schemes does not consider the changing dynamics of heterogeneous networks. The authors of [2] proposed MADM (Multi Attribute Decision Making) methods which consider several factors in choosing best network. The authors of [3] considered user perceived quality as the measurement factor. The Mobile Node (MN) initiated handover also has the overhead of signaling, processing, and battery consumption, hence the network initiated handover with MN signaling would be more efficient. In case of several MNs choosing the same candidate network, they could overload the candidate network and hence a central entity to monitor and balance the network load is required. In this paper, we propose enhanced MIH architecture to address these issues.

II. Related Work

Media Independent Handover (MIH) was introduced by IEEE, in order to facilitate vertical handover efficiently and provide interoperability between IEEE 802 and non-IEEE 802 technologies. The standard specifies the MIH Function (MIHF) which offers three types of primary services as given in [1]

Media Independent Event Service (MIES): It supports a) MAC and physical state changer events, b) Link parameter events like link up, link down, c) Link synchronous events, and d) Link transmission events. It provides event notifications to higher layers of a Mobile Node (MN). The event notifications can be local (link layer) or remote (MIHF to MIH users). Event notifications services are helpful to a detect when handover is possible. Media Independent Command Service (MICS): It is used by higher layers to determine the status of connected links and to execute handover decisions, commands could be local (sent by higher layer) or remote (MIHF to MIH users). Media Independent Information Service (MIIS): It is used to gain information about various heterogeneous networks within a geographical region. This information is vital as it may affect the outcome of target network selection of a handover. The information provided is primarily static. MIH provides an unified interface for any mobility and handover management method in upper layers.

A. Vertical Handover Schemes

Various vertical handover schemes have been proposed in the literature for offering seamless hand-off among wireless access networks. But, most of the existing schemes have not taken into account the context aware information such as user perceived quality, network related parameters such as bandwidth available, delay, throughput etc which

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Table1 : Neighboring PoA

Table 1.1:Neighboring PoA Request

PoA-id	Address	Required Info

Table 1.2:Neighboring PoA Response

PoA-id	Address	Jitter	Delay	Load	Available Bandwidth	Position	Coverage Area

Table2: MN-Details

Table 2.1:MN-Details-Request

MN-Unique-id	In-Address	Required Info

Table 2.2:MN-Details-Response

MN-Unique-id	IP-Address	QoS-Req	User-Exp-Index	Speed

change frequently. In [4], authors have proposed an hand-off decision algorithm for Wi-Fi/3G networks based on the signal strength. But, just only one parameter cannot give optimal target network selection in heterogeneous network environments. In [3], various parameters QoS parameters, network load, context information etc are considered in vertical handover decision phase. In [2], the authors describe the MADM methods in determining the best target network. In [5], the authors define the concept of UPQ (User Perceived Quality) and linking to wireless data primitives.

III. Our Work

We propose an enhancement to 802.21 MIH architecture by adding a network entity known as Handover Agent (HA). Figure 1 shows the proposed enhancement to MIH architecture. As shown in the figure, HA connects to all the PoAs (Points of Attachment) in its given neighborhood and assigns them unique id. Unlike MIH standard, MNs connect to PoAs via HAs. When a MN enters into a new territory, it detects HAs in the region through paging and gets an unique id assigned by the HAs. HA regularly obtains the network state information from PoAs (*e.g.,* bandwidth, delay) and the perceived QoS of user sessions from the MNs.

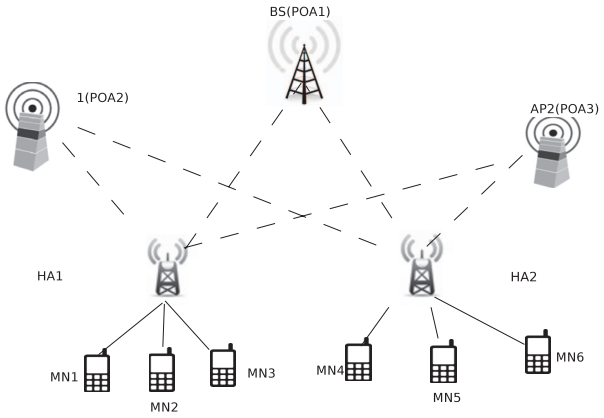


Figure 1. Proposed enhancement to existing MIH Architecture.

PoAs update their state information such as available bandwidth, IP address, throughput, jitter, delay etc at the HA using request and response messages, the state information updated at the HA acts as network level parameters required to select the appropriate PoA during a vertical handover.

Table 1 shows what fields are present in the Neighboring PoA Request and Neighboring PoA Response for the Type length value messages.

Similarly HA connected to MNs assigns unique id to each MN, MNs update their state information such as QoS parameters, UPQ which is given as user experience index, MN speed, MN IP address etc at the HA using request and response messages, the state information updated at the HA acts as application level parameters required to select the appropriate PoA during a vertical handover.

Table 2 shows what fields are considered for the Mobile Node request and Mobile node Response.

We have defined the new message formats similar to [6] for information exchange between PoAs and MNs. HA continuously monitors sessions of MNs and is responsible for handover. In addition to link quality related parameters, UPQ is also considered as a crucial parameter for handover decision making. UPQ is approximated through the following two parameters:- average error rate and average bandwidth as decrement of bandwidth or increment in delay due to errors in medium affects the user experience considerably. The criteria for handover is described in Algorithms 1 and 2. Algorithm 1 is handover condition algorithm where MN intimates the HA when the UPQ is degrading or link is going down, depending on the speed and battery life of the MN the handover will be executed. If the speed of the MN is less than a particular threshold value, if it exceeds the threshold value the handover is not effective as MN will bind with PoA for very short duration, by the time connection is well established MN might leave the PoA coverage radius. Handover will be executed if battery life is greater than a minimum required battery life threshold. Otherwise, handover will not takes place and MN continues with the existing PoA. Algorithm 2 is handover condition algorithm where the HA detects a PoA which provides better QoS, bandwidth etc than existing PoA for a given MN, then depending on the speed threshold and battery life of MN the handover is executed by getting the confirmation request of the MN.

MN initiated Handover Condition Algorithm 1

```
if (link going down || UPQ degradation) then
  if (speed < threshold) then
    if (battery_life > min_value) then
      req_PoA_neighbors_info();
      inform_MN(MN_UID);
      select_PoA(PoA_info, MN_info);
      inform_MN(MN_UID);
      handover();
    else
      Continue with the existing PoA;
    end if
  end if
end if
```


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HA initiated Handover Condition Algorithm 2

```
if (stats(current PoA) < stats(neighboring PoAs) then
  if (speed < threshold) then
    if (battery_life > min_value) then
      confirm_MN(MN_ID);
      informMN(MN_UID);
      handover();
    else
      Continue with the existing PoA;
    end if
  end if
end if
```

Network Selection Algorithm: The appropriate target network selection is very important phase in vertical handover, a Network selection algorithm is employed to select the best target network given multiple target networks. The proposed network selection algorithm takes an MADM to select the best network. To select the best network, we employ SAW (Simple Additive Weighting) which is one of the widely used MADM methods because it is simple and intuitive. Here, the attributes are not only network parameters but also QoS requirements of user and UPQ.

Given n networks with m available attributes, SAW method constructs a decision matrix, D, where $A_{i,j}$ represents i^{th} network's j^{th} attribute, and the attributes are normalized as follows:

$$D = \begin{bmatrix} A_{1,1} & A_{1,2} & \cdots & A_{1,n} \\ A_{2,1} & A_{2,2} & \cdots & A_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{m,1} & A_{m,2} & \cdots & A_{m,n} \end{bmatrix}$$

where,

$$A_{i,j} = \frac{a_{i,j}}{a_{ij}max} \leftarrow \text{Benefit}$$

$$A_{i,j} = \frac{a_{i,j}min}{a_{ij}} \leftarrow \text{Worst Criteria}$$

In this scenario $a_{i,j}$ represents the j^{th} attribute such as Bandwidth available, jitter etc for i^{th} PoA $A_{i,j}$ represents the normalized attribute. Benefit criteria is used normalize the attribute which maximizes the profit such as available bandwidth, throughput etc. Worst criteria is used to normalize the attribute which minimizes the loss such as delay, jitter etc.

If weightage of m attributes is given as

$$W = \begin{bmatrix} w_1 & w_2 & \cdots & w_m \end{bmatrix}$$

$$PoA_Selection_Function = max(PoA_stats(1), PoA_stats(2), \ldots, PoA_stats(m))$$

$$PoA_stats\ (i) = \sum_{i=1,j=1}^{i=n,j=m} w_i \times A_{i,j}$$

In case of handover rejection, the HA selects the next best network and re-initiates handover process. This reduces the signaling overhead compared to MN initiated handover.

IV. Sample Handover Scenario

Figure 5 shows a comparative sample handover scenario where $MN1$ traverses from $PoA1$ to $PoA2$ in presence of HA when compared to the standard architecture is explained in this section.

1. Binding Phase: Here, binding of MN with the HA happens. As shown in Figure 2, the HA first sends the *Paging* request to the MN and get the response message from MN.

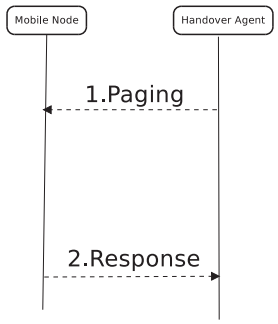


Figure 2. Example of Binding Process.

2. Handover Initiate:

Handover Initiate Without HA:- MIH enabled MN decides that a handover is necessary in order to maintain the connectivity. So, handover initiation takes place as follows (refer Figure 3). a) MIH enabled MN sends HA initiate request to the serving PoA. b) Serving PoA sends the initiate Response to the MIHF of the MN.

Handover Initiate With HA:: In this case, the following actions takes place (refer Figure 4). a) When the MN discovers the link is going down, it contacts HA. b) HA searches for the link. c) HA sends the initiate request to the serving PoA. d) Serving PoA sends the response to the HA. e) HA forwards the initiate response to the MN. f) HA notifies the MIH users of the Mobile Node.

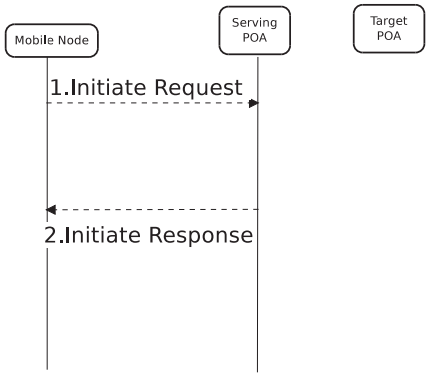


Figure 3. Example of Handover Initiate Without HA.

3. Handover Prepare:

Handover Prepare without HA:- Refer Figure 6. a) MIH enable MN sends MIH-Handover initiate request to the

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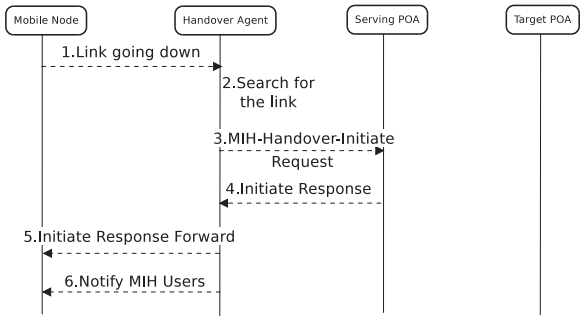


Figure 4. Example of Handover Initiate With HA.

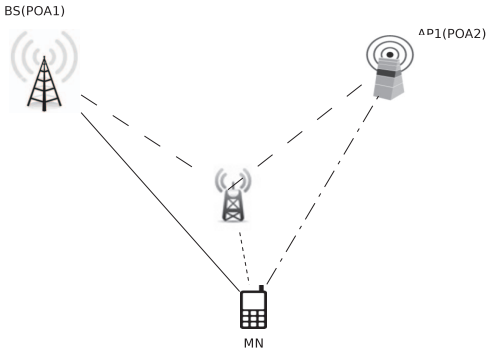


Figure 5. Sample Vertical Handover Scenario between two PoAs

serving PoA of its intent to handover. b) Serving PoA prepares a request and transmits to the Target PoA. c) The MIHF function of Target PoA sends the notification to MIHF Users of Target PoA. d) The MIHF function of the Target PoA sends the initiate response regarding resource status to the Serving PoA. e) The MIHF function of the Serving PoA sends the initiate response regarding preferred link handover acknowledgement to MN.

Handover Prepare with HA:- When the link of the MIH User of MN goes down, handover procedure is invoked. The following is the detailed description of how it happens (Refer Figure 7): a) When the link goes down, MN sends a request to the HA saying that the link is going down. b) HA transmits the request to the serving PoA. c) Serving PoA prepares the request and transmits the same to the Target PoA. d) Target PoA now sends the notification response to the Serving PoA. e) Serving PoA initiates the response to the Handover. f) Finally, the HA initiates the response the MN.

4. Handover Commit: After the completion of the Handover initiation, the Handover commit takes place.

Handover Prepare without HA:- Refer Figure 8. a) Target PoA takes an action and prepares response and sends the same to the Serving PoA. b) Serving PoA sends the commit request to the MIH User of MN. c) MIHF function of the MN sends the commit response to the MIHF function of the Serving PoA.

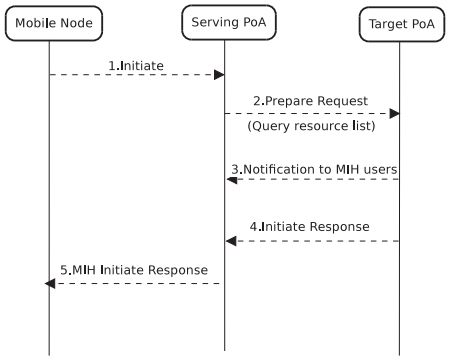


Figure 6. Example of Handover Prepare Without HA.

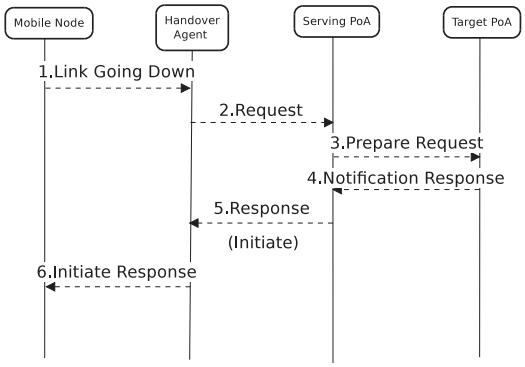


Figure 7. Example of Handover Prepare With HA.

Handover Commit with HA:: Refer Figure 9. a) MN sends the confirmation to commit request to the HA. b) HA transmits the commit request to the serving PoA. c) Target PoA sends the notification to MIH Users of the MN. d) Target PoA sends the commit response to the Serving PoA. e) Serving PoA transmits the commit response to the MN.

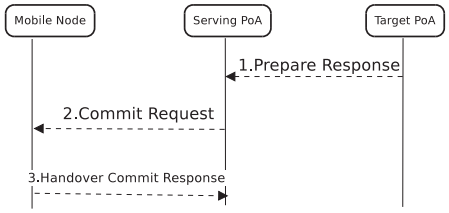


Figure 8. Example of Handover Commit Without HA.

5. Handover Complete: After the handover is successfully finished, it informs the Target PoA that the handover is complete.

Handover Complete without HA:- Refer Figure 11. a) MIHF of the MN sends the handover complete request to the Target PoA. b) Target PoA forwards the request to the Serving PoA. c) Target PoA sends the complete response to the Serving PoA. d) Target PoA forwards the response to MIHF of the MN. e) MIHF gives notification to MNs.

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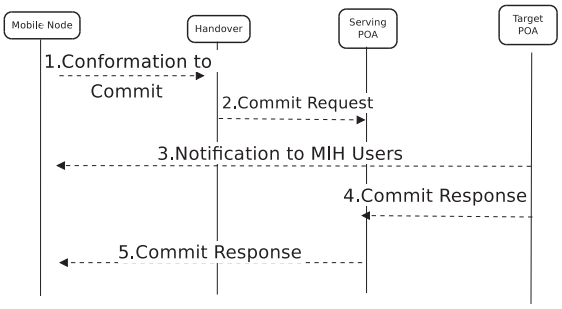


Figure 9. Example of Handover Commit With HA.

Handover Complete with HA:- Refer Figure 11. a) MN sends the complete request to the HA. b) HA then transmits the complete request to the Target PoA. c) Target PoA forwards the request to the Serving PoA. d) Target PoA then sends the complete response to the Serving PoA. e) It sends complete response to HA. f) HA sends the complete response to MIH User of MN.

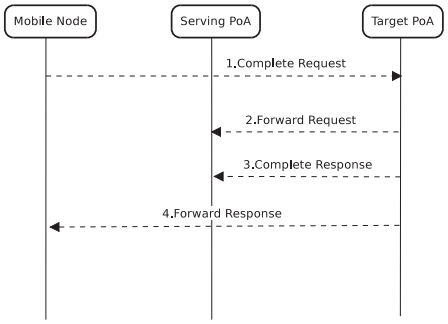


Figure 10. Example of Handover Complete Without HA.

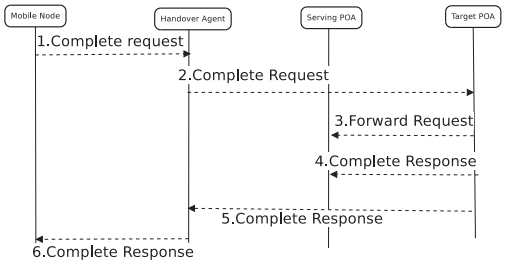


Figure 11. Example of Handover Complete With HA.

V. Mathematical Evaluation

In this section we present a mathematical study of network load balance and signaling overhead for proposed enhanced MIH and legacy MIH systems.

A. Load balancing in enhanced MIH architecture

This section presents the load balancing in our enhanced architecture when compared to the classical MIH system. Assuming there are n mobile nodes and m PoAs, the load on i^{th} PoA is L_i which is given as $L_i = L_{ie} + AR + OR$

where AR are association request messages from MNs to its target PoAs, L_{ie} is the existing load on PoA and OR is the additional message over head incurred due to rejection of handover from neighboring PoAs. In a scenario if there are k MNs having same QoS requirements and l accessing points with similar resource availability there is a possibility that more than one MN would request for resource from single PoA, hence in a worst case scenario the load on a i^{th} PoA would be $L_i = L_{ie} + \frac{k}{l}(AR) + OR + L_{is}$

where L_{is} is the additional load incurred in serving newly associated MN. Hence only l out of m PoAs are overloaded and remaining PoAs are not utilized but in case of the enhanced architecture a load variable ρ is introduced. Load variable ρ is measured in terms of number of MNs connected to a PoA. The load on i^{th} PoA is L_i which is given as

$L_i = L_{ie} + L_{is}$ if $\rho < \rho_{max}$

where ρ_{max} is the maximum number of MNs a PoA can handle at given time.

If load exceeds its threshold then the second best available PoA is reserved for the mobile node, in this way resources are better utilized and network load balance is achieved.

We present a scenario where three PoAs are present and six MNs with two MNs connected to each PoA. PoA1 has better RSSI value with respect to MNs where as PoA2 and PoA3 have lower delay.

In Figure 12 Y-axis shows the load distribution measured in terms of MNs attached to a particular PoA across three PoAs in classical MIH architecture where as X-axis represents number of MNs. Initially six MNs are present where as another set of six MNs added periodically, PoA1 load increases steeply as all the added MNs prefer PoA with a better RSSI value, PoA2 and PoA3 load remains constant as there are no new association requests. Hence the load in the network is not uniform.

In our proposed enhanced architecture PoAs are restricted to serve limited number of MNs with ρ_{max} set as eleven, so new requests are directed to the second best available PoA and MNs consider several other factors such as RSSI, available bandwidth, delay etc in selecting their PoAs.

In Figure 13 Y-axis shows the load distribution measured in terms of users attached to a particular PoA across three PoAs in our proposed architecture where as X-axis represents number of MNs. Initially six MNs are present where as another set of six MNs added periodically, PoA1 load increases gradually as half of the newly added MNs give higher weightage to RSSI value, it reaches the threshold value and remains constant. But in this case load on PoA2 and PoA3 also increases gradually as other half of the newly added MNs give higher weightage to PoAs having lower delay value. Hence the load in the network is uniformly distributed.

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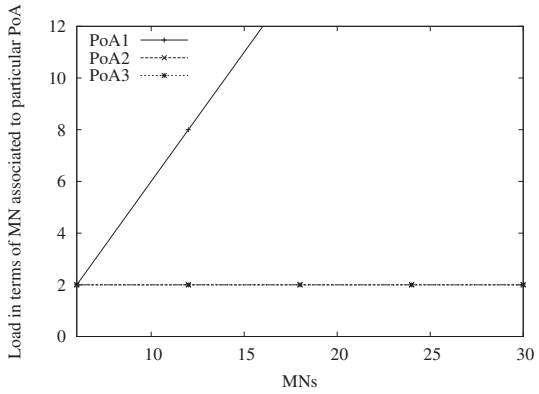


Figure 12. Load comparison of access points in conventional MIH.

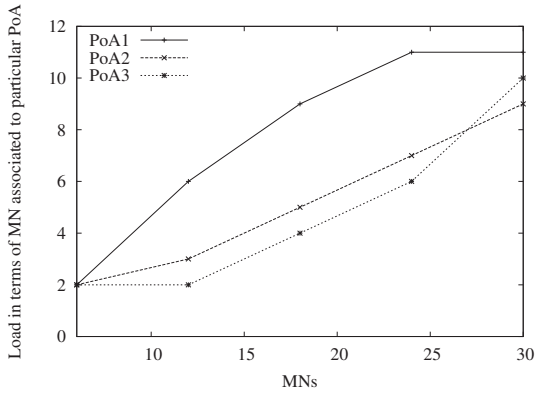


Figure 13. Load comparison of access points in enhanced MIH.

B. Signaling Overhead

Assuming n mobile nodes and m PoAs the number of state update messages of a i^{th} MN and j^{th} PoA in a classical MIH architecture is given below.

Handover initiation trigger is given as HI_i and handover completion message as OC_i. All MNs interchange these messages during execution of handover and completion, hence total number of messages exchanged is $MsgCount_{MN} = \sum_{i=1}^{i=n}(HI_i + OC_i)$

During the course of handover every PoA exchanges the handover initiation trigger with its neighbor PoA hence the total number of messages exchanged would be given as $MsgCount_{PoA} = (m-1)(\sum_{i=1}^{i=n} HI_i)$

Total Signaling overhead would be given as $MsgCount = \sum_{i=1}^{i=n} OC_i) + m(\sum_{i=1}^{i=n} HI_i)$

Assuming n mobile nodes m PoAs and K HAs. The number of state update messages of a i^{th} MN and j^{th} PoA in a enhanced MIH architecture is given as follows handover initiation trigger every update and completion is interchanged with HA the form of state update and it is is given as $MNStatus_i$. Hence total number of messages is $MsgCount_{MN} = \sum_{i=1}^{i=n} MNStatus_i$

Similar to MN the PoAs also exchange information with HA the form of state update given as $PoAStatus_i$. Total number of messages exchanged is $MsgCount_{PoA} = \sum_{j=1}^{i=m} PoAStatus_i$

Total signaling overhead is given as $MsgCount = \sum_{i=1}^{i=n} MNStatus_i + \sum_{j=1}^{i=m} PoAStatus_i$

In comparison $PoAStatus_i$ trigger is equivalent to HI_i trigger, since in our proposed MIH architecture the PoA status is requested before handover initiation trigger, which can be comparable to handover initiation trigger in classical MIH architecture. Hence signaling overhead is less than that of conventional MIH and it also depends on network selection algorithm as bad decision would still incur additional overhead of re-initiation of handover in conventional MIH architecture.

VI. Conclusion

In this paper, we have presented an enhanced MIH architecture, which is context aware and balances the network load. The network initiated handover reduces the processing, signaling and power consumption overhead compared to the mobile node initiated handover process. We have also given mathematical analysis of signaling over head and load balancing of enhanced frame work over the existing architecture. Future work would be proposing a better handover decision algorithm than SAW method and considering multiple MIH users feedback in order to initiate handover.

Acknowledgment

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