Investigations on IEEE 802.21 based Media Independent Handoff Algorithm for Access Network Selection between WiFi and WiMAX

Sahana Bhosale, Rohin Daruwala

Abstract-- The design goal of Fourth Generation (4G) networks is to offer seamless connectivity across existing wired and wireless access technologies under the "Anywhere, Anytime" paradigm. Emerging IEEE 802.21 supports optimization of vertical handoffs amongst heterogeneous access networks under the umbrella of 4G. This paper investigates the IEEE 802.21 based Media Independent Handoff MIH algorithm (handover1) for the access selection in an integrated WiFi and WiMAX networks. Further, the paper proposes an innovative MIH algorithm (handover2) which improves QoS metrics such as latency and packet loss by using layer 2 triggers. 802.21 add-on modules (developed by National Institute of Standards and Technology (NIST)) have been successfully integrated in 2.29 version of network simulator (ns) for investigating and analyzing the performance of the MIH algorithms.

Keywords -- 4G, WiFi, WiMAX, vertical handoff, IEEE 802.21, Media Independent Handover, latency, packet loss.

1 Introduction

The revolutionary Fourth Generation (4G) network is not a new technology but just the integration of existing, well established and well proven wired and wireless systems having worldwide penetration. That's why 4G networks have introduced a concept called as Always Best Connected (ABC) [1]. This refers to being not only always connected, but also being connected in the best possible way, combining, for instance, the worldwide coverage of cellular systems with the high bandwidth of WLAN hot spots. The ABC concept includes virtually all types of access technologies; fixed and wireless, and existing technologies as well as those that are yet to come.

As an example of ABC, let us consider that Sahana gets an Internet connectivity at home using broadband connection. When downloading of a large video is going on, she suddenly unplugs the connection to rush to office. This prompts laptop to check other available networks to continue the video download and finds the availability of 3G network. Then she reaches the office where her laptop automatically connects to the WiFi in the premises for the higher bandwidth required for video download. So in this scenario, Sahana gets ABC network as she uses GSM for coverage while travelling to office and WiFi for higher bandwidth as soon as she enters the premises.

Change of the Mobile Node's (MN) point of attachment (PoA) during active communication is called the handoff [1].

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Seamless Handoff maintains connection of the active session for the applications which are running on MN during the handoff, the ultimate aim being lower latency and packet loss. The term handover and handoff has been used interchangeably throughout this paper.

Traditionally, Handoff is an intra-system handoff which is executed between two homogeneous access networks like between neighbouring Base Stations (BSs) of WiMAX and is called as horizontal handoff (HHO). In contrast, Vertical Handoff (VHO) is an inter-system handoff which takes place between two different heterogeneous network technologies such as WLANs-Cellular networks or WLAN-WiMAX [2]. In 4G, the need for vertical handoffs can be initiated for convenience rather than connectivity reasons (e.g., according to user choice for a particular service).

The rest of this paper is organized as follows. Section 2 presents a detailed description of three phases of handover management procedure and diverse vertical handover algorithms available in the literature. Section 3 extensively describes IEEE 802.21 based Media Independent Handover (MIH) framework found in the IEEE LAN/MAN standard committee's draft. Section 4 discusses the comparative performance analysis of handover1 and handover2 in terms of latency and packet loss. Finally, Section 5 provides concluding remarks.

2 ABC Solution Components or Handoff Management Procedures

As shown in Fig. 1, fundamentally handoffs are of two types, horizontal and vertical. Handoffs are also characterized as hard and soft. When the MN is connected to only one PoA at a time, it can be hard and referred to as a break before make handoff. On the other hand, it can be soft when the MN is connected to two PoAs for a while and is referred to make before break handoff [3]. Network can be coupled with other network in two ways, Loose coupling and Tight Coupling.

Loose coupling enables flexibility for operators as roaming agreements can be made to enlarge WiMAX data service coverage without intensifying or integrating WLAN in a WiMAX network**.** In tight coupling, components of the WiMAX network are already present to hold up user mobility, and integration proxies can be inserted into the core network to maintain seamless connection transfers while avoiding dual traffic flows [4].

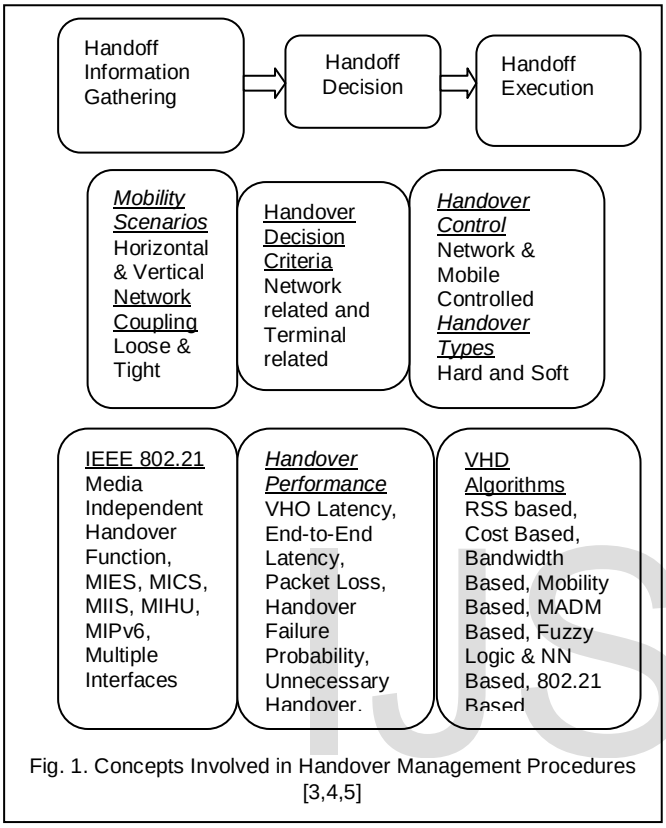

Fig. 1. Concepts Involved in Handover Management Procedures [3,4,5]

VHO process consists of three phases [3,4,5]:

- Network discovery/Handoff Information Gathering Phase
- Network selection/Handoff Decision
- Mobility management/Handoff Execution

2.1 Access Discovery or Handoff Information gathering phase

This phase is in charge of collecting network information and information related to network components. Implementation of the functionalities of this phase can be through events or triggered notifications. Various types such as predictive and event triggers are commonly used for the purpose in addition to monitoring different layers [6].

2.2 Access Selection or Handoff Decision

This phase is the heart of VHO process and execution phase depends on the instructions given by this phase to have seamless connectivity across heterogeneous networks. [4].

In a homogeneous network environment, predefined threshold values of Received Signal Strength (RSS) decide when to handoff and most of the HHO are based on traditional handoff policy (Relative RSS). In heterogeneous networks, relative RSS is not applicable, since the RSS from different types of networks cannot be compared directly due to the heterogeneous nature of the technologies involved. A VHO Decision algorithm considers one or more criteria (single, double, triple, multi…) to interpret the information collected in information gathering phase for optimizing handoff execution [5].

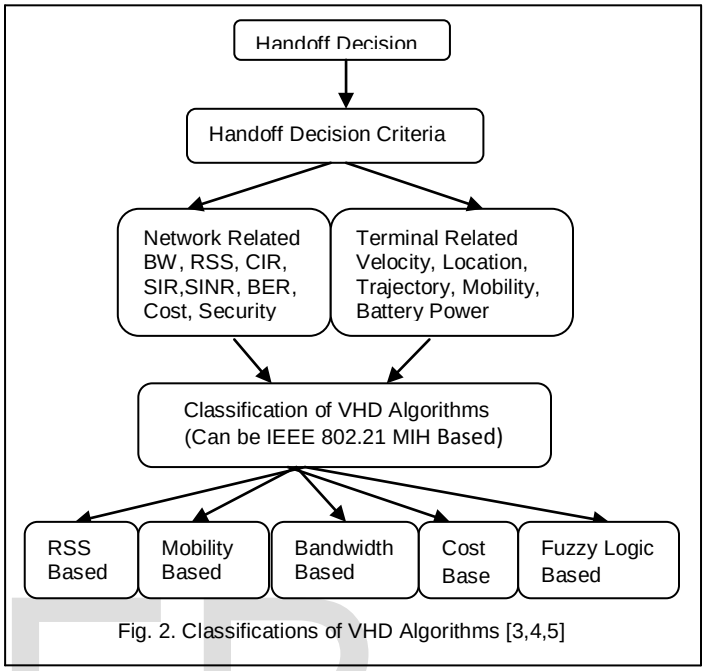

Fig. 2. Classifications of VHD Algorithms [3,4,5]

Any of the algorithms based on RSS, distance, Cost, Bandwidth and Fuzzy Logic category can be combined with Media Independent Handover function to provide seamless mobility across heterogeneous networks. The algorithms are called as MIH based handoff decision algorithms if they are using IEEE 802.21 standard during information gathering phase of vertical handoff management procedure [6].

2.3 Handoff Execution

Handoff implementation or execution phase performs the actual handoff using control signalling and the IP management protocols. Mobility management and Handoff Management are two important components of Handoff Execution phase [2].

3 IEEE 802.21 Based Media Independent Handover (MIH)

IEEE 802.21 ensures interoperability between several types of wired and wireless access network. The standard names vertical handoff as Media Independent Handover (MIH). Henceforth, we refer vertical handoff as MIH. The heart of the 802.21 framework is the middleware protocol called Media Independent Handover Function (MIHF). MIHF is able to encapsulate the different underlying network technologies such as 802.3, 802.11, 802.16, UMTS, CDMA2000, and GSM to the upper layers, allowing the handoff management process to operate independently of the physical and data link layers. MIHF defines three different services [7]:

Media Independent Event Service (MIES) - This service detects the changes on the lower layers, e.g. changes on the physical and data link layer. It provides events triggered by changes in the link characteristic and status. The MIES covers events such as State change events (Link Up, Link Down, Link

parameter changes), Predictive events (Link_Going_Down (LGD), Link_Going_Up (LGU), Link Handover Imminent, Link Handover Complete) and Network initiated events (load balancing, operator preferences).

Media Independent Information Service (MIIS) - MIHF uses MIIS mechanism for information gathering by discovering its neighbouring network environment and their capabilities that the upper layers make use of to make decisions. The information elements refers to the list of available networks, location of Point of Attachment (PoA), operator ID, roaming partners, cost, security, QoS, PoA capabilities, and Vendor specific information, among others.

Media Independent Command Service (MICS) - MICS provides the MIH user necessary commands to manage and control the link behaviour to accomplish handoff functions through a set of commands such as MIH Handoff Initiate, MIH Handoff Prepare, MIH Handoff Commit and MIH Handoff Complete.

3.1 Default Algorithm Handover1 (MIH1)

MIH1 considers RSS of MAC interface as the only criteria (single-criteria) for the handoff decision. It compares RSS of the new connection (RSS_{new}) and RSS of the current connection (RSS_{curr}) with the predefined threshold value. If RSS_{curr} is greater than a predefined RSS threshold value, then it remains connected to WiMAX else the MN initiates handoff to WiFi. Accordingly, it generates LGD event and compares it with the threshold parameter called as Confidence_Th which is set in the ns2 script to avoid ping-pong effect. This simulation uses 80% threshold confidence. Also during handover1, the connection doesn't get transferred to newly preferred BS even after Handover Complete trigger. Through experimentation, it has been observed that connection does not get immediately handed over to new PoA thereby increasing Handoff Latency and Packet Loss [14].

Default Algorithm for Handover1 is given below.

Get_Mac_info
Type of Handoff // MIH1
case_of_scenario //Refer Fig. 3
process_link_parameter_config (scan request)
process_scan_response (mih_scan_response_)
If no network detected {
process_no_ link_detected
process_get_status_response (mih_get_status)
process_link_detected
connected to WiMAX
If ($RSS_{New} > RSS_{Th}$ && $RSS_{curr} < RSS_{Th}$) then
{process_new_prefix
new_address
redirectMac
LGD Generation
Wait for Handover Complete Trigger
WiFi link_up
Shut Down WiMAX
}
Else Continue Current Connection

3.2 Proposed Algorithm Handover2 (MIH2)

MIH2 is modified algorithm which considers both RSS of the MAC interface and Bandwidth of the access network for the handoff decision. LGD event is generated when RSS_{New} is greater than RSS_{Th}, RSS_{Curr} is less than RSS_{Th} and Bandwidth of the new access network (BW_{New}) is greater than the predefined threshold value. Proposed algorithm uses Recv_Redirect_Ack function which instantaneously call Shut_Down on receiving ACK from Handover Complete Trigger thus drastically improving handoff latency and packet loss.

Algorithm for Proposed MIH2 Algorithm
Get_Mac_info
Type of Handoff // MIH2
case_of_scenario //Refer Fig. 3
process_link_parameter_config (scan request)
process_scan_response (mih_scan_response_)
If no network detected {
process_no_ link_detected
process_get_status_response (mih_get_status)
process_link_detected
connected to WiMAX
If ($RSS_{New} > RSS_{Th}$ && $RSS_{Curr} < RSS_{Th}$) && ($BW_{New} > BW_{Th}$)
then
{process_new_prefix
new_address
redirectMac
LGD Generation
Wait for Handover Complete Trigger
WiFi link_up
Recv_Redirect_Ack function for instant WiMAX Shut down
}
Else Continue Current Connection

Default Handover 1 algorithm has been modified to include rerecv_redirect_ack() function which ultimately calls Shut_Down_on_Ack function.

Handover2 scans both RSS from AP/BS and bandwidth for generating LGD trigger. Handover2 takes care of the ACK from the Handover Complete trigger and immediately calls Shut_Down_on_Ack function which shuts the previous connection and starts the new one decreasing Handover Latency and Packet Loss. In the handover2, RSS as well as Bandwidth is compared with the threshold. If the RSS and the Bandwidth are less than the predefined threshold values then the system doesn't wait for the handover complete trigger, it generates shut down on acknowledgment trigger and connection is immediately handed over to the stronger BS/AP. If the RSS and the Bandwidth of the present network is greater than the threshold then the same BS/AP is used to access the network.

4 Performance Comparison of MIH Algorithms in ns2

Most of the studies available in literature use network simulators (ns2), OPNET, QualNET, OMNET etc. for implementation of MIHF. MATLAB is considered to be a good tool for evaluation of mathematical models based on RSS, distance, bandwidth, mobility, SINR, CIR, SIR, BER etc but doesn't support MIH. ns2 is a powerful solution to evaluate MIH in heterogeneous environments since it can model multiple network topologies and mobility protocols [9,10]. Currently ns-2 supports WiMAX (802.16), Wi-Fi (802.11),

UMTS and Ethernet (802.3) in IEEE 802.21 based MIH scenarios through the use of NIST add-on modules. These modules were developed for version 2.29 of ns-2. NIST added and changed numerous files in the standard release of ns-2 in order to support mobility scenarios [11].

4.1 Simulation Scenario and Parameters

The simulation topology has been generated in ns-2 to analyze the performance of Constant Bit Rate (CBR) traffic during VHO between WiMAX and WiFi. The topology consists of two Base Station's (BSs), two Access Points (APs), a Router, one Mobile Node (MN, video sender) and a Correspondent Node (CN, video receiver) as shown in Fig.3.

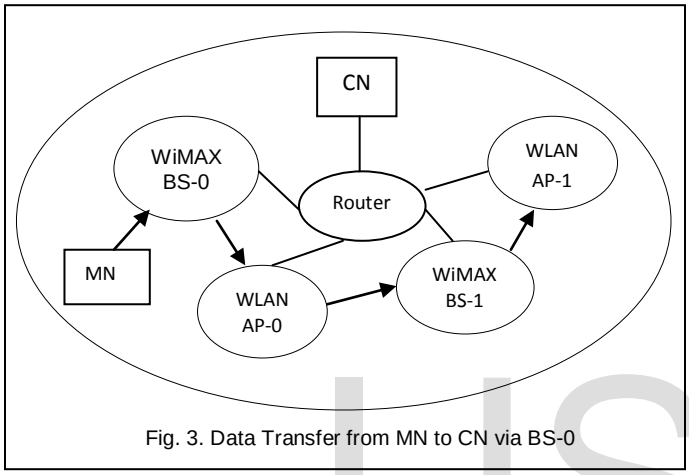

Fig. 3. Data Transfer from MN to CN via BS-0

At the start of simulation, both WiMAX and WiFi interfaces are available. But After receiving a *Download Context Descriptor* (DCD) and an *Upload Context Descriptor*(UCD) from the BS0 of WiMAX, MN triggers a *Link Detected* event and MN's WiMAX interface connects to the BS0 triggering a Link Up event [11]. MN's WiMAX interface receives a Router Advertisement (RA) containing router-lifetime (15 s), network prefix (4.0.0), and advertisement interval (10 s) in response to its Router Solicitation (RS) message. Accordingly, MN's WiMAX interface reconfigures its layer 3 address as 4.0.1. At *t = 10* s, MN starts sending UDP datagram of 1240 bytes and CBR packet size of 512 bytes to the CN through the WiMAX interface. At *t = 15* s, MN moves towards Wi-Fi cell. At approximately *t* = 22 s, MN's WiFi interface detects 802.11 beacons triggering Link Detected event when the Received Signal Strength (RSS) of the beacon frames is above the threshold value. VHO is initiated and MN's Wi-Fi interface and the AP0 exchange *Association request* and *Response* frames triggering a Link Up event. Now, MN's WiFi interface transmits RS to AP0 and AP0 sends RA containing router lifetime (15 s), network prefix (5.0.0) and advertisement interval (10 s). Upon receipt of RA, WiFi interface sets its Layer 3 address as 5.0.1). Now MN redirects transmission of streaming video traffic through WiFi AP1. This type of handoff is called as make-before-break handoff and MN uses both interfaces simultaneously to perform a seamless handoff. Further at approximately *t* = 28s, the MN starts moving towards WiMAX cell and due to increase in speed of MN. This increases the probability of Wi-Fi link going down. When it reaches a predefined threshold value of 80%, WiFi Link Goes Down (LGD) and MN starts sending CBR traffic through BS1. Further, MN connects to CN through AP1. And simulation stops at t=50s [11,12,13]. The simulation parameters are given in Table I.

Table I
Simulation Parameters

Parameter	Value
Network Topology	
WiMAX cell coverage	1000m
WLAN cell coverage	20m
Prop. delay CN – MN(s)	0.09 for RTT plus Mac access delay
Router Configuration	
MAX_RA_DELAY (s)	0.5
Router lifetime (s)Wlan	1800
Router lifetime (s)WiMax	20
802.11 Parameters	
WLAN beacon interval (s)	0.1
Default scanning mode	Passive
MinChannelTime (s)	0.02
MaxChannelTime (s)	0.06
802.16 Configuration	
Dcd_interval	5
Ucd_interval	5
Client_timeout_	50
Default modulation	OFDM_64_QAM
Mobility Model	
Velocity (m/s)	[5,20]
Path	Straight line
Application Traffic for MN	
Type	CBR
Packet size (bytes)	1240

4.2 Performance Analysis of Handover1 and Handover2

Performance analysis of default MIH (Handover 1) between WiFi and WiMAX has been presented by [12,13]. This section discusses the performance comparison of Handover1 and Handover2 based on basic metrics such as Latency and Packet Loss.

4.2.1 Latency

In the graph shown in Fig. 4, we can clearly see that the latency for handover2 is much less as compared to the handover1 (Table II). As we have modified Handover1 to include Recv_Redirect_Ack( ) function which immediately calls Shut_Down_on_Ack function after Handover Complete Trigger. This shuts down the previous connection instantly and starts the new one decreasing Handover Latency and Packet Loss.

Table II
Latency comparison

Latency as per IEEE 802.21	Latency for Default Handover1	Latency for Modified Handover2
2.97 sec	2.00 sec	0.5 sec

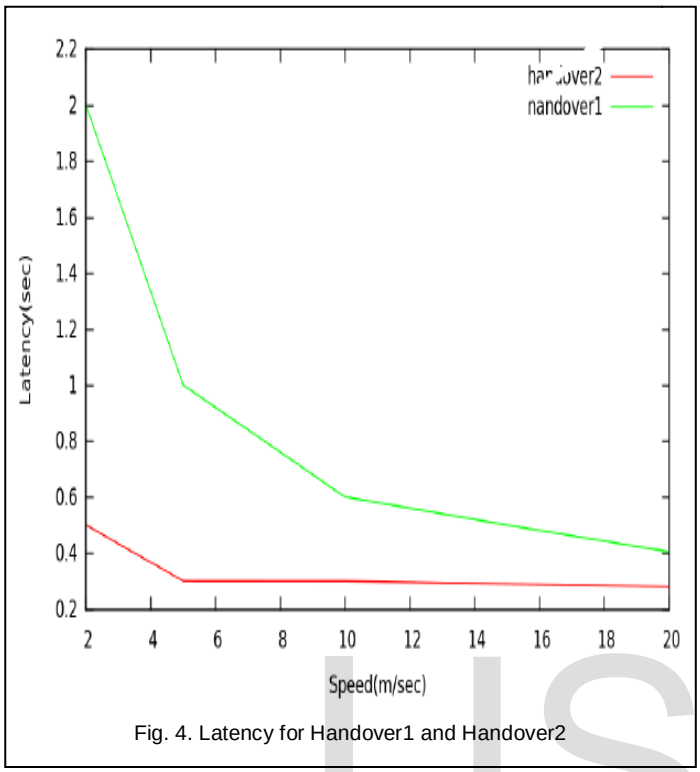

Fig. 4. Latency for Handover1 and Handover2

4.2.2 Packet Loss

With decrease in MIH latency, naturally packet loss also gets reduced. As per the IEEE 802.21 draft, maximum Packet Loss is 137 [14]. As shown in Fig. 5, number of packets lost during Handover1 is 200 which is significantly reduced to 80 during Handover 2.

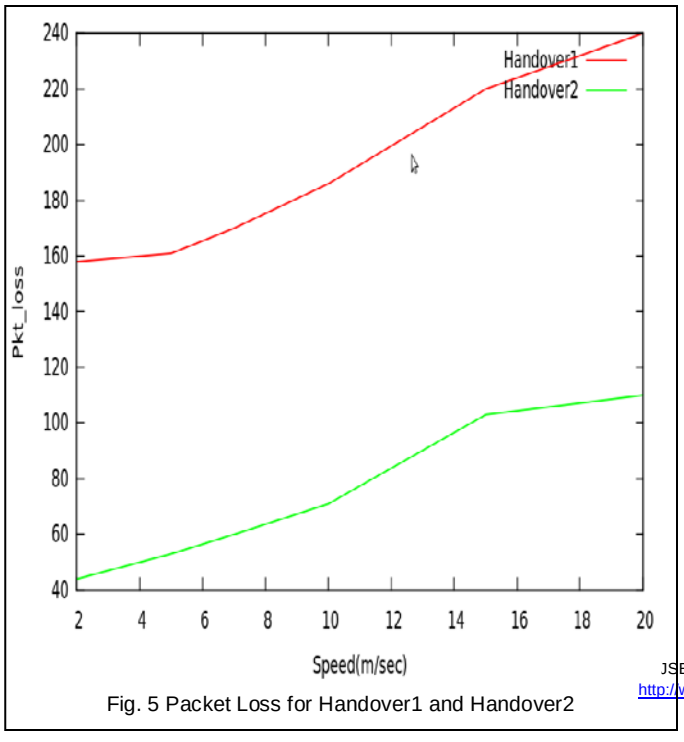

Fig. 5 Packet Loss for Handover1 and Handover2

5 Concluding Remarks and Future Research Directions

This paper thoroughly discusses 802.21 standards so as to enable readers to establish connectivity between fundamental vertical handover management procedures and its implementation through IEEE 802.21. Heart of vertical handover management procedure is Vertical Handover Decision (VHD) algorithms and it has been implemented using MIH Function of 802.21. The paper provides perfect roadmaps and motivation to experiment and simulate vertical handover scenarios for heterogeneous access technologies supported by 802.21 such as WiFi, WiMAX, UMTS, Bluetooth, and Ethernet.

Comparison of MIH algorithms indicate that Handover 2 performs better in terms of metrics such as Latency and Packet Loss. Summarizing the results, Latency has been reduced from 2 sec to 0.5 sec that means handover2 executes the handover process in 0.5 sec and handover2 requires 2 sec. Packet loss for Handover 2 is 200 which is significantly less compared to Handover 1 packet loss of 80.

Future Research Directions

- Devising more sophisticated 802.21 based MIH algorithm by considering number of handoff failures and number of unnecessary handoffs.
- Enhancements in IEEE 802.21 NIST add-on modules to support additional access technologies such as integration of WiFi, WiMAX, UMTS and Ethernet.
- Adaptations in ns-2 to simulate higher number of mobile nodes.

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