A Comprehensive Survey On Power Saving Schemes (CSPSS) In IEEE 802.16E/M Networks

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ABSTRACT

Worldwide interoperability for micro wave access (WiMAX) is a wireless network that have attracted the attention of researchers on the area of power savings, because of the increase in multimedia applications that consumes more battery power of Mobile stations (MS). MS experience an increase in their daily operations with limited power enforced on the MS; hence the need to optimally increase efficiency; due to the excessive power consumption experienced by MS; which significantly affects the performance of MS since, MS are battery powered with a super impose life, improving the life time of MS is imperative. Thus, this has led to numerous research works on energy-savings. Hence, we have presented a survey on the recent and past energy-saving schemes, aimed at understanding some of the most relevant sources of inefficiency in energy savings and how some of these challenges are solved by the existing solutions. We further presented a comparative analysis on these schemes with the aim of identifying current challenges that are yet to be addressed by the research community as well as presents future directions towards efficient energy savings in WiMAX networks.

Keywords: Power-Savings, Consumption, WiMAX, Networks

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1. INTRODUCTION

There have been rapid advancements in wireless communication in recent years. WiMAX networks as one of the growing wireless communication technologies has attracted attention around the world because of it economic and societal benefits. This has led the working group of the IEEE 802.16 to develop a series of WiMAX standards. The earlier standards of the IEEE 802.16-2004 specified the access between a base station (BS) and fixed Subscriber Stations (SSs) as fixed (IEEE, 2004); while in the subsequent standard,

Mobile Stations (MSs) are supported by the IEEE 802.16e (IEEE, 2006). The IEEE 802.16-2009 (IEEE, 2009) consolidated the two standards and added additional mobility characteristics.
With another standard as the IEEE 802.16m (IEEE, 2010), developed to provide the requirements for future International Mobile Telecommunications (IMT) Advanced networks with higher data rate and higher mobility as well. Because of the mobility feature added, prolonging the battery life of MSs became an important problem as well as one of the critical issues since MSs are battery powered with limited lifetime until recharging excise is conducted. As such, efforts have been made to design solutions that will minimize energy consumption with the aim of improving the efficiency of a mobile device with minimal response delay.

Several energy saving mechanisms have been proposed in (Hwang *et al.* 2010) (Eunju *et al.* 2009) (Jianbin *et al.* 2008) (Yang *et al.* 2013) (Shi *et al.* 2006) (Wisdom *et al.*2019) to improve the battery life of a MS. Most of these Mechanisms used Power-Saving Classes (PSC) of type I while a few of the Mechanisms used type II. The PSC Type I recommend for connections such as Best Effort (BE), Non-Real Time Services (NR-TS). Based on the standard, Power Saving Class becomes active at the frame specified as the start frame number for the first sleep windows (Saidu *et al.* 2017).

PSC Type II is recommended for connections of unsolicited grant services (UGS), such as real time variable rate (RT-VR) service connections. Unlike Type I, Type II uses constant sleep window size instead of doubling the sleep interval figure I. More so, contrary to Type I, at the listening windows of Type II the MS can send or receive any Service Data Units (SDUs) or their fragments, based on the standard (Saidu *et al.* 2017). While PSC of type III is used for managing multicast connections and operations as follows: In this paper, we have presented a survey on recent and past energy-saving schemes in WiMAX. The schemes operational mode, strengths and weaknesses are presented. A comparative analysis of these schemes is also presented to identify current challenges for future research. The rest of this research work is organized as follows. Section 2 presents the methodology used. Section 3 presents results and discussion while Section 4, concludes our study.

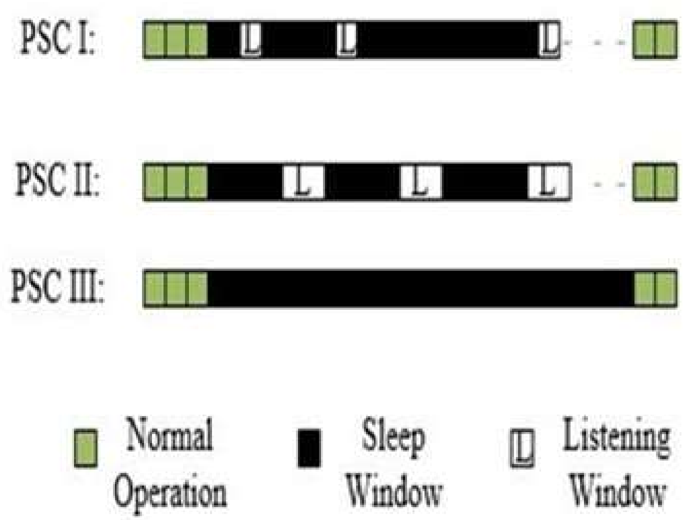

Figure 1. Shows Power Saving Classes (PSC)

Table 1 : The Evolution of the IEEE 802.16 family

	802.16-2001	802.16a	802.16-2004	802.16e
Frequency range	10-16 GHz	2-11GHz	2-11GHz	2-6GHz
Channel condition	Line-of-sight only	Nonline-of-sight	Nonline-of-sight	Nonline-of-sight
Channel Bandwith	20, 25 and 28 MHz	1.25-28MHz	1.25-28MHz	1.25-20MHz
Modulation scheme	QPSK, 16QAM, and 64QAM	OFDM, QPSK, 16QAM, and 64QAM	OFDM, QPSK, 16QAM, and 64QAM	OFDMA,OFDM, QPSK, 16QAM, and 64QAM
Bit rate	32-134Mbps	Up to 75 Mbps	Up to 75 Mbps	Up to 15 Mbps
Mobility	Fixed	Fixed	Fixed	Pedestrian mobility-regional roaming, maximum mobility support: 125km/h
Typical cell radius	1-3 miles	Maximum range is 30 miles on the basis of antenna gain and transmission power	Maximum range is 30 miles on the basis of antenna gain and transmission power	1-3 miles
Applications	Replacement of E1/T1 services for enterprises, backhaul for hotspots, residential broadband access, SOHO(small office/home office)	Alternative to E1/T1, DSL, cable backhaul for cellular and Wifi, VoIP, internet connections	802.16-2001 plus 802.16a applications	802.16-2004 applications plus fixed VoIP, QoS-based applications, and enterprise networking

2. METHODOLOGY

In this section, we have presented an overview of WiMAX Networks and conducted an extensive review of both past and recent related literatures in WiMAX Networks in order to identify individual strength and weaknesses of each scheme, and presents possible future research directions as well as conducted a comparative study of the different power saving classes (PSC) and how their operational procedures, method of activation and deactivation are implemented and present an overview on WiMAX as well as promising issues yet on resolved as directions for further research work.

2.1 Overview of WiMAX

Worldwide Interoperability for Microwave Access (WiMAX) is an important wireless telecommunication technology in use. WiMAX as wireless metropolitan area network (WMAN) technology.

WiMAX is a wireless technology improved for the delivery of IP centric services over a wide area network (WAN); it's a scalable wireless platform used in the building of alternate and matching broadband networks. WiMAX structures are anticipated to deliver broadband access services to residential and enterprise customers in an economic manner. Lightly, WiMAX is a consistent wireless version of Ethernet made mainly as substitute to wire network such as cables modems DSL and T1/E1 Links to offer broadband access to premises.

In addition, WiMAX is a manufacturing organization formed by leading network communication, components, as well as apparatus companies to promote, certify compatibility as well as interoperability of broadband wireless kit that conforms to the IEEE 802.16 Standards. The IEEE802.16 medium access control (MAC) was design for point to multipoint broadband wireless access systems. The main duty of the MAC layer is to provide an interface such that the advanced transport layer as well as the physical layer can communicate each other. The MAC layer transmits data packets through the upper layer; these data packets are usually called MAC Service Data Units (MSDUs) and organize them into MAC Protocol Data Units (MPDUs) for broadcast over the air. For incoming broadcasts, the MAC layer does the reverse. The IEEE802.16-2004 and the IEEE802.16e-2005 MAC design includes a merging sub layer that can interface with a variety of advanced-layer protocols, such as ATM, TDM voice, Ethernet, IP, and any unknown future protocol.

The 802.16 MAC is design for Point to Multipoint (PMP) systems and is on Collision Sense Multiple Access with Collision Avoidance (CSMA/CA). More so, support for QoS is a essential part of the WiMAX MAC layer design; it takes some of the main ideas behind its QoS design from the Data over Cable Service Interface Specifications (DOCSIS) cable modem standard. A better QoS control can be achieved by a connection-oriented WiMAX MAC architecture, where all DL as well as UL connections are meticulously controlled through serving Base Stations (BS). WiMAX also explains the concept of a services flow. A services flow is a unidirectional flow of packets with a particular set of QoS restrictions identified by a Service Flow Identified (SFID). The physical layer is according to Orthogonal Frequency Division Multiplexing (OFDM). It is through the broadcast scheme of choice to enable high speed data, video and multimedia communications and is used by a variety of commercial broadband networks, which includes DSL, Wi-Fi, Digital Video Broadcast-handheld (DVB-H), and media Flo. WiMAX OFDM is a sophisticated and well-organized structure for high data rate broadcast in a non-line-of-sight or multipath radio environment.

The physical layer of WiMAX is relatively flexible therefore; the data rate performance differs based on the operating parameters. Parameters that have a substantial impact on the physical layer data rate are channel bandwidth, the modulation as well as coding scheme used. Other parameters, as number of sub-channels, OFDM guard time, and oversampling rate, have an impact as well. WiMAX operates as Wi-Fi, but advanced in speed over greater distances and used by numbers of handlers. It also has the ability to provide services even in locations that are difficult for wired networks to influence and the ability to overcome the physical limitations of outdated wired network. WiMAX is projected to offer initially up to about 40 mbps capacity per wireless channel for both fixed and portable networks, depending on the particular technical configuration chosen, enough to support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. WiMAX can support voice, video and internet data. WiMAX provides wireless access to buildings, either in competition to existing wired networks or alone in currently un-served rural or less populated places. WiMAX is also used to connect WLAN hotspots to the internet.

It can also provide broadband connectivity to mobile devices, although it may not be as fast as in the fixed networks, but expectations are for about 15 mbps capacity in a 3km cell coverage range. With WiMAX, operators can access and go online at broadband speeds, virtually all the time they wish to, from within a metro zone. Finally, WiMAX network can be installed in a variety of spectrum bands: 2.3GHZ, 2.5GHZ, 3.5GHZ, and 5.8GHZ respectively.

2.2 Survey on Energy Saving Schemes

A survey on existing energy schemes is presented in this section. The schemes are studied by highlighting their operational procedure, strengths as well as weaknesses of each scheme. In addition, the survey is further subdivided into 3 subgroups namely power saving mechanisms, adaptive power saving mechanisms and dynamic power saving mechanisms for better understanding and readability as follows:

2.3 Power Saving Mechanisms

In (Hwang *et al.* 2010), an energy scheme with periodic traffic indications was proposed to decrease energy consumption. The scheme tries to decrease the state transition overhead for both wake as well as sleep modes, hence decreasing the increase delay for state transition as well as improving energy saving efficiency. The mechanism reduced the average rate of consumption of the MS while improving the quality of service (QoS), but suffers little increase in delay. In Eunju *et al.*2009, a mechanism with binary exponential traffic indications message was proposed in order to reduce consumption rate. This mechanism omits MOB-SLP-REQ/RSP messages with a traffic indication (TRF-IND) interval as an important parameter; the mechanism applies the truncated binary exponential increase approach for its length and tries to reduce the scheme overhead for the state transition for both wake as well as sleep intervals, thereby minimizing the delay due to its transition and significantly improve efficiency. The mechanism consumes less energy compared to PSC of type I standard. However, the scheme derivations are intricate that extending the research is an important concern. In Eunju *et al.*2007, power mechanism with periodic traffic indication was introduced to improve efficiency. The mechanism used traffic indication (TRF-IND) messages to initiate data transfer at each constant time.

The TRF-IND messages consist of a listening/wake interval as well as sleep interval. at the listening interval a MS synchronizes with it present BS and decides to switch to wake-mode or remain in a sleep-mode. If there exist traffics in the buffer for the tagged MS the BS sends a positive TRF-IND message and the MS switch to wake-mode. The BS sends data during the wake-state thus end transmission if no traffic arrival during a time-out/fixed time of a constant length T. If any data traffic arrives during the close-down time T, the BS keeps on the wake state and transmits the data. Else, the MS goes to a sleep-mode from the wake state without exchanging MOB-SLP-REQ/RSP messages. The mechanism decreased the rate of consumption while satisfying the QoS. However, it ignores considering up-link traffics.

In (Eunmi *et al.* 2015), a remaining energy-aware quality-of-service (QoS) based binary-exponential sleep mode (BE-SM) scheme was proposed to minimize consumption rate of MS. The proposed BE-SM allocates the sleep cycles as well as enhanced the frequency of LoRE reports while reducing the consumption rate as well as determine a considerable QoS based on the remaining energy and subjective quality degradation. However, it fails to consider the average waiting time. In (Almhana *et al.* 2008), an online Exponential Mixture (EM) algorithm was introduced to fit the exponential distributions to an appropriate inactive time. The algorithm begins when a MS has no traffic to transit; the MS sends a MOB-SLP-REQ message to the BS which includes the duration of the sleep period.

When the request is granted, the MS switch to sleep mode by turning off its receiver for a dedicated sleep interval. When new frames arrives during the sleep interval of the MS, the BS buffers the arriving frames and sets the traffic indicator (TRF-IND) to 1 in order to update the MS. When the sleep interval times out the MS wakes up and listens to the signaling channel for a dedicated period of time known as the listening period. If its TRF-IND is set to 1 it switches to active mode. Otherwise, it doubles its sleep interval and re-enters sleep mode. Once there is no TRF-IND message, the MS initializes the first sleep interval with the minimal duration Tmin, and then doubled the sleep interval until a maximum value Tmax is attained. The algorithm improved power efficiency but ignores developing algorithms that can adapt the power savings for time-varying traffic which may results to waste of energy.

In (Xiao *et al.* 2006), an Enhanced Energy Saving Mechanism (EESM) was proposed to address the Excessive listening operations of ESM which guzzle much energy when traffic is low with high consumption rate. In the proposed scheme, a MS used half of the last sleep session after terminating from the previous sleep-session as the initiate sleep interval in next sleep-session if the initiate sleep interval is less than Tmin, the initiate sleep interval is equal to Tmin. If traffic is low the SDU arrival is set bulky enough such that the proposed EESM can effectively reduce the number of listening intervals in a sleep-session. It improved the battery life of MS efficiently. However, it fails to consider RT-VR traffics which may further improve battery life of MS. In [20], a Scheduled Power-Saving Mechanism (SPSM) was introduced to schedule sleep intervals operations for connections that newly initiate sleep-mode by controlling the main operation mode in PSC, namely: Tmin and Tmax, as well as the initiation time of sleep session of low QoS connections enabling the sum duration of the available state to decrease from 16U to 13U. The proposed scheme improved the battery life by increasing the engaged time during with connections of MS in sleep-state. However, there is an increase delay process.

In (Kim *et al.*2009), Enhanced Mechanism (EPSM) was proposed to adaptively manage the sleep parameters, efficiently reflecting the sleep duration of MS. This mechanism comprises of two conditions X and Y which takes into action the remaining energy state: X is for advanced energy conservation with average delay; Y is for more demanding energy conservation that keeps longer sleep session. The mechanism enhances efficiency at interval periodically for a short time to check for DL traffics and decides to switch to wake/continue to sleep. The scheme sleep intervals increases exponentially when no arrival of traffics, the mechanism significantly saved energy with an increase in response delay. In (Zhang *et al.*2009), an Enhanced Energy Management Mechanism (EEMM) was proposed to expand the battery life of MS. The proposed EEMM provides great performance with a tradeoff, adaptively adjusting the sleep intervals size and significantly reduce consumption. Nevertheless, the EEMM scheme enhanced the battery life with an in appropriate choose of sleep parameters.

In (Wong *et al.* 2009), a real-time heuristic algorithm (RTHA) was proposed to reduce the switching frequency of MS. The scheme negotiates at each listening session after the total sleeping sessions. According to the embedded information in the MOB-TRF-IND message, such as traffic indicator, Packet arrival rate at the BS buffer (λ) and Current buffer occupancy at the BS (i), the MS decides and wakes up to full normal operational mode and receives frames waiting at the BS. The MS continue to sleep with negative indication. The MS then makes the decision to run the algorithm/not. The proposed algorithm three criteria are computed and evaluated. The algorithm performed better with average waiting time kwon as response delay which subsequently results in poor QoS. In (Saidu *et al.*2015), an Efficient Battery Life-Aware Power Saving scheme (EBLAPS) was introduced to reduce the average delay.

The Scheme adaptively tunes the sleep parameters according to the traffic arrival. The schemes reduced the frequent transition to listening session as well as the rate of MS consumption with a longer sleep session. In (Nga *et al.*2007), a Delay-Guaranteed Energy Saving (DGES) scheme was proposed to decrease the consumption rate of MS; the scheme tries to obtain an optimal (Tmax) value with fixed Tmin value. The scheme insured the required response delay by obtaining an optimal value for a fixed Tmin value. The scheme assumed that the Tmin is determined as well as L is fixed. It effectively improve the battery life of MS, with an increase in consumption. In (Wong *et al.* 2009), joint optimal timeout scheme was proposed to minimize switching cost of MS. The scheme comprises of three main components, namely: optimal timeout value, conditional probability of MS energy savings. The scheme runs incessantly on wake interval until it becomes idle, while an optimal timeout value is obtained.

The scheme switches to a timeout period using optimal timeout function. When traffics are not detected, the scheme decides type I/II base on it designed conditional probability. The joint scheme enables MS to be aware when to sleep and how to sleep with less switching cost, with small increase in delay which may lead to energy waste. In (Liao *et al.*2016), a scheduling algorithm for multiple MS was proposed to schedule multiple MS with UGS connections so that the QoS requirement of each MS can be satisfied after scheduling. The scheme prevents occurrence of interference in MSs and tries to meet the QoS requirement of the MS after scheduling. It achieves higher bandwidth utilization with increase in signaling overhead which lead in poor QoS. In (Kong *et al.*2009), a theoretical framework based on the semi-Markov Decision Process (MDP) was proposed to maximize in-efficiency of MS with QoS guarantee.

The MDP model is a transitional diagram where each state represents one unique sleep stage. Based on this proposed scheme, the model is represented in three state, normal mode sleep mode of type I and II with a number of policy (denoted as R) for controlling the operational mode. R is defined as a prescription for taking actions at each decision epoch whether to be a deterministic policy/randomized policy. The scheme achieved higher efficiency with an increase in response time. In (Yang *et al.* 2013), integrated load-based power saving for was proposed for better efficiency. In the first strategy of the proposed scheme, S1, allows BS to switch to sleep mode when all MS are in the sleep mode. The Power Saving Efficiency (PSE) at the BS is limited by traffic load and sleep schedule. The second strategy considers that power saving at BS is more often than not better than power saving at MS.

Hence, a threshold for power saving (PSE_TH) at BS is set earlier in the second strategy S2, where the sleep scheduling algorithm in LBPS schemes must be revised in other to integrate BS and meet the requirement of PSE_TH. The scheme achieves high efficiency for BS and MS. with no balancing between power-saving and the increase response delay. In (Azad *et al.* 2011), an optimal control of sleep periods was proposed to optimally schedule shutting off its transceiver to minimize consumption. The proposed scheme terminal undergoes a sequence of sleep and listening session until an active request is detected. From the beginning of each sleep session the MS choose sleep session length. The scheme reduced the listening session. With no consideration to utilize renewal theory that captures the effects of remaining inter-arrival of the MS.

In (Chen and Tsao, 2006), two algorithms were proposed: periodic on-off scheme (PS) and aperiodic on off scheme (AS) to fully utilize the sleep sessions as well as reduce consumption rate of a MS. PS allows an MS to sleep for a fixed duration and then listen for a fixed duration in a round-robin form. The PS reduced sleep sessions based on the type-2 PSC with QoS considerations.

While the proposed AS on the other hand examine when a MS should sleep/stay awake. That is, the AS schedules resource to MS and inform MS to sleep/listen for every OFDM frame. AS implemented by type-3 PSC. The scheme, first sorts all connections on a MS according to their delay requirements, and assigns high priorities to these connections with tight delay requirements. The PS and AS Schemes increase more sleep time and reduce consumption than the existing schemes. But they ignore increase delay as well as apply the scheduling schemes to a multiple MS environments and the global optimization from a BS point of view respectively. In (Feng *et al.* 2015), a POMDP-based Sleep Window Determination (PSWD) was proposed to extend the battery life of MS. The scheme stochastically determines the adequate length of each sleep window based on traffic arrival. The scheme control the sleep cycles, with each control cycle overlapped with the adjacent one. The first control cycle begins at the last frame of MSs idle time in the normal session. The remainder control cycles are individually started at the exits of every listening interval with the previous control cycle. The proposed scheme significantly conserves energy better than the existing ones with increase in signaling overhead. In (Shi *et al.* 2006), a Longest Virtual Burst First (LVBF) scheduling algorithm was proposed to improve the battery life.

The LVBF scheme, schedule packets of MS in a virtual burst with one primary MS and a multiple secondary MS sharing the wireless link resource. In the proposed scheme, the primary MS has higher priority than the secondary MS in resource allocation, such that almost all the packets of the primary MS are transferred in the burst duration. As a result of burst broadcast, the LVBF scheme prolongs MS life by reducing the response time when MS Stay in the idle state and the number of MS transitions from wake/sleep interval. The proposed scheme achieved significant savings with QoS requirements at the expense of an increase in delay. In (Shih *et al.* 2018), a Wake on wireless technique scheme to enhance battery life of Personal Digital Assistants (PDAs) was proposed.

The scheme shut down the device and the wireless network card when not being used the device is powered only when an incoming call is received, Thereby increasing the battery lifetime. The scheme provided life improvements over other technologies. However, applications such as voice communications do not behave well under the proposed scheme; more so, there is an increase in delay of mobile device.

In (Lee *et al.* 2007), a Probabilistic Sleep Interval Decision (PSID) algorithm was introduced to examine MS sleep time, the scheme examines each Tj by considering the fixed and variable delays. The algorithm makes MS wake up intensively when the probability that a response packet will arrive at the BS is high. The algorithm calculates the target probability from the mean and standard deviation of Y, and examine the extension-allowed interval from the target probability, determine the number of sleep intervals to be included in the extension-allowed interval, divide the extension-allowed interval into subintervals by using the CDF of Y and outside the extension-allowed interval, the scheme repeat the last sleep interval included in the extension-allowed interval. it significantly decrease consumption and buffer delay than the BTE scheme with average response delay.

In (Ritesh *et al.* 2009), a novel Sleep-Mode Manager Architecture was proposed to negotiate the sleep duration of MS, and compute the sleep-time per QoS, by aggregating the unavailability periods of all the active PSC_ID traffic. The architecture reduce the overhead of management messages enabling the architecture to conserve energy and bandwidth at the same time support dynamic adaptation in sleep-mode parameters. The architecture outperformed the standards in conserving energy and bandwidth. It however ignores combining algorithms to classify connections them into PSC along with joint PSC managements.

In (Yang *et al.* 2010), a Load-Based Power Saving (LBPS) Aggr scheme was introduced to improve efficiency. The scheme measures the traffic load and estimates the sleep window size for MS by setting a proper threshold for data accumulation threshold. The scheme significantly improved efficiency better than Type I and II at the cost of slight response delay.

2.4 Adaptive Power Saving Mechanisms

In (Min-Gon *et al.* 2008), an Adaptive Power Saving Mechanism (APSM) was proposed to extend the battery life. The scheme adaptively adopts the sizes of Tmin and Tmax by considering the request period of each initiation of awakening (T initial) in the previous sleep-mode duration. During each sleep-duration, when there is no initiation of awakening in each sleep cycle, the size of operating sleep interval doubles from the size of the previous sleep interval until Tmax, when an initiation of active state occurs, Tmin and Tmax are updated based on the following policies namely: (1) when Tf is equal to Tmin and Tmin is smaller than Tmax, then Tmax is regarded as a relatively larger size compared to Tmin.

Thereby, Tmax is updated and becomes half of the Tmax in the previous operation. (2), when Tf is equal to Tmax and Tmax is smaller than TMAX, Tmax is then regarded as a relatively smaller size compared to Tmin and the Tmax doubles. (3) Else, Tmin is updated to half of Tf. The scheme decrease the number of sleep cycles with increase response time. In (Mugen and Wenbo, 2008), an Adaptive Energy Saving Mechanism (AESM) was proposed to examine the sleep intervals considering traffic load and MS requirements.

The scheme adaptively examine the initial sleep interval and the period sleep interval according to γ and Ψ parameters, The scheme sets between efficiency as well as delay. But ignores examining the traffic load threshold as well as enhancing the AESM. In (Jenhui *et al.* 2014), a novel downlink (DL) and uplink (UL) Alignment (DUAL) scheme was proposed to enhance efficiency of MS. The proposed DUAL scheme used the frame arrival rate of UL (λμ) and a safe threshold of buffer size QT as the parameters to estimate the maximum allowable waiting time to align the UL with the DL connections. The mechanism extends MS energy conservation when UL traffic is greater than DL traffic with increase consumption.

In (Seungkwon and Youngil, 2007), an adaptive initial-sleep window scheme was proposed to decrease consumption rate. The proposed scheme updates old initial-sleep window (W1 old), with the new initial window (W1 New) when the MS ends sleep mode operation. keeps track of TB as well as trie to adaptively make the sum of W 1 and τ be equal to TB. The value of σ parameter adjusts the speed of adaptation; while the scheme allows MS to stay in sleep state as long as possible in burst arrival duration. The scheme utilizes the previously measured TB to decide the New. It improved efficiency in terms of wake and normalized duration, with increase in response time.

In (Liu *et al.* 2011), a novel counter-driven adaptive sleep mode scheme was proposed to decrease signaling overhead and balance power consumption and latency. It ensures that the length of the sleep cycle is adjusted adaptively to enhance effectiveness according to the change of user activity level simultaneously decreasing signaling overhead. The size of the sleep window is decided in real-time by traffic activity level true tracking counters. The scheme reduced signaling overhead and balanced efficiency as well as delivery latency. But ignores parameterization for different data traffic types and their combinations. In (Jin *et al.* 2011), an Adaptive Sleep Mode Management (ASMM) scheme was proposed to minimize consumption of MS. The scheme adjusts MS sleep cycle and listening intervals in an adaptive manner based on online monitoring and estimation of the traffic condition.

The scheme monitors DL frames for each MS and estimates the frames arrival rate online enabling the scheme to adjust the sleep cycle for the MS and use the AAI-SLP REQ signaling message to notify the station of the new sleep cycle length. The proposed scheme decreased consumption of MS with a user-specified packet delay constraint. With challenges of operational performance under a bur-sty and heavy traffic load and signal overhead. In (Sanghvi *et al.* 2008), an adaptive waiting time threshold algorithm was proposed to minimize consumption.

The scheme dynamically adjusts the idle threshold based on DL and UL traffic arrival to predict best duration of response threshold. The idle threshold is determined by using various weighting factors arrival rate and the previously arrived rate. It is chosen to be small during low-traffic load to allow the MS to switch to sleeping mode without additional delay while chosen to be large during heavy traffic to keep MS in an active duration to minimize the sleep/wake duration. The scheme reduced the consumption of MS especially under low traffic, at the expense of an increase in response delay.

In (Hsu and Feng, 2010), an Adaptive Listening Window (ALW) scheme was proposed to improve battery performance. The scheme dynamically tunes the length of the listening window according to the number of both arrival and retransmission packets and the delay constraint. In the scheme, the length of each listening window is adaptively adjusted based on the total number of buffered packets that exist in the arrival buffer and retransmission buffer as well as the delay constraint. The arrival buffer is utilized to preserve the arrival packets in the previous sleep cycle, whereas the retransmission buffer keeps packets that are ready to be retransmitted within the current listening window. The listening window is tuned increased/decreased for each sleep cycle. It diminished packet loss rate and save battery life with minimal packet loss rate for RT-VR connections.

While (Lee *et al.* 2007), an adaptive sleep mode interval control algorithm was proposed to reduce consumption. The scheme adapts Tmin according to DL traffic pattern to predict the next arrival of the DL frame. These cuts the number of listening intervals in the sleep duration as well as reduce consuming power of MS in sleep state, as the sleep interval approaches Tmax; is incrementally increased as an average of nth sleep interval and Tmax. Thus, decreasing the delay, DL frame occurs waiting for the MS to wake up. The scheme improved the amount of consumption at lower traffic as well as at higher traffic but no consideration for uplink traffic.

In (Sanghvi *et al.* 2008), an adaptive waiting time threshold scheme was proposed to reduce consumption. The scheme adjusts the idle threshold according to DL and UL traffic pattern to predict a better duration of waiting time. The idle threshold is determined using various weighting factors to the recently arrived packet rate and the previously arrived rate. The scheme selects wisely during low-traffic load to allow the MS to switch to sleep mode without any further delay while selecting large during heavy traffic to keep MS in an active state in order to reduce the sleep-wake session. The scheme decrease consumption under low traffic at the expense of an increase in waiting time.

2.5 Dynamic Power Saving Mechanisms

In (Jianbin *et al.*2008), a dynamic traffic load-aware scheme was proposed to increase efficiency of a battery life of MS. The scheme used a dynamic scheme to tune the idle check time based on the statistical measurement of traffic load. The scheme enhanced as well as decreased the mean response time as compared to the existing PS scheme with increase in the complexity. In (Zhu *et al.*2007), a heuristic algorithm was proposed to decrease delay and the rate of consumption.

The scheme tunes the sleep parameters based on traffic load and response requirements. The scheme succeeded in bounding the response time with increase in consumption. While in (Chang *et al.* 2012), a Dynamically Alternating Sleep Interval Scheduling Algorithm (DASISA) was proposed to schedule series of PSC. It schedules more proper queue based on frame arrival. As well as examine the sleep mode adjustments, with listening intervals interleaved with the processing frames. Based on frame arrival as well as established a trade-off for consumption and response time. The proposed DASISA improved battery life at the expense of unnecessary response delay.

In (Xue *et al.* 2011), a dynamic scheme was proposed to enhance battery efficiency of MS. The proposed scheme tunes the ratio of the sleep duration and receives frames according to their arrival load. The scheme enhanced efficiency with increase response duration. In (Kwon *et al.* 2010), a dynamic power saving scheme was introduced to increase efficiency of MS, the MS used PSC to adjusts the MS sleep intervals of the sleep mode of PSC I in order to match the start point of the listening intervals of PSC I with the nearest listening window of PSC II. In PSC I the size of the sleeping is double size of previous ones subsequently. While in of PSC II the size of the sleep window is fixed due to UGS. Hence, the sleep interval of PSC I was adjusted. The scheme reduce consumption rate of MSs with no consideration for the adjustments of PSC II.

In (Chen *et al.* 2009), a Maximum Unavailability Interval (MUI) scheme was proposed to enhance energy efficiency for Type II. The MUI dynamically adjust the start frame number of each PSC to enable efficiency of the sleep intervals. The scheme examines the number of frames at the unavailability interval using Chinese Remainder Theorem, when the sleep cycle length is pair-wise as well as relatively prime, all the two main parameters as n and x are found. Such that, when the length of sleep cycle as m_i is not pair-wise as well as prime, then the existence of n solution of x is no longer assured. It reduced consumption. But, ignores considering how to map QoS conditions into the parameters of PSC as well as proposed a scheduling scheme, hence, minimizing the unavailability interval with improved QoS.

While in (Kwon *et al.* 2009), a Dynamic scheme (DPSM) was proposed to increase efficiency of MS. The scheme tunes the sleep intervals of PSC I (III) to match the starting point of listening interval in PSC I (III) with that of the listening intervals in PSC II. The schemes decreased the MS listening session as well as increase the unavailability interval. It reduced battery consumption of MS with an increase unessary response delay requirements which may result to loss of packets. In (Chou *et al.* 2013), a Battery Lifetime-Aware Power Saving Scheme (BLAPS) was proposed to improve battery life performance of MS. The proposed BLAPS dynamically tune the operating parameters based on the remaining battery life of MS and the traffic arrival with frequent switching to listening intervals which increased the rate of consumption.

In (Liu *et al.* 210), a Dual scheme was proposed to balance power consumption as well as response delay requirements. The proposed scheme tunes the initial intervals according to a pre-defined MS threshold. The scheme decrease MS consumption with an increase in response MS. Finally, in (Priya *et al.* 2013), a Queuing model based Scheme (QPS) was proposed to enhance battery life of MS. The proposed QPS adjusts the sleep intervals for different traffic classes of PSC. While it sleep interval size of the sleep mode is examined based on frame arrival as well as type of traffic arrivals. It reduce the consumption rate with increase in delay. Power Saving Scheme (DAPSS) was proposed (Wisdom *et al.* 2019) to minimize the longer sleep intervals of MS.

The scheme successfully minimized the longer sleep intervals of MS; thereby, decreasing the response delay of MS while maintaining power savings respectively. However, the scheme ignores in-cooperating real time services, which may further improve on the overall performance of the MS.

In (Wisdom *et al.* 2019) an Enhanced Battery-Life power saving scheme (EBPSS) was proposed to in-cooperate real time services, which is an improvement of the existing DAPSS Scheme. The Scheme in-cooperates real time services and successfully extends the battery life performance with a little increase in consumption. (Saidu *et al.* 2017) Proposed a Hyper-Erlang Battery-Life Energy Scheme (HBLES) to analytically adjust the sleep parameters based on the remaining battery power and the traffic pattern to simultaneously decrease the ragte of MS consumption and delay. It uses a Hyper-Erlang distribution to determine the behavior of the traffic. The scheme improves the energy efficiency. However, it ignores uplink traffics.

3. RESULTS AND DISCUSSION

The findings of this research are presented in table 1, as well as a comparative analysis of these schemes below in 3.1-3.2 respectively.

3.1Comparison of Power Savings Classes (PSC)

Table 1 presents a comparison of various algorithms. These algorithms are compared in terms of their standards; power saving classes, traffics, operational mode and QoS. While in Figure 2 and 3 an analysis of the percentage of proposed schemes is presented in order to efficiently explore the left behind areas especially in energy Savings.

TABLE 2: Summary of the REVIEW

REF	IEEE 802		PSC		Traffic			Operation Mode		Algorithm	QoS	Strength	Weakness
	16e	16m	I	II	DL	UL	Model	Normal	Sleep				
[6]							M/G/1		✓	TRF-IND	✓	Minimize the average power consumption and satisfy QoS	Ignore considering the little increase response delay
[7]							M/G/1		✓	TRF-IND	✓	Enhance power saving efficiency	Complicated equations derivation
[8]							Markov		✓	TRF-IND		Improve power saving & minimize delay	An increase in the algorithm complexity
[9]							Poisson			Tmin/Tmax		Minimize number of sleep cycles & save energy	An increase response delay
[10]							Markov			Each sleep window		Balance between energy efficiency and delay	Ignore determining the load threshold
[11]							Poisson			Initial sleep window size		Improved energy conservation and prevent buffer over flow	High energy consumption
[12]							M/G/1			TRF-IND		Reduces power consumption & satisfy QoS	Ignores uplink traffic
[13]							Poisson			Initial sleep window		Reduce energy consumption & improved QoS	Did not consider average waiting delay
[14]							Web, voip			Initial sleep window		Improve power saving & minimize delay	Ignores uplink traffics
[15]							Markov			TRF-IND		Bound the delay to a range	But still has a little increase in the response delay
[16]							Poisson			Initial sleep window size		Improve power saving, minimize delay	Did not consider signaling overhead
[17]							Poisson			Tmin/Tmax		Optimized power saving	Did not adopt the mechanism for time varying traffics
[18]							Markov			Tmin/Tmax		Improve energy conservation	Did not consider RT-VR traffic
[19]							Markov			Initial sleep window		Improve battery lifetime of MS	An increase in response delay
[20]							Poisson			Tmin/Tmax		Improve battery life	Ignores signaling overhead and delay

[21]							Markov chain			Initial sleep window size		Minimize signaling overhead & easily & improve power saving	Ignore parameterization for different data traffic
[22]							General			Initial sleep window		Reduce power consumption of MS	Fails to consider the scheme under heavy busty traffic load
[23]							Markov chain			Tmin/Tmax		Enhance energy conservation	with little increase in response delay
[24]							Poisson			Initial sleep window		saved energy	With an increase signaling overhead
[25]							H-Erlang			sleep window size		Minimize power consumption	Fail to consider appropriate sleep window parameters.
[26]							Markov			Sleep window		Improve energy efficiency	With an average response delay
[27]							Poisson			Initial sleep window		Minimize energy consumption	Fails to consider the average waiting time
[28]							Poisson			Tmin/Tmax		Minimize energy consumption	Ignores an increase in average waiting delay
[29]							Poisson			Initial Sleep window size		Reduce energy consumption and delay	Ignores uplink traffic as well as in cooperate real time services
[30]							Poisson			Sleep window		Minimize power consumption of MS	Ignores adjusting PSC II
[31]							Poisson			Initial Sleep window		Minimize packet loss rate for UGS	With an increase in little energy waste
[32]							Poisson			Tmin/Tmax		Extend the life time of MS	Fails to consider little increase in delay
[33]							Poisson			Sleep window		Conserve energy & minimize delay	an increase in signaling overhead
[34]							Poisson			Sleep window		Minimize switching frequency, determine MS sleep mode	Waste energy due to it delay constrain
[35]							Poisson			Initial Sleep window size		Minimize energy consumption	Fails to design a scheduling algorithm, to minimize the unavailability interval

[36]							Poisson			Initial Sleep window size		Minimize power consumption of MS	With an increase waiting delay
[37]							Markov			Sleep windows		Improve energy efficiency	At the expense of an increase in signaling overhead
[38]							Web,Voip			Cycle lenth		Achieved higher band width utilization & management	With an increase delay in response time
[39]							Markov chain			Sleep windows		Achieved higher energy efficiency	An increase delay incurred by the 3 states
[40]							Poisson			Sleep window size		Achieved a higher power saving efficiency for BS & MS	Ignores to balance between power saving & the increase delay
[41]							Poisson			Sleep windows		Minimize the listening session length window	Fails to consider the residual inter arrival time of frames
[42]							Voip, V,S			Sleep windows		Increase more sleep time & minimize energy consumption	Ignores an increase response delay
[43]							M/G/I			Each sleep window		Conserve energy & satisfies QoS	With an average increase response delay
[44]							Poisson			Tmin/Tmax		Saved energy & satisfied QoS	Ignores signaling overhead
[45]							Voip			Turn off		Improve the life of a mobile device	Ignores voice communication
[46]							Poisson			Tmin/Tmax		Saves substantive amount of energy under low traffic	Ignores uplink traffic
[47]							Voip,V,S			Tmin/Tmax		Minimize energy consumption	Ignores an increase in response delay and signaling overhead
[48]							Poisson			Sleep window		Conserve energy	Ignores increase delay & joint power saving management
[49]							Poisson			Initial Sleep window size		Minimize energy consumption and average delay	Ignores increase in delay
[50]							Poisson			Sleep window		Minimize power consumption	Ignores increase in response delay

[51]							Poisson			Initial Sleep window		Significantly reduce energy consumption	Ignores small increase in average delay
[52]							Poisson			Sleep window size		Significantly save power	Ignores little response delay
[53]							Web,Voip			Sleep window size		Minimized power consumption	Ignores little increase in delay
[55]							Poisson			Tt,Tmin/Tmax		Minimized longer sleep intervals	Incurred average power consumption
[56]							Hyper-Erlang			Tth,Tmin/Tmax		Little increase in consumption	in-cooperates real time services and improves power savings
[57]							Hyper-Erlang			Tmin/Tmax		in-cooperates real time services & minimized delay	With an average increase in Energy Consumption

3.2 Comparative Analysis

In this section, we present a comparative analysis of the existing schemes as follows

[6]-[12][14]-[21][22]-[33][35]-[37][39]-[49][51]-[55] of the existing algorithms focused on deriving analytical models for IEEE 802.16e system; while [7][13][22][30][32][34][38][44][50] of the algorithms were on the most recent IEEE 802.16m standard. [1][3][4][11]-[55] models for downlink transmission while [11][21][23][25][26][29][35][44][46][50][53] models for uplink transmission. Sleep mode and operations were developed.

However, [11][21][23][25][26][34][43][48][51] of the Existing schemes focused on uplink transmission and [11][17][27][38][39][43][44] uses normal operational modes while [6]-[19][20]-[37][40]-[53] uses a sleep operational modes. More so, adaptive algorithms were proposed in some of the existing works in order to provide various decision policies, such as sleep window size, to achieve better performance under different traffic status. For example, “each sleep window” implies that the algorithm can adaptively adjust every sleep.

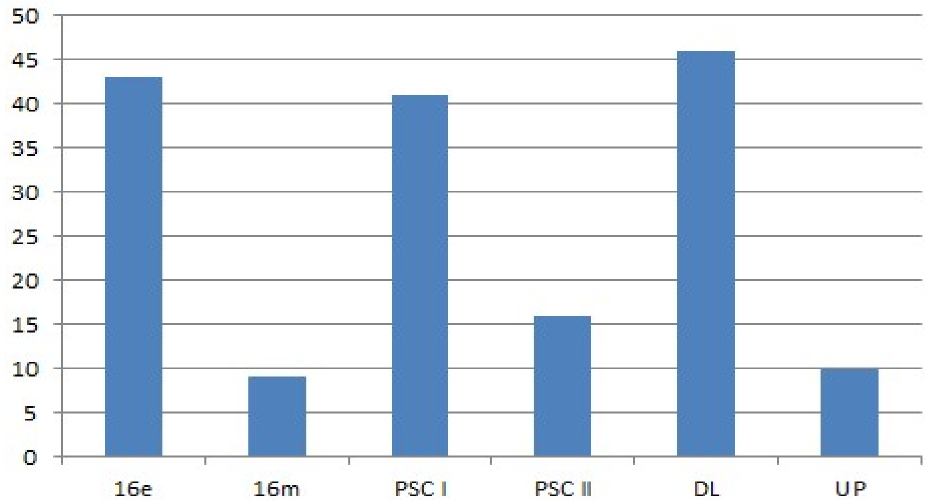

Figure 2. Shows an analysis and the percentage (%) of IEEE 802.16e/m, power saving classes of both type I & II and operations in both downlink and uplink traffics.

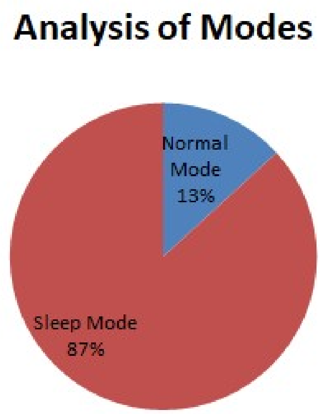

Figure 3: Shows the Analysis of Both Sleep and Normal Modes in PSC.

Window size, while that with the "initial sleep window size" can only adjust the initial sleep window size. The "state status" implies that the mechanism can determine which state the MS should switch to; including normal mode, PSC of Type I, and PSC of Type II. The "TRF-IND interval" implies that the algorithm can adjust the traffic indication interval, in which BS periodically sends Traffic indication messages to inform MS whenever there is a packet to receive or transmit. More so, the QoS requirement among all different schemes may correspond to packet delay constraint or spectrum efficiency. Note that, both sleep mode and normal mode are supported by IEEE 802.16e/m standards. It is clear from the table That most of the existing studies only focused on the power saving in the period of sleep mode with downlink traffic for IEEE 802.16e system. Finally, we also compare their individual strength and weaknesses. The strength; implies the achievement of the researched paper while the weakness: implies the limitations of the paper and possible open issues for future research towards efficient power-saving of mobile devices.

4. CONCLUSION

In this paper, a survey on energy-saving schemes in WiMAX is presented. In the survey, the operational procedure, strengths and weaknesses of each scheme were presented in details, in order to understanding how efficiency of MS battery life are enhanced via different strategies and ways in which some of the left over important problems in WiMAX could be addressed. In addition, a comparative analysis of these schemes is also presented. The analysis identified open issues for possible future directions towards efficient energy savings in IEEE 802.16e WiMAX Networks.

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