# Battery Based Vertical Handover between WiMAX and WLAN Technologies

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## Abstract

Nowadays, the battery life time becomes one of the most important challenges of the next generation wireless networks especially for mobile equipments that support more than wireless technologies. Different wireless technologies have different battery energy consumption levels. In this paper we propose a methodology for triggering the handover process among different wireless technologies based on the user terminal battery level status. Our study will efficiently saves the battery life time of the user terminal based on its surrounding wireless access technologies and its mobile terminal capabilities. Moreover we introduce a simple and easy concept for how to exchange this handover information from the user terminal to the network node to guarantee the smooth handover process.

## 1. Introduction

One of the current wireless networks can satisfy in the same time the high data rate, low latency, and overall coverage demands of the mobile users' service demands. This implies for the needs of integration between all wireless technologies to guarantee ubiquitous always best connection for users. This integration requires handover between different radio access technologies which is different in nature than the handover between network nodes of the same wireless access technology. The handover inside the same wireless network is known as horizontal handover while the handover between different wireless access technologies is known as vertical handover. So we have two types of handover scenarios which may arise, horizontal handoff and vertical handoff [1], [2]. Many studies on vertical handover have been reported in the literature. Mobility management contains two components one of them is called location management while the other is called handover management [3]. Mobility management protocols can operate from different layers of the protocol stack data link layer [4], network layer, transport layer [5] and application layer [6]. Recently, new handover algorithms are raised based on advanced techniques such as pattern recognition [7], neural networks and fuzzy logic system as well [8]–[10]. In [11] a link layer technique is used to improve the handover performance of Mobile IP. However, it does not specify any particular techniques for obtaining the link layer triggers. Different link layer handover algorithms that use received signal strength information at the user side to reduce handover delay and probability of handover failure are introduced in [4], [12]. McNair et al. [13] proposed a solution to achieve seamless handover by investigating various performance metrics for vertical handover decision. The authors of [14] introduced an end to end mobility management system which provides seamless connectivity between different wireless networks. The proposed system estimates precise condition of each network to avoid unnecessary handoff and achieve low latency handoff trial. In [15] the authors proposed a network layer vertical handover scheme. They also evaluated the performance of their technique against real system in heterogeneous networks. In most of the existing vertical handoff mechanisms [13, 14, 15] the energy of the mobile terminal battery is consumed continuously even in the idle mode. For example the WLAN stay in the idle mode about 85% of its overall operating time to check about the beacons comes from the serving access point; this is according to the authors in [16].

The remaining sections of this paper are organized as follows. Section II describes new methodology for exchanging the needed information for battery based vertical handover between different radio access networks. This method uses the option IP header field for information transfer purposes. In section III we introduce the simulation results for the battery based handover between two selected common wireless access networks. The selected two networks are WLAN and WiMAX networks. Finally, section IV summarize our work and introduce the future research.

## 2. Exchanging Handover Information using Option IP Header

### 2.1 Battery Based Handover Flag

Different access wireless technologies consume different energy values from its user terminal battery module. This flag is used to enable the vertical handover among different radio access networks based on the user terminal

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battery status. By using this method we can save the battery life time of the user terminal for long time as possible as we can. Suppose we have a user terminal that equipped with two wireless technologies, one technology belongs to WLAN while the other belongs to WiMAX. Let this user uses WiMAX technology while there is WLAN technology available in the same covered area. We also propose that the user mobility is limited or the terminal vehicular speed is slow enough to have both networks in the same coverage. If the user starts to use WiMAX technology after specific time his terminal energy battery level will become weak. At a certain energy battery level the user device terminal trigger the desire for switching to a WLAN which consumes low energy, this is to save the battery life time. This triggering information is mapped into the battery based handover flag. This information is exchanged from the user terminal device to the corresponding network node through the handover option IP header. Now the network node can read the battery field information and takes the handover decision based on the energy battery levels. A smart software device terminal module enables the user to do this triggering manually or automatically.

## 2.2 Battery Level Indicator Field

This field consists of three bits. We are interested in using this field for any wireless access technology at any energy battery level. So that we introduce this field which gives eight permutations. This means we have eight levels of battery indicators. We assign level zero for the strongest energy battery level which is encoded as '000' while level '7' is encoded as '111' and indicates to the weakest energy battery level. Table 1 gives more details about all codes and its corresponding meaning. The presence of this field depends on the value of the battery based handover flag. If this flag is set by '1' this will reflect the presence of the battery level information in the handover IP header. The user can activate this flag at any time he feels of the need to handover based on his terminal energy battery level. As we said before, the user has the flexibility to choose either to set this flag manually or automatically. Moreover the flag triggering condition can be set at specific terminal energy battery level that can be also determined by the user required setting. Now this battery level can be easily transferred to the network side using this field in the option IP header. The user also can choose a specific battery level for each wireless technology or he can let the software do this for him. For example the software triggers the handover from WiMAX to WLAN based on the battery status even the battery level is the strongest level because this is the optimum choice as we will see later on from the simulation results in the next section. This handover can happen irrespective of the user mobility status, in other words the mobility status is not the only triggering condition for the handover process. Moreover the user may be trigger the handover based on this information from his side. In this case the forced handover expresses the desire of the user to choose a specific wireless technology that guarantee saving his battery life time. Thanks to this proposed methodology that optimize the battery life time.

TABLE 1: BATTERY LEVELS FIELD.

| ***Value*** | ***description*** |
|---|---|
| 000 | Level 0 very strong battery level indicator |
| 001 | Level 1 |
| 010 | Level 2 |
| 011 | Level 3 |
| 100 | Level 4 |
| 101 | Level 5 |
| 110 | Level 6 |
| 111 | Level 7 very weak battery level indicator |

## 3 Mathematical Model

In this section we will introduce a mathematical model that is used to represent the gain from our proposed scheme. Equation (1) gives the energy consumption when the users only use WiMAX network. In the second stage the energy consumption is calculated from equation (2) whereas only WLAN is used. Finally, equation (3) calculates the battery energy gain when the user equipment makes a battery based vertical handover from WiMAX to WLAN while equation (4) is a special case when $\alpha = \beta$.

$$\Delta E)_{WiMAX} = N*P_{wx}*L(1+\alpha)/R_w \tag{1}$$

$$\Delta E)_{WLAN} = N*P_{APx}*L\,(1+\beta)/R_{AP} \tag{2}$$

$$\Delta E)_{WLAN}/\Delta E)_{WiMAX} = [P_{APx}\,(1+\beta)/P_{wx}\,(1+\alpha)] * [R_w/R_{AP}] \quad (3)$$

For simplicity let $\alpha = \beta$

$$\Delta E)_{WLAN}/\Delta E)_{WiMAX} = [P_{wx}/P_{APx}] * [R_{AP}/R_w] \quad (4)$$

The WLAN battery live time will be saved by $\Delta E)_{WLAN}/\Delta E)_{WiMAX} * P_{APx}$ Where $\Delta E$ represents the energy degradation or consumed energy, $N$ number of packets, $P_{wx}$ WiMAX transmit power, $P_{APx}$ WLAN transmit power, $P_{wr}$, WiMAX receive power, $P_{Apr}$ WLAN received power, $L$ packet length, $\alpha = P_{wr} / P_{wx}$ and $\beta = P_{APr}/P_{APx}$. Let for example $P_{wx} = 0.5$ watt and $P_{APx} = 0.005$ watt, in this case if we use the proposed scheme of battery based handover the gain will be 100 at the same rate of both WiMAX and WLAN. In other words for that example the WiMAX consumed energy is 100 times the energy used to transmit the same amount of packets in WLAN.

## 4. Simulation Results

We suppose that WiMAX bit rate is 10Mbps and the transmitted power equals to 0.5 watt whereas WLAN bit rate is 54Mbps and the transmitted power equals to 0.005 watt respectively. The simulation results show that as the number of exchanged packets is increased as the battery energy consumption is increased whereas the battery level is decreased. The energy degradation for WiMAX interface is higher than that of WLAN. For example figure 1 depicts that the battery strength will be totally exhausted (change from 30 to 0 Joule) after transferring only 33300 packets when WiMAX interface is used. On the other hand the energy consumption reaches 0.6 Joule when 360000 packets are exchanged using WLAN technology. In other words using WLAN instead of WiMAX technology at a certain time is very useful to save the energy battery levels of the terminal more than 540.5 times which is very close to the propose analytical model . This requires the vertical handover needs due to battery level weakness. In figure 2 we introduce the simulation results for the handover from WiMAX to WLAN at different terminal battery levels. The levels information is exchanged through the battery field in the IP option header. We have 8 levels that represent the battery range from the strongest level *'L0'* to the weakest level *'L8'*. The simulation results in all cases show that it is better to handover to WLAN technology as long as there is available WLAN coverage while there is no need for high vehicular speed. The network can detect if the vehicular speed is suitable for battery based handover or not based on the terminal vehicular speed. Figure 3 shows the triggering point of the handover process from WiMAX to WLAN at battery level 6. When the battery level reaches 7.5 Joule a handover request is sent to the network node through setting up the battery based handover flag from 0 to 1 and sending the code 110 which represents battery level 6 into battery level indicator field.

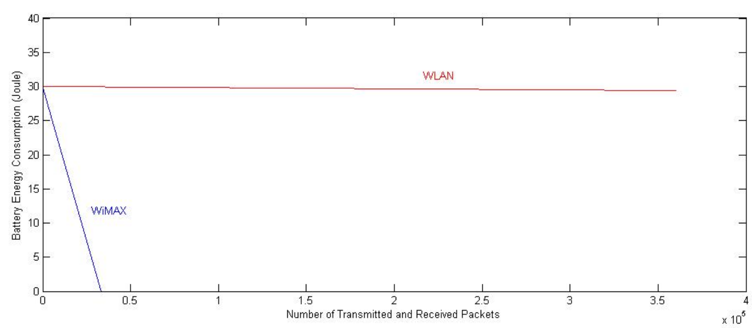


Fig. 1. WiMAX versus WLAN battery energy consumption.

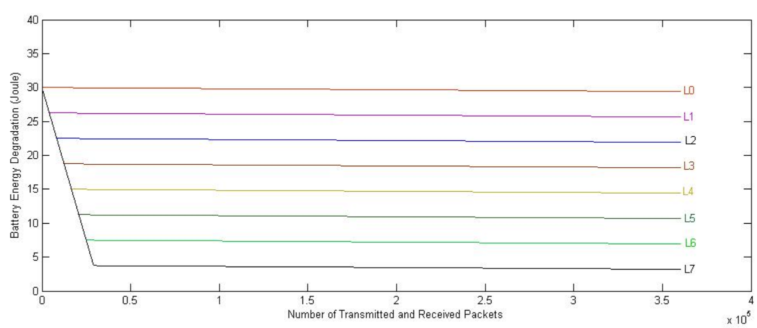


Fig. 2. Different battery energy consumption levels.

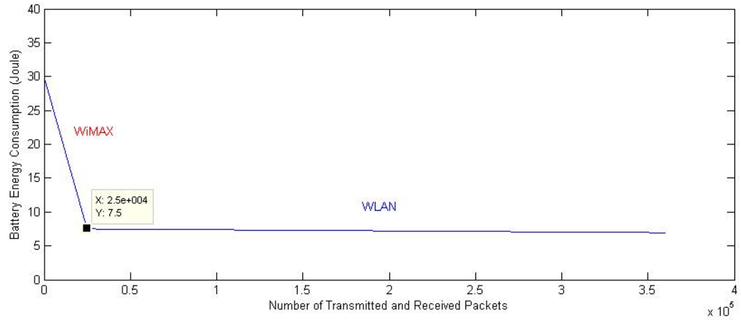


Fig. 3. Triggered vertical handover from WiMAX to WLAN at energy battery level 6.

## 5. Conclusion

In this paper we introduce a methodology for taking the handover decision among different networks based on the battery status. We also show how we can simply transfer this information from a mobile terminal to the network node using the option IP header. We also study how we can achieve this target between WLAN and WiMAX networks as two common wireless access technologies. The simulation results show that it is better to handover from WiMAX to WLAN technology as long as there is available WLAN coverage; this is to avoid quick terminal energy battery exhausting. A future work can study how to extend this research to other wireless technologies.

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