IEEE 802.21 Based Vertical Handover in WiFi and WiMAX Networks

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Abstract—**Seamless handover between different access technologies is a great challenge as it needs to obey different performance of QoS and security constraints. Subscribers are becoming more demanding regarding roaming capabilities across different networking technologies such as WiFi, WiMAX, and CDMA as they claim service continuity with QoS requirement and good security features. In this paper, a QoS based vertical handover mechanism between WiMAX and WiFi networks is proposed by applying the Signal to Interference and Noise Ratio SINR. The Media Independent Handover MIH (IEEE 802.21) protocol is adopted to assist in the handover decisions by providing a suitable platform for vertical handovers. The performance of the proposed SINR based vertical handover algorithm and RSS based vertical handover algorithm have been evaluated in terms of the maximum downlink throughputs.**

Keywords-component; SINR; MIH; vertical handover; WiMAX; WiFi

I. INTRODUCTION

Future network devices will need to roam seamlessly across heterogeneous access technologies such as 802.11, WiMAX, CDMA, and GSM, between wired networks such as xDSL and cable, as well as between packet switched and circuit switched (PSTN) networks [1-2]. Figure 1 shows an example wireless Internet roaming scenario across heterogeneous access networks that involves intrasubnet, inter-subnet, and inter-domain mobility. Supporting seamless roaming between heterogeneous networks is a challenging task since each access network may have different mobility, QoS and security requirements. Moreover, interactive applications such as VoIP and streaming media have stringent performance requirements on end-to-end delay and packet loss. The handover process stresses these performance bounds by introducing delays due to discovery, configuration, authentication and binding update procedures associated with a mobility event [3].

The ability to change access link for better QoS in different wireless communication networks is known as seamless vertical handover [4]. To achieve this object, the Media Independent Handover (MIH) IEEE 802.21 standard has been proposed to permit the exchange of entities belonging to different access networks and assists the handover decisions by defining the set of functional components to be executed [5]. However the standard defines the overall framework only, the actual implementation of algorithms are left to the designers. Several algorithms in vertical handover decisions (VHD) have been proposed in the research literature to fill this gap.

II. WIFI AND WIMAX NETWORKS

Wireless Fidelity (WiFi) is a wireless local area network over limited range. It is known also under IEEE 802.11, and aims to connect devices such as Personal Computers, PDAs, laptops, printers, etc.

IEEE 802.11 allows connectivity in infrastrucure moe or ad hoc mode. In infrastructre mode, the WiFi stations communicate through the access point (AP). In this mode, the 802.11 network architecture, illustrated in figure 2, is hierarchical. Its basic element is the Basic Servise Set (BSS), which is the group of stations covered on the area covered by one AP.

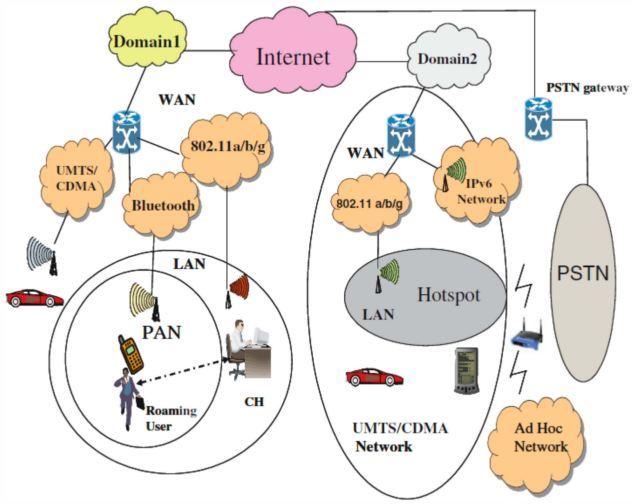

Figure 1. Wireless internet roaming scenario in heterogeneous networks

A BSS may also be part of larger netowork element called Extended Service Set (ESS). The ESS consists of one or more BSSs connected to the same wired LAN so called Distribution System (DS).

In ad hoc mode, devices can communicate directly with each other without Access Point support. In our paper, we focus on infrastructure mode.

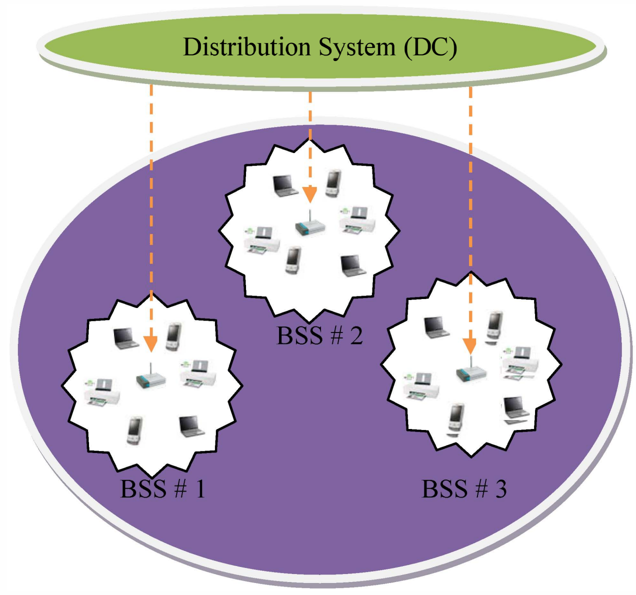

Figure 2. WiFi infrastructure mode

Worldwide Interoperability for Microwave Access (WiMAX) is a Wireless Metropolitan Access Network (WMAN). It is used generically to describe wireless systems based on IEEE 802.16.

WiMAX offers high data rates and large area coverage. It supports fixed and mobile broadband access. In our work we focus on Mobile WiMAX (IEEE 802.16e). The Mobile WiMAX Network, described in figure 3, is divided into three parts: the Mobile Station (MS) which is the user's device, the Access Service Network (ASN) is the radio access and includes one or more Base Stations (BS) and one or more ASN Gateways (ASN-GW). The Connectivity Service Network (CSN) is the core of WiMAX Network. It provides IP connectivity to the MS.

In order to provide mobility, 802.16e supports handover mechanisms. The IEEE 802.16e defines three differents types of handover: Hard Handover (HHO), Fast Base Station Switching (FBSS) and Macro Diversity Handover (MDHO). The HHO is often refered to as a breake-before-make handover: first the MS disconnects from the serving BS and then connects to the target BS. In FBSS and MDHO, the MS maintains a diversity set which includes numerous active BSs in its range. The BS, to which the MS has the connection, is called the anchor BS. In FBSS, the MS transmits to and receives data from a single serving BS. The transition from the serving anchor BS to the target anchor BS in FBSS is done without invocation of the normal handover procedure, only the anchor BS update procedure is needed. In MDHO, the MS maintains a connection to one or more BSs in the diversity set simultaneously [6].

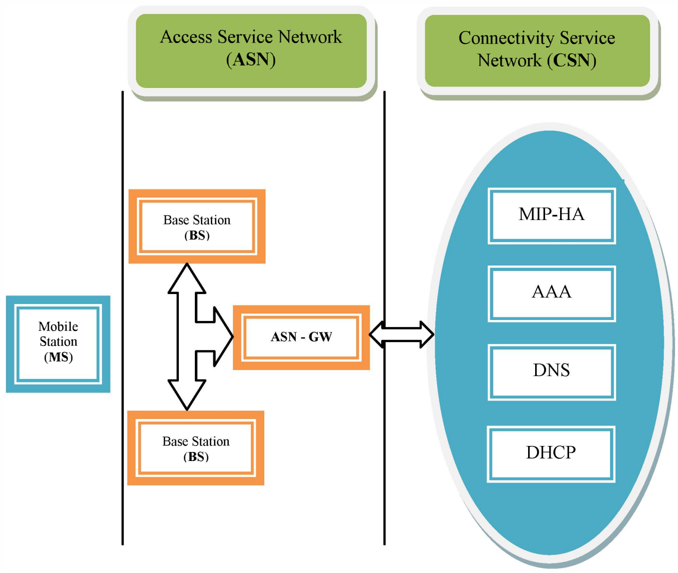

Figure 3. WiMAX architecture

III. VERTICAL HANDOVER

A. Handover Management Process

Handover management process in a mobility scenario is the procedure to maintain continuous connection in active mobile terminal while moving from one access link (base station or access router) to another. Handover management process has been described in several works [7-9] which involve three phases as shown in Figure 4:

- *Handover Information Gathering*: use to collect all information desired to initiate the handover. Also known as system discovery or handover initiation phase.
- *Handover Decision*: use to determine when and how to perform the handover by selecting the best access link available and by giving instructions to the next phase, (ie handover execution). Also known as system or network selection.
- *Handover Execution*: use to change channels conforming to the details resolved during the decision phase.

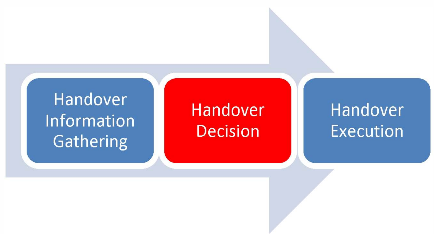

Figure 4. Handover management Process

B. Vertical Handover Decision (VHD) Algorithms

Several algorithms have been proposed in the research literature for use in the vertical handover decision (VHD) as shown in Figure 5. Brief description of each algorithm is as follows:

Received signal strength (RSS) is the easiest way to measure the service quality and the most widely used criterion. RSS reading is directly related to the distance from the MT to its point of attachment. Most of the existing horizontal handover algorithms use RSS as the main decision criterion [10].

Network connection time indicates the length of time that a user connected to an access point or base station. Choosing the proper moment is very important to initiate a quality of service handover [11].

Available bandwidth is a bit/sec expression that indicates the available data resources and is a measure of traffic conditions in the network. Signal to Interference and Noise Ratio SINR is related to availabe bandwidth algorithms [12].

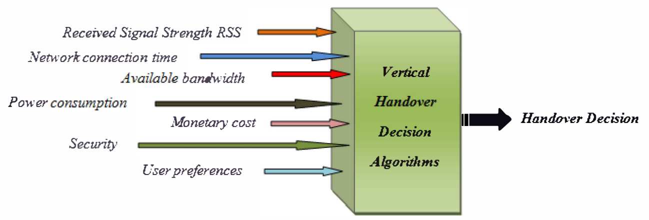

Figure 5. Parameters used for making VHD decision

Power consumption refers to the MT's battery level, which becomes very important in case need to handover to another network that consumes lower power [13].

Monetary cost: some algorithms take into consideration the charging policies for different networks in making their handover decision [14].

Security: Integrity or confidentiality are considered as a critical issue in some applications, where the VHD may be chosen to a higher level of data security.

User preferences: a special user requirement or preference could be the issue that decide to initiate the handover [15].

Many VHD algorithms have been proposed in the research literature, most of them have designed their VHD algorithms depending on the signal strength recieved by the mobile terminal, where handover decisions are made by comparing the received signal strength with the preset threshold values. These algorithms which use signal strength as their basic handover decision indicator are called *Received Signal Strength* (RSS) algorithms. However, the data rate achieved by a mobile terminal is related to its *Signal to Interference and Noise Ratio* (SINR), which is a function of the interference in the network, as well as the distance between Base Station (BS) or Access Point (AP) to the mobile terminal. RSS-based VHD occurs when the mobile terminal recieving power approaches the threshold value regardless of the QoS needed, thus rendering RSS-based VHD not to support user's QoS requirement. On the other hand, SINR-based VHD supports multimedia QoS requirement depending on the achievable data rate which leads to seamless vertical handover.

C. MIH Overview

MIH defines a logical entity, MIHF, located on layer 2.5 between link layer and network layer of the OSI model. It provides a framework that allows interaction between higher layers and lower layers. The MIHF supports three types of services: Media Independent Event Services (MIES), Media Independent Command Service (MICS, and Media Independent Information Service (MIIS). The MIES aims to provide and to predict link changes such as LINK UP, LINK DOWN, LINK GOING DOWN, etc. These events are propagated from lower layers to upper layers through the MIH layer. MIES is divided into two categories, link events and MIH events. Link events are generated from the lower layer and transmitted to MIH layer [6].

The MIH events are the events forwarded from MIH to upper layers. MICS refers to the commands, such as initiate handover and complete handover, sent from higher layers to lower layers. It allows enabling handover mechanism. MICS includes MIH command and LINK command. MIH Commands originate from the upper layers down to the MIHF. Link Commands are specific to the lower layers. MIIS provides a framework by which MIHF can discover homogenous and heterogeneous network information existing within a geographical area to facilitate seamless handover when roaming across these networks. The MIIS provides a bidirectional way for the two layers to share information such as current QoS, performance information and availability of service. Figure 6 illustrates the MIH architecture[12].

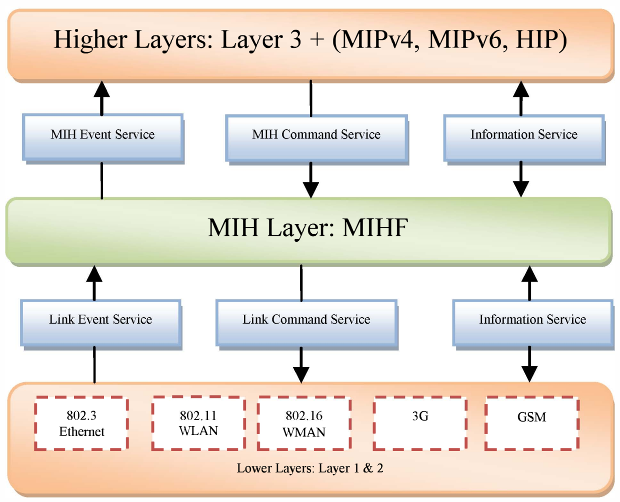

Figure 6. MIH architecture

National Institute of Standards and Technology (NIST) has modified the network simulator NS-2 version 2.29 [16] to implement the Media Independent Handover (MIH). The modified NS-2.29 version [17] consisted of MIH Function

(MIHF) implementation based on the IEEE 802.21 specifications. It helps to evaluate the performance of different handover decision engines.

IV. SINR Based Vertical Handover Strategy

In this paper, a SINR based scenario similar to that proposed by Kemeng et al [18] is proposed instead of RSS as the handover criteria for WIFI and WiMAX integration network. The Shannon capacity determines the maximum achievable data rate for a given Signal to Interference and Noise Ratio SINR and carrier bandwidth as:

$$R = W \log_2\left(1 + \frac{\gamma}{\Gamma}\right) \quad (1)$$

where:

- R is the maximum achievable data rate
- W represents the bandwidth of the carrier
- γ is the received SINR at a MT
- Γ is the gap in decibel between channel capacity and uncoded QAM, minus the gain caused by coding.

Let R_{BS} be the maximum data rate from WiMAX base station, R_{AP} be the maximum data rate from WIFI access point. Shannon formula becomes:

$$R_{BS} = W_{BS} \log_2\left(1 + \frac{\gamma_{BS}}{\Gamma_{BS}}\right) \quad (2)$$

$$R_{AP} = W_{AP} \log_2\left(1 + \frac{\gamma_{AP}}{\Gamma_{AP}}\right) \quad (3)$$

Where, γ_{BS} and γ_{AP} represent the receiving SINR from WiMAX and WIFI respectively. By letting $R_{BS} = R_{AP}$, we can find the relationship between required γ_{BS} and γ_{AP} incase of MT receiving the same data rate from WiMAX and WIFI:

$$\gamma_{AP} = \Gamma_{AP} \left[\left(1 + \frac{\gamma_{BS}}{\Gamma_{BS}}\right)^{\frac{W_{BS}}{W_{AP}}} - 1\right] \quad (4)$$

The SINR-based VHD algorithm becomes applicable by having the relationship between the receiving SINR and the maximum data rate from both WiMAX and WIFI. γ_{BS} which represent the SINR received from WiMAX has been converted to an equivalent γ_{AP} required to achieve the same data rate in WIFI. The flowchart in Figure 7 shows the procedure of equivalent SINR-Based model [18].

With the combined effects of both SINR being considered, handover is initiated while the user is getting equivalent SINR from another access network. It means that given the receiver end SINR measurements of both WIFI and WiMAX channel, the handover mechanism now has the knowledge of the estimated maximum possible receiving data rates a user can get from either WIFI or WiMAX at the same time within the handover zone, where both WIFI and WiMAX signal are available.

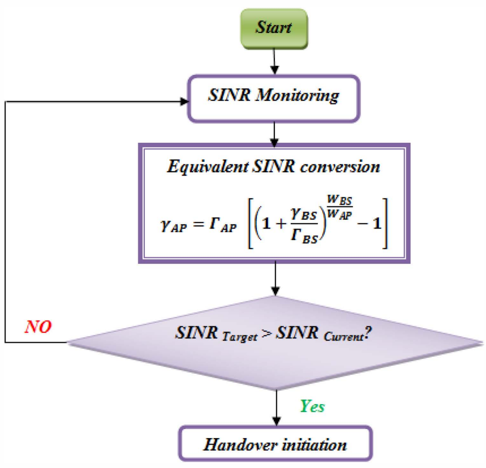

Figure 7. Equivalent SINR based model

We compare our SINR based vertical handover algorithm with the RSS based vertical handover algorithm in terms of the maximum downlink throughputs the user can achieve while traveling through the integrated network. Studies have used various thresholds setting for RSS based vertical handover: -90dBm, -85dBm and -80 dBm along with the proposed SINR based vertical handover.

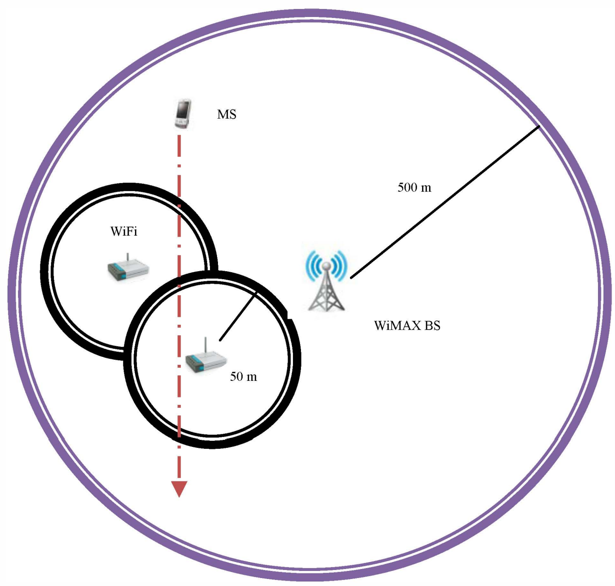

Figure 8. Simulation scenario

The performance of the proposed SINR based vertical handover algorithm and RSS based vertical handover algorithm have been evaluated with the scenario shown in figure 8. The overall system throughput for different data rates are shown in figure 9, which shows that SINR based handover has outperformed the RSS based handover techniques in providing higher system throughput, and increment becomes more prominent at higher data rate.

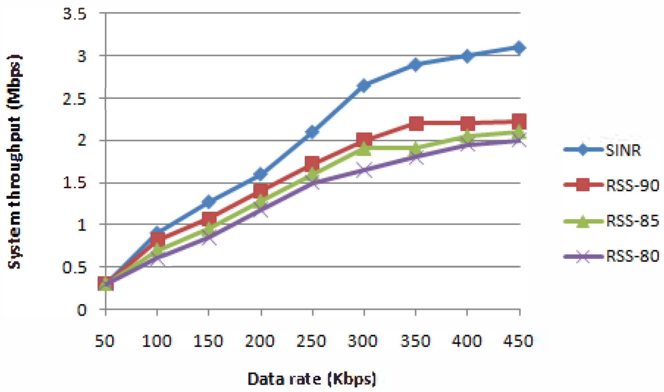

Figure 9. System throughput vs Data rate

V. CONCLUSION AND FUTURE WORK

In this paper, we have proposed an SINR-based Media Independent Handover mechanism with QoS support for coexist heterogeneous WiMAX and WIFI networks. Besides supporting QoS for different traffic flow, the proposed SINR-based VHD will also promote maximum achievable data rate. The performance of the proposed SINR based VH algorithm and RSS based VH algorithm have been evaluated in terms of the maximum downlink throughputs.

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