

ENERGY OPTIMIZATION PACKET SCHEDULING ALGORITHMS ON A MOBILE WIMAX USING NS2

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Abstract

Recently, mobile communication technologies have been developed rapidly. The IEEE 802.16e wireless metropolitan area network (WMAN) standard is an emerging technology to support roaming mobility of mobile stations (MSs) in outdoor environment. For MSs powered by batteries, the standard supports power saving mode to conserve battery power meanwhile fulfilling the requirements of quality of services. Regarding to different service types, standard defines three different power saving types for them and each type has its own power saving parameters. In this paper, Broadband wireless access systems usually provide flexible sleep-mode operations for mobile stations to conserve their energy during idle or active mode. For Mobile WiMAX, the IEEE 802.16e, offers several power-saving classes that can be associated with different types of network connections to minimize power consumption of mobile stations.

Keywords: Mobile WiMAX, Power Saving, Energy Efficiency, Packet Scheduling.

I. INTRODUCTION

This project, two energy-efficient packet scheduling algorithms for real-time communications [1] in a Mobile WiMAX system are proposed. The schemes not only guarantee the quality of services (QoS) of real-time connections [13,14] but also minimize power consumption of mobile stations. This project deals with measuring the effectiveness of the packet contains an average delay, power consumption. By setting appropriate parameters, single type of power saving will work well for extending the battery life. However, if the number of established connections of MS is more than one and the number of associated power saving type is more than one, the sleeping behavior is not following the setting parameters because that the MS will enter sleep mode only when all of connections decide to enter sleep at a same time.

In other words, for a time frame, if there is any one connection is in listening mode, the MS shall not turn down the wireless transceiver. Therefore, such multi-connection case may degrade power saving efficiency. In this dissertation, proposed a smart strategy for base station (BS) to configure the parameters of power saving classes for MSs with multiple connections. At first, its explained and discussed the features of IEEE 802.16e sleep modes and then propose a smart strategy for merging parameters of different power saving classes in order to extend the battery life. Performance of proposed strategy is evaluated by simulations and simulation results illustrate that the proposed strategy with single parameter set outperforms the standard strategy with multiple parameter sets.

To support battery-operated portable devices, mobile WiMAX has power-saving features that allow portable subscriber stations to operate for longer durations

without having to recharge. Power saving is achieved by turning off parts of the MS in a controlled manner when it is not actively transmitting or receiving data. Mobile WiMAX defines signaling methods that allow the MS to retreat into a sleep mode or idle mode when inactive. Sleep mode is a state in which the MS effectively turns itself off and becomes unavailable for predetermined periods.

The periods of absence are negotiated with the serving BS. WiMAX defines three power-saving classes, based on the manner in which sleep mode is executed. When in Power Save Class 1 mode[1,10], the sleep window is exponentially increased from a minimum value to a maximum value. This is typically done when the MS is doing best-effort and non-real-time traffic. Power Save Class 2 has a fixed-length sleep window and is used for UGS service. Power Save Class 3 allows for a one-time sleep window and is typically used for multicast traffic or management traffic when the MS knows when the next traffic is expected. In addition to minimizing MS power consumption[13,14], sleep mode conserves BS radio resources. To facilitate handoff while in sleep mode, the MS is allowed to scan other base stations to collect handoff-related information.

Idle mode allows even greater power savings, and support for it is optional in WiMAX. Idle mode allows the MS to completely turn off and to not be registered with any BS and yet receive downlink broadcast traffic. When downlink traffic arrives for the idle-mode MS, the MS is paged by a collection of base stations that form a paging group. The MS is assigned to a paging group by the BS before going into idle mode, and the MS periodically wakes up to update its paging group. Idle mode saves more power than sleep mode, since the MS does not even have

to register or do handoffs. Idle mode also benefits the network and BS by eliminating handover traffic from inactive MSs.

Sleep Mode in the IEEE 802.16e

Amendment 802.16e adds the mobility component for WiMAX and defines both the PHY and MAC layers for combined fixed and mobile operations in the licensed bands. Due to the promising mobility capability in IEEE 802.16e, the mechanism for efficiently managing limited energy is becoming very significant, since an MSS is generally powered by a battery.

For this, sleep mode operation has recently been specified in the MAC protocol. [1,17] Fig.1 shows the sleep mode message sequence between the BS and MSS. Before entering the sleep mode, the MSS sends a request message MOB-SLP REQ to the BS for the permission to transit into sleep mode.

Upon receiving the request, the BS replies with the response message MOB-SLP-RSP. This response message indicates the parameters initial-sleep window (T_{min}), final-sleep window (T_{max}), and listening window (L). Upon receiving the MOB-SLP-RSP, the MSS enters into the sleep mode. Now we focus on the mechanism in the sleep mode. The duration of the first sleep interval T_1 is equal to the initial-sleep window T_{min} . After the first sleep interval, the MSS transits into listening state and listens to the traffic indication message MOB-TRF-IND broadcasting from the BS.

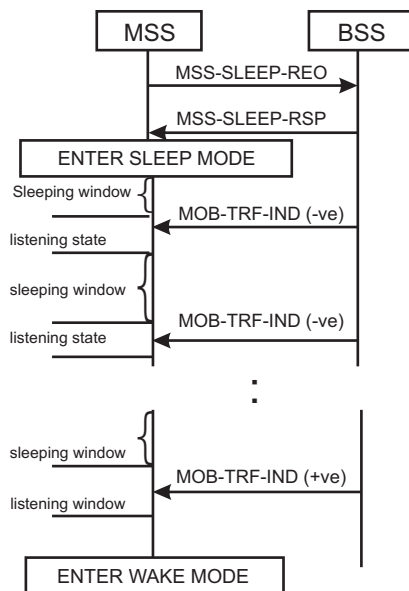


Fig. 1. Shows Sleep Mode in Mobile WiMAX

The duration of the listening state is fixed as the parameter L indicated in the message MOB-SLP-RSP. The message MOB-TRF-IND indicates whether there has been traffic addressed to the MSS during its sleep interval

T_1 . If MOB-TRF-IND shows a negative indication, then the MSS continues its sleep mode after the listening interval L . Otherwise (i.e., the message MOB-TRF-IND indicates a positive indication) the MSS will return to the wake mode. We call the sleep interval and its subsequent listening interval a “cycle.” If the MSS continues in the sleep mode, the next sleep window starts from the end of the previous listening window, and it doubles the preceding sleep interval.

This process is repeated as long as the sleep interval does not exceed the final-sleep window T_{max} . When the MSS reaches T_{max} , it fixes the sleep interval at T_{max} . That is, the duration of the sleep interval in the n th cycle is given by

$$T_n = \begin{cases} T_{min}, & n = 1 \\ \min(2^{n-1}T_{min}, T_{max}), & n > 1 \end{cases} \longrightarrow (1)$$

Energy Consumption Analysis with Downlink Traffic

The energy consumption during the MSS sleeping mode when only considering DL traffic. Here, DL traffic refers to the packets/frames from the BS to the MSS. UL traffic refers to the packets/frames from the MSS to the BS. Assume that the packets addressed to the MSS follow Poisson processes with rate λ . Then, the interarrival time of the DL frame follows the exponential distribution with mean $1/\lambda$. Let e_j denote the event that there is at least one DL frame during the j th sleep window plus its preceding listening window. [7, 8, 10]

Then, $\Pr(e_j = \text{false})$ represents the event that there is no DL frame during the j th sleep window plus its preceding listening window $\Pr(e_j = \text{false}) = e^{-\lambda(T_j+L)}$; $j = 1, 2, \dots$ in principle, the expression for the first sleep window $\Pr(e_1 = \text{false})$ is a little different since there is no preceding listening window before the first sleeping window. However, since the listening window L is sufficiently small, it is acceptable to express the probability $\Pr(e_j = \text{false})$ for all sleeping windows in a similar form. Let E_S and E_L denote the consumed energy units per unit time in the sleep interval and listening interval, respectively.

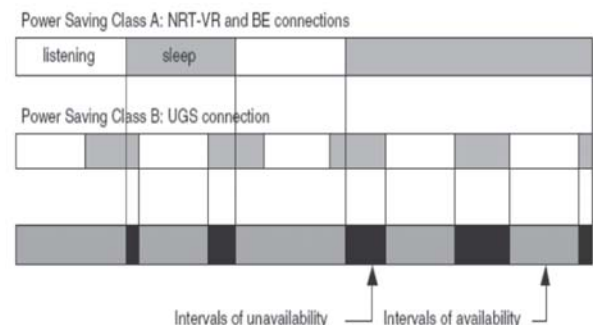


Fig. 2. Shows the Power Saving Class

As shown in Figure.2 sleep mode is terminated during the n th sleeping interval. This supposition implies that there are DL packets during the n th sleeping interval and temporary buffering in the BS. Upon the n th sleeping completion, the MSS transits into the listening state and receive the broadcast message MOB-TRF-IND with positive indication, and consequently terminate the sleep mode. Thus the energy consumption is the sum of the consumed energy during all sleeping intervals and the consumed energy during all listening windows. Denote E_n as the consumed energy provided that the sleeping mode is terminated during the cycle.

Then, E_n is given by

$$\sum_{j=1}^n T_j E_S + n L E_L. \quad \longrightarrow \quad (2)$$

For the sake of presentation

$$W_n = \sum_{j=1}^n (T_j + L). \quad \longrightarrow \quad (3)$$

Let ϕ_n denote the probability that the sleep mode is terminated during the n th sleeping interval. The situation that an MSS is terminated during the n th sleeping interval indicates that there are no DL frames during the 1st, 2nd, \dots , $n-1$ sleeping interval; however, there are DL frames during n th sleeping window. Then, ϕ_n is given by

$$\begin{aligned} \phi_n &= \prod_{j=1}^{n-1} \Pr(e_j = \text{false}) \Pr(e_n = \text{true}) \\ &= [1 - e^{-\lambda(T_n+L)}] e^{-\lambda W_{n-1}}. \end{aligned} \quad \longrightarrow \quad (4)$$

Taking into account all possibilities with respect to the variable n , the consumed energy during a sleep mode is given by

$$\begin{aligned} \text{Energy} &= \sum_{n=1}^{\infty} E_n \phi_n \\ &= \sum_{n=1}^{\infty} \left[\sum_{j=1}^n T_j E_S + n L E_L \right] [1 - e^{-\lambda(T_n+L)}] e^{-\lambda W_{n-1}}. \end{aligned} \quad \longrightarrow \quad (5)$$

Energy-Efficient Packet Scheduling Algorithms

Periodic on-off scheme(PS)

The concept of on-off scheduling algorithms has been applied to wireless devices in reducing the power consumption. Our scheme maximizes the length of a sleep

period in the type-two power-saving class defined in the IEEE 802.16e without violating QoS of all connections.[1]. The PS is performed in two steps; the first step is to compute the length of a sleep period and a listen period for a mobile station. The second step is to let a mobile station enter a periodical sleep mode and schedule the packets according to the parameters obtained in the first step. A mobile station stays idle during sleep periods, and only wakes up to transmit data in listen periods. Packets sent to the mobile station during sleep periods are buffered at the base station and are delivered to the mobile station till listen periods.

In other words, the mobile station only needs to receive and transmit data in listen periods and stay idle to conserve energy during sleep periods. The next paragraphs describe the detail of the first-step procedures of the PS. To schedule downlink packets, the proposed algorithms should be implemented on base stations. On the other hand, the proposed mechanisms have to be realized on both base stations and mobile stations if the proposed methods are applied to the uplink packet scheduler. The base station can know the resource requirements of all mobile stations by negotiations in advanced or bandwidth requests from the mobile stations. Thus, the base station scheduler can determine the uplink packet schedule according to the proposed algorithms, and provides transmission opportunities to mobile stations. Then, mobile stations transmit uplink packets through the given OFDM frames. Without loss of generality, this study considers the above-mentioned QoS parameters to present the basic idea behind the proposed scheduling schemes.

Other parameters such as delay jitters can be also specified as the QoS of a connection and taken into account in the presented approaches. To satisfy the QoS requirements of the connections on a mobile station, both bandwidth and delay constraints specified by all connections need to be considered. For the bandwidth constraint, since a mobile station cannot transmit and receive packets during a sleep period, the total amount of packets that a mobile station can transmit and receive during a listen period must be large enough to provide the needs for all connections during the listen and sleep period. For the delay constraint, the length of a sleep period must not exceed delay requirements of all connections.

Aperiodic on-off scheme(AS)

Since the PS requires a mobile station to always sleep for a fixed period and listen for another fixed period in a round-robin basis, a mobile station might have to stay awake in some frames in the listen period even there is no packet to send or to receive. Thus, an aperiodic on-off

scheduling scheme (AS) is further proposed to determine if a mobile station should go to sleep or not in a frame basis.

In other words, the AS tries to schedule the packet transmission in the minimal number of OFDM frames without violating the QoS of all connections. The length of sleep and listen periods are variable. While a new connection on a mobile station is initiated or any existing connection is released, the AS on a base station is activated to schedule or re-schedule resources in the following frames for the mobile station.

First, the AS sorts all connections on a mobile station based on their delay requirements, and schedules these connections with tight delay requirements first. The reason to schedule connections with tight delay requirements first is that packets of these connections need to be sent or received within a small time window. The scheduler has to consider these packets first in order not to violate their QoS. Conversely, for packets that could tolerate more delays, the scheduler can find more feasible OFDM frames to schedule the packets without violating the delay requirements. After the scheduler decides the scheduling priorities of connections, the packets from the first priority connection, e.g. connection i , are scheduled. $B_{j,i}$ is defined as the amount of data in bytes that are requested by connection i in the j th OFDM frame. The AS tries to group this request with requests from other connections of the same mobile station together. Assume that the k th OFDM frame, where $k \geq j$, has been already scheduled B_k bytes data for other requests of the mobile station. The AS schedules $B_{j,i}$ into the k th frame if both the bandwidth and delay constraints can be satisfied. [1,2,10]. That is, $B_{j,i} \leq B_{\text{frame}} - B_k$, and $(k - j + 1) \times T_{\text{frame}} \geq D_i$. The k th frame can be any frame after the j th frame, but both the bandwidth and delay requirements must be satisfied.

Table 1. Notations and their descriptions

Notation	Description
Q_i	The QoS requirement of connection i . It is denoted as $Q_i\{S_i, T_{I_i}, D_i\}$
S_i	The average packet size in bytes for connection i
T_{I_i}	The average inter-packet arrival time in milliseconds for connection i

D_i	The delay constraint in milliseconds for connection i
T_{frame}	The duration of an OFDM frame in milliseconds
B_{frame}	The maximal capacity of data in bytes that a base station can transmit in an OFDM frame
N_S	The number of OFDM frames in a sleep period
N_A	The number of OFDM frames in a listen period
P_S	The power consumption of a mobile station in Watt during sleep mode
P_A	The power consumption of a mobile station in Watt during listen mode
$B_{j,i}$	The amount of data in bytes which are requested by connection i in the j th OFDM frame
B_k	The amount of data in bytes which has been allocated by the base station in the k th OFDM frame

II. SIMULATION RESULTS

SIMULATION SCENARIOS

An IEEE 802.16e NS2 simulator written in C++ was developed to evaluate the performance improvement by employing the proposed schemes. The simulations in this study use WirelessHUMAN(-OFDM) profile, i.e. ProfP3_10 defined in [1], and 10 MHz channel, 5 ms frame length, and 64-QAM with 3/4 coding rate are assumed. The changes of channel conditions and the adaptive modulation and coding (AMC) are not considered in the simulation. In the simulations, a mobile station could be a standard mobile station which establishes multiple real-time connections such as a multi-party conference call, or a mobile relay router which bridges multiple real-time connections for other mobile stations. These connections on a mobile station have different QoS requirements and real-time characteristics.

Four types of real-time connections with different QoS requirements are defined and their descriptions are summarized in Table 2. AL and AH denote a lowbit-rate audio connection and a high bit-rate audio connection individually. VL denotes a low bit-rate video connection, and VH denotes a high bit-rate video connection. The delay constraints for audio and video connections are set to 50 ms and 100 ms, respectively.

The audio connections are assumed constant-bit-rate (CBR), and they are classified as unsolicited grant service (UGS) connections. On the other hand, the video connections are variable-bit-rate (VBR). The sizes of video packets are generated by a Gamma distribution suggested by [11]. The video connections are classified as real-time polling service (rtPS) connections. Also, IP/UDP/RTP and MAC headers and the signaling overheads to exchange the control messages of sleep-mode operations for the proposed PS and AS are all taken into considerations in the simulation program

Table 2. Four real-time connections with different characteristics

Connection Description

AL	Low bit-rate audio connection using G.723.1 codec at 6.4 Kbps and 30 ms frame length
AH	High bit-rate audio connection using G.711 codec at 64 Kbps and 20 ms frame length
VL	Low bit-rate video connection at 100 Kbps and 30 frames per second
VH	High bit-rate video connection at 300 Kbps and 30 frames per seconds

Analysis of simulation results

Figs.3 shows each mobile station establishes four audio connections and four video connections in this simulation. The real-time connections for a mobile station are four high bit-rate audio and four high bit-rate video connections denoted as $(AH + VH) \times 4$, four low bit-rate audio and four low bit-rate video connections denoted as $(AL + VL) \times 4$. As can be seen from the figure, the maximal number of serving mobile stations for a base station decreases. Also, the percentage of sleep periods of a mobile station decreases for the traditional approach.

Fig.3 shows that a mobile station still can gain sleep

time by applying the proposed AS. While a base station serves 10 mobile stations and implements the PS, each mobile station can have more sleep time than that by applying the traditional approach. The average packet delay of a mobile station by applying the AS is more than that by applying the other two schemes.



Fig. 3. Nodes vs Energy for a mobile station with four real-time connections by employing different scheduling schemes (TR: traditional scheme, PS: periodic on-off scheme, AS: aperiodic on-off scheme).

Fig.4 shows the average packet delay for a mobile station under different base station loadings. The figure reveals that the traditional approach always achieves the lowest packet delay since it processes packets immediately while packets arrive. The average packet delays for a mobile station by employing the proposed PS are higher than that by employing the traditional approach, but are less than that by employing the AS. This is because the AS may buffer the packet to the maximal delay constraint in order to gain more sleep time for a mobile station. Although the delays by employing the proposed PS and AS increase, the QoS requirements of the connections are still satisfied.

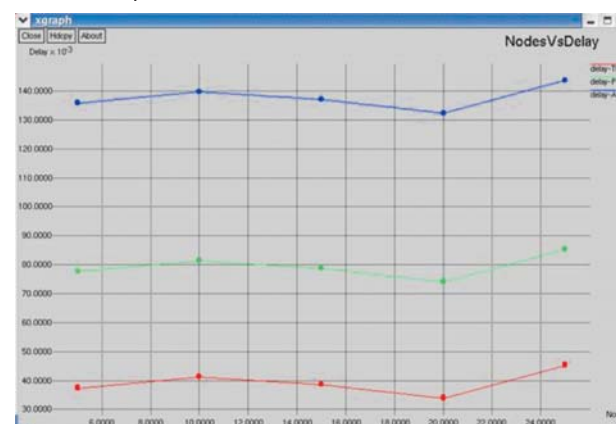


Fig. 4. Nodes vs Delay for a mobile station with four real-time connections by employing different scheduling schemes (TR: traditional scheme, PS: periodic on-off scheme, AS: aperiodic on-off scheme).

CONCLUSION

In this thesis work “Energy efficient two way packet scheduling algorithms is considered. The proposed periodic on–off scheme that allows a mobile station to sleep and listen for fixed periods in a round-robin basis. The aperiodic on– off scheduling scheme that determines if a mobile station should go to sleep or not in a frame basis is further proposed to maximize the length of sleep periods of a mobile station. AS has to maintain the status of each frame for every mobile station and schedules the packet transmission frame by frame. Although, the AS introduces more delay than the PS scheme, the delays by employing the AS are still controlled within the constraints. The proposed schemes minimize the power consumption of mobile stations with multiple real-time connections without violating the QoS of real-time connections. Comparison of Simulation results demonstrate that we are consuming more energy in aperiodic scheme than that of periodic and traditional approach.

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