A Novel Scheme to Enhance Power Conservation Efficiency at Base Station in Wireless Networks

[1]Rewa Sharma,[2]C.K.Jha,[3]Meha Sharma
[1]Assistant Professor,[2]Professor,[3]Assistant Professor
[1]Department of Computer Engineering,
[1]J. C. Bose University of Science and Technology, Faridabad, Haryana, India
[2] Computer Department, Banasthali University, Rajasthan, India.
[2]School of Engineering and Technology, Ansal University, Gurugram, Haryana, India

Abstract : Past researches for power conservation in IEEE 802.16e focused more on Type I or Type II power saving Classes .In our past work, we discussed shortcomings of traditional Type I and II power saving approaches and a novel approach Traffic Dependent Power Conservation (TDPC) was proposed. TDPC determine the current traffic load and generate a proper and flexible sleep schedule for the present traffic conditions. In our past research three TDPC approaches has been proposed for power saving at Mobile Subscriber Station (MSS). In this paper, earlier suggested approaches are revised to amalgamate both Base Station (BS) and MSS sleep scheduling. Two approaches, MSS-Prime and BS-Prime are proposed in the paper. Simulations explain that the suggested schemes can adequately attain high Power Conservation Efficiency (PCE) for both MSS and BS.

IndexTerms **- WiMAX, TDPC, Power Conservation Efficiency, Schedule Feasibility, MSS, BS.**

I. INTRODUCTION

IEEE802.16e extends the market for broadband wireless access solution, as an enhancement to IEEE802.16-2004 [1], by considering mobility of wireless media. This standard supports both fixed and mobile services for both customer and business markets [2].

Mobile Subscribers are highly constrained by battery power since they require high mobility support by IEEE802.16e. The key point of consideration is to look out for mechanisms that can efficiently manage the limited battery power.

In order to decrease the mobile subscriber energy consumption and usage of serving base station resources, MS goes in sleep mode.In sleep mode MS shows some intervals of absence from the serving base station for pre negotiated duration. MS checks regularly if there is any traffic for it. IEEE802.16e defined three power saving classes to add flexibility in scheduling sleep mode and adapt traffics of different types of various services and applications.

These classes differ from each other by parameters set, methods of definition, activation, deactivation and schemes of MS availability for data transmission. Maindifference lies in difference of pattern of sleep in case of long idling, which decides the duration sleep window following the initial sleep window. The performance of existing Type I and Type II power saving classes depends on two important factors, sleep window size and waiting time threshold. Type I is prescribed for NRT-VBR or BE connections and have an exponential increase in the sleep window size. Type II has a constant sleep window size and is preferred for real time connections which are very time sensitive [3]. Past researchers in power saving has been focused on performance enhancement based on Type I or II [4]-[10]. But the performance limitation of these protocols is there inefficiency in dealing Variable Bit Rate (VBR) connections due to their limited sleep patterns i.e. exponential or constant.

Exponential and Constant sleep patterns can't effectively deal with the VBR (variable bit rate) connections. We earlier proposed better approaches to dynamically measure the traffic in the network. Toachieve appropriate sleep schedule, the idea ofTraffic Dependent Power Conservation(TDPC) in the category of TypeIII power saving class has been proposed in our previous work .ThreeTDPC schemes were proposed forMobile Subscriber Station (MSS) sleepscheduling:TDPC-cum [3], TDPC-divide[11], andUnified TDPC [12].Our assumptions consider arrival for each connection as Poisson process and base station is responsible for traffic measurements. In this paper, earlier suggested approaches are revised to amalgamate both BS (Base Station) and MSS sleep scheduling. Two approaches of unified power saving, MSS-Prime and BS-Prime, are proposed in the paper. Simulation results of performance evaluation clearly show the advantages of the proposed algorithm.

II. Literature Review

Researchers have been constantly striving to reduce energy consumption by emphasizing on sleep mode algorithm. Yan Zhang et al [13] considered both the incoming and outgoing frames for analyzing the energy consumption reason being the incoming and outgoing traffic terminate the sleep mode differently. Sleep mode defined in IEEE 802.16e works by employing a method that doubles its duration of prior sleep window from minimum to maximum in case the frames are not coming from the BS till every sleep window ends up [14].However some problems arise because of multiple repetitions of maximum sleep window duration [15].For sleep mode Yang Xio [16] proposed a model for investigating the energy consumption in IEEE802.16e and considered transmission of messages BS to MS. The above mentioned references assume that the power of MS in the sleep duration is constant but actually MS can be thought of powering down gradually.L.Kong et al [17] proposed a semi-markov based theoretical framework to design an appropriate sleep mode algorithm to increase the energy efficiency in the network. In [18-20] the authors have analyzed energy efficiency and delay of response in PSCI of IEEE 802.16e as a function of relative size of them. Some researchers follow Poisson distribution to study traffic pattern characteristics [21] whereas some others consider other distributions like Erlang distributed interarrival time [22] and Hyper Erlang distribution interval time [23]. In 2008 S.Alouf et al [24] have proposed an approach for investigating queuing models with repetitions in homogeneous environment. Zhangiang [25] et al has proposed a discrete time Geom queuing model to derive the average queue length and delay of system mode. A statistical sleep window [26] algorithm has also been proposed for improving energy efficiency of MS considering virtual downlink traffic. Eunju Hwang et al [27] have proposed power saving approach with regular indications about traffic where a TRF-IND message is regularly sent at the start of every constant TRF-IND intervals.In [28] Wen-kuang et al developed a branch and bound algorithm which emphasized on maximizing energy efficiency by considering the cooperation among various layers. In [29] Taha et al incorporated a fitness function to determine the best path from source to destination to minimize the energy dissipation in multipath routing.

III. Traffic Dependent Power Conservation

We earlier proposed TDPC algorithm which adjusts sleep window size of each MSS adaptively to better suit in current load condition using traffic measurements. It accumulates data in buffer for an MSS and sets an appropriate value for the buffer threshold and dynamically calculates the next window size thus increasing the flexibility for different traffic conditions.

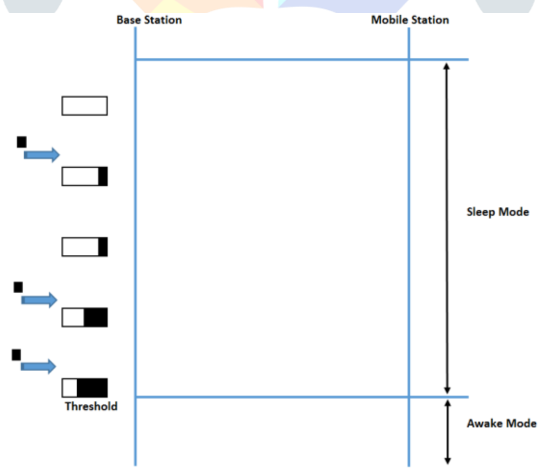

Figure. 1. TDPC

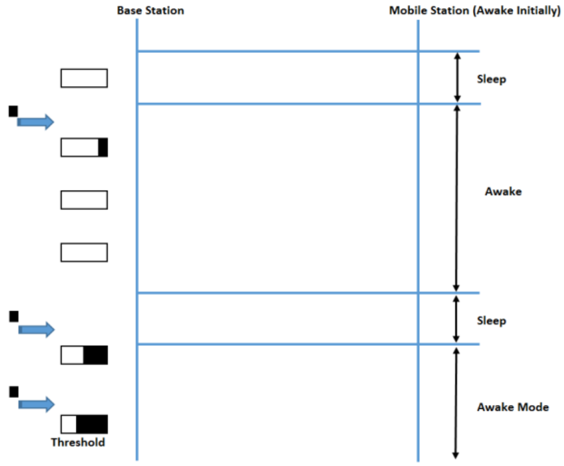

Figure. 2. Type I or Type II.

As Fig 1 and Fig 2 clearly illustrates the advantage of TDPC is that it does not awake the MSS when only a small amount of traffic arrives, which is not the case in Type I and Type II standard. TDPCoutperformed standard Type I and Type II power saving classes even in heavy load conditions. Sleep window size is calculated as the number of time frames required to reach the accumulation threshold. A variation of TDPC was suggested as TDPC-cum, in which all the traffic in the network is treated as a cumulative flow for calculating the size of sleep window.

Current load estimation in the network is done by the base station by collecting and then exponentially averaging the samples of load. The traffic arrival process being Poisson data accumulation under load λ in a time frame can be calculated as

$$\text{Pr[jpacket\_arrivals\_in\_a\_timeframe]} = \frac{e^{-\lambda T}(\lambda T)^{j}}{j!} \quad (1)$$

Here T denotes length of the time frame.

thresh_data (packets) denotes the threshold value of data accumulation.

The probability of exceeding this threshold over M time frames in a row can be given as follows:

$$\Pr_{Accum}(M, thresh\_data) = \sum_{j=thresh\_data+1}^{\infty} \frac{e^{-\lambda MT}(\lambda MT)^{j}}{j!} = 1 - \sum_{j=0}^{thresh\_data} \frac{e^{-\lambda MT}(\lambda MT)^{j}}{j!} \quad (2)$$

The number of time frames before next awake time frame for an MSS can be computed as the minimum value of M such that data accumulation probability over M time frames exceeds a predefined probability threshold, Pr_thresh.

$$\text{Length of one awake and sleep cycle} = Min\{M \mid \Pr_{Accum}(M, thresh\_data) \geq \Pr\_thresh\} \quad (3)$$

As the network load may change instantly and dynamically, the new value of M^* is calculated by base station in every awake frame of Mobile Subscriber Station.

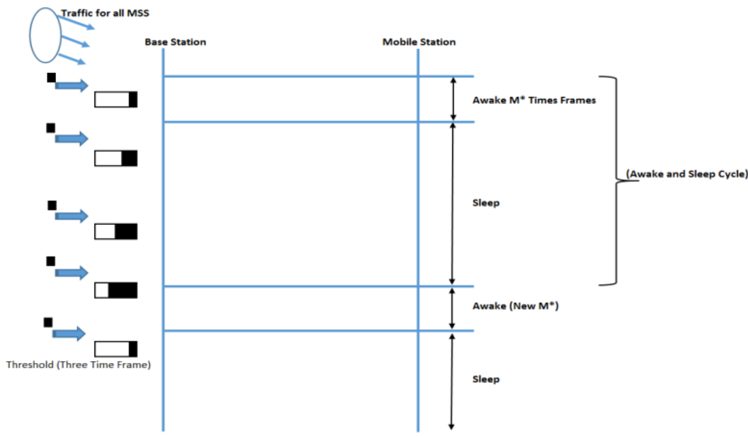

Figure 3.TDPC-cum Protocol

TDPC-cum[3] working is described in Fig 3. All the network load is considered as cumulative flow while calculating value of M^*.Awake and sleep cycles of same length may have a different starting time for each MSS.TDPC-divide[11] algorithm proceeds with the assumption of single group (M^*=1), and then we calculate the current load of each MSS. Then divide all the mobile stations into M^* groups. For each group, calculate M^*_{Grp}≡AwakeSleepCycleLength (λ_{Grp}, thresh_data). Current load of the group can be calculated as the sum of individual loads of the mobile stations with in that group. Minimum value among newly calculated values is chosen as the number of further divisions in next iteration. This process of re-estimating present load of divided groups and length of sleep and awake cycle continues until we get the same value for M^*. Finally awake and sleep cycle of length M^* can be assigned to M^* groups and a distinct awake time frame is assigned to different groups of MSSs.

Unified-TDPC[12] follows different approach of grouping MSS as compared with TDPC-divide. In this algorithm, we assume each MSS as a single member group, which have their own M^*values, which varies due to variation in loads. For better power conservation, sleep scheduling method should be able to deal with different values of M^*as long a viable sleep schedule can be found. And for that, combination of some of the groups becomes necessary. This idea of considering each MSS as a single small group in the beginning and then uniting the groups when required is termed as Unified-TDPC. For the ease of checking schedulability of groups with any possible values of M^*, the values are converted to newer values, to the closest and smaller power of 2 and is given by $M^\#$. For groups having different values of $M^\#$, Schedule Feasibility (SF) can be calculated as

$$SF = \sum_i \frac{1}{M_i^\#} \quad (4)$$

If the value of SF is ≤ 1 feasible schedule can be found else some groups need to be combined. Value of M^* should be kept as large as possible after group unification process. The whole process can be defined to have two stages: Non-Degraded Unification and Degraded Unification. If the process of unification of two groups does not result in a smaller value of $M^\#$, the process is said to be non-degraded but if it leads to smaller value of $M^\#$ it is degraded unification process. We always look for a non-degraded unification but if it is not possible then we opt for degraded one.

IV. Proposed Power Saving Approaches for Base Stations and Mobile Subscriber Stations

We have suggested two differentways for both Mobile subscriber stations and base stations in TDPC. One approach is to permit the BS to be in sleep mode when all Mobile stations are in sleep mode; we have termed this approach as MSS-Prime. The Power Conservation Efficiency (PCE) at BS is constrained by the traffic conditions and the sleep schedule of all MSSs. Implementing this approach doesn't require any improvements or changes to be done in the existing TDPC approaches. Initially find the sleep schedule for each MSS and BS sleep interval can be determined by the time slots during which all the mobile subscriber stations remain in the sleep mode. TDPC-Cum is the simplest case among TDPC approaches for BSpower conservation since all MSSs are treated as a single group. TDPC-dividerepeatedly splits all MSSs according to the new $M*$ value. There are two possible cases to end TDPC-divide algorithm.For the case of the final value of $M*$ greater than the number of MSSs, there are some chances for BS power conservation. On the other hand, when the final value of $M*$ doesnot exceed the number of MSSs, no power conservation can be attained at Base station. For Unified TDPC, Base Station power conservation relies on the last value of *Schedule Feasibility*in the end of the algorithm. When*Schedule Feasibility*< 1, BS power saving can be achieved. For*Schedule Feasibility*= 1, there is no possibility for BS power conservation.

Another approach is BS centered and therefore is termed as BS-Prime. It considers BS power conservation more advantageous than power conservation at individual MSS. This approach initially sets a minimum value for power conservation at BS, which also requires some revisions in TDPC sleep scheduling algorithms. TDPC-cum works in a similar fashion in both the approaches but some changes are required in TDPC-divide algorithm so as to reach the threshold Power Conservation Efficiency (PCE_Thresh) for base station. As we proceed in TDPC-divide algorithm, the more we divide, the longer becomes AwakeSleepCycleLength. So the revision suggests stopping further divisions when AwakeSleepCycleLength is unable to reach threshold value of Power conservation efficiency for base station. Given M_{BS}=PCE_Thresh^{-1}, Base Station PCE_Thresh can't be reached if a) final $M^*(M_f) > M_{BS}$ or

b) $M_f \leq M_{BS}$, but (M_f– 1) frames which are for MSS Sleep Scheduling are not sufficient for all groups.

Unified-TDPC considers each MSS has its own AwakeSleepCycleLength. Same approach can be applied to achieve power conservation at base station. In accordance with BS-Prime approach, base station should be considered as a special mobile subscriber station, with its own $M^{\#}_{BS}$ (M_{BS} is converted to the closest and smaller power of 2). For all MSS groups, the value of K implies one awake time frame out of $M^{\#}$ time frames. Equation of Schedule Feasibility is modified as follows:

$$SF = \sum_i \frac{1}{M_i^{\#}} + \frac{1}{M_{BS}^{\#}} \quad (5)$$

V. Results and Discussions

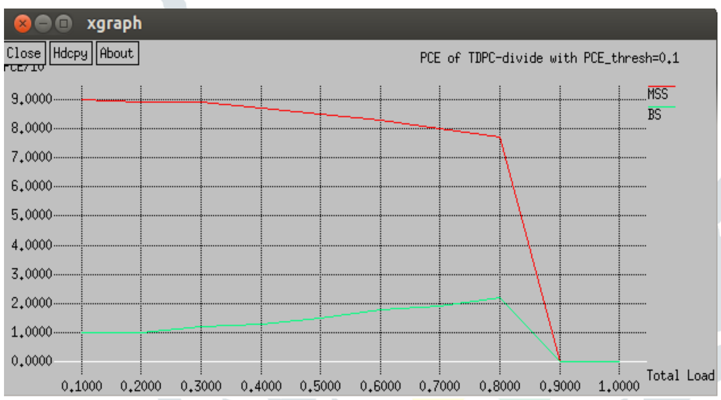

Fig 4:PCE(BS Prime):TDPC-Divide with PCE_Thresh=0.1

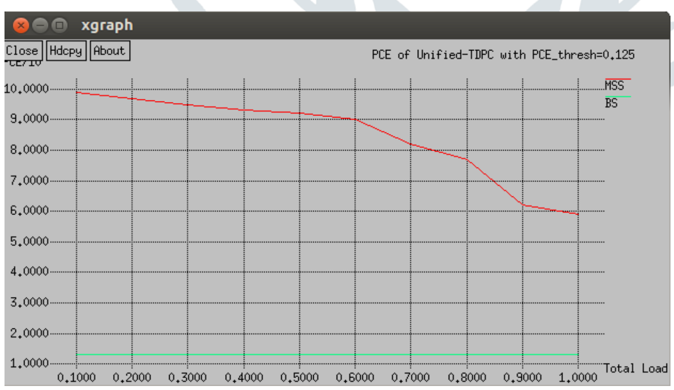

Fig5: PCE (BS Prime): Unified-TDPC with PCE_Thresh=0.125

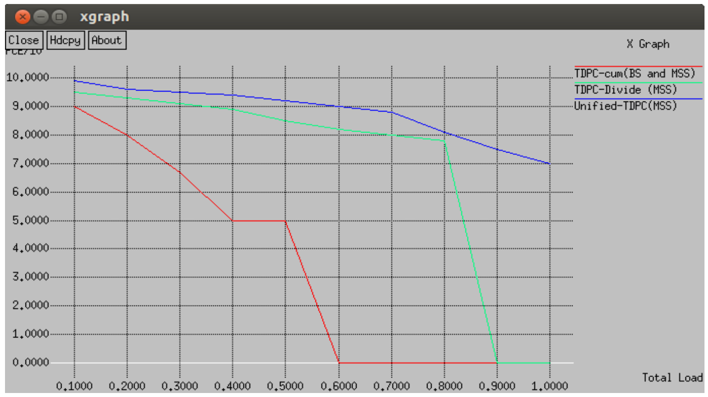

Fig6: PCE Comparison in MSS Prime Approach(MSS and BS)

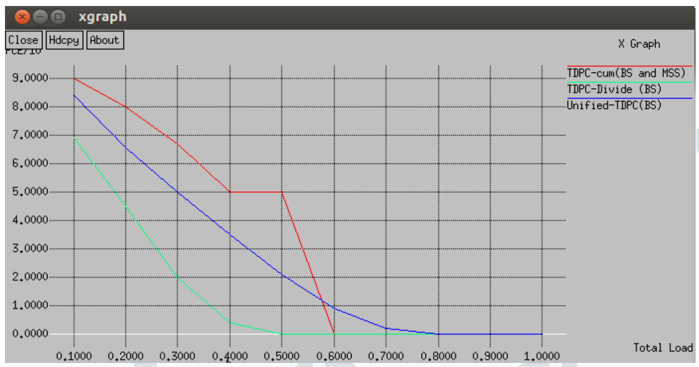

Fig7: PCE Comparison in MSS Prime Approach(BS)

Fig 4 and Fig 5 shows the simulation results for BS-Prime approach. Power conservation efficiency of TDPC-Divide and Unified TDPC are depicted assuming the threshold value as 0.1 and 0.125 respectively. Results clearly illustrate that both the improved approaches can effectively support base station power conservation, besides keeping high PCE for MSS. Fig 6 and Fig 7 shows the simulation results for MSS Prime approach. Results demonstrate that if Power conservation is considered for base station only, TDPC-Cum outperforms other approaches but if we take into account power conservation for MSS and BS, Unified-TDPC shows better performance. It is clearly illustrated that under heavy load conditions Unified-TDPC performs better than TDPC-Divide in conserving power for both MSS and BS.

VI. Conclusion

IEEE802.16e provides support to mobility but constrained with the battery power. Therefore power management has become a critical issue in IEEE802.16e. So there is a need to devise some methods to conserve power. In our previous work, we proposed the idea of Traffic Dependent Power Conservation along with three different power conservation approaches. Most of the past researchers have focused their works in power conservation in MSS only. In this paper, we have proposed power conservation at base station along with MSS power conservation. Two approaches, MSS-Prime and BS-Prime are proposed in this paper, for power conservation in both MSS and BS. Simulation results clearly depicts that proposed approaches enhances PCE and performs better than existing approaches. Future scope of the research is to broaden the concept of Traffic Dependent Power Conservation in Multi-Hop Relay Networks.

References

[1] IEEE Standard for Local and Metropolitan Area Networks-Partl6(2004): Air Interface for Fixed Broadband Wireless Access System.

[2] IEEE Standard for Local and Metropolitan Area Networks-Partl6(2006): Air Interface for Fixed and Mobile Broadband Wireless Access System-Amendent2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands.

[3]R. Sharma, C. K. Jha and M. Sharma,(2014) "Design and implementation of TDPC sleep scheduling algorithm for energy efficient networks," *International Conference on Recent Advances and Innovations in Engineering (ICRAIE-2014)*, Jaipur, 2014, pp. 1-5.doi: 10.1109/ICRAIE.2014.6909273

[4] S.T. Sheu, Y.C. Cheng, and L.W. Chen(2008), "Listening Interval Spreading Approach (LISA) for Handling Burst Traffic in IEEE 802.16eWireless Metropolitan Area Networks," in *Proc. IEEE 68th VehicularTechnology Conference (VTC 2008-Fall)*, Oct. pp. 1-5.

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

[6] J. J. Chen, J. M. Liang, and Y.C. Tseng,(2010) "An Energy Efficient Sleep Scheduling Considering QoS Diversity for IEEE 802.16e Wireless Networks," in *Proc. 2010 IEEE International Conference on Communications (ICC)*, pp. 1-5.

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

[8] E. Hwang, K. J. Kim, J. J. Son, and B. D. Choi(2010), "The Power-Saving Mechanism With Periodic Traffic Indications in the IEEE802.16e/m," *IEEE Transactions on Vehicular Technology*, vol. 59, no.1, Jan, pp. 319-334.

[9] C. Cicconetti, L. Lenzini, E. Mingozzi, and C. Vallati(2010), "Reducing Power Consumption with QoS Constraints in IEEE 802.16e Wireless Networks," *IEEE Transactions on Mobile Computing*, vol. 9, no. 7,pp. 1008 – 1021.

[10] C.H. Hsu, K.T. Feng, and C.J. Chang(2010), "Statistical Control Approachfor Sleep Mode Operations in IEEE 802.16m Systems," *IEEETransactions on Vehicular Technology*, vol. 59, no. 9, Nov, pp. 4453-4466.

[11] Sharma, R.; Jha, C.K.; Sharma, M.(2014), "A novel traffic dependent sleep scheduling method for energy conservation," *Confluence The Next Generation Information Technology Summit (Confluence), 2014 5th International Conference* - , vol., no., pp.8,13, 25-26 Sept. 2014

[12] Sharma, R.; Jha, C.K.; Sharma, M.(2015),"Performance Modeling of Unified TDPC in IEEE 802.16eWiMAX", Information Systems Design and Intelligent Applications, Advances in Intelligent Systems and Computing Volume 339, 2015, pp 199-207

[13] Zhang, Y., Fuise, M.(2006): Energy Management in the IEEE 802.16e MAC.IEEE Communications Letter, Vol. 10, No. 4, pp. 311- 313.

[14] Xiao, Y.(2005): Energy Saving Mechanism in the IEEE 802.16e Wireless MAN. IEEE Communications Letter, Vol. 9, No. 7, pp. 595-597.

[15] Lee, N. -H., Bahk, S.(2005): MAC Sleep Mode Control Considering Downlink Traffic Pattern and Mobility. Proceedings of IEEE VTC,Vol. 3, pp.2076-2080.

[16] Yang Xiao(2005), "Energy Saving Mechanism in the IEEE 802.16e Wireless MAN", IEEE Communication Letters, Vol.9, No.7, Pp 595-597.

[17] L. Kong, G. Wong, and D. Tsang,(2009) "Performance study and System optimization on sleep mode operation in IEEE 802.16e," *IEEE Transactions on Wireless Communications*, vol. 8, Sep. 2009, pp. 4518-4528.

[18] M.-G. Kim, J. Choi, and M. Kang,(2009) "Enhanced power-saving Mechanism to maximize operational efficiency in IEEE 802.16e systems, "*IEEE Transactions on Wireless Communications*, vol. Sep. 8, 2009, pp. 4710-4719.

[19] S. Zhu and T. Wang,(2007) "Enhanced power efficient sleep mode Operation for IEEE 802.16e based WiMAX," *2007 IEEE Mobile WiMAX Symposium*, Orlando, FL, USA: 2007, pp. 43- 47.

[20] Kwanghun Han and Sunghyun Choi,(2006) "Performance Analysis of Sleep Mode Operation in IEEE 802.16e Mobile Broadband Wireless Access Systems," *2006 IEEE 63rd Vehicular Technology Conference*, Melbourne, Australia: , pp. 1141- 1145.

[21] Yang Xiao(2006), "Performance analysis of an energy saving Mechanism in the IEEE 802.16e wireless MAN," *CCNC 2006. 2006 3rd IEEE Consumer Communications and Networking Conference, 2006,* Las Vegas, NV, USA: pp. 406-410.

[22] N.M.P. Nejatian and M.M. Nayebi(2007), "Evaluating the Effect of Non-Poisson Traffic Patterns on Power Consumption of Sleep Mode in the IEEE 802.16e MAC," *2007 IFIP International Conference on Wireless and Optical Communications Networks*, Singapore: 2007, pp. 1-5.

[23] Y. Zhang, (2007)"Performance Modeling of Energy Management Mechanism in IEEE 802.16e Mobile WiMAX," *2007 IEEE Wireless Communications and Networking Conference*, Kowloon, China: 2007, pp. 3205-3209

[24] S. Alouf, E. Altman, and A.P. Azad(2008), "Analysis of an M/G/1 Queue with Repeated Inhomogeneous Vacations with Application to IEEE 802.16e Power Saving Mechanism," 2008 Fifth International Conference on Quantitative Evaluation of Systems, St Malo, France: 2008, pp. 27-36.

[25] Zhanqiang Huo, Wuyi Yue, Shunfu Jin, and Naishuo Tian(2008), "Modeling and performance evaluation for the sleep mode in The IEEE 802.16e wireless networks," 2008 11th IEEE Singapore International Conference on Communication Systems, Guangzhou, China: 2008, pp. 1140-1144.

[26] C.-H. Hsu, K.-T.Feng and C.-J. Chang,(2010) "Statistical Control Approach for Sleep-Mode Operations in IEEE 802.16m Systems," IEEE Transactions on Systems," IEEE Transactions on Vehicular Technology, vol 59, Nov. 2010, pp. 4453-4466.Vehicular Technology, vol 59, Nov. 2010, pp. 4453-4466.

[27] Eunju Hwang, Kyung Jae Kim, Jung Je Son, and Bong Dae Choi,(2010) "The Power-Saving Mechanism with Periodic Traffic Indications in the IEEE 802.16e/m," IEEE Transactions on Vehicular Technology, vol. 59, Jan. 2010, pp. 319-334.

[28] W. Kuo and S. Chu(2016), "Energy Efficiency Optimization for Mobile Ad Hoc Networks," in *IEEE Access*, vol. 4, pp. 928-940, 2016.
doi: 10.1109/ACCESS.2016.2538269

[29] A. Taha, R. Alsaqour, M. Uddin, M. Abdelhaq and T. Saba(2017), "Energy Efficient Multipath Routing Protocol for Mobile Ad-Hoc Network Using the Fitness Function," in IEEE Access, vol. 5, pp. 10369-10381, 2017.
doi: 10.1109/ACCESS.2017.2707537