Vertical Handover in Wireless Mesh Networks and its Impact on Routing

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***Abstract* —This paper proposes a new idea to improve routing in wireless mesh networks using IEEE 802.21's Media Independent Handover (MIH) functions. First, we evaluate the performance of a vertical handover using IEEE 802.21 protocol between WiFi and WiMax networks. Then, we present our proposal of using MIHF for optimizing the performance of IEEE 802.11s Wireless Mesh Networks (WMN) routing protocols, such as Hybrid Wireless Mesh Protocol (HWMP).**

Keywords-Wireless mesh networks; routing protocol; Handover; MIH; packets loss ratio; handover delay.

I. INTRODUCTION

In recent years, wireless communication technologies have evolved thanks to their utility and flexibility. This has led to the emergence of new wireless network solutions.

One such solution consists of Wireless Mesh Networks (WMN), which are gaining importance [1].

IEEE 802.11s Group [2] was established in January 2004 to provide mesh functions to IEEE 802.11 architectures and protocols.

Research in the field of WMNs [3] is broad and diverse. Indeed, substantial works are currently carried out by researchers on routing protocols and their performance indicators. In addition, many other works focus on higher-level protocols (Quality of Service (QoS), service discovery, etc.). Mobility is also a very active area of research.

Handover process causes a number of problems in routing, which degrades the service continuity. We have noticed, however, that works that connect routing and handover or use the characteristics of one to enhance the other are extremely rare. Our idea then is to link these two operations.

For this, we exploit the handover protocol described in IEEE's Media Independent Handover (MIH) [4] in order to improve routing between different network components and maintain service continuity.

This paper is organized as follows: Section II presents an overview of WMNs and popular routing protocols. Section III presents the MIH standard and Section IV describes related works found in the literature. Then, Section V describes simulation experiments. Different applications are used for this topic such as Constant Bit Rate (CBR) video and voice traffic.

Our approach to improve routing in WMNs using MIH is presented in Section VI. In Section VII, we discuss simulation results and present the advantages and disadvantages of our proposed idea. Finally, Section VIII provides a summary of this paper and some perspectives.

II. OVERVIEW OF IEEE 802.11S AND ROUTING PROTOCOLS

WMN technology is widely used in the world and its standardization becomes very necessary for large-scale applications. Currently, WMN standards are: IEEE 802.15.5, IEEE 802.16 and IEEE 802.11s.

IEEE 802.15.5 [5] is a standard which aims to introduce the MESH technology at the personal area networks level. This standard aims to identify and develop mechanisms that must be present at the physical and MAC layers in order to implement the MESH technology in WPANs. This standard provides personal area networks that offer higher rate and ensure transmissions over longer distances.

IEEE 802.16 standard group [6] introduces the Mesh structure in the IEEE 802.16 d/e standard. In IEEE 802.16 Mesh, any node in the network can form several links with its adjacent nodes and one of the links is selected to transmit the information from local node or other nodes.

IEEE 802.11s is a flexible and extensible standard for WMNs based on IEEE 802.11 family. One of the important functionalities of IEEE 802.11s is the wireless multi-hop routing, which sets up paths for wireless forwarding.

IEEE 802.11s mesh networks can be used in a wide range of application scenarios. These scenarios include residential for the digital home, companies and public places and temporary infrastructure in case of a disaster. Mesh networks are extensible to allow support for diverse applications and future innovation.

Routing, also called path selection, consists of finding the optimal route from source to destination. IEEE 802.11s routing protocols are particularly based on the work of the IETF MANET [7], but operate at layer 2 unlike MANET protocols, which operate at layer 3. The 11s group has as target configuration a network which contains 32 entities that participate in routing.

Two routing protocols are considered: Hybrid Wireless Mesh Protocol (HWMP) and Radio Aware Optimized Link State Routing Protocol (RA-OLSR) [8].

The HWMP is the default routing protocol for wireless mesh networks. It combines two approaches: reactive routing and proactive tree-based routing [9].

The main characteristic of reactive routing is that a path is computed only if one is needed for sending data between two mesh points.

Proactive routing is based on three routing bases:

- A distance vector routing tree is built and maintained if a root portal is present.
- Tree-based routing is efficient for hierarchical networks.
- Tree-based routing avoids unnecessary discovery flooding during discovery and recovery.

The RA-OLSR Protocol is an improvement of the Optimized Link State Routing Protocol OLSR [10]. The shortest path algorithm uses a radio-aware metric instead of the hop count metric. For that reason, a metric field is added to all

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topology information messages. RA-OLSR uses MAC addresses rather than IP addresses.

III. MEDIA INDEPENDENT HANDOVER (MIH)

The scope of the IEEE 802.21 MIH standard is to develop a standard that would provide generic link layer intelligence and other network related information to upper layers to optimize handovers between different heterogeneous media such as the 3rd Generation Partnership Project (3GPP), 3GPP2 and both wired and wireless media of the IEEE 802.21 family [11].

The main objective of MIH is to provide a framework that enables seamless handover between heterogeneous technologies. It uses a protocol stack implemented in all the devices involved in the handover which provides the necessary interactions among devices for optimizing handover decisions.

The standard allows providing information which could help at the phase of selection of the network and the activation of the interface. The execution and the decision of handover is not part of the standard.

In the mobility management protocol stack of both the MN and network element, the Media Independent Handover Function (MIHF) is logically defined as a sub-layer between L2 data link layer and L3 network layer. The upper layers are provided services by the MIH function through a unified interface.

The services exposed by the unified interface are independent of access technologies. This unified interface is known as Media Independent Handover Service Access Point (MIH_SAP). The lower layer protocols communicate with the MIHF via media dependent SAPs [11].

This standard defines services that comprise the MIHF services. These services which facilitate handovers between heterogeneous access links are:

- Media Independent Event Service (MIES) that provides event classification, event filtering and event reporting corresponding to dynamic changes in link characteristics, link status, and link quality.
- Media Independent Command Service (MICS) that enables MIH users to manage and control link behavior relevant to handovers and mobility,
- Media Independent Information Service (MIIS) that provides details on the characteristics and services provided by the serving and neighboring networks. The information enables effective system access and effective handover decisions.

MIHF provides asynchronous and synchronous services through SAPs for link layers and MIH users. In the case of a system with multiple network interfaces of arbitrary type, MIH users employ event service, command service, and information service provided by MIHF to manage, determine, and control the state of underlying interfaces.

These services provided by MIHF help the MIH users in maintaining service continuity, service adaptation to varying quality of service, battery life conservation, network discovery, and link selection.

The handover is considered as “hard” or “soft,” depending on whether the handover procedure is “break-before-make” or “make-before-break”.

IV. RELATED WORKS

Many papers associated with MIH have focused on improving handoff performances.

Several research studies have investigated the improvements that MIH could make to different mobility protocols at various levels.

At the network layer, Mussabbir and Yao [12] proposed using MIH services in order to optimize the procedure of handover for Mobile IPv6 Fast Handovers (FMIPv6).

Magagula [13] shows that Proxy Mobile IPv6 is a protocol for mobility management. It is effective in improving the performance indicators of the operation such as handover latency and packet loss in particular when used with the IEEE 802.21 protocol services MIH.

At the transport layer, Chen [14] proposed an interaction between SCTP and 802.21. This optimizes the handover mechanisms in networks within the campus for VoIP applications.

At the application layer, Choong [15] analyzes the improvements that can be gained by interaction between SIP and MIH.

Lee et al. [16] proposed a framework for the integration of IEEE 802.21 MIHF with OLSR to improve the performances of this ad-hoc routing protocol using the Hello interval.

Several research works evaluated routing protocols performances in mesh networks IEEE 802.11s. For example, N.R.Nomulwar et al. [17] presented performance analysis of routing protocol in Wireless Mesh Network such as HWMP, Ad hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Destination-Sequenced Distance-Vector (DSDV).

Baumann [18] introduced a notification protocol driven by the access points and independent of used routing protocol. When access points detect the clients’ macro mobility by the change of addresses, the MAPs send to source node a notification message which contains the new configuration parameters. The notification message will be sent periodically for each client, which may cause a heavy additional signaling overhead in Wireless Mesh Network.

A fast handoff management scheme in WMN have been developed by Kowalik et al. [19]. It is called MeshScan. It includes three main steps. First, a client device maintains a list of active Mesh Nodes (MNs) (SmartList). Then when it receives a disassociation message from the serving MN or when the measured signal strength from the serving MN exceeds the threshold, it performs the handoff. Finally, when handoff is required, a client transmits Authentication Request frames to all MNs on the list instead of broadcasting Probe Request frames as is usually the case in an active scan in order to discover available MNs.

The goal of our proposal is to achieve improvements in network performances for wireless mesh network environments through the integration of MIH with mesh routing protocols like HWMP.

V. SIMULATION MODEL BASED ON MIH PROTOCOL

The simulation scenario consists of one WLAN cell and a WiMAX cell. It is assumed that one MN, equipped with multiple interfaces, is connected to WiFi before it goes through the WiMAX coverage area.

The handover between the WLAN cell and WiMAX is performed when the MN leaves the coverage area of the WLAN AP.

Figure 1 shows four main elements:

- The WLAN AP
- WiMAX BS
- The router connected to CN (Correspondent Node)
- The multi-interface MN

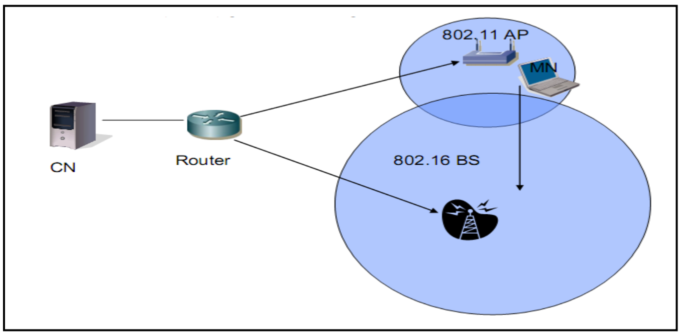

Figure 1. Simulation scenario

A. *Simulation Parameters*

Table I summarizes parameter values used in the simulations which illustrates the generic network topology used.

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Network Topology	
WiMAX cell coverage	1000 m
WLAN cell coverage	20 m
Router Configuration	
MAX_RA_DELAY (s)	0.5
Router lifetime (s)Wlan	1800
Router lifetime (s)WiMax	20
802.11 MAC Layer Configuration	
WLAN beacon interval (s)	0.1
Default scanning mode	Passive
MinChannelTime (s)	0.02
MaxChannelTime	0.06
802.16 Configuration	
Dcd_interval	5
Ucd_interval	5
Client_timeout_	50
Default modulation (s)	OFDM_16_QAM
Application Traffic for Mobile Node	
Type	Depends on application
Packet size (bytes)	Depends on application
Packet inter-arrival time (s)	Depends on application

To evaluate handover performances, we have chosen to compare results between two applications. These are:

- CBR Video traffic (real-time data).
- CBR Voice traffic (real-time data).

We used a real-time traffic to study the effect of the handover on this type of application that requires a good Quality of Service (QoS).

The realization of our simulations is based on the NIST NS-2 implementation [20] of IEEE 802.21 for infrastructure-based network environments.

B. *Performance criteria*

The performance criteria adopted in our simulations to evaluate the vertical handover between WLAN and Wimax are Delay and Packets Loss Ratio. These parameters are the main criteria of QoS in the networks.

C. *Simulation results:*

1) *Packet Loss Ratio*

We calculate in this section the percentage of lost packets. Figure 2 demonstrates that the handover causes a jump in packet loss. Each curve contains a peak, which corresponds to the Packet Loss Ratio during roaming period. As expected, the handover process causes an increase in the number of dropped packets.

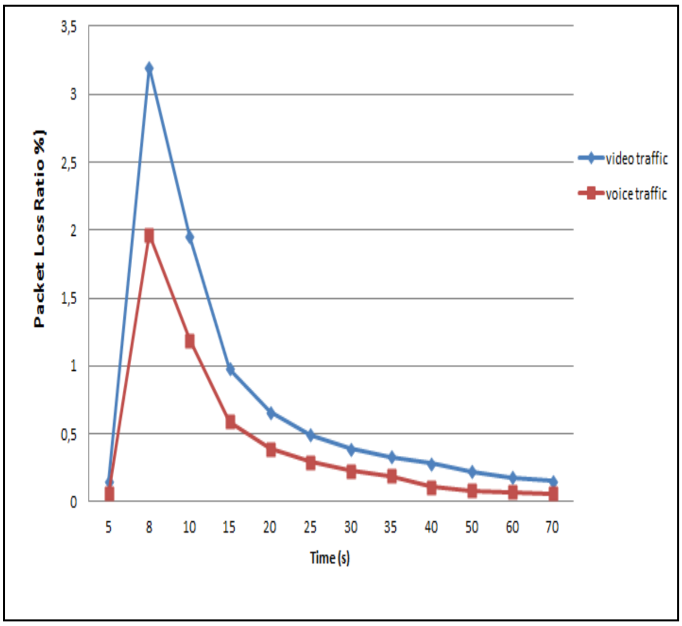

Figure 2. Packets Loss Ratio during simulation: voice and video traffic

For voice traffic, the packet size is 160 bytes, the CBR interval is 0.02 seconds and the mobile node velocity is 13 m/s. Figure 2 shows that the packet loss ratio increases suddenly at the beginning of handover to a value of 1.95%.

In the foreign network, the packet loss ratio for the mobile node degrades to achieve 0.06%.

For video traffic, we use a packets size of 1240 bytes, a CBR interval of 0.1 seconds and a velocity of 13 m/s.

We deduce that for low mobility handover performances are acceptable. Indeed, for a speed of 13 m/s the packet loss ratio is less than 3.2%. The higher value of loss appears during the execution of the handover (the peak of the curve), which reached 3.2% (see Figure 2).

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When the mobile moves to the foreign network (WiMAX) the packet loss ratio decreases to a value below 0.5%.

The packets loss ratio for voice traffic during handover was 1.95%. Compared to the packets loss ratio of video type traffic (3.2%), it is much smaller. The result was as expected since the packet size will necessarily affect the packets loss ratio.

2) Delay

The delay is a very important parameter to evaluate the QoS for real time traffic. This is the time needed for a packet to be transmitted across a network from source to destination (end-to-end).

In this section, we discuss packet delays during the simulation time when applying the scenario of the handover from WLAN to WiMAX.

We present voice traffic results first. We notice the existence of a peak at the moment of the handover execution because the transfer time becomes quite important (between 0.76 and 1.18 s).

After executing the handover, the delay of packet transmission falls, it becomes almost constant and less than 0.2 seconds.

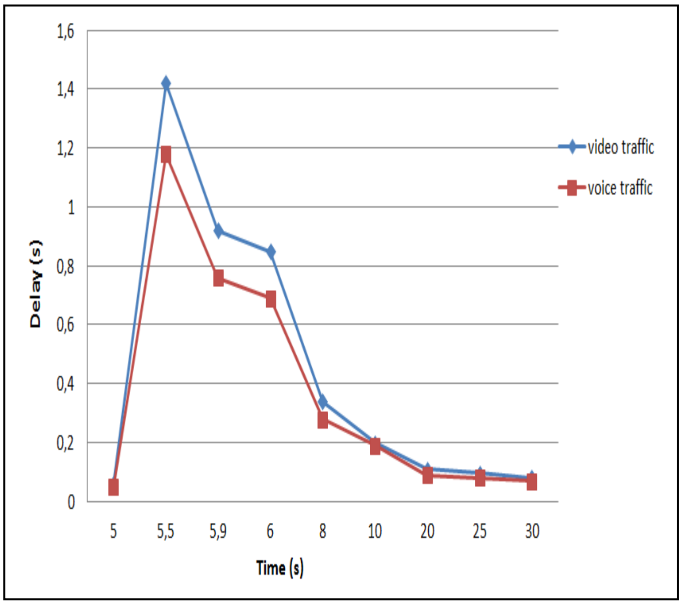

Figure 3. Delay during simulation: voice and video traffic.

For video traffic, we note that at the time of handover execution, the delay of packets transmission becomes important (between 0.8 and 1.43 s). The delay increases with the execution of the handover. This explains the occurrence of the peak at the starting moment of handover.

After executing the handover, the delay falls and becomes almost constant and less than 0.2 seconds.

VI. Proposed Approach to Improve Routing in WMN with MIH

A mobile node that implements MIH module includes two agents: MIH agent and routing agent. In wireless mesh networks, the routing agent used is HWMP or RA-OLSR.

MIHF in the ad hoc node interacts with the MAC Layer and MIH users in higher layers.

Triggers for handoffs may be initiated from MAC, PHYSICAL or upper levels through the MAC SAP either at the Mobile node or at the BS [11]. The cause for these triggers can be either within the local stack or from the distant stack.

Layer 2 triggers are classified into two types, predictive and event triggers. Predictive triggers express a probability of a change in system properties in the future. Event triggers describe an exact event that has occurred. Link_Up is an example of an event trigger. Link-Going-Down is an example of a predictive trigger.

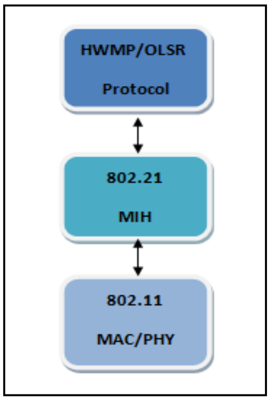

Figure 4. MIHF interaction to uper and lower layers.

The MAC layer receives measurement data of neighboring nodes and provides information to MIH. The MIH triggers the handover and HWMP/OLSR routing agent registers as a user and performs MIH stains triggered by the MIH agent.

For this, we propose to exploit the messages exchanged during the procedure of handover by the routing agent to detect the mobility of nodes faster and consequently routing can take place quickly.

We propose to use 2 messages to realize our approach:

- **MIH_Link_Down.indication** is sent to local MIHF users to notify them of a local event, or is the result of the receipt of a MIH_Link_Down indication message to indicate to the remote MIHF users who have subscribed to this remote event. Parameters used in this case are Type of link, MAC Address of mobile node, MAC Address of old Access Router and of course "Reason" for the link down.
- **MIH_Link_Up.indication** is sent to local MIHF users to notify them of a local event, or is the result of the receipt of a MIH_Link_Up indication message to notify remote MIHF users who have subscribed to this remote event. Parameters for this trigger are Type of link, MAC Address of mobile node, MAC Address of old Access Router, MAC Address of new Access Router, and Network Identifier for detecting possible change in subnet.

Figure 5 below illustrates the communication between the MIH agent and HWMP protocol.

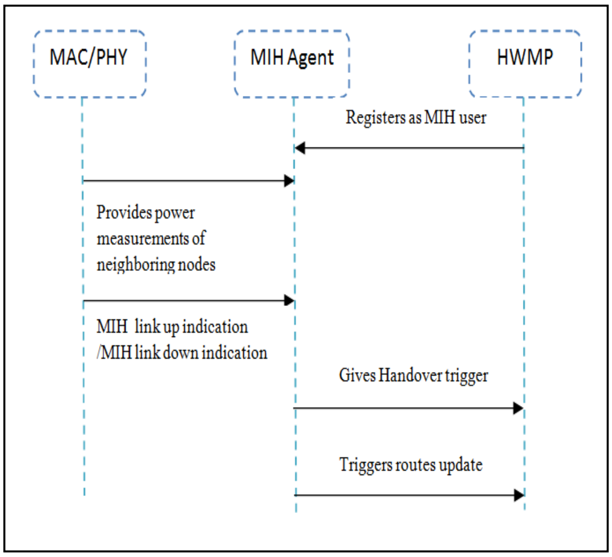

Figure 5. Communication between HWMP and MIH agent.

At the beginning, we must register the routing protocol HWMP as an MIH user to receive messages issued by the MIHF. This can be implemented by providing an interface between the MIHF and HWMP agents in NS2 simulator, as in [16].

We will study two cases of mobility:

- A mobile node leaves a wireless mesh network to a foreign network.
- A new MN joins a wireless mesh network from another network.

We start by explaining the first case. As we have already indicated, when the received signal quality drops, the link layer of the terminal can anticipate the handover and triggers the event service Link_Going_Down on both MIH entities: MIHs terminal of the local mobile network and the MESH.

Then, the MIH agent informs the HWMP routing agent to update its routing table and remove the node corresponding to this link. A routing table's update must be invoked at all nodes in the network. They must in turn remove the node associated with the message MIH_Link_Going_Down and do not wait for the periodic updating of routing tables. With this method, the node mobility is detected faster by all network users.

In the case when a mobile node tries to join a wireless mesh network while executing a handover and once all steps of link attachment are completed and the link is ready to send packets, a trigger event link-up indication may be sent to the MIH function on the local and remote link.

Once the MIH agent receives this message, it triggers the HWMP routing agent to update routes. The access point, then, triggers a links update throughout the network by broadcasting a PREQ message and putting the MN as destination. Thereafter, when an intermediary Mesh Point receives PREQ, it creates a path to the request source and forwards PREQ to the destination and so on until it reaches the mobile.

When the mobile node receives PREQ, it sends in unicast a PREP message to the source. When the source node receives the PREP message, it creates a path to the mobile node. This update will accelerate the detection of a new node that joins the network, which will therefore accelerate the data routing to that node.

VII. Discussion

Through the simulation of MIH protocol and according to our results, we note that the delay of a vertical handover can reach a maximum value of 1.43 s. To evaluate the performance of the this protocol, we can compare this value with that of a vertical handover without the MIH protocol like the case of [21], in which for streaming traffic between CDMA 2000 and IEEE 802.16e networks, handover delay can reach a value of 2 seconds. Concerning the packet loss ratio, in our scenario we have a maximum value of 3.2%. This value is lower than that of [21], which can reach 5%. We can conclude that the MIH provides a transaction from one network to another with a low delay and an acceptable packet loss ratio.

Our idea to accelerate routing data in WMN using messages exchanged during handover process may have positive and negative impacts.

When node movement is detected faster than before even by few seconds, it will accelerate data routing to the mobile node since the corresponding nodes will be informed of its new location and route data based on this new information. Consequently, Packets Loss Ratio will be reduced.

On another side, this route update needs a significant exchange of extra control messages, which can cause additional signaling overhead. It can also cause loss of energy of the mobile node.

VIII. Conclusion and Future Work

In this paper, we studied the mechanisms of vertical handover between WiMAX and WiFi networks by the implementation of protocols related to these mechanisms.

We defined a simulation scenario to implement this principle. Then we gave an analysis of vertical handover between WiFi and WiMAX and performance figures with the use of NS-2 simulator.

The objective of this work was to propose an approach that creates a link between the handover process and routing operation. Our main idea consists of using Media Independent Handover protocols in order to optimize routing in wireless mesh networks.

As a future work, we propose to simulate other scenarios. Indeed, we can illustrate the effect of the number of mobile nodes on the performance of vertical handover between WiMAX and WiFi. Other types of applications can also be simulated, such as a non-real time applications like FTP and best effort services (TELNET).

Another possible investigation may consist of evaluating the performance of MIH and other mobility protocols with other types of heterogeneous networks such as LTE, MPLS, etc.

Finally, it would also be interesting to run further simulations with our approach in order to further study its impact on routing in other mesh network scenarios.

References

[1] G. R. Hiertz, S. Max, E. WeiB, L. Berlemann, D. Denteneer, and S. Mangold, "Mesh Technology enabling Ubiquitous Wireless Networks," in Proceedings of the 2nd Annual International Wireless Internet Conference (WICON), Boston, USA, Aug. 2006, pp. 11-23.

[2] IEEE, "Draft amendment: ESS mesh networking", IEEE P802.11s Draft1.00, November 2006.

[3] I.F. Akyildiz, X. Wang, and W. Wang, "Wireless mesh networks: a survey", Computer Networks, vol. 47, no. 4, Mar. 2005, pp. 445-487.

[4] IEEE 802.21, "IEEE 802.21 Media independent handover," vol. 2006: IEEE 802.21 standards, http://ieee802.org/21/, 06.14.2013.

[5] M. Lee, R.Zhang, Ch.Zhu , and T.Park "Meshing wireless personal area networks: Introducing IEEE 802.15.5", Communications Magazine, IEEE (Volume: 48, Issue: 1), January 2010, pp. 54–61.

[6] IEEE Std 802.16-2004, "IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems, IEEE Revision of 802.16-2001", Oct 2004.

[7] "Mobile Ad-hoc Networks (MANET) Working Group," Internet Engineering Task Force (IETF), http: //www.ietf.org/html.charters/manet-charter.html, 06.14.2013.

[8] M. Bahr, "Proposed Routing for IEEE 802.11s WLAN Mesh Networks", The 2nd Annual International Wireless Internet Conference, Boston, ,2006, pp. 6-13.

[9] A. Amir Pirzada, M. Portmann, and J. Indulska. "Hybrid Mesh Ad-hoc On-demand Distance Vector Routing Protocol", Proceeding ACSC '07 Proceedings of the thirtieth Australasian conference on Computer science-Volume 62, Australian Computer Society, Inc. Darlinghurst, Australia, 2007, pp. 49-58.

[10] P. Jacquet, P.Mühlethaler, A. Qayyum, A. Laouiti, T. Clausen, and L. Viennot, "Optimized Link State Routing Protocol", IEEE INMIC Pakistan, Dec 2001, pp.62–68.

[11] Draft IEEE standards ,"IEEE802.21 Standard and Metropolitan Area Networks: Media Independent Handover Services", Draft P802.21/D00.05, March 2006

[12] Q.B. Mussabbir, and W. Yao, "Optimized FMIPv6 handover using IEEE802.21 MIH Services", Proc. of MobiArch 2006, ACM Press, New York , 2006, pp. 43–48.

[13] L Magagula, O.E. Falowo, and H.A. Cha. , " PMIPv6 and MIH-enhanced PMIPv6 for mobility management in heterogeneous wireless networks." Proceedings of Africon,Kenya, September 2009, pp. 23-25.

[14] Y.M. Chen, M.Y. Lai, S.C. Lin, S.C. Chang, and T.Y. Chung, "SCTP-based handoff based on MIH triggers information in campus networks", The 8th International Conference of Advanced Communication Technology (ICACT'06), February 2006, pp. 1301-1305.

[15] K.N. Choong, V.S. Kesavan, S.L. Ng, F. de Carvalho, A.L.Y. Low and C. Maciocco, "SIP-based IEEE802.21 media independent handover - a BT Intel collaboration", BT Technology Journal, vol. 25, no. 2, April 2007, pp. 219–230.

[16] J. Lee, A.McAuley and S.Das, "Framework for Integration of IEEE 802.21 MIH Function with Ad Hoc Routing Protocol", Vehicular Technology Conference (VTC Spring) IEEE 73rd, Budapest-Hungary, 2011, pp. 1-6.

[17] N.R.Nomulwar, J. N. VarshaPriya, B. B. Meshram, and S. T. Shinghade, "Comparision of performance of routing protocol in Wireless Mesh Network", The International Journal of Computer Science & Applications (TIJCSA), vol. 1, no. 3, May 2012, pp. 61-65.

[18] R. Baumann, O. Bondareva, S. Heimlicher, and M. May, "A Protocol for Macro Mobility and Multihoming Notification in Wireless Mesh Networks", Advanced Information Networking and Applications Workshops (AINAW '07), 2007, pp. 34-37.

[19] Chen, Y., K. Kowalik, and M. Davis, "MeshScan: Fast and Efficient Handoff in IEEE802.11 Mesh Networks", The 7th ACM International Symposium on Mobility Management and Wireless Access (MobiWAC 2009), Tenerife, Canary Islands, Spain, October 2009, pp. 105-108.

[20] The Network Simulator NS-2 NIST add-on IEEE 802.21 model, NIST January 2007.

[21] S. Park, S. Kim, J. Cho, I. Ryoo, D. Lee, J. Yu, J. Lim, and S. Oh, "A Performance Evaluation of Vertical Handoff Scheme between IEEE 802.16e and cdma2000 Networks", Communications in Computing, Las Vegas, Nevada, USA, 2006, pp. 104-109.