

Factors Affecting Sleep Mode Operation in WiMAX Networks

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Abstract

In recent years, concerns on energy consumption due to the operation of wireless devices have triggered a vast amount of research work, so IEEE 802.16e standard defines sleep mode operation for different power saving classes. Our goal is to find out the factors in which energy consumption of mobile device depends, so we used Qualnet 4.5 simulator, And compared different varying factors which affect sleep mode operation in WiMAX networks as speed, application, distance and number of nodes, And measured the effect of it on the energy consumption of mobile device in transmit as well as receive mode.

Index Terms: WiMAX, QoS, PCS, Sleep mode, MS, BS, UGS, rtPS, nrtPS, BE.

1. Introduction

Wireless Metropolitan Area Networks (WMAN) is emerging as a highly promising Broadband Wireless Access (BWA) technology that provides high-speed, high-bandwidth, and high-capacity multimedia services for residential as well as enterprise subscriber stations [3]. In December 2005, the IEEE released the IEEE 802.16e standard known as mobile WiMAX which targets for mobility enhancement in Mobile Subscriber Stations (MSS).

Wireless communication systems to use for a quite long time. Many standards are available based on which these devices communicate with each others, IEEE 802.16 WiMAX provides specification for both fixed Line of Sight (LOS) communication in the range of 10-66GHz (802.16c), and fixed, portable, Non-Line of sight

communication in the range of 2-11GHz (802.16a, 802.16d), also it provides wireless communication for mobiles, moving at speed of 125KMPH, in the range of 2-6 GHz (802.16e)[9]. IEEE 802.16e is well implemented with OFDMA as its physical layer scheme. In year 1998, The Institute of Electrical and Electronics (IEEE) formed a group to work on new "IEEE 802.16" standard. Initially, when the standard was first approved in December

2001, it was using Single Carrier (SC) modulation techniques in high frequencies of 10 to 66 GHz. As a multiplexing scheme, burst Time Division Multiplexing (TDM) was chosen, that could handle both Frequency Division Duplexing (FDD) as well as Time Division Duplexing (TDD)[9].

2. Features of WiMAX Networks

Mobile WiMAX supports full mobility, nomadic and fixed systems [5]. It addresses the following needs:-

- 1) Cost effective
- 2) Offers high data rates
- 3) Supports fixed, nomadic and mobile application
- 4) Easy to deploy and flexible network architecture
- 5) Supports interoperability with others networks

IEEE 802.16 aims to extend the broadband access up to kilometres in order to facilitate both point-to-point and point- to-multipoint connections [1]. Mobile subscriber station is powered by a battery with limited capacity, a power saving mechanism is one of critical concerns in designing the MAC layer for MSS. IEEE 802.16e introduced three kinds of sleep mode operations named Power Saving Classes (PSCs) of types I, II and III. PSC I is recommended for Best Effort (BE) and Non-Real Time Variable Rate (NRT-VR) traffics, PSC II is recommended for Unsolicited Grant Service (UGS) and Real Time Variable Rate (RT-VR) traffics, and PSC III is recommended for management operations and multicast connections[3]. Each PSC class differs by others by their parameters, procedures of activation and deactivation and policies of MSS availability for data transmission.

The basic principle of a power saving mechanism is to implement sleep mode operation to minimize Mobile Sub- scriber Station (MSS) power consumption. Sleep and listen periods must be in unit of Orthogonal Frequency Division Multiplexing (OFDM) frame[6]. If an MSS has multiple connections, the actual sleep periods are determined by the sleep-mode operations with all the connections. It is obviously that without a proper schedule of the sleep -mode operations on an MSS with multiple connections, the power consumption of the MSS not to be reduced even the sleep mode is activated.

3. Sleep Mode IN 802.16e

Sleep mode is a state in which MS conducts pre-negotiated absence from Base Station (BS) air interface. These unavailability intervals are observed by serving BS from the DL and UL traffic of MS. Sleep mode is intended to minimize power usage and decrease usage of bandwidth of BS. For each MS the BS keeps several contexts which are related to one on other power saving classes. Power saving class is a group of connection having same demand properties. Activation of certain power saving class means starting sleep and listen interval for that connection. There are three different power saving classes which is differentiated by several parameter sets and activation and deactivation.

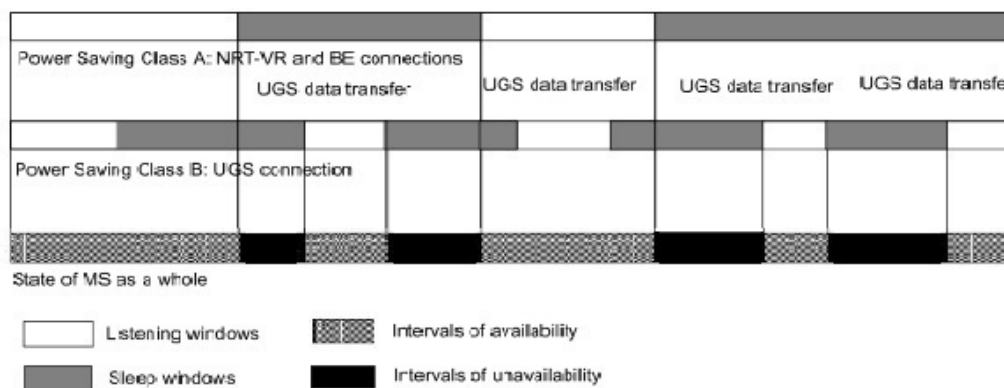


Fig. 1: Sleep mode operation with two power saving class.

Unavailability is a time which does not overlap with any other listening window of any active power saving class. And in availability interval it does not overlap with unavailability interval. In unavailability interval the BS shall not transmit to MS, So the MS may power down one or more components or perform other activities that do not require communication to BS as scanning neighbour BS etc. During availability interval the MS is expected to receive all DL transmissions as in normal mode[2]. For synchronization it examines all DCD and UCD count. Unless using the broadcast control pointer IE, for tracking and updating DCD and UCD changes, The MS shall continue reception until receiving the update message. If the BS transmits broadcast control pointer IE, the MS shall read and react to the message. During unavailability interval for MS, the BS may buffer MAC SDU addressed to unicast connection bound to MS. The BS bound to delay transmission until the availability interval. The serving BS may verify MS exit from sleep mode by making a UL allocation for MS at any time subsequent to waking event by transmitting at least BR message.

Figure 1 describes example of behaviour of two power saving classes: class A contains connection of BE and NRT- VR type, class B contains connection of UGS

type of MS. In class A type connection allocated listening window of fixed size and double sleep window while in class B connection the listening and sleep windows are of fixed size[2]. So the unavailability interval for both power saving classes are different but the overall sleep mode for MS is the intersection of both the unavailability intervals.

3.1 Power saving of class of type I

Power saving class of this type is recommended for connections of BE, NRT-VR type. For activation of one or several power saving class of type I, the MS sends mobile sleep request or bandwidth request and uplinks control header[2]. The BS responds with mobile sleep response message or DL sleep control extended sub header. The MS may retransmit sleep request message, if it does not receive sleep response within the T43 timer. The following are relevant parameters:-

- 1) Initial-sleep window
- 2) Final-sleep window base
- 3) Listening window
- 4) Final sleeps Window Exponent
- 5) Start frame number for first sleep window
- 6) Traffic triggered awakening flag

Power saving class becomes active at the frame specified as start frame number for first sleep window [2]. For next sleep window is twice the size of previous one, but not greater than specified final value.

$$\text{SlpWin} = \min(2 \cdot \text{prevSlpWin}, \text{FinalSlpWinBase} \cdot 2^{\text{finalSlpWinexp}})$$

(1) Sleep window is interleaved with listening interval of fixed duration. The BS terminates active state of power saving class by sending mobile traffic indicator message on broadcast CID. When an MS receives an UL allocation after receiving a positive mobile traffic indicator message indicate that the send at least the BR message [2]. The power saving class is deactivated either by bandwidth request and uplink sleep control header or sleep control extended sub header messages or one of the following events:-

- 1) BS transmits a MAC SDU or fragment thereof over connection, belonging to the power saving class.
- 2) MS transmit the bandwidth request with respect to connection belonging to the power saving class.
- 3) MS receives mobile traffic indicator message indicating presence of buffered traffic addressed to the MS.

The power saving class shall be deactivated if MS fails to receive mobile traffic indicator message during availability window.

3.2 Power saving of class of type II

Power saving class of this type is recommended for connections of UGS, RT-VR type. The following are relevant parameters:-

- 1) Initial-sleep window
- 2) Listening window
- 3) Start frame number for first window

Power saving class of type II becomes activate at frame specified as, “Start frame number for first sleep window”. All sleep windows are of same size as initial window [2]. The process of activation and deactivation is same as type I PSC. An opposite to PSC of type I, during PSC type II the MS may send or receive any MAC SDU or their fragment connection, comprising PSC as well as acknowledgements to them.

3.3 Power saving of class of type III

Power saving class of this type is recommended for multi- cast connection as well as for management operation[2]. PSC of this type is activated by mobile sleep request or bandwidth request and uplink sleep control header. The following are relevant parameters:-

- 1) Final-sleep window base
- 2) Final-sleep window exponent
- 3) Start frame number for sleep window

PSC becomes active at frames specified as, “Start frame no. for first sleep window”, Duration of sleep window is specified as base exponent. After expiration of sleep window PSC automatically becomes inactive.

4. Simulation Environment and Results

The simulation results were carried out in Qualnet 4.5 simulator of Scalable Network Technologies. It is a comprehensive suite of tools for modelling large wired and wireless networks [4]. The simulator is a GUI based program fully implemented in C++ and the graphical tool kit is implemented in java. It can be used to visually used network scenarios and then run simulations of these networks. Qualnet enables users to: design new protocol models, optimize new and existing models; design and analyse wired and wireless networks using pre user defined parameters. Qualnet Scenario Designer which allows the user to specify all the network components and conditions under which the network will operate.

Table 1: Simulation parameters.

Property	Value
Simulation time	30 Sec
Channel Bandwidth	20 MHz
Simulation area	1500X1500 m ²

Mobility	Random waypoint
Energy models	User specified
Transmission power(BS)	30dBm
Scheduling algorithm	Strict priority
MAC protocol	802.16e with sleep mode

The scenario of WiMAX IEEE 802.16e developed having different parameters as mobility, number of nodes, number of application by which a physical layer parameter percentage of time in sleep mode is changed.

Fig (2) depicts the behaviour of MS with varying mobility as well as application as CBR, VOIP, FTP. The CBR application and VOIP belong to rtPS QoS category so that it comes in type II PSC while FTP belongs to best effort services so that it comes in type I services. So as the speed is increases the percentage of time in sleep mode is reduced differently for different application.

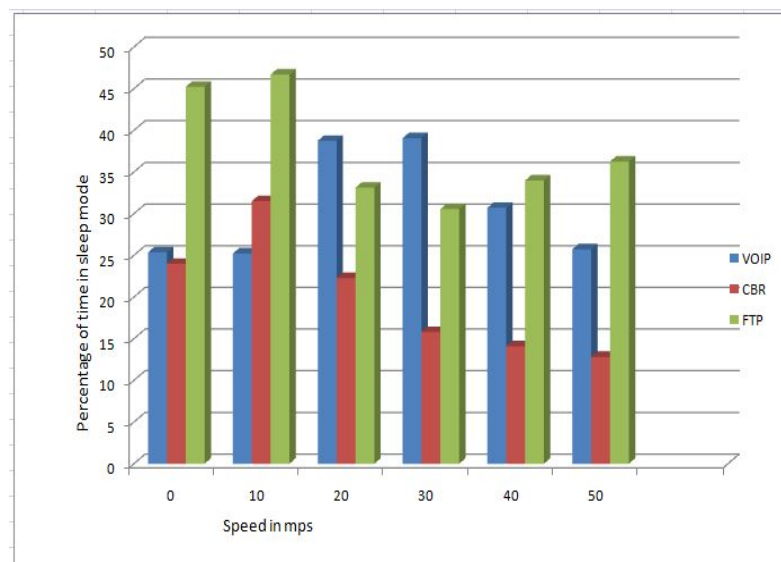


Fig. 2: Percentage of time in Sleep mode Vs mobility in mps for different application.

Fig (3) depicts the behaviour of MS with varying number of MS as well as varying mobility. As the number of nodes in- creases with same resources in BS the distribution of resource among MS is changed. Mobility also play the role because the effect of Doppler spread. In case of Super application it belong to both UDP and TCP type of connection so it depends upon application which one is taken.

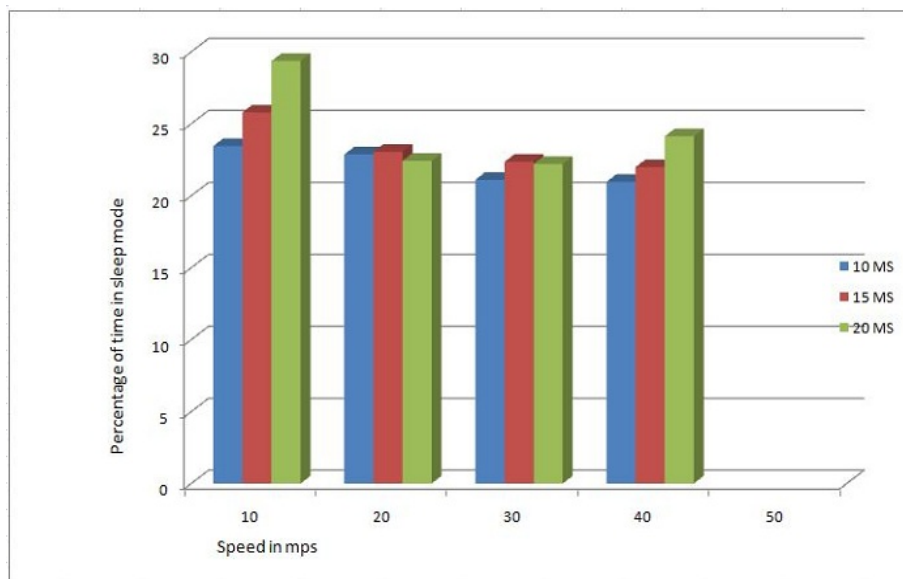


Fig. 3: Percentage of time in Sleep mode Vs mobility for varying number of nodes.

Fig (4) shows the behaviour of MS with varying mobility and different application and seen the effect on the parameters energy consumed in Receive mode. In MS it plays a significant role. In this graph we see that its depend on mobility as well as application.

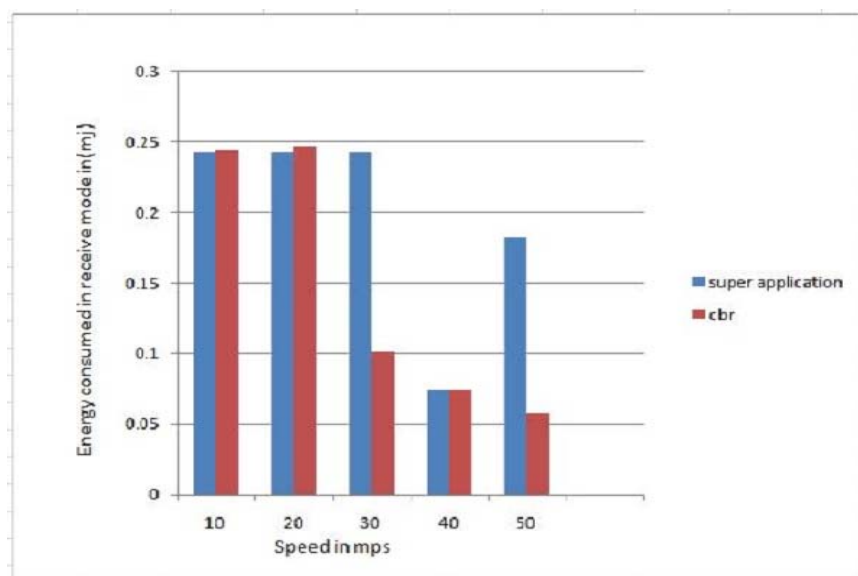


Fig. 4: Mobile station receive power consumption Vs mobility for different application.

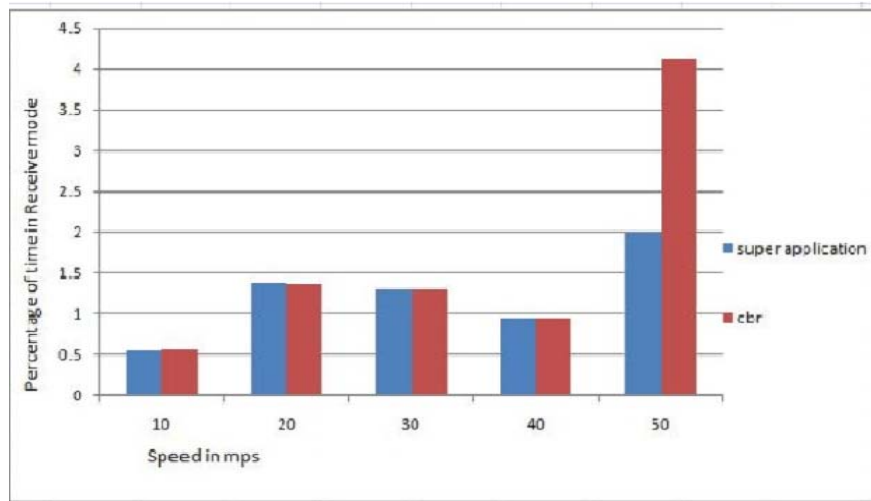


Fig. 5: Percentage of time in receive mode of BS Vs mobility for different application.

Fig (5) depicts the behaviour of BS with varying mobility. Generally BS is in transmitting mode but when the MS is transmitting it receive. The variation of this parameter is because of scheduling of application differently.

Fig (6) depicts the behaviour of MS Vs mobility for varying distance. The energy consumption of MS is varying for different distance because of fading is different for different distance in the channel. So the percentage of time in receive mode is increases with distance.

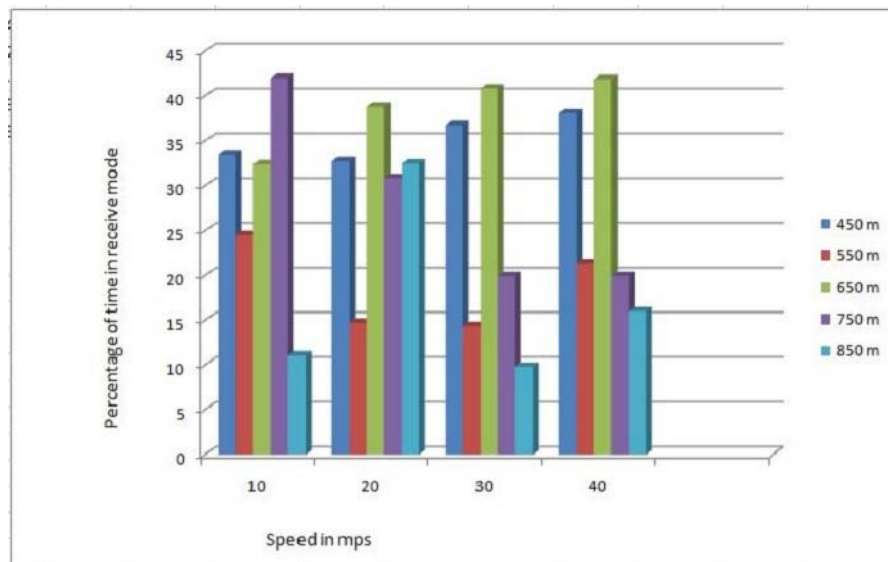


Fig. 6: Percentage of time in receive mode of MS Vs mobility for different distance.

5. Conclusion

In this paper different parameters for different classes of application have taken by which the energy consumed by MS can be controlled. The CBR application is UGS or rtPS type of connection so that it come in the category of PSC of type II therefore it require maximum attention from the BS. In case FTP it belong to BE type of connection therefore it is going maximum time for sleep and required less attention of BS. Therefore for different application required different type of scheduling of resources for efficient use of bandwidth as well as power. For efficient use of power we have to reduce consumption of receive power in MS because it is main cause of energy consumption in MS. Energy consumption of MS is depends upon several parameters as mobility, application, distance etc.

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