An Improvement of Power Saving Class Type II Algorithm in WiMAX Sleep-mode

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***Abstract*—Because of the fact that users can connect to a WiMAX (IEEE 802.16) network wirelessly with large-scale movement capability, it is inevitable that they cannot access electrical power sources at their desired time. As a result, a mechanism is needed to reduce power consumption; and therefore three power saving classes have been defined in WiMAX that each one is designed for a specific application. Although using a suitable power saving class (PSC) can reduce power consumption significantly, but lack of cross-layer coordination can reduce the efficiency of the power saving mechanism. Since real-time services which are related to power saving class type II (PSC II) have great importance and vast applications, an improved PSC II algorithm for WiMAX is proposed in this paper which not only guarantees WiMAX quality of service (QoS), but also makes the cross-layer coordination using a proactive buffer resulting in less power consumption. There is also a comparison made between the performance of the proposed algorithm and the predefined PSC II algorithm in WiMAX using computer simulations and it shows that using the proposed algorithm reduces power consumption by 60 percent, while WiMAX QoS is still guaranteed.**

Keywords*—WiMAX; IEEE 802.16; sleep mode; power saving class type II (PSC II); proactive buffer; quality of service (QoS)

I. INTRODUCTION

Considering the widespread usage of smartphones, tablets, laptops, etc. as devices to connect to internet and also vast coverage of wireless and cellular networks, nowadays mobile users tend to connect to the internet wirelessly. Wireless networks like cellular networks or WiMAX not only give users a large-scale movement capability, but also provide them with a high-speed and broadband internet connectivity. Despite these advantages, a fundamental challenge still remains; since users of these networks are mobile, probable unavailability of electrical power sources for them at their desired time is inevitable. As a result, designing a mechanism to reduce power consumption is vital, so that users can stay connected to the network, needless of recharging their devices.

In this article, the main goal is to propose an improved PSC II algorithm which saves more power than WiMAX predefined PSC II algorithm and yet guarantees WiMAX QoS. The approach to reach this goal is to design a proactive buffer to impose delay to delay-tolerable sporadic traffic generated by application layer such as keep-alive messages, so that the device stays more in sleep mode; and therefore more power is saved, without applying harsh changes to QoS parameters that result network instability and undesirable performance.

The reason to choose this subject is because PSC II aims to reduce power consumption in real-time services such as VoIP, IPTV, etc. and since these services are widely used, saving power in them gives users the ability to have a longer experience using these services, needless of recharging their devices.

In order to better understand the subject, there will be an insight about WiMAX power saving mechanisms in Section II and the literature review will be in Section III. In Section IV there will be an explanation about the proposed algorithm (methodology), Section V will be the results and comparison and there will be the conclusion and future works in Section VI.

II. POWER SAVING MECHANISMS IN WIMAX

A. Idle mode

Idle mode allows the Mobile Station (MS) to save power by restricting listening intervals (in which the MS is actively transmitting data) and completely turning off the air interface as well. This provides the network with a useful method called paging. The main role of paging is to create an alarm when there is downlink traffic [1]. When idle mode is activated, the air interface of Base Station (BS) and MS are powered off.

B. Sleep mode

In sleep mode, unavailability intervals are related to the BS, and the MS receives sleep mode parameters from BS. Unlike idle mode, in sleep mode the MS stays connected to the BS. This can help the device return to normal operation mode faster. There are two main states in sleep mode and the MS switches between them [2].

In the first state, the sleep window is activated. In fact, sleep window is a time span in which power is saved. In the second state, listening window is activated and the MS checks if any downlink traffic should be received from the BS or not.

Unlike idle mode which has only one operation mode, in sleep mode there are three different operation modes called "power saving class (PSC)", each designed for a specific application. They are named power saving class type one (PSC I), PSC II and PSC III.

PSC I is designed to save power in Best-Effort (BE) and Non-Real-Time Variable Rate (NRT-VR) services and consists of listening window and sleep window. The length of the listening window in this power saving class is fixed and a MS associated with PSC I checks if there are any buffered packets for it in the listening window. If there were buffered packets, the MS will return to normal operation mode to receive the packet. Otherwise, the sleep window will be activated, so that the device will save power. Then this procedure repeats and the length of sleep window is doubled until it reaches the maximum length defined in WiMAX standard [3].

PSC II is designed for unsolicited grant services and also Real-Time Variable Rate (RT-VR) services. Similar to PSC I, PSC II is also consisted of listening window and sleep window. Unlike PSC I, the length of listening and sleep windows are both fixed and the summation of them is called a sleep cycle. A MS associated with PSC II can still transmit data packets without returning to normal operation. As a result, the length of listening window should be long enough to receive all packets arrived during a single sleep cycle in PSC II [4].

As shown in Fig. 1, unlike PSC I and PSC II, PSC III consists only of a single sleep window and it is used for multicast services. By activating this PSC, a single sleep window with defined length in WiMAX standard starts and then the MS returns to normal operation mode [5].

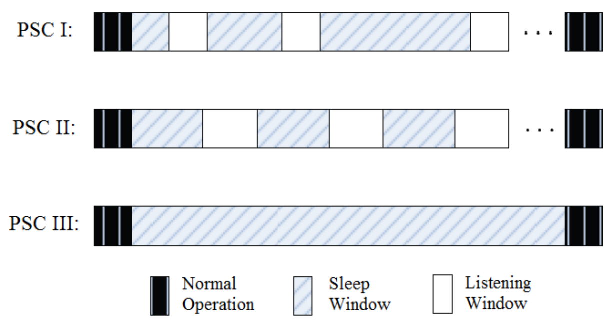

Fig. 1. WiMAX power saving classes.

III. Literature Review

Many researches have been done to reduce power consumption in WiMAX, each using a specific approach and we will point out some of the major ones. As in [6] a power saving mechanism for WiMAX was proposed to maximize energy efficiency. They have actually proposed a theoretic frame based on semi-Markov decision process along with a performance study on the power saving procedure. In [7] a power saving mechanism called Maximum Unavailability Interval (MUI) was proposed to increase energy efficiency in PSC II for WiMAX. They believe that their mechanism can calculate the maximum unavailability interval. They proposed a mathematical technique to reduce calculation complexity too. In [8] a research has been done to improve sleep mode's performance by applying a proactive algorithm to uplink traffic and also an efficient approach to numerically calculate power saving parameters has been proposed. In the end, they proved that a proper scheduling and a controllably delayed uplink traffic can have a huge positive impact on system performance and power saving procedure. In [9] a power saving mechanism has been proposed to guarantee delay parameter of QoS that synchronizes sleep cycles by imposing a slight delay. Based on WiMAX cross-layer design, a power saving strategy has been proposed in [10], in which they evaluated WiMAX power saving performance, as well as that of mobile stations in sleep mode by a Markov chain model. Then, they found the relationship between network load and power consumption and in the end they proposed a method to calculate power saving parameters. In [11] a power saving method for WiMAX was proposed to increase unavailability intervals in a MS which is using PSC II. This method configures sleep window's scheduling in a way that maximizes unavailability intervals. They also proved analytically that their method saves 20 percent more power in comparison with the predefined PSC II in WiMAX. [12] was a research aiming to design a scheduling algorithm for real-rime services in order to maximize unavailability intervals in PSC II. Using an Adaptive Bandwidth Reservation (ABR) algorithm, they reduced calculation complexity and proved that their proposed algorithm not only maximizes unavailability intervals, but also reduces power consumption significantly.

IV. Methodology

As explained in Section II, an MS associated with PSC II can transmit data packets without existing sleep mode. But some control packets (e.g. keep alive messages or time synchronization messages) that are sent to MAC layer of WiMAX (shown in Fig. 2) by application layer will terminate sleep mode. As a result, the MS will return to normal operation and this lack of cross-layer coordination will reduce the positive effect of sleep mode to save power.

In order to solve this problem we have made some changes in the predefined PSC II algorithm of WiMAX to make the cross-layer coordination between MAC and application layer. Therefore, we have implemented a proactive buffer between MAC and application layers to impose delay to control packets, so that the MS will longer stay in sleep mode and as a result, more power is saved.

WiMAX supports 2.5, 4, 5, 8, 10, 12.5 and 20 millisecond packet lengths [13]. Since the overhead of 5 millisecond packets cause PSC II operate optimally in saving power [14], [15], we have adjusted transmitted packet lengths to 5 milliseconds.

An assumption made in the simulations is to use UGS scheduling when sleep mode is activated. Since this transmission scheduling method is delay-sensitive, it can evaluate our proposed algorithm well; meaning if our proposed algorithm is proper, packets will be transmitted without problem. Otherwise, network delay will be increased and the network will be unstable. Moreover, the real-time traffic will no longer be real-time, resulting in network failure. One last assumption is that the MS moves in the BS's coverage area in random vector-like paths.

Major changes that we have made in the predefined PSC II of WiMAX are mostly related to sleep control (sleep-ctrl) and higher layer packets (hl-pk) states in WiMAX MAC layer.

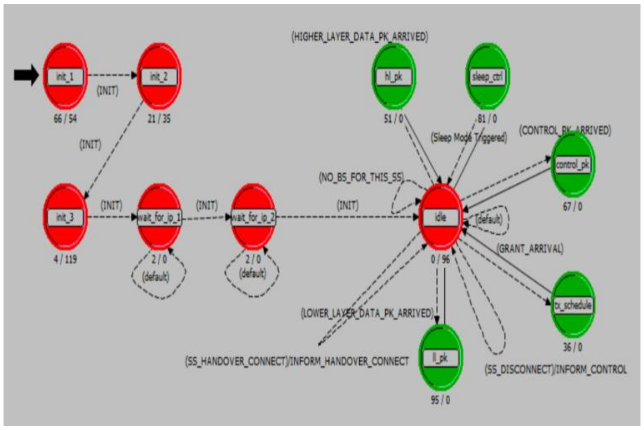

Fig. 2. WiMAX MAC layer.

A. Defining the buffer

Since the length of control packets from application layer to MAC layer is 4 milliseconds [16] and generally there are two types of control packets in WiMAX real-time services named time synchronization and keep alive messages [17] that are delay-tolerable [18], therefore we have set the buffer length to 100 milliseconds. As a result, there will be a queue of 25 control packets which will be delayed 100 milliseconds. This buffer length is neither too short to make a congestion inside the buffer, nor too long to exceed the packet delay bound of control packets and failing the network accordingly [19].

In order to optimally design the buffer, we should consider the fact that this buffer (like other common buffers) is actually a memory and it is only capable of recognizing the incoming packet sizes, not their types. So we have set a condition for the buffer to only let the 4 millisecond packets enter the queue; so that no extra delay would be applied to our 5 millisecond data packets by the buffer. (For a service like VoIP, even if we apply the 100 millisecond delay to data packets, if there were no more than 50 millisecond delay in other parts of the network, the service would still be real-time and functioning properly. [20])

Sleep window's duration in the predefined PSC II of WiMAX is 10 milliseconds [21]. According to our trial and error, if the buffer length and sleep cycle's duration are equal, the cross-layer coordination is best made; and therefore the sleep mode would function optimally. So the other change we have made in the predefined PSC II of WiMAX is to increase the sleep cycle's duration to 100 milliseconds; meaning that sleep window and listening window's duration should each be 50 milliseconds. Another obvious point to mention about the buffer is that it should be activated only when the sleep mode is triggered.

V. Results and Comparison

As mentioned before, in this section a comparison is made between the performance of the proposed PSC II algorithm and the predefined PSC II algorithm in WiMAX, when a real-time VoIP service with PCM quality speech is simulated in one hour duration in the network. This service is actually the service offered by most of social media applications (e.g., WhatsApp, telegram, etc.).

In this comparison, the first scenario (scenario 1) indicates the performance of the predefined PSC II algorithm in WiMAX and the second scenario (scenario 2) refers to the proposed algorithm (all simulations are run by OPNET simulator).

A. Power consumption

As shown in Fig. 3, power consumption for scenario 1 is 30 dBm, while for scenario 2 is 25.8 dBm; meaning that the power consumption for the proposed algorithm is 4.2 dBm less than that of the predefined PSC II of WiMAX.

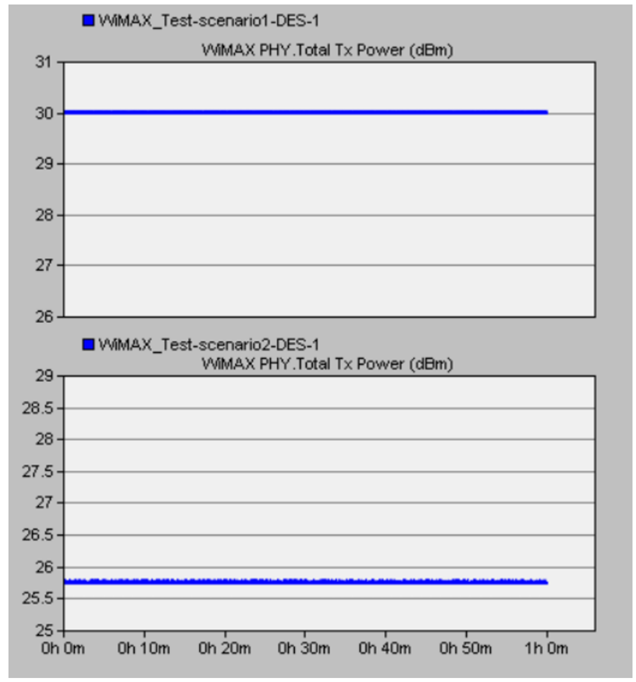

Fig. 3. Comparison of power consumption

In fact, power consumption for scenario 1 is 1 watt, while for scenario 2 is about 0.4 watts; meaning that the proposed algorithm saves about 60 percent more power.

B. Delay

Fig. 4 shows that both scenarios have 2.4 milliseconds (0.0024 seconds) delay. This means that the proposed algorithm has not imposed any extra delay to the network. QoS for WiMAX real-time services indicates that a delay less than 100 milliseconds is excellent and a delay less than 150 milliseconds is acceptable [22]. In fact, using UGS scheduling has not made any problems for the proposed algorithm and the delay in scenario 2 is far less than 100 milliseconds. As a result, the performance of the proposed algorithm is excellent in the field of delay.

C. Network load

As shown in Fig. 5, average network load for both scenarios is nearly the same and as expected, for both scenarios at their steady state stability, average network load is about 200,000 bits per second (25 kilobytes per second) which is actually the bit rate of a PCM quality speech VoIP service. Furthermore, since the network load has reached a steady state stability, we can conclude that no network failure has occurred.

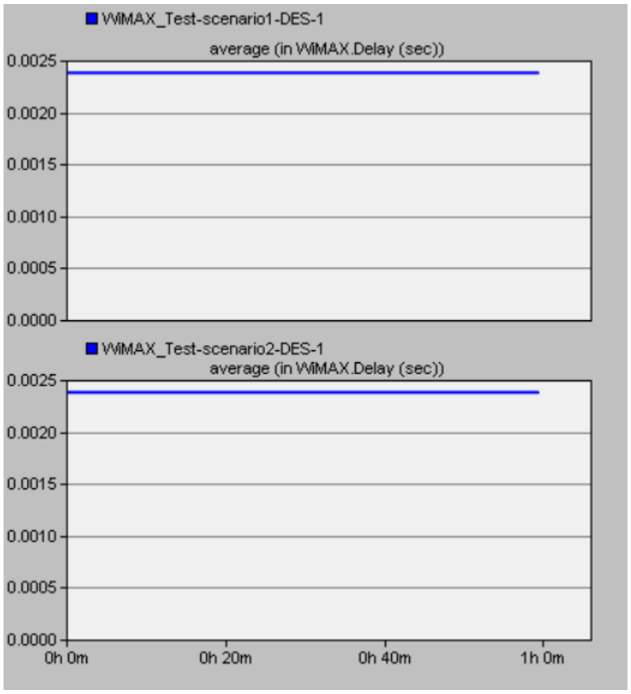

Fig. 4. Comparison of delay.

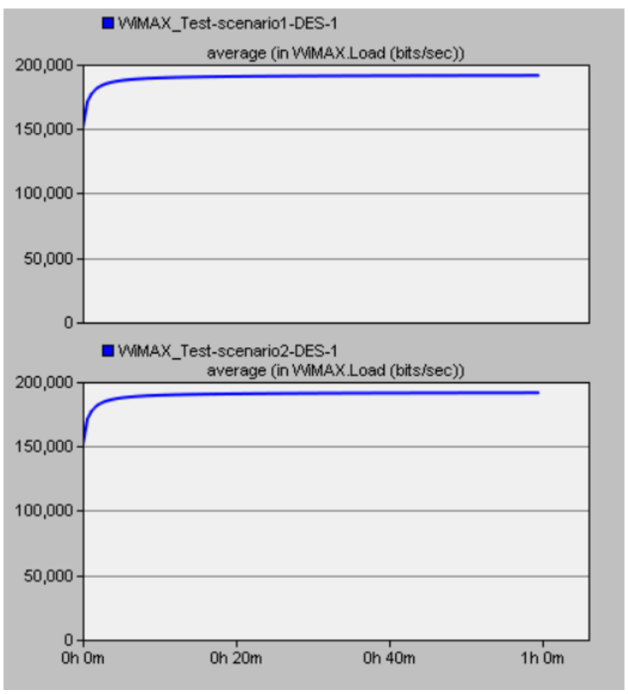

Fig. 5. Comparison of network load.

D. Dropped packets

From Fig. 6, it is clear that at the beginning of the simulation, dropped packets for both scenarios is 0.59 packets per second. But towards the end of simulation, average dropped packets is about 0.5 and 0.8 packets per second for scenario 1 and scenario 2, respectively. As a result, an average of 0.3 packets per second in the proposed algorithm is dropped more than that of the predefined PSC II algorithm of WiMAX. QoS for WiMAX real-time services indicates that at most 5 percent of packets can be dropped per second [22]. Since we chose that data packet lengths in the proposed algorithm to be 5 milliseconds and also 0.8 packets are dropped per second, one can conclude that 0.4 percent of packets are dropped in the proposed algorithm which is 4.6 percent less than the highest acceptable value in WiMAX QoS.

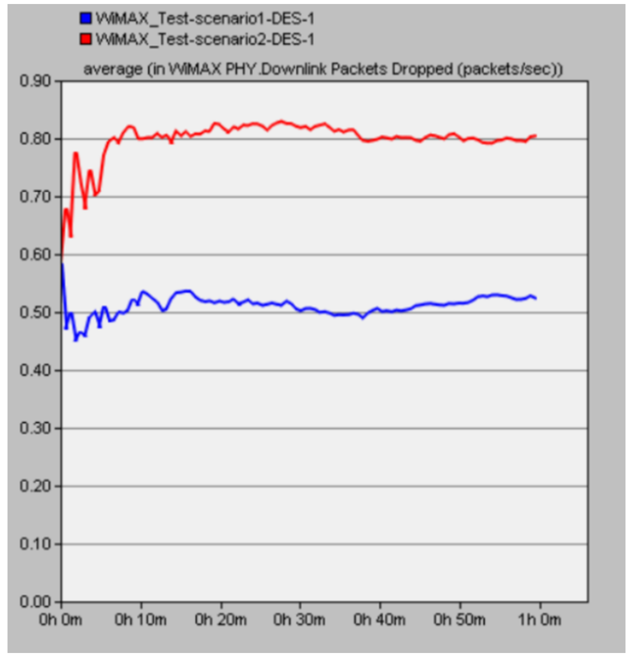

Fig. 6. Comparison of dropped packets.

E. Block error rate (BLER)

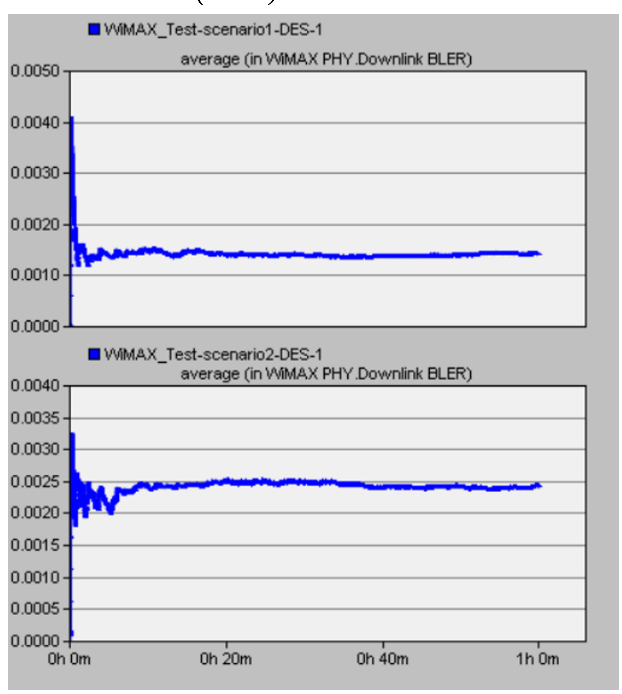

Fig. 7. Comparison of block error rate.

Fig. 7 shows that although the Block Error Rate (BLER) at the beginning of the simulation for scenario 2 is less than that of scenario 1, but towards the end of simulation, BLER is about 0.0014 and 0.0024 for scenario 1 and scenario 2 respectively. This means that BLER for the proposed algorithm is about 0.001 more than that of the predefined PSC II of WiMAX, but the BLER for the proposed algorithm still guarantees the QoS of WiMAX real-time services [22].

F. Signal to noise ratio (SNR)

As shown in Fig. 8, average SNR for scenario 1 and scenario 2 is 4.2 and 3, respectively and as expected, the SNR for the proposed algorithms is less than that of the predefined PSC II of WiMAX.

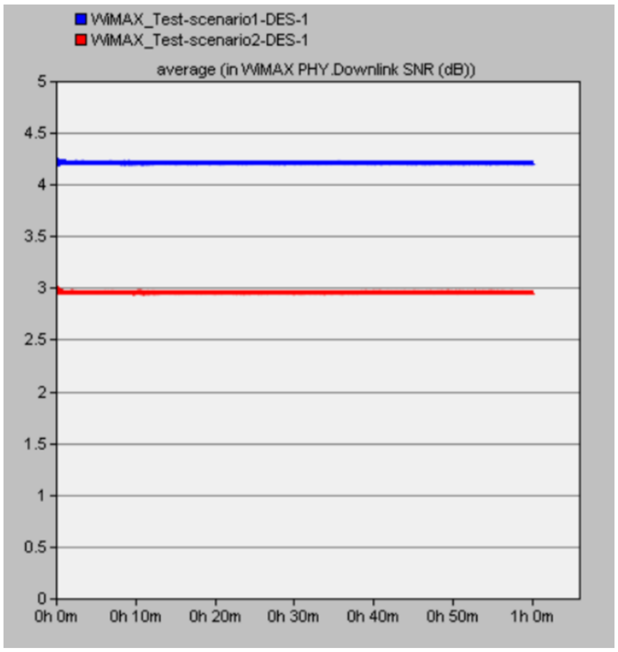

Fig. 8. Comparison of signal to noise ratio.

Since in this simulation the value of noise power is constant, it is the signal power that has made the difference. As expected, because cross-layer coordination has been made in the proposed algorithm (scenario 2), sleep mode has done a better job saving power; so it has used less signal power to transmit data packets accordingly. As a result, SNR has been decreased in the proposed PSC II algorithm. WiMAX QoS for real-time services indicates that this signal to noise ratio is quite enough for a WiMAX network to operate properly [22].

VI. Conclusion and Future Work

In this article a PSC II algorithm for WiMAX sleep mode is proposed to replace the predefined PSC II of WiMAX. Although PSC II can save power when using WiMAX, but lack of cross-layer coordination reduces the positive effect of WiMAX PSC II, thus we decided to make the cross-layer coordination by implementing a proactive buffer that delays delay-tolerable control messages like time synchronization and keep alive messages sent to MAC layer by application layer. In fact, we have made changes in the predefined PSC II algorithm of WiMAX (e.g., applying the buffer between MAC layer and application layer, alteration of sleep window and listening window length, etc.) to develop a new algorithm that makes the cross-layer coordination and saves more power accordingly.

We have also evaluated the performance of the predefined WiMAX PSC II algorithm and the proposed algorithm by comparing power consumption, delay, network load, dropped packets, block error rate (BLER) and signal to noise ratio (SNR) using OPNET simulator.

The comparison indicates that the proposed algorithm saves about 60 percent more power and no extra delay has been imposed to the network; moreover, network load has not been changed tangibly. The comparison also shows that 0.3 packets per second are dropped more in the proposed algorithm which is acceptable by WiMAX QoS. Also in the proposed algorithm, the block error rate is 0.001 more than that of the predefined WiMAX PSC II, but this is still acceptable by WiMAX QoS for real-time services. At last, the comparison of SNR shows that the proposed algorithm has less signal to noise ratio as expected; since less signal power has been used, regarding the constant noise power.

As a summarized conclusion one can say that the proposed algorithm saves 60 percent more power and it does not impose any extra delay to the network and it does not change the network load; but it increases the dropped packets and block error rate and also decreases the signal to noise ratio which are all acceptable by WiMAX QoS for real-time services.

A point that makes this research different from other related researches is the percentage of saved power which is 60 percent. Also the fact that no extra delay has been imposed to the network and no tangible alteration has been made in network load; meaning that the reason of less power consumption is cross-layer coordination; not imposing extra delay or reducing network load.

From the results and comparison, one can anticipate that since the proposed algorithm has done a good job saving power in a single connection between one mobile station and a base station, it can also perform well in a multiple connection where there are more than one mobile stations. This requires a research team to investigate the performance of the proposed algorithm when there are more than one mobile stations in a WiMAX network.

References

[1] S. Ahmadi, “An overview of next-generation mobile WiMAX technology,” IEEE Communications Magazine, vol. 47, no. 6, 2009.

[2] B. Kim, J. Park and Y.-H. Choi, “Power Saving Mechanisms of IEEE 802.16e: Sleep Mode vs. Idle Mode,” Springer, Frontiers of High Performance Computing and Networking, pp. 332-340.

[3] J. Jang, K. Han and S. Choi, “Adaptive Power Saving Strategies for IEEE 802.16e Mobile Broadband Wireless Access,” IEEE Communications, 2006. APCC '06. Asia-Pacific Conference, 2006.

[4] W.-H. Liao and W.-M. Yen, “Power-saving scheduling with a QoS guarantee in a mobile WiMAX system,” Journal of Network and Computer Applications, vol. 32, no. 6, p. 1144–1152, 2009.

[5] O. J. Vatsa, M. Raj and R. Kumar, “Adaptive Power Saving Algorithm for Mobile Subscriber Station in 802.16e,” IEEE, Communication Systems Software and Middleware, 2007. COMSWARE 2007. 2nd International Conference, 2007.

[6] L. Kong, G. K. Wong and D. H. Tsang, “Performance study and system optimization on sleep mode operation in IEEE 802.16e,” IEEE Transactions on Wireless Communications, vol. 8, no. 9, 2009.

[7] T.-C. Chen and J.-C. Chen, “Maximizing Unavailability Interval for Energy Saving in IEEE 802.16e Wireless MANs,” IEEE Transactions on Mobile Computing, vol. 8, no. 4, pp. 475 - 487, 2009.

[8] K. D. Turck, S. Andreev and S. D. Vuyst, "Performance of the IEEE 802.16e Sleep Mode Mechanism in the Presence of Bidirectional Traffic," Communications Workshops, 2009. ICC Workshops 2009. IEEE International Conference, 2009.

[9] Y. Wu, Y. Le and D. Zhang, "An Enhancement of Sleep Mode Operation in IEEE 802.16e Systems," Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th, pp. 1-6, 2009.

[10] J. Xue and Z. Yuan, "An Adaptive Power Saving Strategies based on Cross-layer Design in IEEE 802.16e," Journal of Networks, vol. 5, no. 3, pp. 359-366, 2010.

[11] S. Kwon and D. Cho, "Enhanced power saving through increasing unavailability interval in the IEEE 802.16e systems," IEEE Communications Letters, vol. 14, no. 1, 2010.

[12] C.-Y. Wu, H.-J. Ho and S.-L. Lee, "Minimizing energy consumption with QoS constraints over IEEE 802.16e networks," Computer Communications, Wireless Green Communications and Networking, vol. 35, no. 14, p. 1672–1683, 2012.

[13] M. Ergen, Mobile Broadband: Including WiMAX and LTE, Berkeley, CA, USA: Springer, 2009.

[14] A. Bestetti, G. Giambene and S. Hadzic, "MAC layer performance assessments," IEEE Wireless Pervasive Computing, 2008. ISWPC 2008. 3rd International Symposium, pp. 490-494, 2008.

[15] W. Hrudey, Steaming Video and Audio Content Over Mobile WiMAX Networks, British Columbia, Canada: School of Engineering Science Simon Fraser University, PhD Dissertation, 2009.

[16] J. Wang, M. Venkatachalam and Y. Fang, "System architecture and cross-layer optimization of video broadcast over WiMAX," IEEE Journal on Selected Areas in Communications, vol. 25, no. 4, 2007.

[17] M. Sukru Kuran, G. Gur and T. Tugcu, "Applications of the cross-layer paradigm for improving the performance of WiMax," IEEE Wireless Communications, vol. 17, no. 3, 2010.

[18] A. Alamdar Yazdi, S. Sorour and S. Valaee, "Optimum Network Coding for Delay Sensitive Applications in WiMAX Unicast," INFOCOM 2009, IEEE, pp. 2575-2580, 2009.

[19] B. Li and S.-k. Park, "Maximizing power saving with state transition overhead for multiple mobile subscriber stations in WiMAX," Frontiers of Information Technology & Electronic Engineering, vol. 17, no. 10, p. 1085–1094, 2016.

[20] S. Jadhav, H. Zhang and Z. Huang, "Performance Evaluation of Quality of VoIP in WiMAX and UMTS," IEEE, Parallel and Distributed Computing, Applications and Technologies (PDCAT), 12th International Conference, pp. 375-380, 2011.

[21] W. F. N. W. Group, WiMAX Forum Network Architecture—Stage 2: Architecture Tenets, Reference Model and Reference Points—Release 1, Version 1.2, New York, USA: WiMAX Forum, 2008.

[22] I. 8. W. Group, IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, New York, USA: IEEE Computer Society, 2006.