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Queuing Model-based Prediction Scheme (QMPS) for Conserving Power in BWA Networks

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Abstract: **In mobile Worldwide interoperability for Microwave Access (WiMAX), a mobile node is battery powered with restricted capacity. It is challenging to prolong battery lifetime by reducing the quantity of power consumed. Power saving is a significant issue which must be taken into consideration while designing the Medium Access Control (MAC) layer. Schemes are designed for saving power based on packet delay and amount of power consumed. In this paper, Prediction Scheme based on Queuing Model (PSQM) is proposed for defining Power Saving Classes (PSCs) in the MAC layer of IEEE 802.16e networks. Power is saved by turning off Mobile Stations (MSs) when they do not actively transmit or receive data. The size of Sleep Window (SW) is dynamically determined using M/M/1/N queuing model based on channel, exponential service time and Poisson arrival. The size of the buffer is restricted and is based on the First-in First-out (FIFO) queuing model. Instead of exponentially or linearly increasing the size of SW based on traffic type, Arrival Rate (λ) is taken into consideration. Time of arrival of packets is determined, thus reducing the delay involved.**

Index Terms: **BWA networks, WiMAX, Power, QMPS, Arrival Rate (λ), Service Rate (μ), SW size.**

I. Introduction

Users are more familiar with broadband access. WiMAX is a telecommunication technology which provides wireless access involving increased distances in diverse ways from Point-to-Point (P2P) links to cellular access. IEEE 802.16 supports broadband communication in Metropolitan Area Network (MAN) and seems to be appropriate for providing wireless access and sufficient bandwidth, thus offering Quality of Service (QoS) assurance [1]. It offers the missing link for the 'last mile' link in MAN, where Digital Subscriber Line (DSL), cable and broadband access schemes are unavailable or seems to be costly [2]. It supports mobility and offers an alternative to internet services in rural regions. Both fixed and mobile WiMAX involve several attractive features like connection-based MAC layer, providing QoS, effective mobility as well as power-saving characteristics [3].

To conserve power, a Mobile Station (MS) can be turned on and off whenever necessary. Sleep and awake modes are the power saving modes available in WiMAX [4]. There are two stages in sleep mode - sleep and listen stages. The MS can be made to move to sleep mode at regular intervals. Power can be saved by turning off MS for pre-set time period, making it inaccessible when it does not actively transmit or receive data. To enable handoff during sleep mode, the MS scans the Base Stations (BSs) to gather handoff-based information. The periods of unavailability of MSs are made known to the BS.

During the listening stage, MS wakes up to check whether packets are destined for it. An inactive MS may enter sleep mode by turning off device modem, thus dropping the amount of power consumed during RF inactivity. Device can wake up at pre-defined intervals and enter the Listening Window (LW) to receive paging beacons. The paging beacons indicate inclusion of buffered packets at the BS. MS continues to be awake to obtain buffered packets and moves to sleep mode during successive periods of inactivity. If no packets are addressed to it, the MS sleeps for another interval. Alternate wakeup and sleep intervals lead to considerable conservation of power by limiting the RF activity of the device.

A. QoS in WiMAX

WiMAX features diverse flow types for optimizing performance for data, voice and video [5]. Without ensuring QoS, it is impossible to guarantee reduced latency and jitter necessary for providing carrier grade services like VoIP.

To support QoS, it is vital to manage traffic. In WiMAX, different services are offered, and traffic can be prioritized. Classes include Unsolicited Grant Service (UGS), real-time Polling Service (rtPS), non-rtPS (nrtPS), extended rtPS (ertPS) and Best Effort (BE) [6]. These classes are intended for specific applications [7, 8].

- **UGS:** It supports periodic and fixed size packets in real-time like VoIP and is also suited for Constant Bit Rate (CBR).
- **rtPS:** It offers periodic, varying sized packets like Variable BR (VBR) services in real-time.
- **ertPS:** It is a blend of rtPS and UGS.
- **nrtPS:** It is suitable for nrt-VBR services like bandwidth demanding variable sized packets and file transfer with loose delay requirements.
- **BE:** It provisions BE traffic.

II. Power Saving in WiMax

Conserving energy is highly essential for prolonging network lifespan. Multi-hop communication preserves power but determining an ideal path to the destination is tedious. Path stability represents the duration for which the path can support communication. By detecting stable paths, controlling traffic and quantity of connection disruptions can be reduced and power can be conserved.

Power in WiMAX networks is conserved in 2 ways. One is by deploying Power Saving Classes (PSCs) in mobile WiMAX network (IEEE 802.16e) and the other by using Relay Stations (RSs) in a multi-hop network (IEEE 802.16j).

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PSC for IEEE 802.16e Networks

The PSC includes a collection of connections which necessitates collective features for sleep mode. It can be either activated/deactivated. When activated, the MS goes to sleep mode or LW. During deactivation, the MS moves to awake mode from sleep mode. The factors for PSC of Type II include initial SW, LW and start frame number for initial SW. Once communication amid MS and the BS is complete, the MS moves to sleep mode by forwarding sleep request to the BS.

Sleep request involves sleep interval limits (T_{Min}, T_{Max}) and listening interval (L). In case the BS which offers service receives request from an MS to go to sleep mode, it forwards a reply that comprises of initial and final SW, LW and traffic activated wakening flag. The MS moves to sleep mode after obtaining response. The listening interval is positioned amid 2 sleep intervals. Total sleep duration includes sleep as well as listening intervals. First, 'T_{Min}' is used. Once sleep interval expires, the MS commences to listen and waits for traffic. In case packets are buffered for MS during former time interval, PSC for MS is disabled, and MS remains awake to obtain packets. As traffic in the network keeps changing, the PSC must be dynamically chosen. An MS may wake up when the amount of data received during SW cannot be handled in the subsequent LW.

The PSCs for every class define separate schedules of sleep and awake modes depending on the type of traffic at the MS. The IEEE 802.16e includes diverse PSCs for traffic depending on the way the sleep mode is applied. Three classes are defined, and each class differs in parameters, activation and deactivation procedures.

- **Class I:** It is suitable for nrtPS and BE traffic which are delay tolerant. The size of SW is doubled every time to maximum limit with LWs amid them. The BS alerts mobile node about arrival of Downlink (DL) traffic by sending a message on the broadcast channel. It sends message on a sleep mode multicast channel during LW intervals. The node may wake up early, deactivate the PSC and send the BW-REQ to BS in case new UL traffic exists.
- **Class II:** It can be used for rtPS, ertPS, and UGS kinds of traffic. The SWs are of similar size with in-between LWs. There is no deactivation based on arrival of traffic as in type I. PSC of type II employs a constant SW size, and packet delay is reduced by fixing the size of SW to initial size. As stated in IEEE 802.16e-2006, the MS can send or receive packets and acknowledgments during LWs, enabling short messages to be transmitted or received without interruption of sleep mode, thus avoiding unnecessary switching costs. It involves more number of LWs, resulting in more power consumption.
- **Class III:** It can be used for management or multicast traffic. LW is not defined for type III PSC. PSC gets deactivated automatically once SW terminates.

A trade-off amid the amount of power consumed and packet delay must be attained. Delay must be at a satisfactory level.

IEEE 802.16j

In IEEE 802.16j (IEEE 802.16e-2006), the relay nodes are deployed as a promising solution to replace IEEE 802.16e mesh mode for extending coverage and enhancing throughput. Further, it conserves power as relays close to MS enable multi-hop communication and increases network capacity. A multi-hop wireless network based on relay architecture comprises of small relays that are related to the BSs. Though multi-hop communication preserves power, determining an ideal route to destination is tedious. There are many routing protocols available in the literature grounded in various factors. They decide the path to the destination based on factors like the shortest distance, geographic location, stability of links etc. A protocol which determines a stable ideal route based on node energy extends network lifetime.

Delay

Data packets for an MS are queued until they are accepted by it. In case the MS is in sleep mode, the packets are buffered by the BS and are delayed for a wakeup interval till LW is seen. Extended sleep duration leads to a drop in the amount of power consumed but raises the amount of delay. This has an impact on the packet delay constraints causing overflow of buffer. Short sleep intervals involve reduced delay but upsurge power drain owing to repeated awake modes. A trade-off must be obtained. An effective sleep-wake up schedule should be designed for balancing delay and power.

As accurate information concerning future traffic flow is not known, the sleep window size can be determined from traffic history and recent traffic changes. In this paper, a power saving mechanism is propounded for mobile networks. Queuing Model based Prediction Scheme (QMPS) is designed for dynamically alternating sleep interval for diverse traffic classes. Sleep interval is dynamically determined based on arrival (λ) and service rates (μ) of traffic. An appropriate sequence of PSCs is got and trade-off amid packet delay and power consumption is achieved. Average delay is highly reduced (22.4%) and power is conserved to a greater extent (19.6%). Throughput is increased (82%) and the PLR is reduced (79.3%).

III. Related Work

In this section, the schemes of power saving designed for WiMAX networks are discussed in detail.

Suranga Sampath et. al. (2020) [9] have employed an M/M/1 queuing system that integrates various vacation policies, customer impatience and scenarios involving waiting server. Transient probabilities are derived for the size of the system by explicitly using techniques such as probability continued fractions, producing functions, Laplace transforms and confluent hypergeometric functions. Time-based mean and variance are used as performance metrics, including an example to show the behavior of a system. Mai et. al. (2020) [10] have addressed scheduling of both Real-Time (RT) and Non-RT (NRT) traffic by proposing Load-Based Power Saving-RT (LBPS-RT) scheme. Simulations demonstrate that the proposed scheme offers better power-saving efficiency in contrast to standard

Type I and II approaches and successfully meets the required traffic delay constraints. Isaac et. al. (2020) [11] have introduced Battery-Life Management with Efficient Sleep-Mode Power Saving Scheme (BM-ESPSS), an enhancement of ESPSS. BM-ESPSS focuses on adjusting sleep intervals and improving average-based sleep mode to reduce longer sleep durations aiming at enhancing QoS. The scheme is evaluated through analytical models and discrete event simulations showing improved performance based on energy consumption, delay reduction and extended battery in contrast to existing mechanisms.

Wisdom et. al. (2020) [12] have proposed Delay Aware Power Saving Scheme (DAPSS) and its enhanced version (EPSS), which are designed to mitigate excessive response delays by adjusting power-saving parameters based on traffic load. EPSS introduces minimum and maximum sleep intervals to reduce power usage and enhance QoS. The mechanism dynamically adapts to varying traffic conditions and is assessed through discrete event simulations, showing significant improvements over previous schemes in power consumption and QoS. Jin et. al. (2021) [13] have developed a discrete-time queuing model involving varied vacations for analyzing communication networks through IEEE 802.16m protocol. They have described the operational principles of the system and have used a discrete-time embedded Markov chain to assess steady-state performance measures, including average packet response time and energy savings. The numerical outcomes investigate effects of sleep cycles and packet arrival rates on system performance. Asafa et. al. (2022) [14] have assessed the energy efficiency of an optical-wireless access network combining Long Term Evolution - Advanced (LTE-A) and Passive Optical Network (PON) technologies. Dynamic Bandwidth Allocation (DBA) algorithm is implemented using OPNET and it is seen that DBA involves reduced energy, demonstrating significant energy savings while maintaining QoS in the network.

Naik et. al. (2022) [15] have proposed traffic grooming algorithms for hybrid networks that incorporate renewable energy sources. This approach involves decentralized renewable energy production at network nodes, with brown energy used as backup. The algorithms optimize energy usage and traffic routing while minimizing reliance on fossil fuels and ensuring service level agreements at data centers. Emara (2022) [16] have introduced a power conservation algorithm for VoIP services in WiMAX systems depending on Artificial Neural Network (ANN-VPSM). Feed-Forward Neural Network (FFNN) model predicts silent periods for finding sleep intervals to save power in IEEE 802.16 systems. The results indicate that ANN-VPSM involves reduced power during VoIP calls while maintaining QoS. Mohammed Shapique et. al. (2024) [17] have examined energy management strategies for WiMAX and have tethered High Altitude Platform (HAP) systems. The model includes a close-down period followed by either a functional state or ordinary vacation based on system occupancy. During ordinary vacations, if the system is empty, a Working Vacation (WV) mode is used, where jobs are served at a reduced rate. Explicit transient as well as steady-state probabilities are derived through continued fraction and hypergeometric functions, and performance is evaluated in terms of mean, variance, throughput, and abandonment rate along with cost-profit analysis.

IV. Dynamically Alternating Sleep Interval Scheduling Algorithm

In a changing network traffic environment, PSC must be dynamically selected for rtPS or nrtPS traffic types. Dynamically Alternating Sleep Interval Scheduling Algorithm (DASISA) [18] aids in determining SW sizes of MSs. It uses historic and dynamic information to regulate previously made decisions and values of parameters. Data traffic is categorized into non-real-time (Class I) and real-time (Class II). Diverse classes of traffic are taken into consideration and PSCs are scheduled. Two PSCs are alternately included in power saving sequence. LWs are positioned close to arrival frames of packet.

Type I and II PSCs support similar operations with varying sizes of SW. Type II PSC employs fixed size of SW depending on initial size rather than doubling the size, leading to a greater number of LWs and increased power consumption when compared to Type I PSC. Size of SW is dynamically determined depending on arrival time of packet, interval amid packets and packet types. The PSCs are constructed by considering initial SW cycle length based on Rank Number (Rn) which varies with the traffic load.

V. Queuing Model Based Prediction Scheme (QMPS)

In case of IEEE 802.16e networks, forecasting the SW is challenging. Packet delay increases with SW size. As packets reach an MS, it must listen so as to drop delay consumed in getting packets. In case a packet reaches before an MS wakes up, the BS must wait until MS shifts to listening mode. In case, an MS does not listen in a short interval on receiving packets at the BS, there may be an increase in delay. Packets may collect at BS for an MS, and the MS will not be ready to obtain it. To overcome this, the LW must follow packet arrival as far as possible. QMPS is designed to determine the time when an MS must commence listening for packets.

Mean Arrival Rate (λ) refers to predictable quantity of packet arrivals in a unit time. Mean Service Rate (μ) represents anticipated packet service completion per unit time for MS. No PSC depending on 'μ' and 'λ' determined from arrival time is available. Instead of taking distinct schedules for diverse classes, 'λ' and 'μ' based models may be implemented on different traffic classes. Each MS has one connection. An MS may shift to listening mode by forecasting the time in which packets may reach it. Prediction is performed based on 'λ' of packets. In case, an MS is in sleep mode when packets arrive at the serving BS, the respective MS must be awakened. The time at which packets destined for the MS reach the BS must be forecast depending on 'λ' and 'μ' of packets. MS after servicing packets, checks whether frames are available at the BS intended for it. If pending packet frames are present, they are received and serviced. Else, it switches to sleep mode for a specific amount of time.

A. Mathematical Model

Markovian queuing models represent queuing systems which involve exponential inter-arrival and service times. M/M/1/N queue is a model based on a server with limited capacity. Arrival of customers is modelled as a Poisson process with ‘λ’. Inter-arrival as well as service times follow exponential distribution that signifies Markovian model. As buffer size is restricted, the quantity of packets it can hold is limited.

M/M/1/N represents a stochastic process with state space including a set of packets and the one presently being served. In case of a server, packets are served based on First Come First Serve (FCFS) basis. This model is employed for forecasting the sleep interval of MS based on ‘λ’ of packets intended for the MS.

B. Window Size Based On Arrival Rate

In case, the time of packet arrival (T_a) is appropriately predicted, delay may be reduced to a greater extent. LW is set at time slot ‘T_a’. Size of SW is determined dynamically based on ‘λ’ and ‘μ’ of packets. Service time refers to the time between the beginning and end of service.

$$\text{Expected service time} = \frac{1}{\mu} \tag{1}$$

‘P_0’ represents the probability that packets are not buffered at the BS for a MS.

$$P_0 = \frac{1}{N+1} \text{ if } \lambda = \mu P_0 = \begin{cases} \frac{1}{N+1} \text{ if } \lambda = \mu \\ \frac{1-\rho}{1-\rho^{N+1}} \text{ if } \lambda \neq \mu \end{cases} \tag{2}$$

where, ‘$\rho = \frac{\lambda}{\mu}$’, ‘λ’ indicates traffic intensity and ‘μ’ denotes utilization factor

Let ‘P_n’ represent probability that ‘n’ packets are buffered for the MS at the BS.

$$P_n = \begin{cases} \frac{1}{n+1}, \text{if } \lambda = \mu \\ \rho^{\left(\frac{n}{\mu-\lambda}\right)}.P_0, \text{if } \lambda \neq \mu \end{cases} \tag{3}$$

With increase in ‘λ’, ‘ρ’ shows an increase, where ‘μ’ is a constant. Probability (P_n) that packets are serviced shows a drop with increase in ‘λ’. This demands that the size of the sleeping window is dropped.

Arrival time (T_a) of packets is determined as follows.

$$P_N = 1 - e^{-(\mu-\lambda)T_a} P_N = 1 - e^{-\rho(\mu-\lambda)T_a} P_n = 1 - e^{-\rho(\mu-\lambda).T_a} \tag{4}$$

Time with increased probability for packets to arrive (T_a) is given by,

$$T_a = \frac{\ln(1 - P_n)}{\rho.(\lambda - \mu)} \tag{5}$$

As ‘λ’ approaches ‘μ’, afore mentioned relation may not hold. With drop in probability of packets that are being serviced, an increase in the size of SW is observed.

Time at which MS commences to listen (T_l) is given by,

$$T_l = T_l - 1 + T_a \tag{6}$$

As ‘λ ‘and ‘μ’ vary with traffic type, ‘T_a’ is determined dynamically. The parameter ‘T_a’ represents the prediction factor for assigning size of SW (SW_{Size}) in terms of slots.

$$SW_{Size} = T_a = T_l - T_{l-1} \tag{7}$$

The time at which MS must wake up is dynamically determined depending on ‘SW_{Size}’. This leads to a reduction in the amount of delay and power consumed.

VI. Performance of QMPS

The system is implemented using ns-2 and performance is analyzed for several power saving schemes. Simulation parameters are shown in Table 1. QMPS offers improved results in contrast to DASISA. It shows better results based on Throughput, delay, Energy consumed, and Packet Loss Ratio (PLR).

TABLE I.
SIMULATION PARAMETERS OF CPSR AND QMPS

Parameters	Values
MAC Protocol	MAC 802.16e
Routing protocol	DSDV/ GPSR
Queue Type	Queue/DropTail/ PriQueue
Bandwidth	50 Mbps
Beacon interval (Sec)	0.5
Queue Length	512
Number of MSs	50
Simulation time (Sec)	40
Initial Energy	100 J
Transmission / Receiving Power (mW)	0.6 - 35 / 0.2
Packet size (Bytes)	1024
Data rate (Mbps)	2
Transmission range (m)	250 - 400
Speed of nodes (ms^{-1})	20

Data packets destined for an MS are queued until accepted by it [19]. In case the MS switches to sleep mode, the packets are buffered at the BS and delayed for another interval (wakeup) until LW is seen. Extended sleep period reduces the amount of power consumed, but on the other hand increases the quantity of delay involved. This violates the constraints related to packet delay and causes overflow of buffers [20]. Smaller sleep intervals involve less delay but increased power drain owing to recurrent awake modes. This demands a trade-off. An effective sleep wakeup schedule is essential for balancing delay and power factors.

QMPS offers 82% better Throughput in contrast to DASISA (Fig. 1).

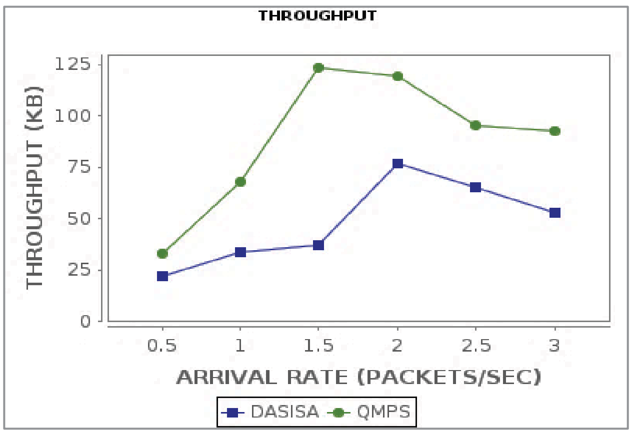

Figure 1. Throughput of QMPS

DASISA involves 19.6% more amount of energy in contrast to QMPS (Fig. 2).

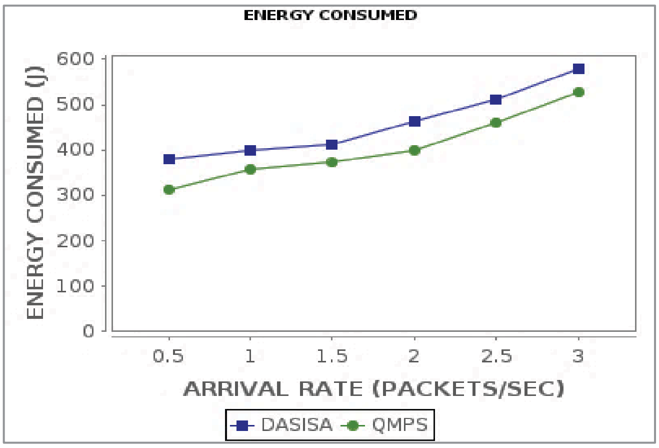

Figure 2. Energy of QMPS

QMPS involves 22.4% less delay in contrast to DASISA (Fig. 3).

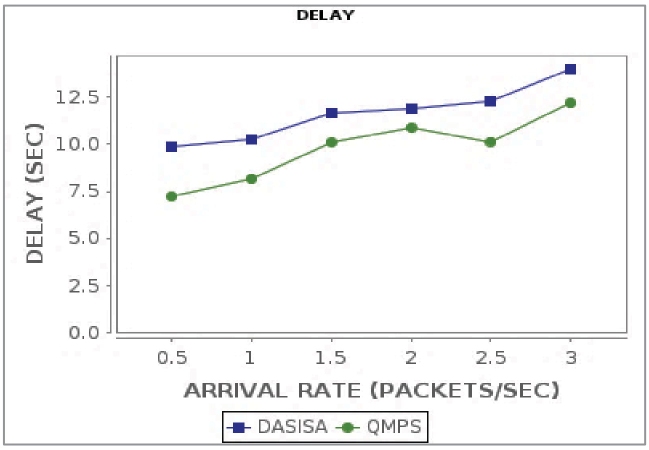

Figure 3. Delay of QMPS

QMPS involves 79.3% less PLR in contrast to DASISA (Fig. 4).

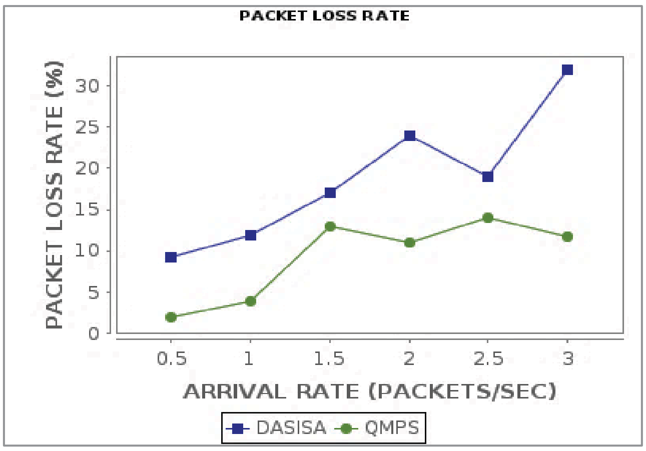

Figure 4. PLR of QMPS

VII. Conclusion

In this paper, Queuing Model based Prediction Scheme (QMPS), an efficient power saving is designed to offer improved lifespan of MSs for IEEE 802.16e networks. The size of SW is adjusted dynamically based on Arrival (λ) and Service (μ) rates of packets destined for the MS. As an MS wakes at the most probable time of arrival of packets, the proposed scheme involves reduced power and delay.

References

[1] Abichar, Z., Peng, Y., & Chang, J. M. (2006). WiMAX: The emergence of wireless broadband. IT Professional Magazine, 8(4), 44.

[2] Eklund, C., Marks, R. B., Stanwood, K. L., & Wang, S. (2002). IEEE standard 802.16: a technical overview of the Wireless MAN/sup TM/air interface for broadband wireless access. IEEE communications magazine, 40(6), 98-107.

[3] Ahmed, Z., & Hamma, S. (2012). Two-level scheduling algorithm for different classes of traffic in WiMAX networks. In 2012 International Symposium on Performance Evaluation of Computer & Telecommunication Systems (SPECTS) (pp. 1-7). IEEE.

[4] Hwang, E., Kim, K. J., Son, J. J., & Choi, B. D. (2009). The power-saving mechanism with periodic traffic indications in the IEEE 802.16 e/m. IEEE Transactions on Vehicular Technology, 59(1), 319-334.

[5] Li, B., Qin, Y., Low, C. P., & Gwee, C. L. (2007). A survey on mobile WiMAX [wireless broadband access]. IEEE Communications magazine, 45(12), 70-75.

[6] So-In, C., Jain, R., & Tamimi, A. K. (2009). Scheduling in IEEE 802.16e mobile WiMAX networks: key issues and a survey. IEEE Journal on selected areas in communications, 27(2), 156-171.

[7] Safa, H., Artail, H., Karam, M., Soudah, R., & Khayat, S. (2007). New scheduling architecture for IEEE 802.16 wireless metropolitan area network. In IEEE/ACS International Conference on Computer Systems and Applications, pp. 203-210.

[8] Cicconetti, C., Erta, A., Lenzini, L., & Mingozzi, E. (2006). Performance evaluation of the IEEE 802.16 MAC for QoS support. IEEE Transactions on mobile computing, 6(1), 26-38.

[9] Suranga Sampath, M. I. G., Kalidass, K., & Liu, J. (2020). Transient analysis of an M/M/1 queueing system subjected to multiple differentiated vacations, impatient customers and a waiting server with application to IEEE 802.16e power saving mechanism. Indian Journal of Pure and Applied Mathematics, 51, 297-320.

[10] Mai, Y. T., Chen, J. Y., & Lin, M. H. (2020). Design of load-based power saving and scheduling scheme integrating real-time and non-real-time services in WiMAX networks. Journal of Internet Technology, 21(5), 1263-1275.

[11] Isaac, S., Wisdom, D. D., Nigeria, S., Ahmad, M. A., & Christian, A. U. (2020). Battery-life management with an efficient sleep-mode power saving scheme (BM-ESPSS) in IEEE 802.16e networks. Int J Mechatron Electr Comput Technol (IJMEC), 7(2).

[12] Wisdom, D. D., Ahmed, M. A., Farouk, N., Isaac, S., Idris, H., & Hassan, J. B. (2020). An enhanced power saving scheme (EPSS) in IEEE 802.16e networks. International Journal of Information Processing and Communication IJIPC, 8(2).

[13] Jin, S., Yue, W., Jin, S., & Yue, W. (2021). Bernoulli Arrival-Based Sleep Mode in WiMAX 2. Resource Management and Performance Analysis of Wireless Communication Networks, 87-96.

[14] Asafa, M., Lasisi, H. O., Olawumi, O. O., & Awofolaju, T. T. (2022). Energy Efficiency In Optical-Wireless Access Network Using Dynamic Bandwidth Allocation. Journal of Energy and Safety Technology (JEST), 5(2), 21-29.

[15] Naik, D., Bauri, A., & De, T. (2022). Renewable Energy Aware Traffic Grooming in Hybrid Optical and WiMAX Networks. Wireless Personal Communications, 1-23.

[16] Emara, T. (2022). Adaptive Power-Saving Mechanism for VoIP Over WiMAX Based on Artificial Neural Network. In Research Anthology on Artificial Neural Network Applications (pp. 471-489). IGI Global.

[17] Mohammed Shapique, A., Sudhesh, R., & Dharmaraja, S. (2024). Transient Analysis of a Modified Differentiated Vacation Queueing System for Energy-Saving in WiMAX. Methodology and Computing in Applied Probability, 26(3), 23.

[18] Chang, J. Y., & Lin, Y. C. (2012). Dynamically alternating power saving scheme for IEEE 802.16e mobile broadband wireless access systems. Journal of Communications and Networks, 14(2), 179-187.

[19] Priya, M. D., Sengathir, J., & Valarmathi, M. L. (2010). ARPE: an attack-resilient and power efficient multihop WiMAX network. International Journal on Computer Science and Engineering, 2(4), Vol. 02, No. 04, pp. 1201-1208.

[20] Priya, M. D., Shanmugapriya, R. K., & Valarmathi, M. L. (2014). An Enhanced Relay Selection Scheme (ERS) for Cooperative Relaying in Mobile WiMAX Networks. International Journal of Science, Engineering and Technology Research, 3(5), 1401-1407.