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VHO Strategy for QoS-Provisioning in the WiMAX/WLAN Interworking System

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Abstract: In IEEE 802.16, one of the main features is the QoS-Provisioning. The limited bandwidth and the increasing of the high data rate service users will impact the performance of the system. In this study, we propose a VHO algorithm that can support the provisioning of QoS in mobile WiMAX networks by handing over some Best-Effort (BE) low-speed WiMAX Subscriber Station (SS) to an overlaid WLAN network subject to the QoS guarantee for the SS. Our simulation results show that by utilizing the overlaid WLAN hotspots we can gain some free band for the new SS requests. According to our simulation results a significant improvement in the capacity and the probability of blocking (PB) in WiMAX network was achieved.

Key words: Heterogeneous network, vertical handover, QoS

INTRODUCTION

Next-generation wireless networks have been envisioned as an Internet Protocol (IP) based infrastructure with the integration of various wireless access networks such as GSM, GPRS and UMTS for cellular networks and WLAN and WiMAX for broadband access networks. The trend of future wireless network is accessibility for connecting to the network anywhere and anytime. Therefore, the integration of different wireless data networks such as WLAN, WiMAX and UTRAN to establish a multi-tier heterogeneous wireless network is becoming more popular issue (Hwang *et al.*, 2008). In such system, user will be roaming among different Radio Access Technologies (RATs) which is known as vertical handover/handoff. One of the major challenges in the inter-working of heterogeneous networks is seamless vertical handover. Several issues should be studied such as handover metrics, handover decision algorithms and handover management in order to achieve seamless handover. A factor which can affect seamless vertical handover is how and when to make a handover decision.

In horizontal handover, which occur between similar networks, the handover decision is mainly based on Received Signal Strength (RSS) in the border region of two cells. However, in vertical handover, the situation is more complex, compared to the horizontal handover, the signal strength is sometime not sufficient to trigger the vertical handover because of heterogeneous networks have different system characteristics and their performance cannot be simply compared using the signal strength of two cells. Other new metrics such as service type, system performance, network conditions, mobile node

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conditions, user preference etc. must be considered. Another challenge is that the vertical handover may not only take place at the cell edge. In fact, it could occur at any time (even when the MS does not move) depending on the network condition and user preference such as in a situation of network congestion. For instance, in the WiMAX/WLAN interworking network, when the user moves into a double coverage area, handover from WiMAX to WLAN cannot be triggered by monitoring connection quality since no sign of losing the connection will be detected. The decision to trigger a vertical handover according to the system performance and QoS parameters becomes the main part of vertical handover process. Therefore, an effective and efficient vertical handover decision algorithm for interworking system between is needed to maximize the resource utilization and to improve the system performance. In fact, it is a challenge to develop a vertical handover decision algorithm for optimal radio resource utilization with various QoS support.

Based on the aforementioned observations, some design requirements for handover between WLAN and WiMAX networks are; (1) reducing unnecessary handovers to avoid overloading the network with signaling traffic, (2) maximizing the network utilization and minimizing users = energy consumption, (3) avoiding moving into a congested network, (4) smooth and fast handover and (5) providing applications with the required degrees of QoS (Yang and Tseng, 2008).

The main issue of this study is to study on how to make a decision to trigger a vertical handover based on the WiMAX-QoS improvement. Since IEEE 802.16 is provision for QoS where WiMAX users would have QoS guaranteed, this paper will be focusing on the performance improvement of WiMAX networks by introducing two QoS improvement schemes to provide more chances to the mobile users to maximize the overall resources utilization of the integrated network. If the bandwidth of WiMAX is insufficient to satisfy a connection initiated by WiMAX user for certain type of service and the admission of this call in WiMAX network can degrade QoS of existing traffic flows, the proposed handover scheme will not simply block the call. In such environment, these schemes start to distribute the traffic using WLAN overlaid coverage cells and try to make more WiMAX bandwidth available for the new call before deciding to block the call.

Some researches have been done on a decision algorithm in WiMAX/WLAN vertical handover. The systems in heterogeneous wireless networks are able to maintain the delivered QoS to different users at the target level with the combination of call admission control and resource management techniques.

Hwang *et al*. (2008) proposed two bandwidth management and reservation schemes to decrease call reject probability for better resource utilization. The strategies include admission control and resource reservation mechanism for real-time services. And in real-time services, some traffic has bursty features which cause difficulty to reserve appropriate bandwidth. Fuzzy controller is proposed to adjust bandwidth of real-time service adaptively and enhance resource reservation mechanism. The system performance can be improved such as decreasing rejecting probability and increasing system throughput by sharing the system loading between different wireless access technologies. Nie *et al*. (2005) suggested a bandwidth optimization scheme to make vertical handoff between networks of IEEE 802.16 and IEEE 802.11.

For handovers from WMAN to WLAN, triggering by the MAC layer can be initially registered before the handover of network layer, which reduces the access delay and aids the handoff decision for better connectivity. The bandwidth cannot be obtained directly from MAC layer. Instead, by listening to and collecting the Network Allocation Vector (NAV) in MAC layer. The IEEE 802.11 network is providing higher bandwidth than IEEE 802.16

network. Therefore, the user can choose the best AP with maximum bandwidth for connecting to the Internet. The scheme of utilizing the average of RSS takes into account the subsequent signal strength, so it is able to avoid the unnecessary handoff. The system can utilize temporary channel quality variation to achieve higher capacity and extend the coverage range of IEEE 802.11 networks.

An accurate estimation for utilities of target systems must be preceded a handover for the efficient use of system resources. The vertical handover decision algorithm based on the utility function is proposed to satisfy wireless QoS. The integration of heterogeneous system included cdma 2000, WiBro, WiMAX (based on IEEE 802.16e) and WLAN. Utility function is required for evaluating the value of the wireless systems so that a mobile can decide a target system to handover. The utility function is developed effectively by considering signal to interference plus noise ratio (SINR), bandwidth, traffic load and user's mobility, which are the main factors to decide throughput. Shannon's capacity formula is used as a QoS function in order to maximize throughput and traffic load is considered to utilize systems evenly (Lee *et al*., 2006).

Dia *et al*. (2008) established new user centric algorithm for vertical handover combining data rate and channel occupancy in order to fairly balance users among the two networks and maximize the user throughput. The proposed algorithm raises the system capacity which resulted increasing the gain that can be achieved with a WiMAX and WLAN heterogeneous deployment.

Zhang (2008) discussed the handover signaling procedure in different scenarios when considering vertical handover scheme aims at reducing handover signaling overhead on the wireless backbone and providing a low handover delay to mobile nodes. On top of call admission control, the vertical handover scheme directs a new call request in the 802.11 network to the 802.16 network to avoid QoS degradation on existing real-time traffic flows.

System Model

The integrated system considered in this paper consists of single WLAN-cell overlaid with singe mobile WiMAX-cell deployed in a suburban environment. However, the users connected to the WiMAX network can move freely within the WiMAX cell boundary and can probably cross the WLAN network cell boundaries, the case in which the VHO can be triggered according to the requirements of the WiMAX resource management algorithm. The following sections present the details of the system models and algorithms.

Network Topology, Mobility and Traffic Scenarios

The network topology as shown in Fig. 1 consists of micro-cell (WLAN) with radius of 50 m overlaid with single macro-cell (WIMAX) with radius of 1000 m with omni-directional antenna located at the center of each cell. As shown in the Fig. 1 the initial location and mobility scenario of mobile users generated randomly with different speeds 10 and 120 km h^{-1} for WLAN and WiMAX users, respectavely. In this study we assumed that the users who are initially connected to WLAN network are always active, while the activity of the users connected to the WIMAX network follows the traffic scenario. The SS activity status presented in the Fig. 1 by red and black paths for the active and idle status, respectively.

WLAN Throughput Estimation Model

In the 802.11 protocol, the fundamental mechanism to access the medium is called Distributed Coordination Function (DCF). This is a random access scheme, based on the

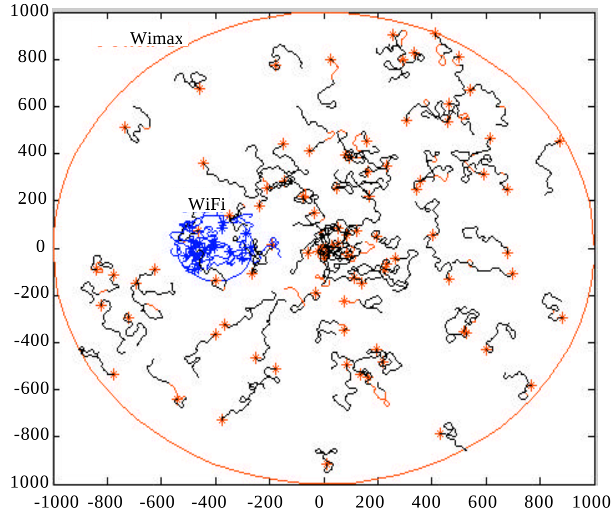

Fig. 1: Location and mobility scenario of MSs

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. Retransmission of collided packets is managed according to binary exponential back-off rules. The standard also defines an optional Point Coordination Function (PCF), which is a centralized MAC protocol able to support collision free and time bounded services. We limit our investigation to the DCF scheme (Bianchi, 2000).

In this study we use the simplified model presented by Bianchi (2000) to estimate the throughput of WLAN network. Bianchi (2000) presented an analytical model based on several assumptions and approximations has been developed; the author assumed an ideal channel conditions (i.e., no hidden terminals and capture) and finite number of terminals. Also assumed a constant and independent collision probability of a packet transmitted by each station (each transmission Asees@ the system in the same state, i.e., in steady state) regardless of the number of retransmissions already suffered. According to this model the normalized system throughput S is defined as the fraction of time the channel is used to successfully transmit payload bits. To compute S, we need to analyze a randomly chosen slot time. Assuming P_{tr} is the probability that there is at least one transmission in the considered slot time. Since, n stations contend on the channel and each transmits with probability τ:

$$P_{tr} = 1 - (1 - \tau)^n \quad (1)$$

The probability P_s that a transmission occurring on the channel is successful is given by the probability that exactly one station transmits on the channel, conditioned on the fact that at least one station transmits, i.e.,

$$P_s = \frac{n\tau(1-\tau)^{n-1}}{P_{tr}} = \frac{n\tau(1-\tau)^{n-1}}{1-(1-\tau)^n} \quad (2)$$

We are now able to express S as the ratio:

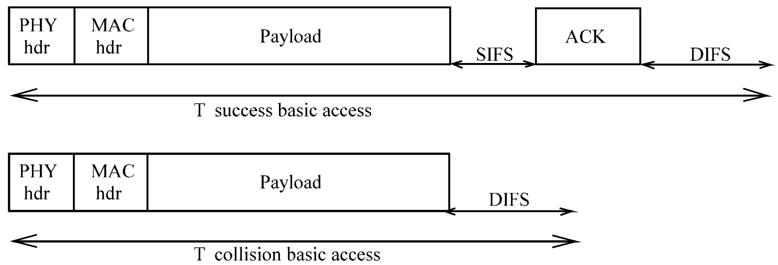

Fig. 2: T_s and T_c for basic access (Bianchi, 2000)

$$S = \frac{PL_{slottime}}{T_{slottime}} \tag{3}$$

Where:
$Pl_{slottime}$ = E (Payload information transmitted in a slot time)
$T_{slottime}$ = E (length of slot time)

Being E (P), the average packet payload size, the average amount of payload information successfully transmitted in a slot time is $P_{tr}P_sE[P]$, since a successful transmission occurs in a slot time with probability $P_{tr}P_s$. The average length of a slot time is readily obtained considering that, with probability 1- P_{tr}, the slot time is empty; with probability $P_{tr}P_s$, it contains a successful transmission and with probability P_{tr} (1- P_s) it contains a collision. Hence, Eq. 3 becomes:

$$S = \frac{P_s P_{tr} E[P]}{(1-P_{tr})\sigma + P_{tr}P_sT_s + P_{tr}(1-P_s)T_s} \tag{4}$$

where, T_s is the average time the channel is sensed busy (i.e., the slot time lasts) because of a successful transmission and T_c is the average time the channel is sensed busy by each station during a collision. σ is the duration of an empty slot time. Of course, the values E[P], T_c, T_s and σ must be expressed with the same unit.

Note that the throughput expression Eq. 4 has been obtained without the need to specify the access mechanism employed. To specifically compute the throughput for a given DCF access mechanism it is now necessary only to specify the corresponding values T_s and T_c. Let us first consider a system completely managed via the Basic Access mechanism. Let H = PHY_{hdr} + MAC_{hdr} the packet header and δ be the propagation delay. As shown in Fig. 2, in the Basic Access case we obtain:

$$\begin{aligned} T_c^{bas} &= H + E[P] + SIFS + \delta + ACK + DIFS + \delta \\ T_c^{bas} &= H + E[P^*] + DIFS + \delta \end{aligned} \tag{5}$$

where, E[P*] is the average length of the longest packet payload involved in a collision. In the case all packets have the same fixed size, then: E[P*] = E[P] = P.

By using the parameter values in Table 1, the estimated throughput for our system model using this simplified analytical model is shown in Fig. 3.

Table 1: System parameters for system throughput

Parameters	Value
Slot time	20 μsec
DIFS (distributed interframe space)	50 μsec
SIFS (short interframe space)	10 μsec
Contention window (CW_{min})	32
Packet payload	8224
Propagation delay	1 μsec
PHY header	192 bits
MAC header	224 bits
ACK	112 + PHY header

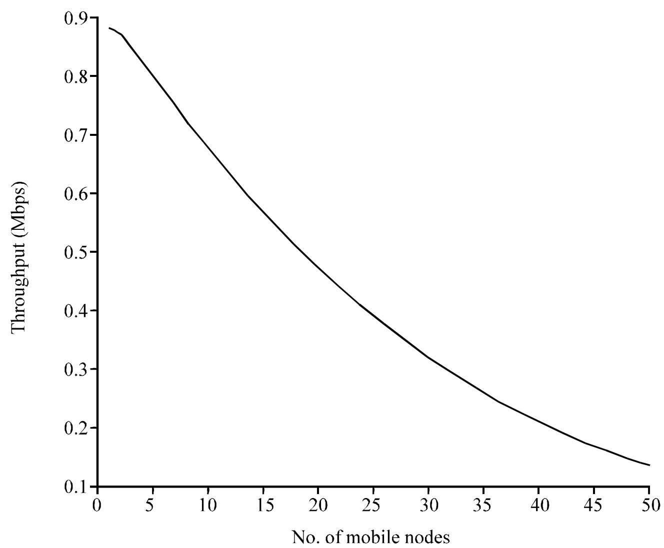

Fig. 3: Estimation of system throughput

WiMAX-QoS Improvement Scheme

The proposed algorithm for VHO in this paper shown in Fig. 4 aims to improve the performance and reduce the call blocking probability of the mobile WIMAX network when there are no enough resources by utilizing the WLAN hot spots to provide more chances to the users before deciding to block the call. The algorithm consists of two strategies, the first strategy shown in Fig. 5, aims to transfer the request from WIMAX-user to the WLAN network if the user is being inside the WLAN coverage. The 2nd strategy in Fig. 6, when the WIMAX user is outside the WLAN coverage we transfer other WIMAX users who are inside the WLAN coverage to WLAN network and allocate the sum of their resources in WIMAX network for the user under consideration. The following procedure describes the two strategies:

// VHO Algorithm:

If ($BW|_{WiMAX} < BW\_req|_{new\_SS}$. && $RSSI\_WLAN|_{new\_SS} = RSSI\_th$)

// strategy 1:

If ($S|_{WLAN} = S\_th$)

$VHO|_{new\_SS}$*

Update WLAN system resources

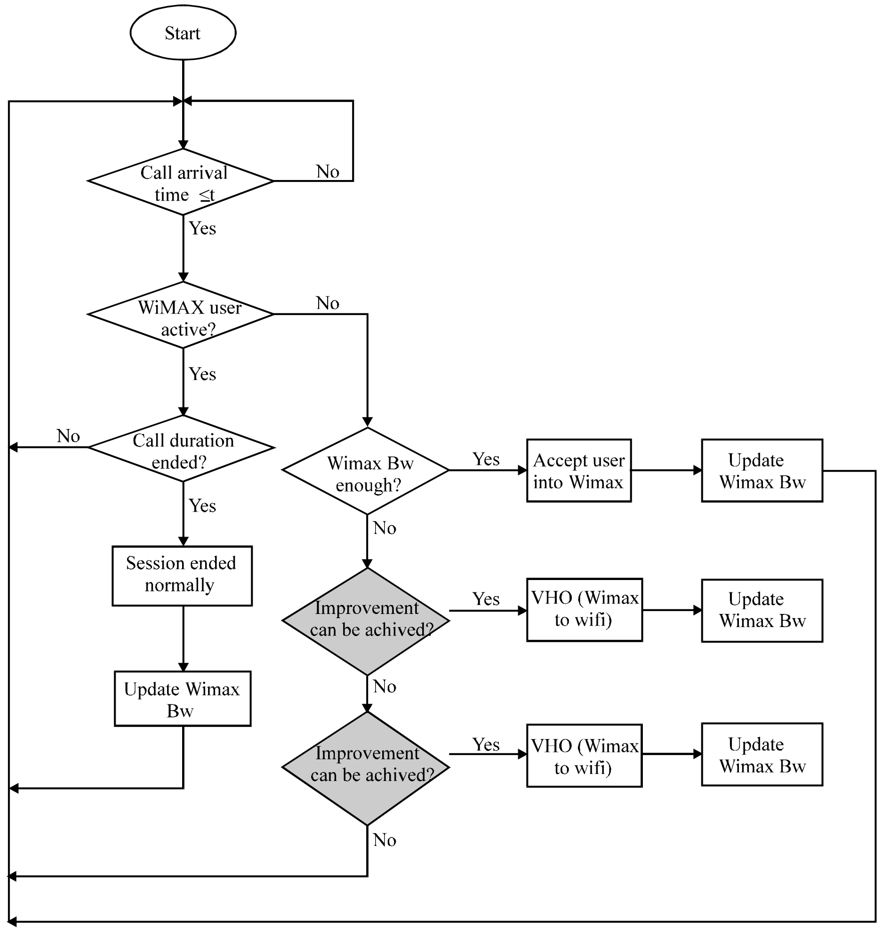

Fig. 4: Proposed VHO

Endif
//strategy 2:
Elseif (BW$|_{WiMAX}$ < BW_req$|_{new_user}$ && RSSI$|_{WLAN}$ < RSSI_th)
If (RSSI_WLAN$|_{other_SS=s}$ = RSSI_th && BW$|_{other_SS}$ = BW_req$|_{new_SS}$)
VHO$|_{other_SS=s}$**
Admission$|_{new_SS}$***
Update WLAN & WiMAX system resources
Endif
Endif
// *i.e., transfer the New_SS request to WLAN
// ** i.e., transfer the other_SS=s connections to WLAN
// *** i.e., accept the current_SS in WiMAX

where, S_th is the throughput threshold of WLAN network and S$|_{WLAN}$ is the WLAN system throughput.

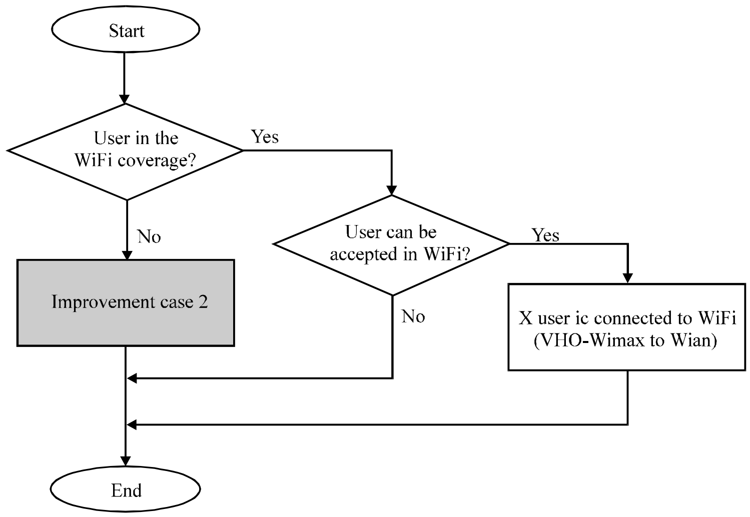

Fig. 5: Strategy 1

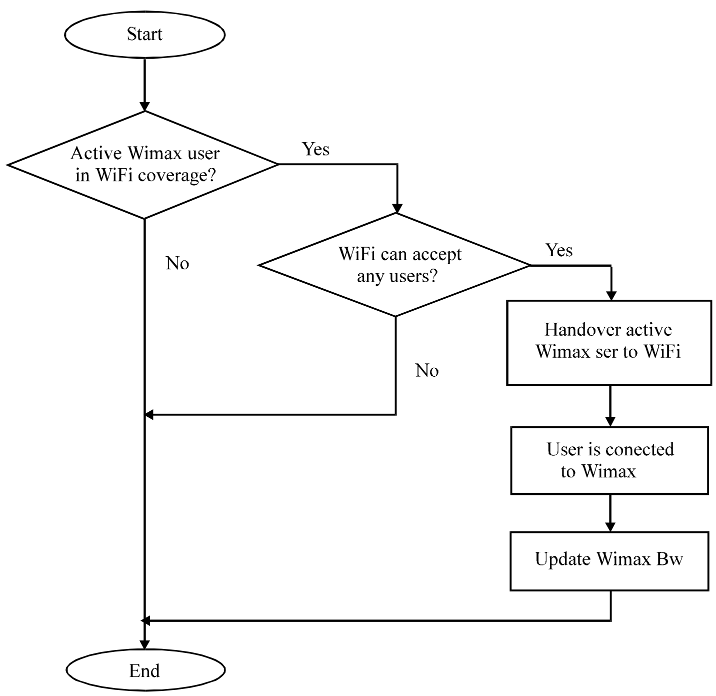

Fig. 6: Strategy 2

Performance Comparison and Analysis

Here, we present the simulation results obtained using the assumbtions and models presented in the previous sections. From these results we show the degree of improvement in the mobile WiMAX network. The PB for WiMAX system has been evaluated and compared among the three strategies: normal strategy (i.e., without improvement), strategy

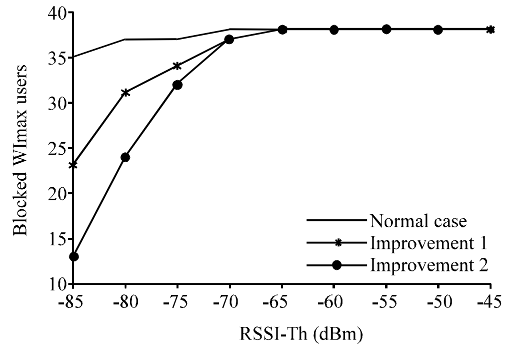

Fig. 7: No. of blocked WiMAX users vs. RSSI threshold

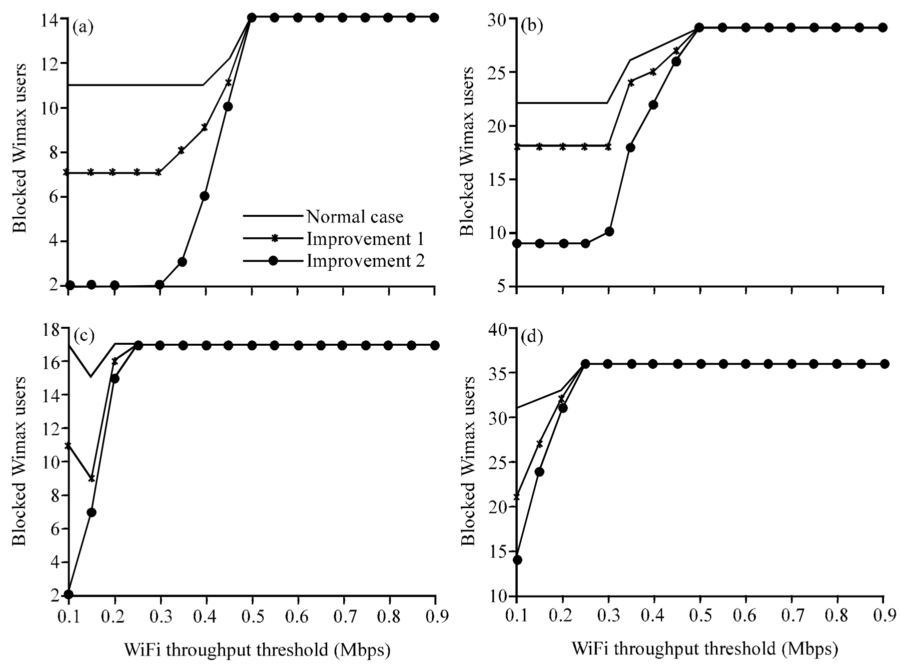

Fig. 8: No. of blocked WiMAX users vs. WLAN throughput-threshold. (a) both networks are low density traffic, (b) WiMAX high and WLAN low density, (c) WiMAX low and WLAN high density and (d) both networks are high density traffic

1 and strategy 2. By taking the RSSI_Th of WLAN Acess Point (AP) as a criteria for the VHO decision we found that the improvement in PB is about 34 and 63% for strategy 1 and 2, respectively. As we can see in Fig. 7 this improvement reduces as RSSI_Th increases until -65 dBm where no more improvenment achieved due to the shrinking of the WLAN coverage and then the WiMAX users loos the opportunity to be handed over to WLAN. This results obviously reflects the advantage of utilizing WLAN hotspot inside the coverage of Mobile WiMAX BS=s to improve the QoS or to increase the capacity of the WiMAX network.

In Fig. 8a-d the number of blocked calls versus WLAN throughput-threshold with different network density has been simulated. It is observed that at lower throughput threshold, the number of blocked call for strategy 1 and 2 is much lower compared to the normal strategy.

When the throughput-threshold of WLAN increases especially with high traffic density the improvement is no longer achieveable, since both networks tends to be overloaded and the number of blocked calls for the three strategies are the same. In this simulation, high and low density for WiMAX network is 90 and 50 users, respectively. While for WLAN network is 40 and 20 users, respectively.

CONCLUSION

The main benefit of interworking system which combining different wireless access networks with multiple tiers topology is the sharing of the system resources to serve one or both of these networks and hence improving system performance such as decreasing blocking call. In this study, two VHO strategies were proposed in the WiMAX-WLAN interworking system. Simulation results show that the proposed strategy 1 and strategy 2 decrease the blocking call compared to normal strategy. Some future works can be envisaged in order to improve this algorithm by including the QoS as a second criterion and consider the per-link throughput as well as the system throughput to make a VHO decision.

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