Handover Between Wi-Fi and WiMAX Technologies Using GRE Tunnel

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Abstract The next era of wireless grid inclines to be heterogeneous in the composition, i.e., wireless technologies like Wi-Fi and WiMAX networks desire co-breathe, so there is a demand for the best utilization of the accessible mixed chains. This paper considers the issue of handover between Wi-Fi and WiMAX grids with seamless connectivity. For this, first, a mobile terminal that abuts both IEEE 802.11 and IEEE 802.16 technologies was designed in the simulator. The developed mobile node was then introduced in the simulation scenario to study the various metrics. Second, we present the incorporation of GRE tunnel between the home agent and base stations for doing away with latency and packet drop and thereby improving the MOS value of the interest of consumers, giving impetus to efficiency day instant and day forth.

Keywords Wi-Fi · WiMAX · Heterogeneous network · GRE
Handover · Packet loss · Packet

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1 Introduction

Along the inroads in wireless technology, Wi-Fi [1–4] and WiMAX [5, 6] will coexist. The Wi-Fi has unlicensed array [7] for its order plus WiMAX shares licensed range. If a user supports both technologies, i.e., the user is served by unrestrained of expense Wi-Fi and afterward, due to the drastic decline of the incoming signal intensity [2] the ambulant station resolution change against the WiMAX, and hence a trade-off between SOS (strength of the signal) and expense. The handover (intra- and inter-technology [7, 8] handover) is required to pedestal both Wi-Fi and WiMAX which results in the continuity of service. Handover is a procedure of changing current call/session from one cell to other [9]. Horizontal Handover (HHO) [10] is used in homogeneous networks and is a comparatively simple mechanism. It is better from the user's viewpoint because it tends to be imperceptible. However, for Hybrid Networks complexity tends to be higher due to the implementation of Vertical Handover (VHO) [11] mechanisms. A serious consideration for this is that moving from one technology to the other is moving from one standard to another with certainly a different set of protocols. So this handover seems to be difficult and time consuming, causing the active sessions to break down and as a consequence user likes to continue with the current network, resulting in restricted mobility of the user. Hence, Vertical Handover is indispensable for integrated grids. The mobile terminal (MT) cannot admit packets amid the handover process until it entirely associates with the new network [12]. This handover process leads to a disruption in the latest meeting and is irritating to users [13]. To ensure a seamless handoff [14], the interruption duration (i.e., time required by total transitions of handover to be integral) should be less than the time taken by the movable depot to license its latest Access point's (AP'S) neighborhood [2].

This paper is arranged through a series of systematic investigations given as Compilation of seamless handover is presented in Sect. 1. Related work, double-layered node model, and GRE (Generic Routing Encapsulation) Tunnel are discussed in Sects. 2, 3, and 4 respectively. Section 5 describes the simulation scenarios used to assess the performance of the proposed model; with and without GRE tunnel. After running the simulation, we collect several statistics over the designed model which generates the voice traffic. Section 6 discusses the tracing of the graphs and their comparative analysis. Section 7 concludes the successful mechanism and basis for future work on this investigation.

2 Related Work

Pontes et al. [8] illustrated the wear of MIH (Media-Independent Handover) anatomy for integrating Wi-Fi and WiMAX structures to give seamless handover, through Backhaul and Dual-Mode Client Scenarios. However, it lacks the concept of multi-hop MIH. The authors in [15] have improved MIH solution by introducing a fuzzy inference engine wherein various inputs like signal intensity, distance from AP, etc., are assigned to sets. These sets are subject to the fuzzy rule base later. Gawk tools are used to analyze data, and the simulations show reduced handover packet loss and delay. However, it lacks the implementation of multi-network environment parameters. In [16], a fuzzy-based network selection model has been proposed wherein the multi-threshold mechanism makes the handover choice. This multi-criteria procedure has proven successful, but the multiple interfaced hardware node model is absent. The vertical handover algorithm proposed in [17] declares that it flaunts lower converging than established mechanisms to meet behaviors like MIH as the proposed algorithm processes on an adaption layer over the MAC layer. Also, the authors have converted the WiMAX signal into Wi-Fi signal to increase the range of the device. The end device is only Wi-Fi compatible, thereby lacking heterogeneity. Edward and Sumathy [18] analyzed various protocols for achieving seamless handover between Wi-Fi and WiMAX at different layers concluding that SIP Bicast (Session Initiation Protocol) plus MIH confirm to be the elite answers to give fast, seamless upright handoff. The performance evaluated is based on the assumption that mobile terminal supports both Wi-Fi and WiMAX but the design of such end terminal is absent. The authors in [10] reviewed various answers for handover based on parameters like handover delay, dropped packets, repetition of events, scalability, etc. To reduce the re-setup delay in WiMAX/LTE during IMS session, the author in [19] has proposed a scheme called SIP prior handover with a cross-layer design. The proposed system improved the exchange of SIP messages to 1% in contrast to the MIP. Shi et al. [7] provided a less latency handover arrangement. As per the authors, in homogeneous networks, the MT can discover its movement and estimate the handoff that diminishes the direct expense amid the MN (Mobile Node) besides its AP. In heterogeneous systems, they have used velocity as an essential metric to cause handoff. Naeem and Nyamapfene [20] proposed a decision-making algorithm for seamless handover amid Wi-Fi hot spots besides a spread WiMAX web. According to this algorithm, the MT switches from Wi-Fi to WiMAX chain when signal strength sinks inferior to the predefined satisfactory point. But for an optimal solution, seamless handovers need to be augmented with network layer information. The authors in [21] have carried out VHO between Wi-Fi and WiMAX using the NS2 simulator. It is, however, observed that the ratio of packet loss increases with the increase in the speed of MN. Similarly, the authors in [22] have summarized on how radio interfaces are selected in heterogeneous wireless networks. Wang et al. [23] used dual property that permits to receive data at the handover time. From their projected formula, the output decreased as the latency increased. Besides, the way to expeditiously operate with twin connectivity opens a variety of analysis queries. In [24], the authors have extended routing protocols for lower networks (RPL) in IoT (Internet of Things) architecture wherein handover mechanism is incorporated.

This paper aims at performing seamless VHO between Wi-Fi and WiMAX using double interfaced node. We used OPNET (Optimized Network Engineering Tool) [25] to design such node. Also, GRE tunnel [26] is used to reduce factors that decrease QoS (Quality of Service) during handover.

3 Double-Layered Node Model

Wi-Fi besides to WiMAX appear to be splendid partners to liberate favorable, inexpensive portable broadband internet utility's [1]. So there is a need for a wireless scheme that desires multiple interfaces [8]. In this paper, a double-interfaced movable station supporting Wi-Fi plus WiMAX broadcast interfaces has been designed and used in OPNET. Figure 1 shows the design of the mobile node (Double-layered [1] node). The Double-layered module composes of physical plus MAC layers for both WiMAX and Wi-Fi. The data link layer (DLL) together with the physical layer (PHY) of the OSI stack for the MN's of the twin standards can be combined keeping the upper layers alike. Figure 2 outlines the steps carried out by a double-layered node model while it comes back and forth to Wi-Fi and WiMAX base stations (BS). The MAC layers of Wi-Fi and WiMAX node take the HHO (Layer 2 handover) decision, i.e., in the module denoted as wlan_mac and wimax_mac (Fig. 1). While as the VHO (Layer 3 handover) is taken from the IP layer. The decision undertaking layer verifies the conditions described in the above algorithm and sends an interrupt to the upper layers. If the handover is

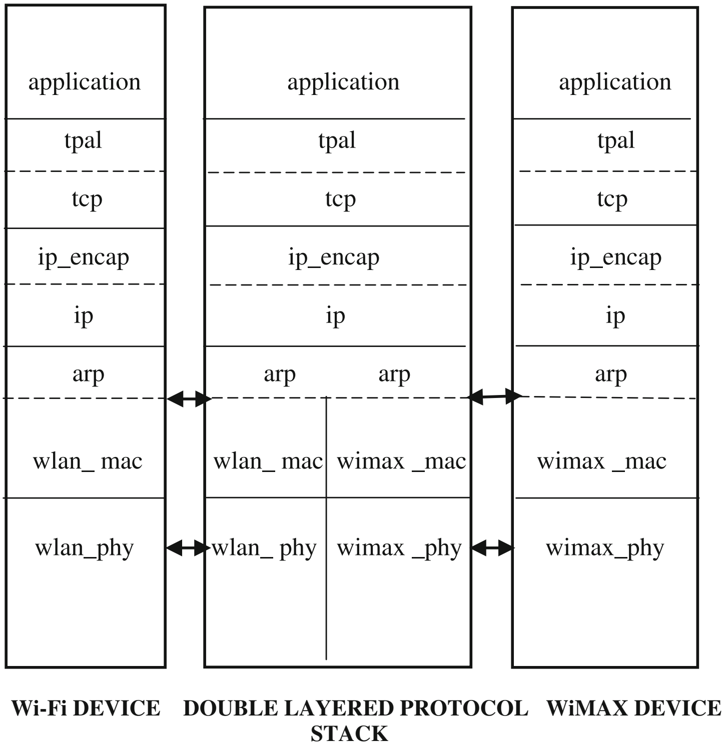


Fig. 1 Double-layered protocol stack with the Wi-Fi and WiMAX components

toward the Wi-Fi network (i.e., if SOS1 > Threshold) the voice application on the Wi-Fi node starts receiving data and voice application on WiMAX port ceases data generation. The operations are performed in reverse order if the algorithm is toward WiMAX network.

The primary requirement for simulating the vertical handover in OPNET is the design of a double-layered node. We achieve this aim by combining protocol stacks of these two different technologies in OPNET.

4 GRE Tunnel

Tunneling is a mechanism which involves encapsulation and decapsulation of the packets such that the path traversed by the packet does not depend on the address of the destination, but is prespecified [27]. The GRE tunnel is such a virtual point-to-point data passage that allows encapsulation of packets of one protocol in the body of another protocol [28]. Thus, an entirely new packet forms after stamping IP packets with GRE header. The GRE is used when packets, demand to be sent from one network to alternative, without being processed like IP packets by intervening routers, hence desirable for handover. We also choose the least hop path while drawing the GRE tunnel due to which processing occurs at the lesser number of intermediate routers. GRE also increases the efficiency and security of topology. The efficiency of handover is increased by tunneling the data from the home agent to foreign agents due to which minimum packet loss occurs when the end devices switch the network. Unlike IP-in-IP tunnel used in MIP solution, [29] in which data travels in unencrypted form, the data traverses in encrypted form in GRE thereby making eavesdropping difficult and enhancing security. GRE configuration does not include static access lists to traffic data rather the dynamic protocols like RIP, OSPF, etc., are used for network management. GRE also supports multicast. It uses the keep-alive mechanism in which the router keeps its port up even if the other side's router is unreachable. Further, GRE tunnel has not degraded the throughput due to the addition of new header because the maximum MTU (Maximum Transfer Unit) is greater than the fragment size, which has been manually set [28]. Figure 3 depicts the Signaling Scheme for vertical handover using GRE Tunnel.

1. WiFi_AP (Foreign Agent: FA _current) sends the beacon to MN which includes various QoS parameters provided by it.
2. MN compares the SOS of WiMAX_BS2 (FA_previous) and WiFi_AP to decide handover and sends an Association Request to WiFi_AP which in turn establishes a connection by sending Association Response.
3. In the meantime, the server sends data destined for the MN to HA (Home Agent). The MN is doubly connected while performing handover so it can receive the packets from HA through WiMAX_BS1 although it is associated with WiFi_AP too.

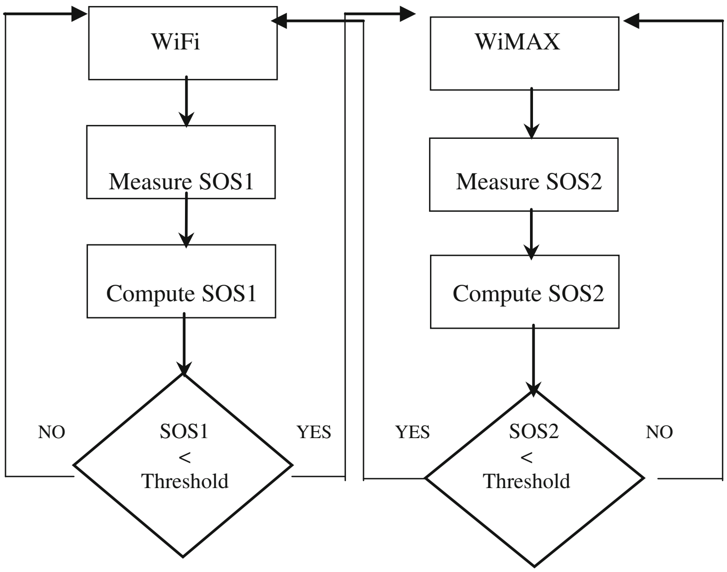


Fig. 2 Proposed flowchart for seamless vertical handover

4. It then informs the HA about its new COA (Care of Address) by sending it a Registration Message through WiFi_AP. HA replies WiFi_AP back with Registration Reply and forwards it to the MN. In the meantime, a tunnel establishes between WiFi_AP and HA. Further, the connection between WiMAX_BS2 and HA terminates.
5. Now all the data destined to MN are forwarded to WiFi_AP by HA which in turn sends it to the MN.

5 Simulation Scenario Setup

The OPNET simulation tool was used [25] to examine the performances of the proposed node model in a network during the handover. We evaluated performance parameters under the following scenarios:

5.1 Scenario 1

In Scenario 1 as shown in Fig. 4a, we deployed two WiMAX base stations (WIMAX_BS_1 as Home Agent) and one Wi-Fi Access point. A Point-to-Point

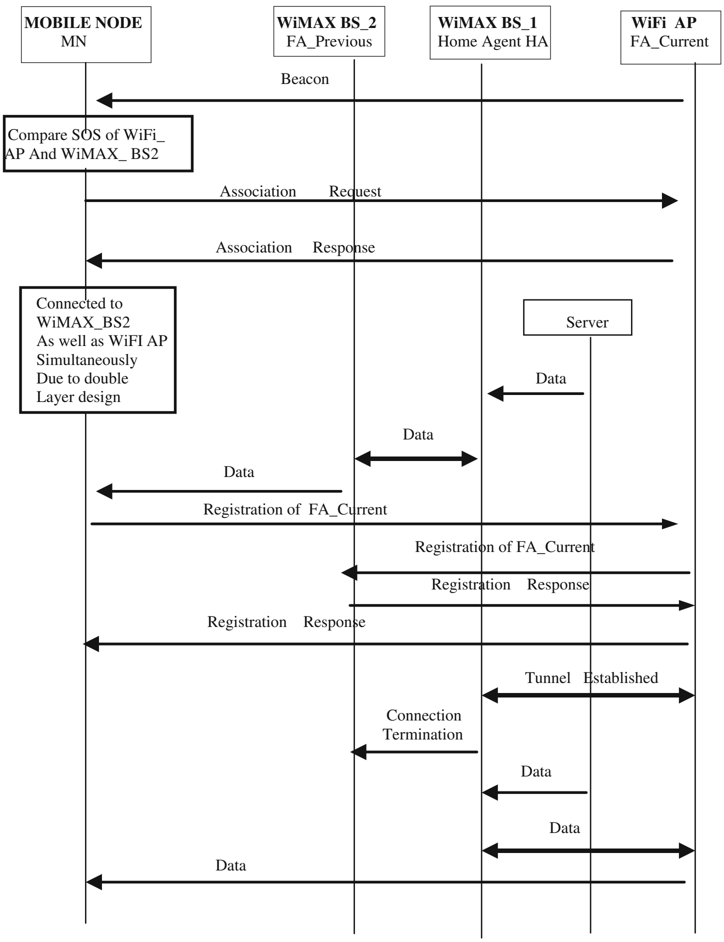


Fig. 3 Signaling scheme

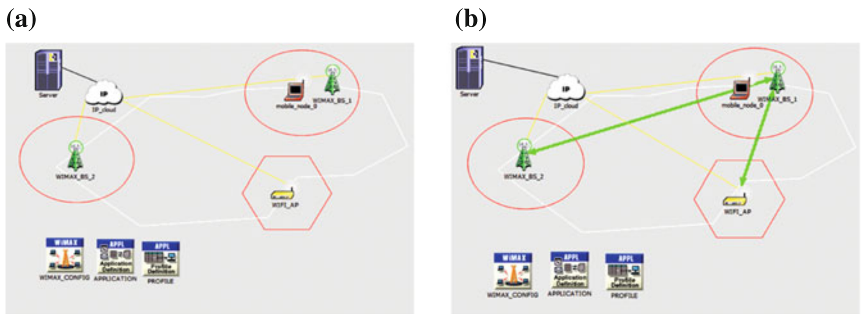


Fig. 4 **a** Scenario 1 for handover process, **b** Scenario 2 for handover process

(PPP) link connects each BS with the IP cloud. The server (corresponding node CN) also associates to the IP_ cloud. The double-layered node is moving at varying pace and covering different distances throughout the scenario giving rise to horizontal and vertical handovers respectively.

5.2 Scenario 2

Scenario 2 as shown in Fig. 4b, is a homogeneous replica of Scenario 1 but with GRE tunnels established between WiMAX_BS_1 and WiMAX_BS_2 and between WiMAX_BS_1 and Wi-Fi AP. The fundamental purpose of inducing GRE tunnel in the topology is to decrease the loss of user information during handover.

6 Results and Analysis

This section discusses the performance evaluation of deployed topologies. The Simulation is run for 60 min, and the analyzed metrics are addressed below.

6.1 Results Obtained for Scenario 1

Global Traffic Sent and Received: Figure 5 shows global traffic sent and received on the network. As mobile_node_0 moves from WiMAX_BS1 to WiMAX_BS2 then to WLAN AP, it gives rise to two drops. The first drop (50 packets/s lost) occurs due to the HHO while the second one (20 packets/s lost) takes place due to the VHO. More packets are lost during HHO than VHO because simple MAC layer takes HHO decision and the complex IP layer takes the VHO decision.

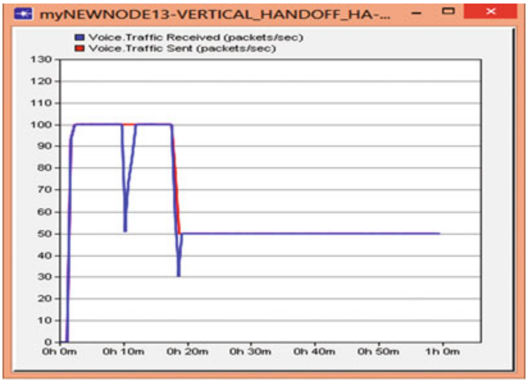


Fig. 5 Scenario 1: global voice traffic sent and received

The predefined trajectory compels the mobile node to progress through the different points and then returns to WiMAX_BS1.

6.2 *Overlapped Results Obtained for Scenarios 1 and 2*

In Scenario 2, the analysis of the same performance parameters is carried out again.

Voice traffic received by mobile_node_0: The voice traffic received by the mobile_node_0 (Fig. 6) is the average number of packets per second forwarded to all voice applications at the transport layer in the network. This figure shows that the packets dropped during the HHO were nearly 45(50-5) Packets/s in Scenario 1. However, by using GRE tunnel, the packet drop reduces to 23(50-27) packets/s. Similarly, for the VHO, the number of packets dropped were initially 22 Packets/s which reduces to 14 packets/s in Scenario 2 indicating that packet drop was impressively decreased using GRE tunnels.

MOS value for mobile_node_0: MOS (Mean Opinion Score) is a mathematical formula of expressing the perceived class of the media received and is expressed in names of digits, ranging from 1 to 5, 1 living in the inferior and 5 is the ultimate [30]. The MOS value of mobile_node_0 in both scenarios is compared in Fig. 7. Initially, in Scenario 1, the topology started with the MOS value of 3.5 but at 10 m 0 s due to HHO the MOS value reduced to 3.3; which further degraded to 2.9 at 19 m 0 s owing to VHO. It then started to escalate and acquired a permanent value of almost 3. However, in the case of Scenario 2, the very appraise of 3.2 is obtained which tends to be superior. Since the number of packets dropped is inversely proportional to MOS value, so fewer packets dropped implies higher MOS value and vice versa.

Packet End-to-End delay: Packet End-to-End Delay refers to the duration taken to deliver a packet from source to sink across the network [31]. Figure 8 compares the

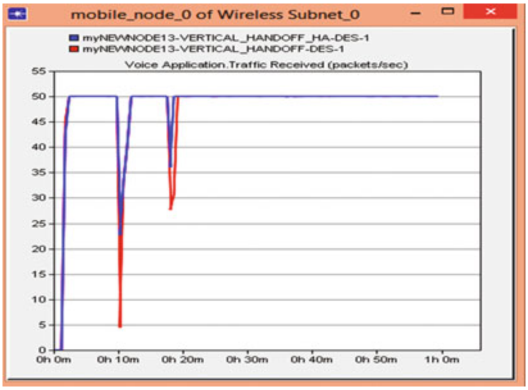


Fig. 6 Overlapped voice traffic sent and received by mobile_node_0

Fig. 7 Overlapped MOS value of mobile_node_0

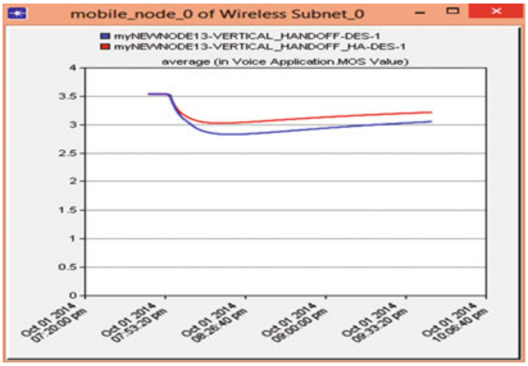
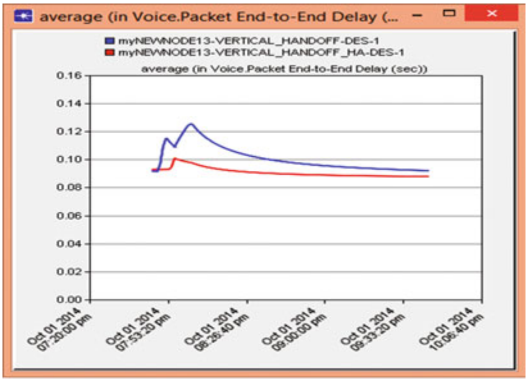


Fig. 8 Overlapped global packet end-to-end delay value in both scenarios



Global Packet End-to-End values of both the scenarios. It is evident from the graph that due to the GRE tunnel Packet End-to-End delay value decreases as GRE routes packets quickly. In Scenario 1, the delay finally acquires the value of 0.95 s, but in the second one, it reduced to approximately 0.94 s.

We may conclude from the results that GRE-implemented scenario resulted in fewer packet drops and the end-to-end delay because GRE encapsulates the payload and routes the encapsulated packets through desired IP networks. As a result of which routers along the way hardly get to parse the whole payload leading to lower processing pace at every router. Thus, the buffered packets swiftly route from the home agent to new BS such that the new BS is ready to transmit the packets to the mobile station as readily as it befalls in its locality. Introducing GRE tunnel simply speeds up the conventional handover procedure and thereby minimizing delay and in turn increasing the MOS value.

7 Conclusion and Future Work

This paper examined seamless handover between two different well liked technologies, viz., Wi-Fi and WiMAX. We incorporated and implemented Wi-Fi and WiMAX technologies in the double-layered node model to perform seamless vertical handover. We also examined the impact of GRE Tunnels to obtain a low latency handover arrangement as a result of which the user can move from a network of one standard to another standard while continuing the session. The simulation results depict that the implementation of GRE tunnels in such heterogeneous environment improves the performance and thereby reducing packet drops. The maximum delay obtained was 0.13 s which was outperformed by the GRE-implemented scenario to 0.10 s. The simulations carried also revealed that the packet drop considerably reduced to 23 packets/s against 45 packets in Scenario 1.

As in this paper path loss was selected to be “Free Space”, consequently, transmitter beside recipient own a clear line of sight among them, i.e., no additional source of impairment. This path loss is hardly practical. Therefore, in future more realistic path loss models need to be assessed. The future work further involves proposing a better and an efficient handover scheme between Wi-Fi, WiMAX, and other technologies such as LTE, UMTS, and ZigBee, etc. that can significantly decrease the two most important parameters in handover, i.e., packet loss and delay.

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