Asian Journal of Information Technology 15 (17): 3153-3170, 2016
ISSN: 1682-3915

A Survey of Vertical Handover Decision Algorithms for PMIPv6 Domain

[1]A. Prithiviraj, [2]K. Krishnamoorthy, [1]M. Usha and [3]A. Maheswari
[1]Sona College of Technology, Salem
[2]Sudharsan College of Engineering, Pudhukottai
[3]Dr. M.G.R Educational and Research Institute, Chennai, India

Abstract: In the current generation of heterogeneous wireless network environment, a glut of access networks has to be interconnected in a fine way to meet for all time the best connected concepts. Lately, Proxy Mobile IPv6 (PMIPv6) has been an IP network support mobility management protocol which does not occur any modification of Mobile Nodes (MN). During the process of handover several parameters are affected by this such as delay, packet loss, handover latency etc. There are various vertical handover decision making algorithms to recover this problem but still, it's a challenging one. In this study, we analyzed the operational doctrine of various handover decision algorithms and present an efficient comparison which aid us to know and to propose a new handover decision algorithm.

Key words: Heterogeneous, PMIPv6, QoS, mobility management protocol, handover decision, vertical

INTRODUCTION

In Heterogeneous wireless networks, maintaining a best QoS (Narayanan *et al*., 2014) and continuity of service among different networks is important (Kim and Choi, 2010a). NGWN's goal is to provide a ubiquitous environment of wireless access for mobile terminals equipped with multiple network interfaces. Handover is a procedure which offers the continuity of service without any interruptions (Radhika and Reddy, 2011). One of the main reasons for unnecessary handover is identifying the temporary coverage. Handover (Bhuvaneswari and Raj, 2012; Sharna *et al*., 2011) is processed either in horizontal or vertical. The data which are moved within the same network is referred to as horizontal handover (i.e., intra domain) whereas the data which are moved between various heterogeneous networks are known as vertical handover (i.e., inter domain) (Sharna *et al*., 2011). Two types of protocols are available in IPv6. They are host based and network based. Hierarchical and mobile protocols are the examples of host based protocols and they are involved at the IP layer. Proxy mobile IPv6 is the example of network based protocols. Host based protocols drives mobile node to execute the handover and do modifications in it. Whenever the MN (Mobile Node) moves from the home network to some other available network (Dong *et al*., 2010) the MIPv6 (Mobile IPv6) protocols require MN alterations during handover and boot the MN in order to fulfill the requirements of the mobile users (Kim *et al*., 2013). With the help of stateful or stateless configuration, the MN seeks to obtain an IPv6 (Rasem, 2011) address whenever it moves to a new network. MIPv6 has some drawbacks (Chandavarkar and Reddy, 2012) in managing seamless handover of MN's at the network layer which affects the overall performance. Seamless mobility (Vetrivelan and Narayanasamy, 2012) provides continuous and spontaneous experience for mobile users. HMIPv6 (Hierarchical Mobile IPv6) protocol is responsible to diminish the quantity of signaling and latency between the mobile node and its native agent. HMIPv6 is contrasting to MIPv6 (Muslam *et al*., 2010).

To solve IP mobility challenge (Kim and Choi, 2010b) network based mobility is another approach. In proxy mobile IPV6 protocol all the functionalities have to be based on networks and it does not involve mobile node for IP mobility operation. Handover will occur in network based on the network based protocol (Hussain *et al*., 2012), PMIPv6 and it utilizes the home network address inside that domain. PMIPv6 adds two logical entities (Gondim and Trineto, 2012) to the network to offer mobility support in order to retain inside the localized region. The mobile access gateway (Melia *et al*., 2011) handles all the signals from the MN related to its mobility and it works on the access router. The local mobility domain attaches different mobile access gateways. Mobile access gateways are accountable for trailing the mobile

Corresponding Author: A. Prithiviraj, Sona College of Technology, Salem, India

node's mobility (Magagula *et al*., 2010a). The mobile access gateway is responsible for authenticating the mobile nodes. It also initiates the mobility related signaling by itself. In the PMIPv6 domain, the local mobility anchor acts the same role as a home agent (Magagula *et al*., 2010b, c) as in mobile IPV6. Local mobility anchor accumulates all the informations that are needed for routing to attain the mobile nodes in the equivalent local mobility domain. PMIPV6 is obvious to mobile node (Pandey *et al*., 2013). Three main steps in a vertical handover process (Singhrova and Prakash, 2007, 2012) are:

- System discovery: mobile nodes are integrated with multiple interfaces which are used to determine active networks and the services
- Handover decision: mobile node (Anwar *et al*., 2013) determine which network it can be connected to
- Handover execution: connections are re routed in a seamless manner from existing network to the new network

MATERIALS AND METHODS

The adaptive data rate oriented vertical handoff algorithm: In his research Agarwal *et al*. (2014) proposed an adaptive multiple attribute vertical handoff algorithm by fuzzy logic concept and allows the wireless networks to select the mobile terminal. Here, the parameters like velocity, signal strength, network bandwidth utilization is considered to achieve the load balancing named as adaptive data rate adjustment. In heterogeneous networks, the user achieves the QoS and free moving experience. The algorithm determines the handoff, best access network selection, QoS requirements, user preference, service cost and mobile terminal conditions. The algorithm is divided into five parts namely:

- Velocity analysis
- Bandwidth analysis and adaptive data rate adjustment
- Fuzzy logic
- Handoff execution and decision making
- Performance evaluation

In Fig. 1, three types of networks are used, namely WLAN, WiMax and UMTS. The message signaling flow of adaptive multiple attribute vertical handoff algorithm is shown in Fig. 2.

The velocity and the link type are first checked by the mobile terminal whenever it receives the input information. Different networks have different coverage among that

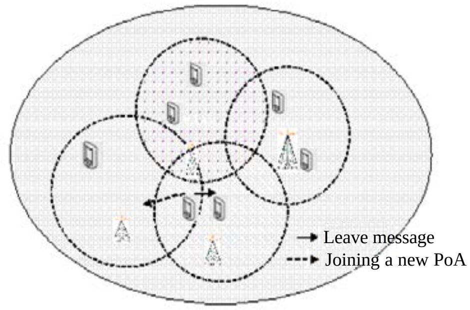

Fig. 1: Architecture diagram (Agarwal *et al*., 2014)

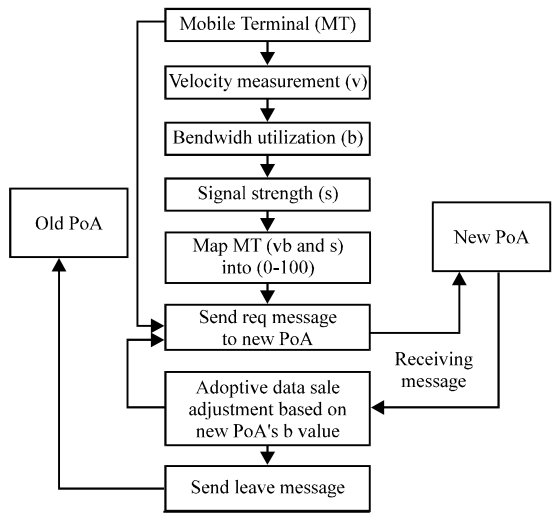

Fig. 2: Message flow (Agarwal *et al*., 2014)

the mobile terminal should select the proper network based on the speed. For each type of network three types of threshold values are defined. Coverage is directly proportional to the velocity threshold of network.

The bandwidth utilization and the link type are checked by the mobile terminal whenever it receives the input information. Different networks have different coverage so three threshold values for bandwidth are defined for a specific type of network. Here, the mobile terminal has to choose the proper network which suits its bandwidth. The network gets the threshold bandwidth utilization that is higher for the smaller coverage area. Bandwidth utilization is mapped from number ranging 1-100. If the new point of attachment is not suitable for the bandwidth utilization then the data rate is adjusted before by sending a request message to the new point of attachment.

Fuzzy control is the values between 0 and 1 are taken continuously in contrast to digital logic that operates on discrete values of either 0 or 1. The reasoning of fuzzy logic is approximate rather than fixed or exact value and transforming the information into fuzzy sets are necessary. Here, two parameters are considered, namely Received Signal Strength (RSS) and load balancing. The packets are received successfully if the RSS is stronger than the received power threshold, i.e., denoted by (Prx). The values of RSS are ranged as weak, medium and strong. Then the load conditions ranging 0-100 are determined by the Access Point (AP) as 0 denotes that any user is not using the link and 100 denotes that the link does not provide with any resource. Another important parameter is the user preference. Here when a user prefers a new link the user preference is mapped as high. In case if the user does not want to perform the handoff then the user preference is mapped as low.

The input sets are transformed into fuzzy sets in the handoff decision. The decision of handoff is taken on IF-THEN rules based on some times. Once, the handoff decision is made then the handoff execution has to be done. The Mobile Terminal (MT) sends a request to the new Point of Attachment (PoA) then the PoA reserves the resource and replies with an acknowledgement to the MT. When MT receives the acknowledgement, it establishes a new connection with the new link and while leaving the old link, it sends a message to the old PoA. So, the old PoA releases the resources and disconnects the link.

They have concluded that by including adaptive data rate adjustment on bandwidth utilization ensures better destination network than traditional RSS based handoff algorithm and the handoff efficiency is improved. It also, gives better performance and reduces the packet loss control and unnecessary handoff times. Their future work is to consider the mobility direction of the MT during the handoff decision.

An intelligent vertical handover decision algorithm for wireless heterogeneous networks: In the research Narayanan *et al*. (2014) proposed a decision algorithm to reduce unnecessary handover by combining fuzzy logic system, multiple attribute decision making and context aware strategies. Here, the intelligent decision algorithm is performed before the handover by detecting the network which offers the best connectivity then authentication is performed and mobile IP registration is done. In this algorithm, the packet loss is reduced, ensures high quality of service, maximizes battery life time and load balancing is maintained. The integration of cellular network with WLAN using the proposed intelligent decision algorithm reduces the call dropping rate.

Handover decision algorithm: The vertical handover algorithm is based on mobile controlled because the mobile only has the knowledge about the unplanned

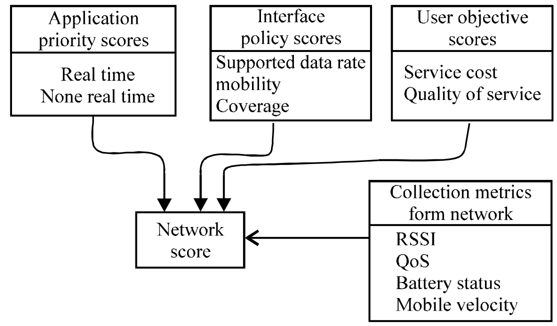

Fig. 3: Handover information gathering (Narayanan *et al*., 2014)

Wi-Fi networks. The mobile devices have limited resources due to that the decision algorithm should be easily computable, energy efficient, processing time should be less and also for intelligent decision it should have the capability of making decision on multiple attributes. The multiple attributes include the scores like application priority, interface policy and user objectives. The characteristics of the current network like RSSI, QoS parameters, battery status and mobile velocity are collected while the handover decision is based on context aware scheme. The predefined weights are assigned to those collected metrics and passed to the fuzzy based multiple attribute decision making scheme. The values which are collected from different networks are analog values then, it is normalized to a common scale and passed to the fuzzy logic system. But, the fuzzy logic system cannot process the analog values so it the values are converted to linguistic values. To get the fuzzy sets based membership functions the mobile node input parameters are fed into fuzzifier, transforms them to convert into linguistic values and those values are fed into the fuzzy inference engine. To obtain the fuzzy decision sets a set of fuzzy IF-THEN rules are applied and the fuzzy output decision sets are strongly yes, yes, uncertain, no and strongly no. Then those output fuzzy decision sets are combined into a fuzzy single set and passed onto the defuzzifier to convert it into handover decision metric value. The handover decision is made based on those values. According to the appropriate time, network and user preference the Fuzzy based strategy handover decision is performed. The various information gathered during handover is shown in Fig. 3.

Handover execution: In the Handover decision phase the best suited network is selected and the handover is executed in the handover execution phase. Here, the make before break handover is made; authentication and mobile IP registration is done. The decision algorithm

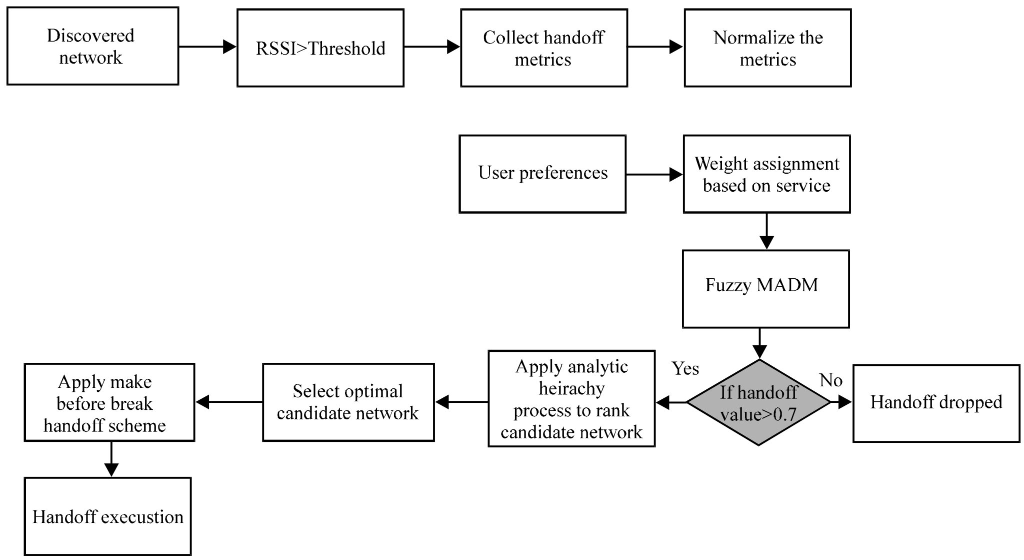

Fig. 4: Working flow of intelligent vertical handover decision algorithm (Narayanan *et al.*, 2014)

routes the traffic to the selected network interface when it becomes active with minimum packet loss.

Working flow of the algorithm: Figure 4 shows the flow diagram of the intelligent vertical handover algorithm:

- In handover discovery phase to identify the new network, the network discovery is done periodically and identifies the network with good RSSI and quality
- Then it gathers all the handover metrics if it satisfies the threshold value. By gathering values from different network the metrics have different scales and has to be normalized to a common scale
- In decision criteria the user preference and all the attributes are assigned with preferred weights are taken
- The normalized parameters with preferred weight are fed into fuzzy logic systems and multiple attribute decision making scheme
- The best network interface will be activated based on the candidate network scores.

Performance evaluation of enhanced velocity-based handoff algorithm for VANET: In this study, Emami *et al.* (2014) proposed an "enhanced velocity-based handoff algorithm for VANET" and the performance is evaluated. The transmission of packets is affected when the vehicle is moving from one base station to another so to minimize the disruption the handover latency should be kept for minimum duration. In this Enhanced Velocity Handoff

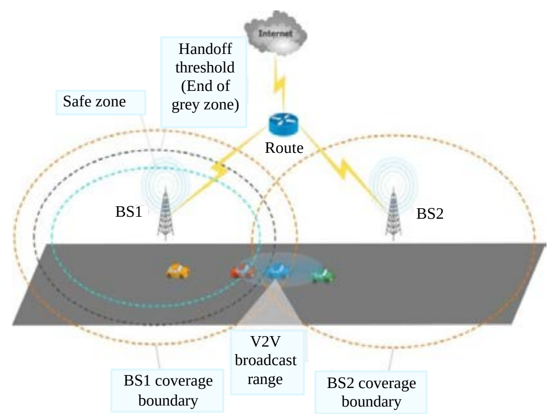

Fig. 5: EVHO Mechanism in Vehicular Networks (Emami *et al.*, 2014)

(EVHO) algorithm two rules of mobility models called vehicle speed and handoff latency are defined and those rules provides different equations and transforms them into EVHO algorithm. In this EVHO algorithm, a new packet frame is created for neighboring vehicles for transmission. The parameters used in this algorithm are packet delay, packet loss and throughput.

Enhanced Velocity-based Handoff algorithm (EVHO): The EVHA algorithm is depicted with the scenario in Fig. 5. In the scenario (Emami *et al.* 2014), the cars at the overlapping coverage region have reached the handoff threshold and the handoff is performed to the new Base Station (BS). Based on the Received Signal Strength (RSS) the total coverage area of the BS is divided into three zones. The yellow vehicle is at the safe zone and handoff is not required. In the grey zone area the handoff is high and when the red vehicle enters into the grey zone, it starts accepting the BS broadcast messages from the blue vehicle. While the blue vehicle is handoff from BS1 to BS2, the base station 2 id and channel information is broadcasted to the neighboring vehicles. So, now the red and green vehicles receive the broadcast messages from the blue vehicle. The red vehicle updates the BS table with BS2 ID and channel information. The green vehicle remains in the same based station so it discards the message.

An analytical model and algorithm for velocity-based handoff is used in VANET handoff computation by two rules called vehicle spends Time in wireless coverage and handoff latency. In figure given below a router is connected with two nodes and two base stations BS1 and BS2.

The nodes are considered as vehicle 1 and 2. When the vehicle 1 is moving from BS1 to BS2, handoff is performed due the received signal strength is getting weaker than the threshold value.

When the RSSI<RSSI_Threshold, the active scanning is performed to find the next BS for handoff. At this point if the BS is known by the vehicle_2 then the active scanning can be avoided and re-authentication process is restarted with the next BS. The vehicle_1 has already performed the handoff and has the information of the next BS.

When both the vehicles are in a close range to each other then the vehicle_1 which has the information like BSSID and the transmitting channel can broadcast all the information to the neighboring vehicles. In this way when Vehicle_1 reaches handoff threshold, it has the information about its next point of connection. When authentication is requested, instead of broadcasting information to each channel to find the best BS a packet is unicasted on the channel with next BSSID. If the authentication performed was successful then the scanning phase can be avoided and the overall handoff time can be reduced. If the authentication performed was not successful then the normal scanning has to be done to find the next BS. To broadcast the BS address a new packet frame is created for the front vehicle and it must contain the same information of the BSSID, channel and supported data rate similar to the beacon frame. By using this packet broadcast overhead is caused and to limit it an additional attribute called Time To-Live (TTL) is needed. In related to velocity-based handoff, three algorithms are used namely enhanced velocity-based handoff, base station update and broadcast. Figure 6 shows the process of enhanced velocity-based handover.

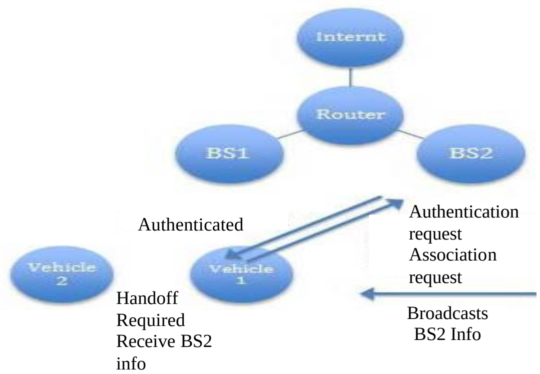

Fig. 6: Schematic View of Enhanced Velocity-Based Handoff Process (Emami *et al*., 2014)

Dynamic load balancing scheme based on access selection and calls transfer in heterogeneous wireless networks: Zhu proposed a dynamic load balance scheme based on access selection and calls transfer in heterogeneous wireless networks. To optimize the access selection problem, all the base stations were assigned with the access calls evenly. A call transfer strategy based on the threshold of the base station load rate was given for load balancing. They have concluded that access blocking rate, calls dropping rate, load balance and system utilization rate are improved.

In access selection mechanism to minimize the load factor and achieve the load balancing between the base stations the optimization of the network performance takes each base stations load rate as a target. The process of access selection is designed here as follows: First the timer is reset and counting is started. The multi mode terminal MTj sends the access request to the cell's base station BSi where the request contains calls demanding for the bandwidth whenever new calls reaches the multi mode terminal Mtj. Then, the Base Station BSi forwards the received access request to the access router. When the access router receives the access request it gains optimal access scheme by:

$$\sum_{i=1}^{m} x_{ij} \le 1, j(x+a)^n = (1 \le j \le n) \text{and} \min_{1 \le i \le m} \left(\frac{\max \eta_i}{\max \eta_i} \right)$$

Based on the formula the optimal access scheme is obtained by this scheme the access router notifies a base station BSi is responsible to access the calls by broadcasting. The BSi assigns the multi mode terminal with appropriate bandwidth to access calls when it receives the broadcast information. Once, the timer is expired, the current loads with assigned bandwidth information are sent to the access router by all the base stations then, the timer is reset and starts the counting otherwise the multi mode terminal MTj sends the access request to the cell's base station BSi where the request contains calls demands for the bandwidth whenever new calls reaches the multi mode terminal MTj.

To ensure until the transferred non-real-time calls don't lead to the base station cell becomes from light-load state to overloaded state, a pre-judgment operation is made during calls transfer. The calls transfer process is designed as follows:

The timer is set to reset and the timing is started. The information of each base station cell is collected by the access router and the load state of each base station cells is computed. According to the load rate, the base station is arranged in the light load state for the L1 queue by the access router ascendant and the base station is arranged in the overloaded state for the L2 queue by the access router reducibly If the L1 queue is empty, the process ends or else the head BS11 is taken from the overloaded base station queue and head BS21 is taken from the light load base station queue. From the base station BS11 the most consumed bandwidth MT11 calls are selected. The calls transfer operation is executed and BS21 remains light load state if the MT11 calls are transferred from the base station BS11 to BS21 and BS21 is moved to the queue of L2's tail. Transfer the call is executed and BS21 is in an equilibrium state when the MT11 calls are transferred from the base station BS11 to BS21 and BS21 is removed from the queue L2. Then, the head station BS11 is deleted from the L1 Queue. If the scheduling cycle timer times out, then the timer is reset and starts the timing again or else the base stations are arranged according to the load rate. The process is ended.

Extended seamless proxy-based handoff scheme: Seamless Proxy-based Handoff (SePH) is proposed (Cho *et al*., 2013) as an extension of proxy-based PMIPv6 handover technique. The primary goal of SePH is to lessen the service disruption from the beginning of the handover by achieving the task of proxy. By reducing the search process, the SePH supports seamless and IP-based mobility more efficiently. The IHDA (Integrated Handoff Decision Algorithm) enables the Assurance mapping which is needed to interpret specifications provided for the session on a heterogeneous wireless network and QoS which is shown in Fig. 7. This scheme reduces the packet loss, handover latency and signaling overhead and increases the throughput. The following procedure states the Seamless Proxy-based Handoff (SePH) scheme. When MN enters into PMIPv6 network for the first time, the MAG1 receives the information of MN's identity, gets the address of LMA and then the MN is assigned a network prefix. Then, the MN receives the RA (Router Advertisement) message from MAG1 and it group its own IP address with the information obtained from the MAG1. MAG1 receives the information from the server, creates a PBU message (Proxy Binding Update) and forwards it to the LMA. By receiving the PBU message from MAG1, LMA matches the information with its BCE (Binding Cache Entry). It adds the MN's information to the storage space if the information does not match. With the help of address information of MAG1, a tunnel is established between MAG1 and LMA.

When the MN moves to MAG2, MAG2 obtains the MN information from the policies storage. Then the MN information is advertised to the MN by the same network prefix and it is distributed in the same network. If the network prefix is same, the mobile node assumes that it is connected to the same network.

By using the information of the MN obtained from the server, a PBU message is created by MAG2 and transmitted to LMA. By receiving the PBU message, LMA trusts that the mobile node has moved to a new network with the help of the mobile node's ID and MAG2's address information. Then the previously established tunnel is removed between the LMA and MAG1 and a new tunnel is established between MAG2 and LMA. Then the further transmitting messages delivered to LMA are routed in this way.

Operation procedures: The SePH process as shown in Fig. 8, performs the search on the AR and network based messages among the IHDA and the moving agents, the use of radio resources limited to minimal for providing the session tunneling with the help of the MN patterns and the session mobility to provide fast mobility and secured transmission.

To reduce the service interruption, restarting the signaling is avoided by the SePH. The HDreq (handoff decision request) message is sent by the MN is based on the AT (Anticipated Trigger) generation. On behalf of MN, the AEN executes the Binding Update procedure. The Binding Update (BU) procedure is done by the AEN on behalf of the MN. The information which is copied to the cache of AR/AEN is periodically updated based on the MN's earliest BU list.

Average signaling cost of BU:

$$C_{BU} = E(N_l)C^l + E(N_d)nC^g = \frac{1}{SRM\sqrt{m}}\left[C^g + \left(\sqrt{m-1}\right)C^l\right]$$

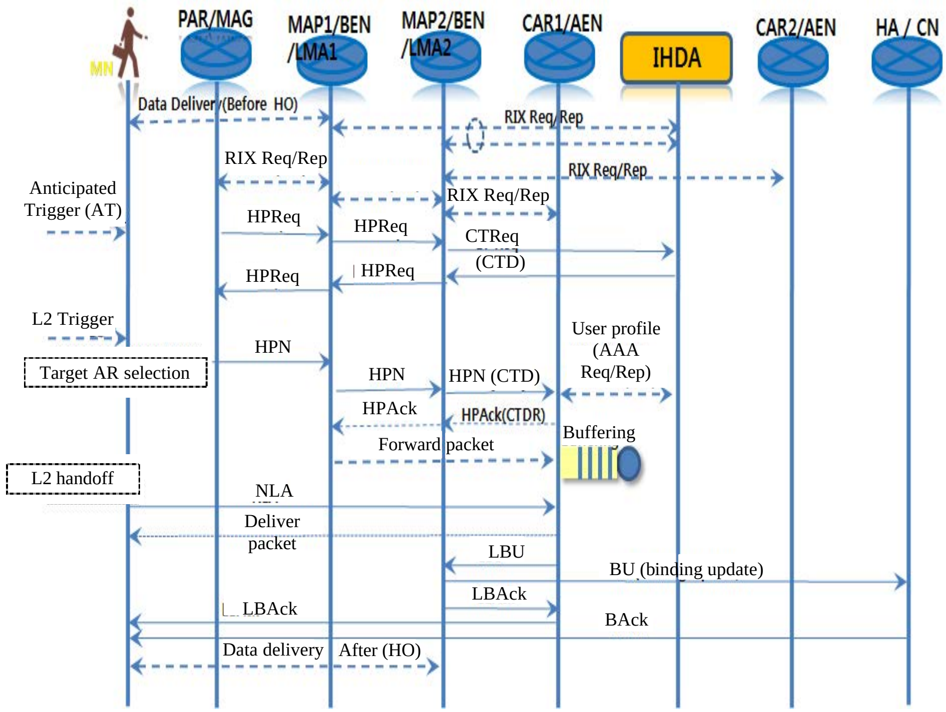

Fig. 7: Message signaling flow (Cho *et al*., 2013)

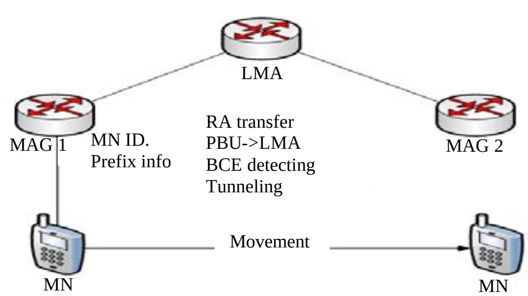

Fig. 8: Process of SePH (Cho *et al*., 2013)

Session mobility ratio:

$$\text{SMR} = \frac{\lambda_s}{\mu_c}$$

Costs of local/global BU signaling at SePH:

$$C^g = P_s S_s^g + (1-P_s)\left(S_f^g + S_r^g\right) + C_{ru}$$

$$C_l = P_s S_s^l + (1-P_s)\left(S_f^l + S_r^l\right) + C_{mu}$$

Average handoff delay of seamless proxy-based handoff for MAP/BEN/LMA roaming:

$$D^l_{HPAHN} = t_{L2} + 2t_{MN-AEN} \; D^l_{HPAHN} = t_{L2} + 2t_{MN,AEN} + 2t_{AEN,BEN}$$

For inter-MAP/BEN:

$$N^g_{HPAHN} = T_{L2} + 2t_{MN,AEN} + 2\left[t_{AEN,ben} + t_n^{BEN}, P^{BEN}\right]$$

Enhanced FPMIPv6 handover: The enhanced FPMIPv6 technique (Chung *et al*., 2013) is proposed to reduce the packet-delay that occurs during handover in PMIPv6. In FPMIPv6, experiments were conducted for vertical handoff between Long Term Evolution (LTE) to other heterogeneous wireless networks over Evolved Packet Core (EPC). Due to the limitations in FPMIPv6, it was identified that reliable seamless VHO operations were difficult in FPMIPv6. When the Target Node (TN) is in a heterogeneous protocol domain, the Serving Network (SN) has information lacking of the TN and resulted in VHO performance degradation.

The VHO performance is also degraded by the packet loss and congestion problems that occurs in specific network gateway interfaces and also by using long packet-forwarding paths. Here, handover is done in predictive and reactive procedures that are shown in Fig. 9.

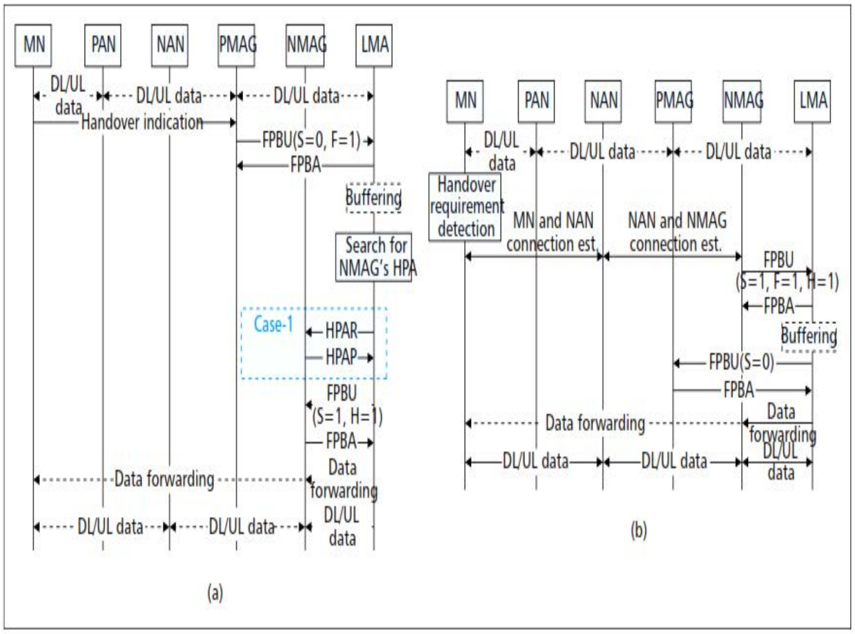

Fig. 9: Enhanced FPMIPv6 HO procedure a) Predictive; b) Reactive (Chung *et al*., 2013)

Some additional messages that are used in enhanced FPMIPv6 are: HO Packet forwarding Address Request (HPAR) message-if LMA does not have the target NMAG's HPA in its database then this HPAR message is used to request the HO packet forwarding address of the NMAG in predictive handover. HO Packet forwarding Address Response (HPAP) message-HPAP message is used to response the HPAR message. Fast Proxy Binding Update (FPBU) message-For Fast connection establishment between MAG and LMA FPBU message is used. Fast Proxy Binding Acknowledgement (FPBU) message-FPBA message is used to provide acknowledgement for FPBU message.

Predictive handover procedure: If the handover is detected by the Mobile Node (MN), an HO Indication message is sent to the previous MAG (PMAG) through a Previous Access Node (PAN). By receiving the HO indication message, PMAG sends a FPBU message (with Flag s =0) to LMA i.e., the request to release the connection between LMA and itself. Buffering of data packet is initiated by LMA and it searches the NMAG's HPA in its database. [IF case-1-if LMA doesn't have the NMAG's HPA, it sends a HPAR request message to NMAG for HPA. Then, the NMAG responds to LMA with HPAP message by including NMAG's HPA. By receiving the NMAG's HPA to establish the connection the LMA sends a FPBU message (by setting Flag s = 1) to NMAG. If NMAG's HPA is available with LMA then case-1 steps are skipped and the LMA sends a connection establishment message FPBU (with Flag S = 1) to NMAG. The connection establishment procedures are executed simultaneously between the MN and NMAG and between the NMAG and LMA.

TN data path switching is not done immediately to avoid the data interruption between the buffered and newly arrived packets. When all the connections are established, the buffered data packets during HO procedure are forwarded to MN by the LMA. When LMA forwarded all the buffered data packets to the MN then the further IP packets are directly forwarded to MN when the data path is switched towards the TN.

Reactive handover procedure: The MN executes network re-entry with the NAN and the NMAG when there is an HO requirement and then the HO procedures are initiated by the NMAG in advance. Once, the network re-entry procedures are over, the NMAG sends a FPBU message, including the NMAG's HPA (with Flag s = 1). The LMA releases the connection from the previous network by sending the FPBU message (with Flag s = 0) and also initiates the data packet buffering When LMA completes the buffered packets, forwarding to the MN, data-path switching towards TN is conducted to avoid the data interruption between the buffered and newly arriving packets.

Performance of enhanced FPMIPv6 handover: Handover signalling delay for enhanced FPMIPv6 in Predictive mode:

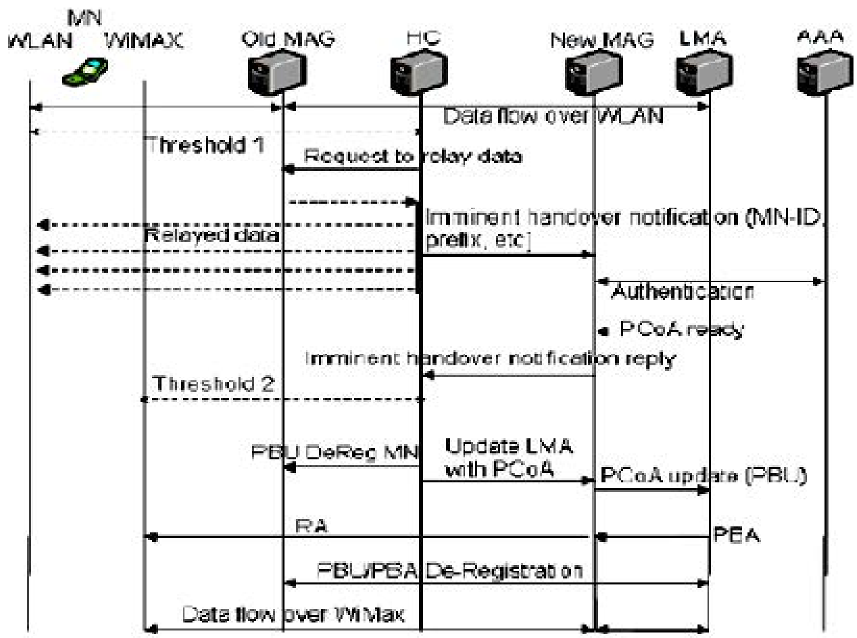

Fig. 10: Signaling call flow of PMIPv6-HC (Magagula *et al*., 2010a-c)

$$T_{E-HO,\,pre} = T_{h.ind} + 2T_{FPBU} + 2T_{FPBA} + T_{conn} + (T_{HPAR} + T_{HPAP})$$

Data forwarding delay for enhanced FPMIPv6 in Predictive mode:

$$T_{E-DF,pre} = 2T_{df} + T_{LMA-MAG} + T_{MAG-MN}$$

Handover signalling delay for enhanced FPMIPv6 in reactive mode:

$$T_{E-HO,\,rea} = T_{conn} + 2T_{FPBU} + 2T_{FPBA}$$

Data forwarding delay for enhanced FPMIPv6 in reactive mode:

$$T_{E-DF,\,rea} = 2T_{df} + T_{LMA-MAG} + T_{MAG-MN}$$

Total time delay of the enhanced FPMIPv6 handover procedure:

$$T_{E-FPMIPU6,x} = T_{E-HO,x} + T_{E-DF,x}$$

Where x = pre or x = rea that representing predictive or reactive mode

Pmipv6-HC in NGWN: The Handover Coordinator (HC) is further optimized to improve the handover performance among the heterogeneous wireless networks (Magagula *et al*., 2010a-c). The handover procedures are co-ordinated dynamically among the heterogeneous wireless networks which further enhances the performance of the handover. Signaling call flow of PMIPv6-HC is shown in Fig. 10. The configuration of the handover coordinator and the LMA are done in the domain gateway router and the HC is interoperable with the LMA functionalities. When the mobile host enters into the overlapped region of the foreign network, the handover coordination takes place by triggering the handover coordinator. The functional operations of the HC are shown in Fig. 11.

Operation procedures: When the Mobile Node (MN) entered into the overlapped region, MAG1 detects the Link_Going_Down while the signal strength falls below the threshold. Here, the multi interface MN came to know that the signal will be lost soon so it informs the user interface to find other foreign access network available to perform handover. The HC reacts as an ODE (Observer and Decision Engine) receives a handover trigger message from the MAG1 which alerts about the forthcoming MN detachment. The handover trigger message carries the ID of the candidate MAG for which the MN likes to attach. By periodical advertisements, the MN receives the ID while it traverses the overlapping area of different networks. The responsibilities of the HC are to receive the message from the MAG1, triggering the

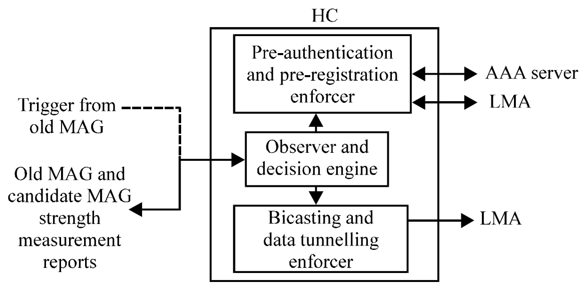

Fig. 11: The functional operations of HC's handover coordination (Magagula *et al*., 2010a-c)

coordination of the applicable network elements to initiate and to prepare the handover operations and performs the respective handover procedures. Pre-authentication is done for the MN in the newly attached network with the AAA servers by the Pre-authentication and Pre-registration Enforcer (PPE) with the help of the instructions given by the ODE. On behalf of the MAG2, the HC(PPE) can able to create a valid PBU message which is sent to the LMA in advance before the MN connection with MAG1 is terminated, because the HC has already received the MN and MAG2 ID's via the handover trigger from the MAG1.

The multi-interface MN can use the ID when it attaches to the new network which is specified in the PBU message. The MN (new interface ID) is registered by the LMA in its binding cache and there is a tunnel establishment between the LMA and MAG2. Now the MAG2 has MN's new proxy care of address. When MAG1 realizes the signal strength is going down to the MN, the ODE sends a notification to the HC (Bicasting and Data Tunnelling Enforcer) and HC (BTE) tunnels the packets towards the MH or it requests the LMA to bicast the subsequent packets to old MAG (MAG1) and new MAG (MAG2).

Based on the strongest signal strength in the overlapping region, the packets will be routed to the MN by bicasting or tunneling through any one of the MAGs. Through, the updation of PBU periodically the HC's ODE is monitored by the MAG1. So as long as the MN was in the overlapped area, the MAGs and the LMA exchanges the updated PBU messages between them. The HC gets aware when the MAG1 detects the Link_down event or MAG2 detects a Link_up event in the overlapping area and informs the LMA to stop bicasting the packets and transmit the subsequent packets to the MN only through the new MAG (MAG2) with the newly formed tunnel.

IEEE 802.21 assisted PMIPv6: IEEE 802.21 assisted PMIPv6 mechanism (Kim *et al*., 2013) is introduced to minimize the handoff delay and signaling cost among heterogeneous wireless networks. The handover process is shown in Fig. 12. The Mobile Node (MN) vertical handover is supported by the mechanism without the MN participation during handover in any Media Independent Handover (MIH) related signaling. Here, the MIH functionality enabled base station will perform the handover instead of MN. This scheme minimizes the MN's power consumption with narrow resource and battery power. To enhance the user's experience of mobile devices, MIH function provides unified interface and supports handover among heterogeneous networks. The service continuity, service adaption, battery consumption, network discovery and selection of links are maintained by the MIH function. In this mechanism, a wireless base station, enabled with MIH functionality (MIH-BS) is introduced. The basic idea of this mechanism is, the MIH related signaling will be managed by the MIH-BS in lieu of the mobile node that is attached to its L2.

Operation procedures

Acquiring information about adjacent networks: When the MIH-BS's signal strength becomes more weak, the mobile node senses it and decides L2 handover. A handover trigger is sent to MIH-BS which was produced by the MN's L2. The current PoS which was located on the current access router receives MIH_Link_Going_Down_Indication sent by the current MIH-BS. The MIIS (Media Independent Information Service) server is queried by the serving PoS to which the MN attached may handover by retrieving the available adjacent network information. By exchanging the MIH_Get_Information_Request and MIH_Get_Information_Response messages the MIIS gathers the information about the neighbouring networks, the MN performs handover.

Handover target determination: The handover is triggered by the serving MIH-BS by transmitting a MIH_Net_HO_Candidate_Query_Request message to the serving PoS. At candidate networks, the resource availability query is done by the serving PoS by sending the MIH_N2N_HO_Query_Resource_Request message to more than one candidate PoSs to provide QoS. The serving PoS receives the MIH_N2N_HO_Query_Resource_Response message as a response by the candidate PoS. Based on the MIH_N2N_HO_Query_Resource_Response message received by the serving PoS, the available resources information is known. Then it identifies the new MAG (nMAG) and the target network to perform handover. Once, the target network is determined, it is informed to

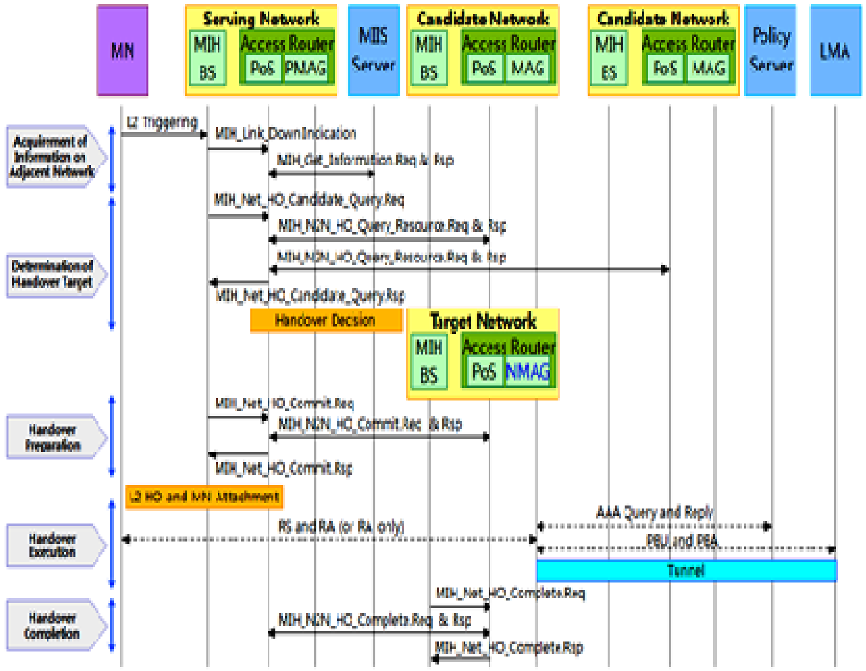

Fig. 12: IEEE 802.21 assisted PMIPv6 (Kim *et al*., 2013)

the serving MIH-BS by sending a MIH_ Net_HO_Candidate_Query_Response message from the serving PoS.

Handover preparation: A MIH_Net_ HO_Commit_ Request message is sent to serving PoS in the serving network for a handover commitment by the serving MIH-BS. With the help of the MIH_N2N_HO_Commit_Request message, the MN is connected to the nMAG after moving to the new network and it is informed to the target PoS about MN's mobility by the serving PoS. A MIH_N2N_HO_Commit_Response message is sent as response to the serving PoS by the target PoS. The serving MIH-BS is informed about the handover commitment by receiving a MIH_Net_HO_ Commit_Response message from the serving PoS. The profile information of the MN is replied from the AAA server as a response to the query by the target networks nMAG when it receives the MIH_N2N_HO_Commit_ Request message. For the processes of PMIPv6, the profile information is obtained by the nMAG related to the MN.

Handover execution: After the L2 connection establishment from the MN to the target networks MIH-BS, the MN's attachment is detected by the nMAG. Then a Router Advertisement (RA) message is sent to the MN by the nMAG. Based on the MN's profile information, the RA message is created. Then the MN sends a Router Solicitation message to the nMAG in periodic transmission.

The IP addresses are configured by the MN based on the RA message received from nMAG for connection establishment between them. Then a Proxy Binding Update (PBU) message is sent by the nMAG for registering the current location of the MN to LMA. The nMAG in the target network sends a Proxy Binding Update (PBU) message and registers the current location of the MN to LMA.

After receiving the PBU message LMA replies with a Proxy Binding Acknowledgement (PBA) and updates the MN's entry to its Binding Cache Entry (BCE). Then the buffered data are transmitted all the way through the tunnel from the LMA to nMAG. Now, the packets are routed to the MN from both the LMA and nMAG.

Handover termination: The handover procedure is completed by sending a MIH_Net_HO_Complete_ Request message from the target MIH-BS to target PoS. Both the PoS in the target network and the serving network exchanges the MIH_N2N_HO_Complete_ Request and MIH_N2N_HO_Complete_Response messages between them. The handover procedure will be terminated when the target MIH-BS receives the MIH_Net_HO_ Complete_Response message from the target PoS.

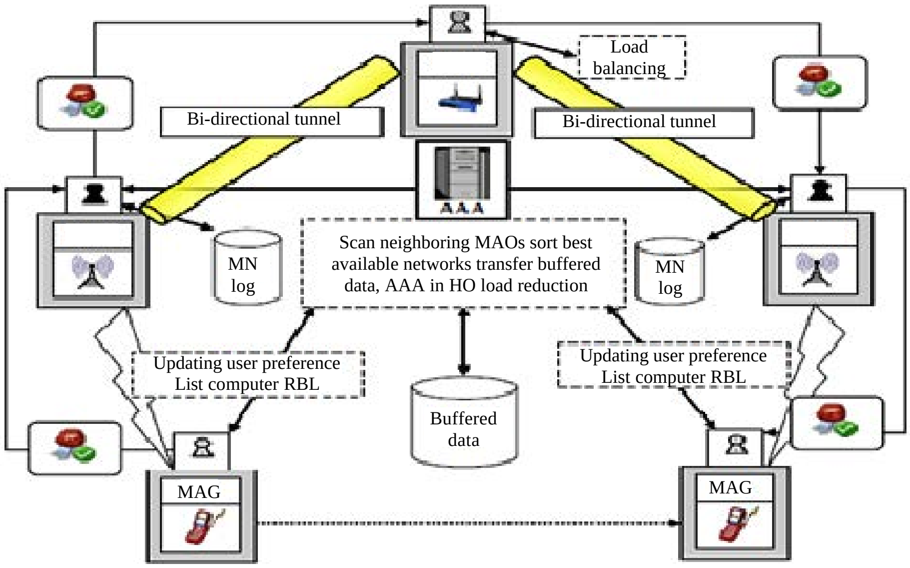

Fig. 13: Intelligent Agent Framework for PMIPv6 (Kailash, 2012)

Handover Latency for IEEE 802.21 assisted PMIPv6 is calculated by:
Handover latency

IAF-PMIPv6-An intelligent agent framework for proxy mobile IPv6: A new IAF-PMIPv6 framework is proposed (Kailash, 2012) for improving the PMIPv6 Performance. In different levels of PMIPv6 domain, Intelligent Agents were deployed such as and. The architecture of IAF-PMIPv6 is shown in Fig. 13. To select a best Network during Handover process these agents are collectively used to reduce packet loss and balance the Load. In PMIPv6 domain, these agents are deployed at MN, MAG and LMA.

The step by step handover processes are as follows the maintains the user preference list at the initial stage based on the message received from which can be updated periodically. If the MN attaches to the corresponding MAG, sends the Proxy Binding Update (PBU) message to its and starts buffering the packets and also maintain for future interaction. In order to select the best available network roams to its neighboring based on the factors such as cost of service, signal strength, Network traffic and data transfer rates. Transfer MN preference list to for updation and also, computes the Remaining Battery Life (RBF) for shifting a device to less power consumption.

When number of Mobile Node (MN) is attached to MAG, MAG gets overloaded and causes end to end transmission delay. So in order to overcome that plays a role to reduce a Load of each MAG by comparing a Threshold value of each MAG. Traditional PMIPv6 is represented as Where LS = Link Switching, AAA = Authentication, Authorization and Accounting, REG = Registration and RS-RA = Router Solicitation and Router Advertisement. IAF-PMIPv6 is represented as

Pmipv6 with handover coordinator: PMIPv6-HC, a network based entity (Magagula *et al*., 2010c) organizes the handover actions on behalf of the mobile node by conversing with both the MAGs (e.g., MAG1 and MAG2) when the mobile node entering into the overlap region, is shown in Fig 14. Without incurring extra signaling overhead, the delay occurred during handover and packet loss can be reduced. The HC is an additional standalone network entity runs along with the mobility management protocol PMIPv6 to improve the handover performance further.

Operation procedures: When MN attaches to MAG1, the data packets from Corresponding Node (CN) flow to MN. When the mobile node moves away from MAG1 and entering into an overlap region, it observes the Link_Going_Down event with esteem to signal strength from MAG1 and realize that the handover is imminent. A handover triggering signal is generated by MN which is send to HC through the currently attached network and the HC obtains the signal from MN through MAG1 and request the MAG1 to send the packets to MN through HC.

HC establishes an IP tunnel between the MN and corresponding interfaces and MAG1 forwards the packet

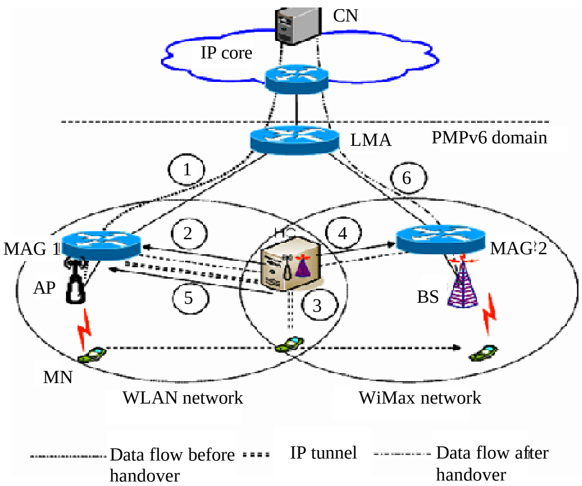

Fig. 14: Architectural Framework of PMIPv6 –HC (Magagula *et al*., 2010a-c)

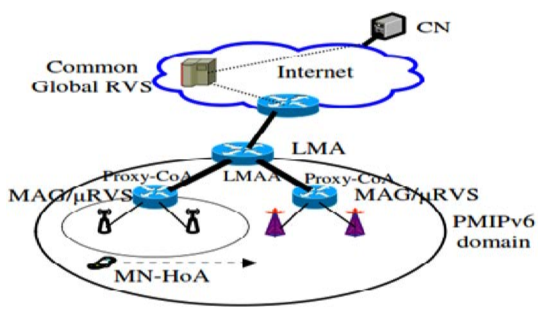

Fig. 15: HIPPMIP architectural framework (Muslam *et al*., 2010)

to MN via the HC through tunnel. When the received data packets in overlaps region are decapsulated by the MN, it realizes that the packets are received with the help of HC.

Imminent notification attachment signal message is generated by HC which is send to MAG2 where MAG2 receives the notification message to verify the MN's Identity (ID) and associates proxy care-of-address with the MN. After the MN entered into the overlap region the proxy care-of-address is updated in the LMA and then MN starts to perform deregistration from MAG1. Proxy Binding Registration is exchanged between the MN and MAG2 by informing that HC is ready for MN attachment. Once the MN is attached to MAG2, HC transmits a notification message quickly to MAG1 to deregister the MN and then the flow of packets will be redirected from LMA to MAG2 where the data packets are delivered to MN from MAG2. Handover Delay Performance in basic PMIPv6 is calculated by:

$$D_{PMIPU6} = D_{Attach} + D_{Auth} + D_{Auth\,2} + D_{Binding} + D_{RA}$$

IEEE 802.21 assisted PMIPv6 Handover Delay Performance is calculated by:

$$D_{PMIPU6} = D_{Binding} + D_{RA}$$
$$i = \left[(T+1)\log_b\left[\alpha(b-1)+1\right]\right]$$

Hybrid HIP and PMIPv6 (HIPPMIP) mobility management for handover performance optimization: In this study Muslam *et al*. (2010) proposed a mobility management scheme called HIPPMIP by integrating the PMIPv6 and HIP to manage the mobility securely with improving handover delay in a localized heterogeneous or homogeneous environment. HIPPMIP is an effective handover optimization scheme. Figure 15 shows the HIPPMIP architectural framework. The algorithm for the HIPPMIP scheme for registration is given as.

Algorithm:

The MAG detects the Mobile node attachment event through the MIH services and a PBU message is sent the LMA on behalf of the mobile node when the mobile node enters into the PMPv6 domain.

During the mobile node attachment event, the collocated μRVS obtains the mobile nodes HIT and this HIT is sent as a mobile node's identifier in the PBU message.

The LMA replies with the acknowledgement message PBA with the home network prefix to the MAG.

The mobile node's home network prefix is copied and sent to the mobile node as Router Advertisement (RA) message by the MAG.

The HNP which is sent by the MAG is stable throughout the PMIPv6 domain is configured by the mobile node.

The μRVS has the mobile node's HIT (s) and IP address when the mobile node alerts the μRVS

Now the mobile node is informed by the μRVS of its proxy care-of-address and proxy care-of-address of MAG.

Then on behalf of the mobile node, μRVS registers the mobile node's HIT (s) and mobile node's HOA (s) to a common global RVS.

In PMIPv6 domain when the MN performs a handover between PoAs then localized location update has to be done in the LMA. In HIPPMIP there is no need to update the mobile node's parameters at the common global RVS and respective CNs since the mobile node's home of address and identifier are stable as long as the mobile node roams within the same PMIPv6 domain. So, there is no exchange of HIP update locator packets and the problems signaling overhead and handover delay are reduced.

RESULTS AND DISCUSSION

The performance of the handover execution relies on various parameters such as network cost, network bandwidth, power consumption, throughput, received signal strength, handover latency, packet loss, handover delay, etc. A vertical handover decision algorithm may give a better handover performance if several parameters were considered but the decision time and the complexity of the algorithm will be a trade-off. In this survey, we have overviewed few parameters that are considered for various decision algorithms.

Throughput: Throughput is the measure of the average data rate that is transmitted to the mobile nodes over a communication path in a network. Handover to network usually prefers higher throughput. The comparison of throughput for Enhanced velocity based handoff algorithm for VANET and Analytical Approach is shown in Fig. 16.

Received signal strength: Received Signal Strength (RSS) should be good to maintain a quality of service between two stations in a network. It should not below the certain threshold value of networking. The handover initiation process depends on the measure of received signal strength obtained.

Load balancing: Distributing the work across multiple resources like computers network links. The system load is balanced with the resource allocated by providing the resources to the users where most of them are located. Load balancing aims to direct the traffic where the resources are unused. The results obtained for load balancing is shown in Fig. 17.

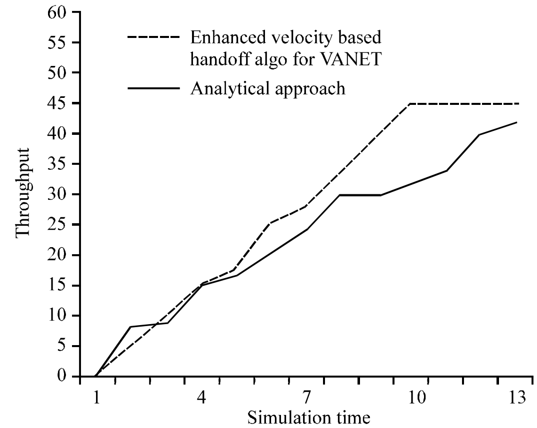

Fig. 16: Comparison for throughput

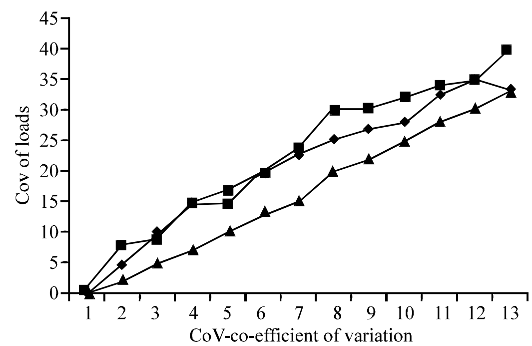

Fig. 17. Results for load balancing

Handover latency: Latency in a network is defined as the elapsed time between the data packets to transmit from one point of location to another point. The mobile node changes its point of location over a time in wireless networks, so the time in between the last packet received in the home network and the first packet received in the newly attached network is referred to as the handover latency. The Handover Latency performance of various handover algorithms is shown in Fig. 18. The user will never be satisfied with the service when the handover latency is high.

Packet loss: The number of packets which are vanished or not transmitted to reach their destination due to network failure and traffic overload is referred to as packet loss. A number of factors which lead to packet loss such as degradation of signal over the network, packets dropped due to congestion or due to faulty network drivers and hardware. The performance of the mechanisms which preferred packet loss as one of their parameters is shown in Fig. 19.

Delay: Delay refers to the amount of time the packets are delayed to reach their destination. The amount of time taken from initiating the handover till the handover termination is referred to as handover delay. In our survey, there are few mechanisms that considered the handover delay as a metric, the performance of those mechanisms with respect to handover delay is shown in Fig. 20.

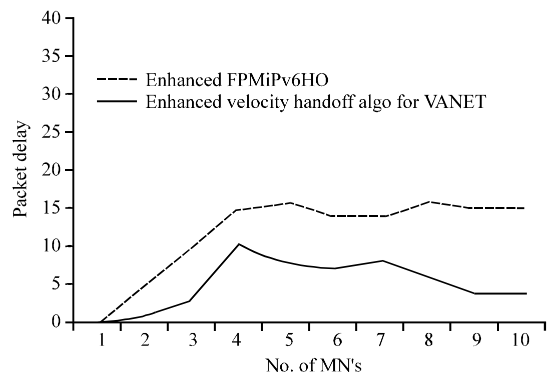

Fig. 18: Performance of handover latency

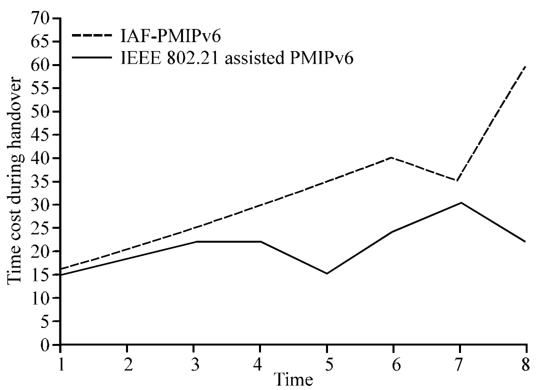

Fig. 19: Performance of packet loss

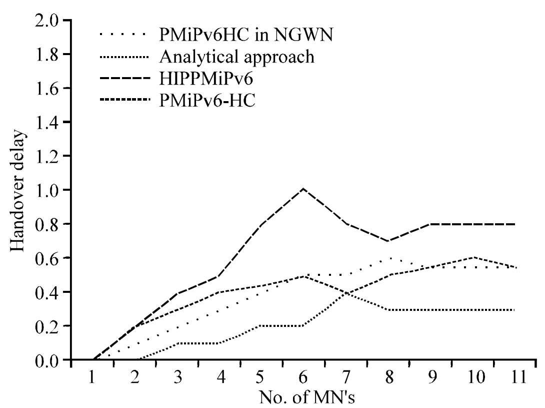

Fig. 20: Packet delay performance

Network cost: The costs of the network are considered based on the factors such as policies and the type of traffic that are used. Network cost includes signaling overhead and packet tunneling cost. Signaling overhead is the cost of replacing managerial packets over the network to finish the location update process of mobile nodes. Packet tunneling cost, referred as encapsulation or decapsulation cost. It is a measure of time required to encapsulate and decapsulate the packets. The cost measurement of a few mechanisms in our survey is shown in Fig. 21.

Comparison of vertical handover decision algorithms for Pmipv6 domain: In our survey, we analyzed various vertical handover algorithms for PMIPv6 domain. From Table 1, it is clear that more handover decision algorithms consider the packet loss, handover delay as the major parameters which affects the handover performance.

There is more possibility of false handover when the mobile node connects to the best available network due to signal strength or some other reasons. The signaling overhead, load balancing, throughput, packet delay were also having much influence on the performance of handover between heterogeneous wireless networks.

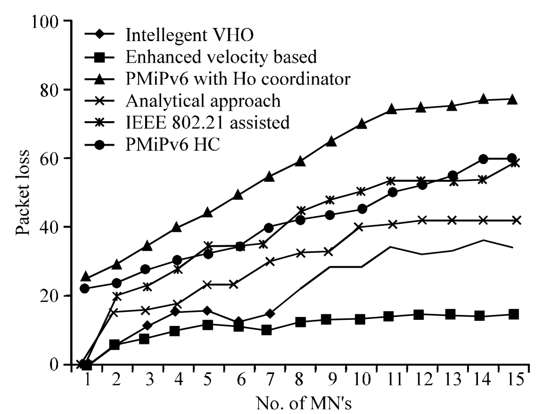

Fig. 21: Performance of cost

Table 1: Comparison of vertical handover decision algorithms

Vertical handover decision algorithm	Parameters	Features	Advantages	Disadvantages
Adaptive data rate oriented vertical handoff algorithm	RSS, load balancing, velocity, Bandwidth utilization	The algorithm is featured on data rate adjustment based on fuzzy logic	Better destination network discovery Handoff efficiency is improved	Mobile terminal direction problem occurs while deciding the handoff

Table 1: Continous

Vertical handover decision algorithm	Parameters	Features	Advantages	Disadvantages
			Reduces packet loss Unnecessary handover delay is reduce	
Intelligent vertical Handover decision algorithm for wireless Heterogeneous networks	Packet loss, load balancing	Fuzzy logic system, multiple attribute decision making and context aware strategies are combined The decision algorithm executes before the handover happens Authentication issues are considered	Packet Loss is reduced Maximizes battery life Load balancing is maintained Reduces call dropping rate Ensures high quality of service	Multiple attribute decision making
Performance evaluation of enhanced velocity-based handoff algorithm for VANET	Packet delay, packet loss, throughput	EVHO algorithm is based on the mobility model considering the vehicle speed	Reduces packet loss and delay Throughput is increased	A new packet frame is created for neighboring vehicles for transmission Message broadcasting
Dynamic load balancing scheme based on access selection and calls transfer in heterogeneous wireless networks	Load balancing, system utilization rate	To optimize the network performance each base stations load rate is taken as a target	Access blocking rate, call dropping rate, load balancing and system utilization rate is improved	Implementation complexity due to dynamic load balancing
Seamless Proxy based Handoff (SePH)	Packet loss, handover latency, signaling overhead and throughput	Uses Integrated Handoff Decision Algorithm (IHDA) maps various heterogeneous networks The SePH avoids restarting of the signal, transmitted to the mobile node to reduce the service interruption during handover initiation	Better handover performance when compared to MIPv6, HMIPv6, FHMIPv6 and FMIPv6 Searching process is reduced	Implementation complexity is medium
Enhanced FPMIPv6	Packet delay	Additional messages such as HPAP, HPAR, FPBU and FPBA are used	Packet forwarding, limitations to acquire MN information earlier and excessive load occurs due to several handover at a time are reduced	More decision parameters are required to ensure better quality of service False handover initiation may be possible
PMIPv6-HC	Handover delay, packet loss, signaling overhead	Handover was seamless and transparent to the services currently running, because the main cause for the delay in handover processes are done in the background in advance through coordination	Resolves problem in basic PMIPv6 and FMIPv6 Better delay performance than basic PMIPv6 and FMIPv6	There was a minor exchange in signaling overhead when the number of handovers increases per unit time
IEEE 802.21 assisted PMIPv6	Packet loss, handover latency and signaling cost	MIH enabled wireless base station (MIHBS) to manage MIH related signaling in aid of the MN which is attached to L2	A MIH enabled base station itself performs handover without involving the mobile node	Implementation complexity
IAF-PMIPv6	Performance, effectiveness, scalable, trustworthy	The agents such as Mn_{agent}, MAG_{agent} and LMA_{agent} are used to select the best network and also carries a trust certificate along with X.509 certificate	Multi criteria consideration Security issues are addressed	Implementation complexity, time consuming if there is an increase in available access points
Enhanced PMIPv6	Handover delay, packet loss	Real-time data relaying, tracking the overlap region of the MN, facilitating MN pre-registration and pre-authentication	Handover delay time and packet loss are minimized without incurring extra signaling overhead Better delay performance than basic PMIPv6	The more number of heterogeneous networks accessing the overlap region was not considered
Hybrid HIP and PMIPv6 (HIPPMIP) Mobility management for handover performance optimization	Handover delay	Effective handover optimization scheme	Handover delay is improved Signaling overhead problem is reduced	Addition of mechanisms should be included for inter-domain handover

CONCLUSION

Today, mobility is one of the most demanding developments in IP networks. In this study, we presented a comparative study of various vertical handover decision algorithms for Proxy Mobile IPv6 which affects the overall performance during handover among heterogeneous wireless networks. Recent area in wireless networks is to discover an appropriate handover decision algorithm which fulfills both the network and the user. In this study, few vertical handover decision algorithms have been analyzed which improves the handover performance but still there is a need of much efficient and apposite handover decision algorithms to satisfy both the user and network requirements in terms of Quality of Service (QoS). This survey study can help out the potential researchers in the field of interest by giving the general idea about the current developments in the area of Mobility management and also encourage them towards the advance design and development of IP based network.

REFERENCES

Agarwal, A., R.S. Shukla and P.K. Keshwani, 2014. Adaptive data rate oriented speed and capacity based vertical handoff algorithm. Int. J. Eng. Comput. Sci., 3: 7535-7539.

Anwar, F., M.H. Masud, S.M. Bari and S. Abd Latif, 2013. Enhanced handoff latency reduction mechanism in layer 2 and layer 3 of mobile IPv6 (MIPv6) network. Aust. J. Basic Appl. Sci., 7: 658-671.

Bhuvaneswari, A. and E.G.D.P. Raj, 2012. An overview of vertical handoff decision making algorithms. Int. J. Comput. Netw. Inf. Secur., 4: 55-62.

Chandavarkar, B.R. and G.R.M. Reddy, 2012. Survey paper: Mobility management in heterogeneous wireless networks. Proc. Eng., 30: 113-123.

Cho, C., J. Choi and J. Jeong, 2013. Analytical approach of an extended seamless proxy-based handoff scheme in IP-based heterogeneous mobile networks. Int. J. Smart Home, 7: 309-318.

Chung, J.M., D. Lee, W.J. Song, S. Choi and C. Lim et al., 2013. Enhancements to FPMIPv6 for improved seamless vertical handover between LTE and heterogeneous access networks. Wirel. Commun. IEEE., 20: 112-119.

Dong, P., H. Zhang, H. Luo, T.Y. Chi and S.Y. Kuo, 2010. A network-based mobility management scheme for future internet. Comput. Electr. Eng., 36: 291-302.

Emami, A., A. Jalooli, O. Michael, R. MdNoor and I. Ahmedy et al., 2014. Performance Evaluation of Enhanced Velocity-based Handoff Algorithm for VANET. Malaysian J. Comput. Sci., 27: 124-137.

Gondim, P.R. and J.B. Trineto, 2012. DSMIP and PMIP for mobility management of heterogeneous access networks: Evaluation of authentication delay. Proceedings of the 2012 IEEE Globecom Workshops (GC Wkshps), December 3-7, 2012, IEEE, Anaheim, CA., ISBN: 978-1-4673-4942-0, pp: 308-313.

Hussain, H.N., K.A. Bakar and S. Salleh, 2012. Using media independent handover to support PMIPv6 inter-domain mobility based vehicular networks. Int. J. Commun. Netw. Inf. Secur., 4: 182-195.

Kailash, C., 2012. An analysis of intelligent agent framework for proxy mobile IPv6 (IAF-PMIPv6). Int. J. Adv. Technol., 3: 35-46.

Kim, H.J. and S.G. Choi, 2010a. A method to support multiple interfaces a mobile node in next generation wireless network. Proceedings of the 2010 Sixth International Conference on Networked Computing and Advanced Information Management (NCM), August 16-18, 2010, IEEE, Seoul, South Korea, ISBN: 978-1-4244-7671-8, pp: 276-281.

Kim, P.S. and J.H. Choi, 2010b. A fast handover scheme for proxy mobile IPv6 using IEEE 802.21 media independent handover. World Acad. Sci. Eng. Technol., 43: 654-657.

Kim, M.S., S. Lee, D. Cypher and N. Golmie, 2013. Performance analysis of fast handover for proxy Mobile IPv6. Inf. Sci., 219: 208-224.

Magagula, L.A., H.A. Chan and O.E. Falowo, 2010a. PMIPv6-HC: Handover mechanism for reducing handover delay and packet loss in NGWN. Proceedings of the 2010 IEEE Conference on Global Telecommunications (GLOBECOM 2010), December 6-10, 2010, IEEE, Miami, FL., ISBN: 978-1-4244-5636-9, pp: 1-5.

Magagula, L.A., H.A. Chan and O.E. Falowo, 2010b. Handover coordinator for improved handover performance in PMIPv6-supported heterogeneous wireless networks. Proceedings of the 2010 IEEE Conference on Wireless Communications and Networking (WCNC), April 18-21, 2010, IEEE, Sydney, NSW., ISBN: 978-1-4244-6396-1, pp: 1-6.

Magagula, L., O. Falowo and H. Chan, 2010c. Enhancing PMIPv6 for better handover performance among heterogeneous wireless networks in a micromobility domain. EURASIP. J. Wirel. Commun. Netw., 2010: 1-13.

Melia, T., F. Giust, R. Manfrin, D.L.A. Oliva and C.J. Bernardos, 2011. IEEE 802.21 and Proxy Mobile IPv6: A Network Controlled Mobility Solution. In: Future Network and Mobile Summit (FutureNetw). Cunningham, P. and M. Cunningham (Eds.). IEEE, Warsaw, Poland, ISBN: 978-1-4577-0928-9, pp: 1-8.

Muslam, M., H.A. Chan, F.N. Ventura and L.A. Magagula, 2010. Hybrid HIP and PMIPv6 (HIPPMIP) mobility management for handover performance optimization. Proceedings of the 2010 6th International Conference on Wireless and Mobile Communications (ICWMC), September 20-25, 2010, IEEE, Valencia, Spain, ISBN: 978-1-4244-8021-0, pp: 232-237.

Narayanan, V.A., A. Rajeswari and V. Sureshkumar, 2014. An intelligent vertical handover decision algorithm for wireless heterogeneous networks. Am. J. Appl. Sci., 11: 732-739.

Pandey, D., F. Bashir, G.Y. Kee and J.Y. Pyun, 2013. Performance evaluation of vertical handover for IEEE 802.21 enabled proxy mobile IPv6. Proceedings of the International Conference on Computing, Management and Telecommunications, January 21-24, 2013, Ho Chi Minh, Vietnam, pp: 21-31.

Radhika, K. and A.V. Reddy, 2011. Vertical handoff decision algorithm for heterogeneous wireless networks based on 2-level analytic hierarchy process. Proceedings of the 2011 Annual IEEE India Conference (INDICON), December 16-18, 2011, IEEE, Hyderabad, India, ISBN: 978-1-4577-1110-7, pp: 1-6.

Rasem, A., 2011. 0-PMIPv6: Optimized proxy mobile IPv6. PhD thesis, Carleton University Ottawa, Ottawa, Ontario, Canada.

Sharna, S.A., M.R. Amin and M. Murshed, 2011. An enhanced-MDP based vertical handoff algorithm for QoS support over heterogeneous wireless networks. Proceedings of the 2011 10th IEEE International Symposium on Network Computing and Applications (NCA), August 25-27, 2011, IEEE, Cambridge, MA., ISBN: 978-1-4577-1052-0, pp: 289-293.

Singhrova, A. and N. Prakash, 2007. A review of vertical handoff decision algorithm in heterogeneous networks. Proceedings of the 4th International Conference on Mobile Technology, Applications and Systems and the 1st International Symposium on Computer Human Interaction in Mobile Technology, September 12-14, 2007, ACM, New York, USA., ISBN: 978-1-59593-819-0, pp: 68-71.

Singhrova, A. and N. Prakash, 2012. Vertical handoff decision algorithm for improved quality of service in heterogeneous wireless networks. Commun. IET., 6: 211-223.

Vetrivelan, P. and P. Narayanasamy, 2012. Multi-interface mobile node in 4G heterogeneous wireless networks. Asian J. Inf. Technol., 11: 276-284.