Power Saving Sleep Mode Enhancement Mobile WiMAX Networks

Dr. Ibtesam R. K. Al-Saedi
Communication Engineering Department, University of Technology/Baghdad
Email:drkarhiy@yahoo.com
Farah F. H. Alkhalid
Information & Communication of Technology Center, University of Technology/Baghdad
Email:eng_farah1982@yahoo.com

Received on:13/1/2016 & Accepted on:9/3/2016

ABSTRACT

Recently, the use of mobile devices to run multimedia applications is becoming more popular. Such applications are known to be energy consuming. Since these devices are mostly battery powered with a limited battery life, energy saving strategies becomes vital for such systems operation. WiMAX systems utilize a standard sleep mode in order to reduce the mobile station (MS) power usage. It is also used to reduce the usage of base station (BS) air interface resources. IEEE 802.16e proposes three power saving classes (PSCs), depending on the type of the application(s) running on the device. However, when multiple applications that belong to different service types are operating simultaneously, the power consumption may increase due to overlapping among the used PSCs. In this work, a new mechanism is proposed to minimize power consumption of mobile WiMax devices. The proposed mechanism tries to eliminate the overlapping of PSCs by synchronizing the different PSCs. A simulation study is conducted and the simulation results indicate that the proposed mechanism can significantly reduce power consumption of MS; OPNET 14.5 modeler is the simulation tools that used in this work. However, this version of OPNET does not support sleep mode, but the sleep protocol is programed (in this work) using C Language inside the modeler, in order to show the effect of the proposed mechanism to enhance the power saving.
Keywords: WiMAX, Power saving classes, Power consumption.

INTRODUCTION

IEEE 802.16e is an IEEE wireless broadband network standard that describes a developed broadband wireless communication technology in series of worldwide interoperability for microwave access (WiMAX).

The mobile WiMAX standard IEEE 802.16e introduces several new concepts related to mobility management and power management, two of the most fundamental requirements of a mobile wireless network. Although mobility and power management are often referred together, they are conceptually different. Power management enables the mobile station (MS) to conserve its battery resources (which it is the main subject of this paper). Also, mobility management enables the MS to retain its connectivity to the network while moving from the coverage area of one base station (BS) to the next [1].

The standard specifies sleep mode as power saving mechanism. Sleep mode is a state in which MS conducts renegotiated periods of absence from the serving BS air interface. In this mode, the operation time of MS is extended by periodically turning off the MS transceiver in order to save power. IEEE 802.16e standard specifies three types of power saving classes (PSCs) that are designed to handle different types of traffic. The main difference between these types is in the way that the sleep window is determined. The sleep window in type I is doubled every time if no traffic is sensed. In type II, the window remains constant. In type III, only one sleep window is used. According to the standard, PSCs of type I (PSCI) is recommended for best effort (BE) and non-real time (NRT) traffic, while type II (PSCII) used on the unsolicited guaranteed service (UGS) and real time variable rate (RTVR) service connection, PSCs of type III (PSCIII) is only used for multicast or management traffic [2][3]. PSCIII is not considered in this work.

This work aims to solve the problem of power consumption that occurred when multi PSCs operated simultaneously in the same MS of WiMAX network, this problem generated because the overlapping between available interval and unavailable interval.

To reduce the amount of transmission power in overlapping, our mechanism has suggested for synchronizing the PSCI with PSCII, by equaling the Tmin (initial sleep window) with the Tmax (final sleep window) of PSCI and let PSCI works like PSCII.

Extensive research has been done on the power management of a mobile WiMAX, some of them tried to analyze and others tried to enhance.

[4], [5] and [6], studied, proposed and designed power saving strategies for IEEE 802.16e sleep-mode operation. They evaluated performance of operation to find the optimal algorithm of different PSCs.

[7] and [8], proposed power saving mechanism to adjust unavailability interval when MS uses PSCs. They simulated mechanism for the sleep-mode parameter to reduce consumption of the MSs

[9] and [10], proposed an enhanced method to minimize the energy consumption of the MS as a whole while keeping the QoS requirements satisfied both non-real time and real time traffic.

[2] and [11], derived and used a algorithm with models for two performance metrics: initial sleep window Tmin and final sleep window Tmax. Their models showed the optimal Tmin and Tmax in minimizing the power consumption about 21-52 %,

Our work is an extended version for that has done in [12], a new mechanism is proposed that changes the PSCI settings and synchronize it with PSCII, therefore, the MS behaves as if it is under one PSCII. The simulation is used to evaluate the proposed mechanism. Three different scenarios are studied and compared. In the first scenario, the MS runs different applications with different service classes without power management. In the second scenario, the original sleep mode in the MS is enabled, and in the third scenario, the proposed mechanism is applied.

Sleep Mode Operation

Power saving requires turning off parts of the MS in a controlled manner when it is not actively transmitting or receiving data. Sleep mode is a state in which the MS effectively turns itself off and becomes unavailable for predetermined period. This period is negotiated with the serving BS. WiMAX defines three power saving classes, based on the manner in which sleep mode is executed. In PSCI, the sleep window is exponentially increased from a minimum value (*Tmin*) to a maximum value (*Tmax*). This is typically done when the MS is running BE service class and NRT traffic [2].

Let T_j denote the n[th] sleep window, which is given by (1):

$$T_j = min\{2^{j-1} Tmin, Tmax\} \quad \ldots (1)$$

PSCII, on the other hand, use a sleep window with fixed length. As shown in (2):

$$T_j = Tmin \quad \ldots (2)$$

This mode is used for UGS and RTVR traffic. PSCIII is normally used for multicast traffic or management traffic to allow for one time sleep window [1].

Figure 1 shows the algorithm of sleep mode in case of PSCI and PSCII, and let:
Tp: Transmission Power measured by W.
SWTP: Sleep Window Transmission Power measured by W.
LWTP: Listening Window Transmission Power measured by W.

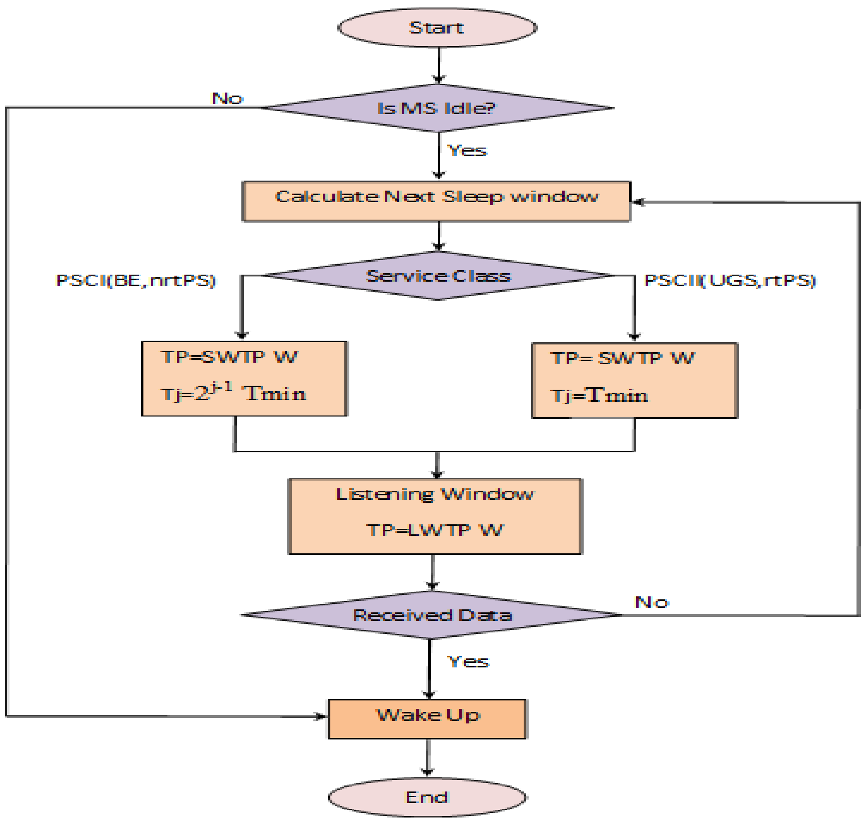

Figure (1) Sleep mode algorithm

Figure 1 is used when programming the normal sleep protocol using C language and Proto-C inside OPNET modeler.

The Proposed Mechanism

The main goal of this work is to design an energy saving mechanism that reduces the energy consumption when multi PSCs are running simultaneously. The overlapping of the PSC modes reduces the sleep intervals of MS, which increases the transmission energy consumption.

In a typical scenario, an MS may run multiple applications at the same time. A scenario is considered the MS runs voice over internet protocol (VoIP) and heavy hypertext transfer protocol (HTTP) at the same time. These two applications belong to different service classes, UGS and BE respectively, two PSCs are applied, PSCII for UGS service class and PSCI for BE service class.

Figure 2 shows sleep mode operation for modes PSCII (first row) and PSCI (second row). The third row shows the overlapping of these two modes.

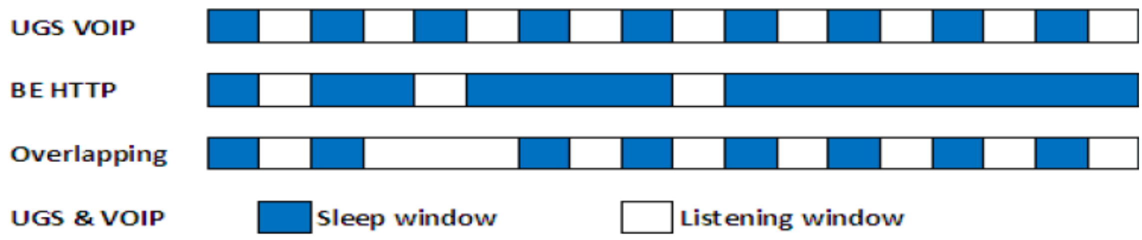

Figure (2) Normal overlapping in different classes of PSCs

The proposed mechanism modifies PSCI in order to increase the number of sleep windows. It does so, by modifying PSCI settings in order to make it behaves similar to PSCII. This is done by equating *Tmin* to *Tmax*, this way PSCI does exactly as PSCII does. Hence, PSCI starts with *Tmin* and ends with *Tmax*. In this case, both modes use sleep windows that are synchronized. In this case, the overlapping of PSCI and PSCII looks as two PSCII operated simultaneously with the same listening and sleep windows.

Figure 3 demonstrates the operation of the suggested mechanism. It shows how changing the settings of PSCI by equating the minimum sleep window with the maximum sleep window leads to constant sleep window (second row) that matches those of PSCII (first row).

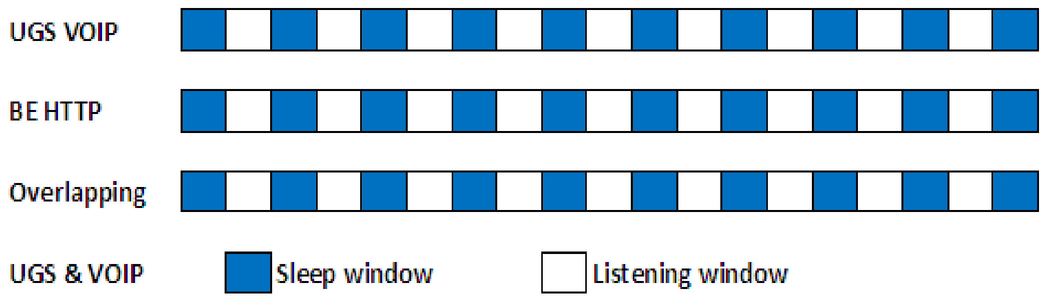

Figure (3) Overlapping in different classes of PSCs with new mechanism

Comparing between Fig. 2 and 3, it can be noticed that the sleep windows in Fig. 3 have more overlapping than those in Fig. 2, which results in less energy consumption compared to Fig. 2. It is important to emphasize that this strategy is useful only when MS operates multiple multimedia applications that belong to different service classes. This strategy may not be useful in situations where the MS is running one class of service only.

Figure 4 shows the algorithm of the new proposed mechanism**.**

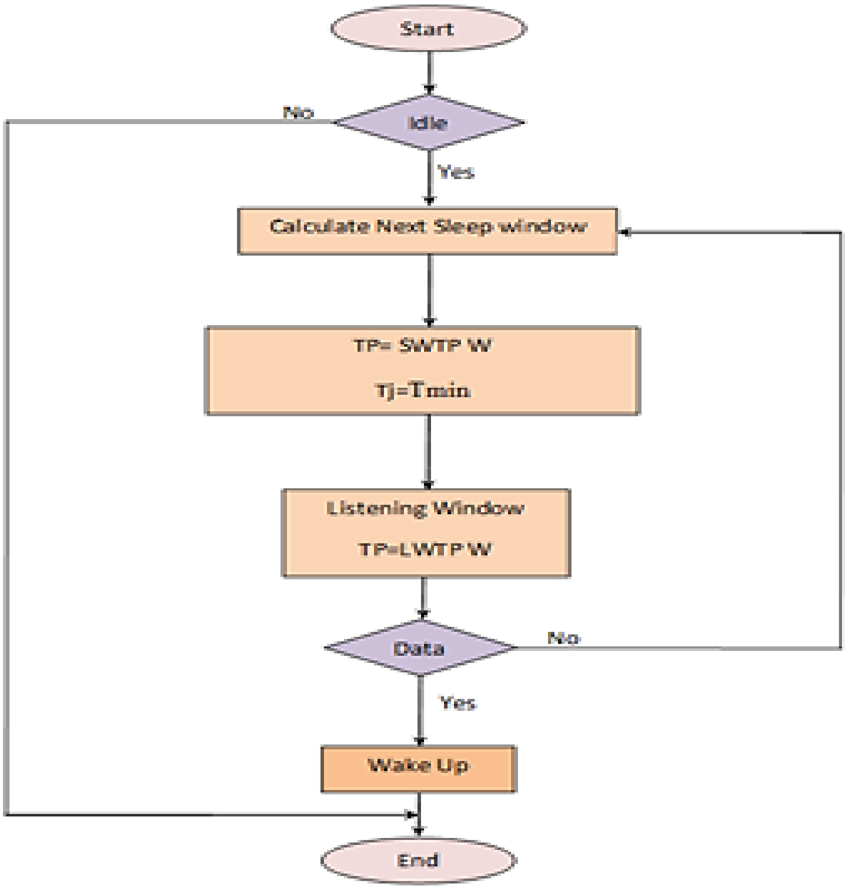

Figure (4) The new proposed algorithm

Figure 4 shows the algorithm that depends to program the new proposed mechanism inside OPNET modeler. In this algorithm, the next sleep window calculates depending on (2) for the two service classes BE and UGS.

Modeling

WiMAX is implemented with PSCI and PSCII sleep mode support using OPNET 14.5 modeler. The main scenario consists of WiMAX network consisting of one BS and one MS, no need to increase the number of MS, because the main goal is to study the influence of power consumption in MS, where the MS runs two applications, namely, VoIP and HTTP.

It is very important noted that the listening windows and sleep windows are measured in frames. Each frame has a fixed duration of a few milliseconds [13], this parameters defines the size, or length, of a frame [14].

Available frame durations are {2.5, 4, 5, 8, 10, 12.5, 20 msec}[15]. A 5 msec frame duration has a faster response at the trade off of increased overhead since the overhead is fixed, while the

20 msec has lower overhead in relation to the 5 msec frame at the cost of a slower system response [16].

5.8 GHZ frequency band is used in our model, which typically is licensed by various government authorities [17]. Table (1) shows the most important simulated system parameters.

Table (1) Predefined parameters used in Modeling

Parameter	Attribute
Mobility	Supported
Sleep Mode	PSCI & PSCII
Frame Duration	5 msec
Sleep Window	5 msec
Listening window	5 msec
Simulation Duration	10 min
Base Frequency	5.8 GHz from [12]
Bandwidth	20 MHz
Min. Sleep Window	5 msec
Max. Sleep Window	1024 msec From [13]
Application	VOIP & HTTP
Service Class	UGS & BE
Browsing Type	Heavy
VoIP Type	PCM Quality Speech
Distance between BS and MS	1 km

Results Analysis

To analysis the affect of sleep mode on the transmission power and delay by comparing the output figures after activate the sleep mode.

Transmission Power Measurement

The topology for the simulated WiMAX network is shown in Fig. 5.

Figure 5 shows the MS which serves with BS of WiMAX network, is connected with two servers; one server provides VoIP service and the other provides HTTP service.

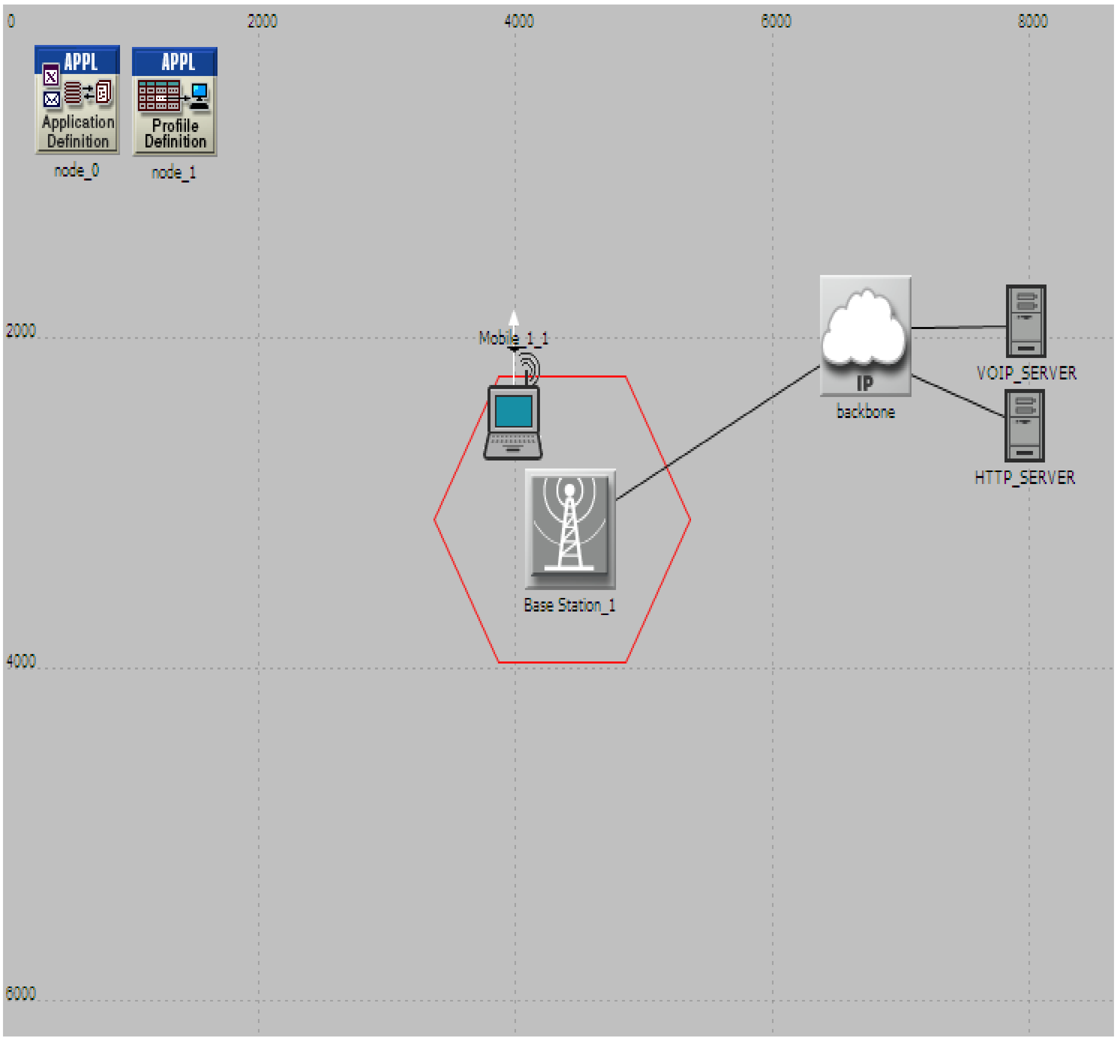

Figure (5) Scenario of WiMAX

Three scenarios are considered in this simulation study:

(a) Sleep mode disabled: The MS runs two classes of service, UGS and BE, without sleep mode support. This scenario serves as a baseline for the simulation study.

(b) Normal sleep mode operation: In this scenario, the standard sleep mode is activated. The sleep mode operates according to the standard mechanism shown in Fig. 2.

(c) The proposed sleep mode mechanism: In this scenario, the MS employs the suggested sleep mode mechanism as shown in Fig. 3.

In Fig. 6, the transmission power (in dBm) is compared for all three scenarios, this figure is got from the standard outputs of OPNET modeler depending on the programmed algorithms defined in Fig. 1 and 4.

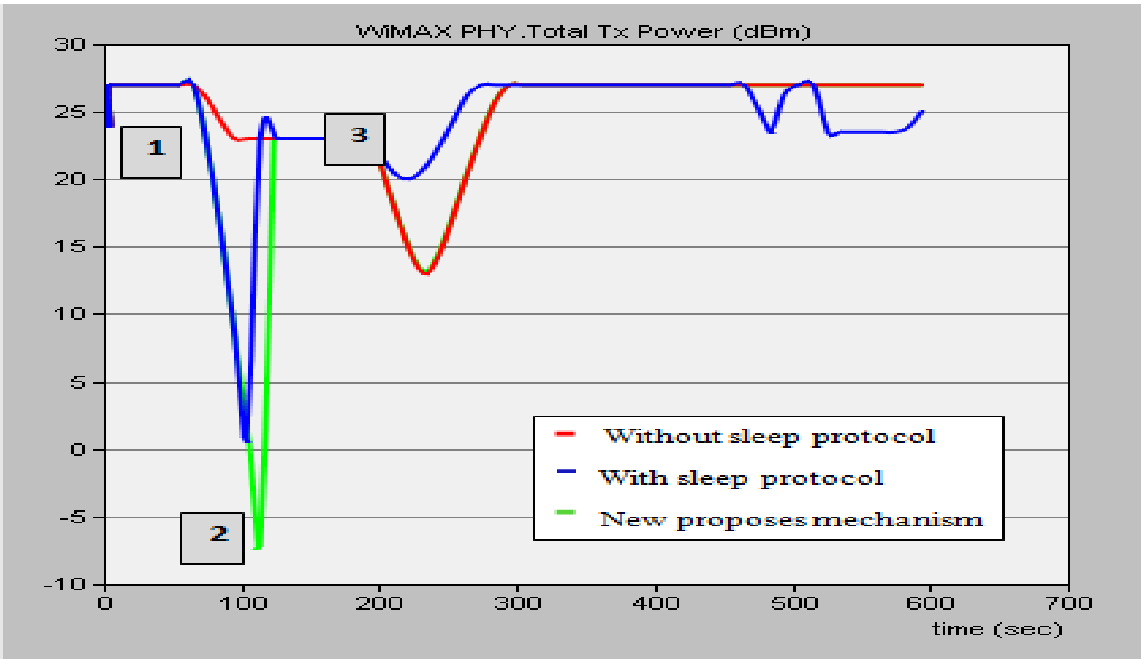

Figure (6) Transmission power of MS

Figure 6 describes the following three states:

1: No send/receive data duration, sleep cycle activated with the proposed mechanism.

2: No send/receive data till this point, after this point the MS wakes up.

3: Received data, the MS wakes up.

Scenarios: (a), (b), and (c) are represented by the red curve, the blue curve and the green curve respectively. The energy consumption under the suggested mechanism is clearly less than that under the original mechanism, where the red curve is the transmission power without sleep mode, while the blue curve refers to the transmission power with normal sleep mode, the transmission power with new proposed mechanism represents with green curve. Also Fig. 6 shows that the green curve is passing close to the red because the power measurement is calculated by (3) [18]:

$$X = 10 \log_{10} P + 30 \qquad \dots (3)$$

Where X is the power in dBm, and P is the power in W, the algorithms relation means a sensed difference in dBm leads to big difference in W. In order to see the difference with more indication, the average of transmission power is one of the standard outputs in OPNET modeler is used to explain the average value of any figure as shown in Fig. 7, which shows the average of transmission power with the three states in scenarios (a), (b) and (c).

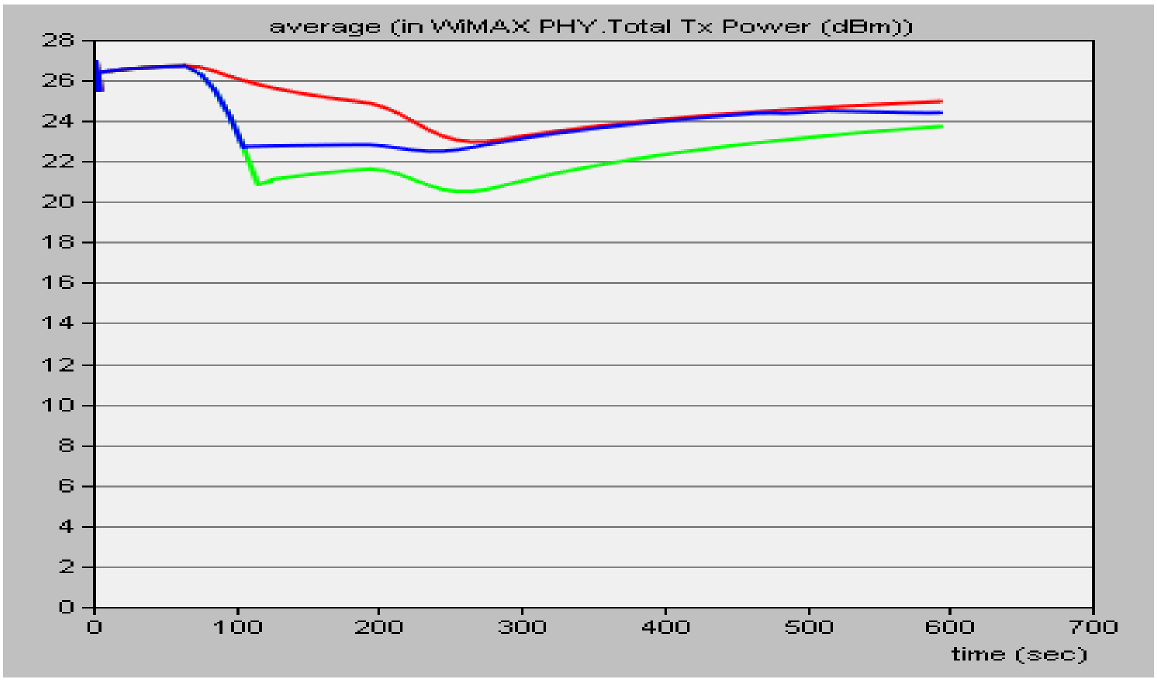

Figure (7) MS average transmission power

The green curve shows transmission power less than the others, and this is the main goal of this work, where the proposed mechanism aims to reduce the transmission power.

The percentage amount of power saving using the proposed mechanism can be calculated from the difference between blue signal and green signal is 2 dBm approximately, and the average value of blue signal is about 25 dBm.

Delay Measurement

In generally, the sleep mode affects the delay performance because the data has to wait in buffer till listening window reach, this waiting causing delay.

The aim of proposed mechanism is matching the PSCI with PSCII, in other words, changing the settings of PSCI to be mannered as PSCII by equaling the *Tmin* with *Tmax* and listening intervals with sleep intervals. This process is leading to make the multi sleep levels behaves as a single level of sleep mode.

MS feels PSCII operated, and as known, this type of class serves real time applications, so it can be supposed that the delay will be tiny, accepted and less than the delay in PSCI.

Figure 8 shows the delay when using HTTP application and describes the following two states:

1: No send/receive data during this duration, so sleep cycle activated.

2: Received data at wake up of MS.

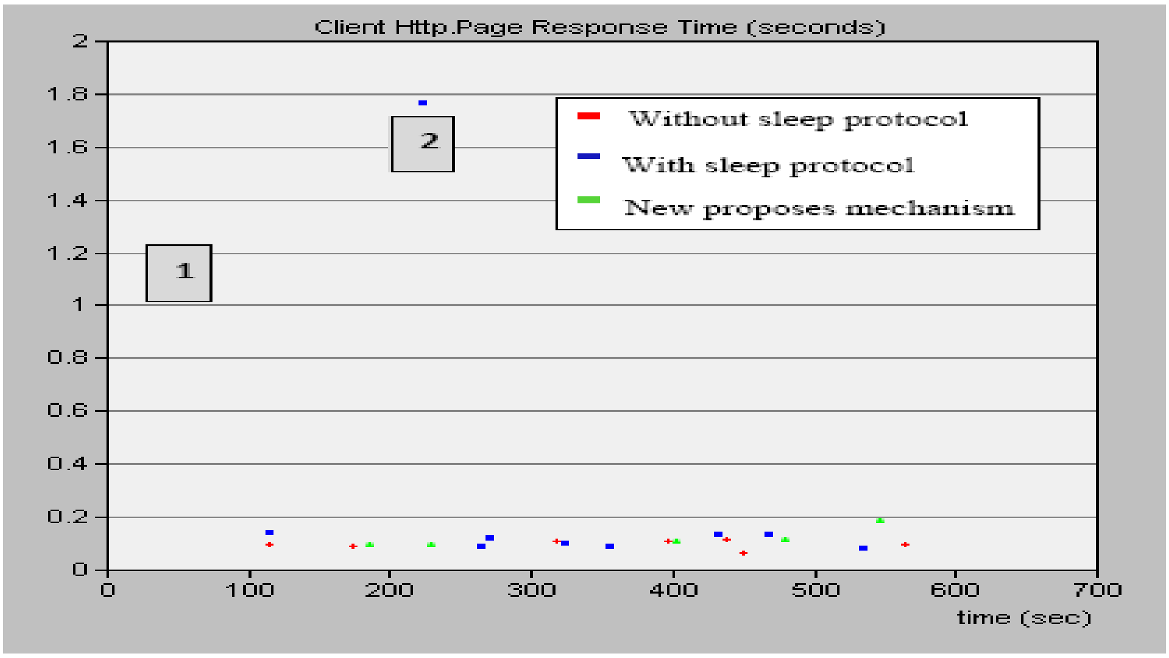

Figure (8) Page response delay

Hence the HTTP application under BE service type which uses PSCI with double sleep window each next time; in this mechanism the HTTP application will be similar to PSCII, which its sleep windows remain constant, this eliminates the waiting of data leading to eliminate the delay, for this reason the green signal has delayed less than the blue signal.

The delay in VoIP remains as it is without any changing because the setting of its PSC does not change.

CONCLUSION

A power saving mechanism is proposed for a WiMAX MS that runs multiple classes of multimedia applications. A simulation study is conducted in order to compare the proposed energy saving mechanism to the original one. The presented simulation results show considerable enhancement in energy consumption over the original mechanism, the outputs of transmission power in OPNET modeler shows 8% of enhancement for this scenario.

The proposed mechanism changes the settings of PSC I to overcome the overlapping between PSCI and PSCII, this is very simple to do with no cost comparing with literature studies which present a new design for layers that is a little increase of complexity.

The enhancement is attributed to the fact that the proposed mechanism synchronizes the sleep periods of PSC I with those for PSC II. It is important to mention that this mechanism is useful only when PSCI and PSCII are operated together and will not be useful when the MS operates applications under the same service class.

REFERENCES

[1] J. Andrews, A. Ghosh, R. Muhamed, "Fundamentals of WiMAX - Understanding Broadband Wireless Networking", prentice Hall, USA, ISBN: 0-13-222552-2, 2007. http://www.e-reading.club/bookreader.php/138779/Fundamentals_of_WiMAX:_Understanding_Broadband_Wireless_Networking.pdf

[2] D.T.T. Nga and H. Lim, "Power Saving Mechanism with Delay Bound for Mobile WiMAX Systems", *Bell Labs Seoul*, June 23, 2011. http:// dx.doi.org/ 10.1049/iet-com.2010.0838

[3] http://en.wikipedia.org/wiki/IEEE_802.16, last visited in 10 February, 2012.

[4] J. Xue, Z. Yuan, "An Adaptive Power Saving Strategies based on Cross-layer Design in IEEE 802.16e", Academy publisher, China, Journal of Network, Vol. 5, NO. 3, MARCH 2010. http:// dx.doi.org/ 10.4304/jnw.5.3.359-366

[5] L. Kong, G. Wong, D.Tsang, "Performance Study and System Optimization on Sleep Mode Operation in IEEE 802.16e", IEEE, Transactions on Wireless Communication, Vol. 8, NO. 9, September 2009. http:// dx.doi.org/ 10.1109/TWC.2009.071210

[6] H. Kim, T. Chen, "A Study of Energy Efficient Transparent Relay using Cooperative Strategy", IEEE, 978-1-4244-8331-0,2011. http:// dx.doi.org/10.1109/VETECS.2011.5956278

[7] S. Kwon, D.Cho, "Enhanced Power Saving Through Increasing Unavailability Interval in the IEEE 802.16e Systems", IEEE Communications Letters, Vol. 14, NO.1, 1089-7798, January 2010. http:// dx.doi.org/10.1109/LCOMM.2010.01.091086

[8] C. Kao, Sh. Yang and J. Wang, "A Sleep-Mode Interleaving Algorithm forLayered-Video Multicast over Mobile WiMAX", IEEE, WCNC-Network, 978-1-61284-254-7, 2011. http:// dx.doi.org/10.1109/WCNC.2011.5779203

[9] Y. Wu, Y. Le, D. Zhang, "An Enhancement of Sleep Mode Operation in IEEE 802.16e Systems", IEEE, 978-1-4244-2517-4, 2009. http:// dx.doi.org/ 10.1109/VETECS.2009.5073382

[10] S. Jin, M. Choi, S. Choi, "Performance Analysis of IEEE 802.16m Sleep Mode for Heterogeneous Traffic", IEEE, Communications Letters, Vol. 14, NO. 5, 1089-7798, May 2010. http:// dx.doi.org/ 10.1109/LCOMM.2010.05.091730

[11] P. Simoens, F. A. Ali, B. Vankeirsbilck, L. Deboosere, F. D. Turck, B. Dhoedt, P.Demeester, R. Torrea-Duran, "Cross-Layer Optimization of Radio Sleep Intervals to Increase Thin Client Energy Efficiency", IEEE, Communications Letters, 1089-7798, 2010. http:// dx.doi.org/ 10.1109/LCOMM.2010.100810.101450

[12] Al-Saedi, Ibtesam & Alkhalid, Farah, "Power Saving Sleep Mode Enhancement Mobile WiMAX Networks", paper #48C-510, 1st International Conference on Telecommunication Systems and Networks (MIC-Telecom 2013), Barcelona, Spain in the period 20-22 December 2013.

[13] A. Bestetti, G. Giambene and S. Hadzic, "WIMAX: MAC Layer Performance Assessments", This work has been carried out with the support of Alcatel- Lucent in the framework of the EU FP6 WEIRD project, University of Siena, Italy, 2005. http:// dx.doi.org/ 10.1109/ISWPC.2008.4556256

[14] A. Makelainen, “Analysis of Handoff Performance in Mobile WiMAX Networks”, This work has been fulfillment for the degree of Master of Science in Engineering, Espoo, Finland, December 2007. http:// dx.doi.org/ 10.1109/ICSGRC.2011.5991847

[15] M. Ergen, Mobile Broadband Including WiMAX and LTE, Springer, Library of Congress, USA, 2009. http:// dx.doi.org/ 10.1007/978-0-387-68192-4

[16] W. Hrudey, "Streaming Video and Audio Content over Mobile WiMAX Networks", *School of Engineering Science. Simon Fraser University,* May 2009. http://www2.ensc.sfu.ca/~ljilja/cnl/pdf/hrudey.pdf

[17] http://www.motorola.com/networkoperators/pdfs/Wi4-the-promise-article.pdf, Last visited in 24 October, 2012.

[18] http://en.wikipedia.org/wiki/DBm, Last visited in 10 February, 2012.