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Re:	IEEE 802.16m-07/040 - Call for Contributions on Project 802.16m System Description Document
Abstract	This contribution addresses the enhanced power saving requirement as specified in IEEE 802.16m System Requirements and proposes a wake-up signal before the broadcast paging message to reduce mobile station (MS) power consumption during the idle mode.
Purpose	Discuss and Adopt
Notice	
Release	
Patent Policy	

Wake-up Signal for 802.16m OFDMA Idle Mode

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Introduction

This contribution addresses the enhanced power saving requirement as specified in [1] and proposes a wake-up signal before the broadcast paging message to reduce mobile station (MS) power consumption during the idle mode. The proposal reduces power consumption of an idle mode MS by inserting a wake-up signal before a relevant broadcast paging message such that the MS only needs to perform simple detection without activating its entire demodulation and decoding device for DCD, DL-MAP and BS Broadcast Paging message in each MS paging listening interval. The proposal also satisfies the legacy support requirement as specified in [1].

We propose that a section on enhanced power saving be added in the system description document. We recommend that this wake-up signal proposal be included in the enhanced power saving section of the System Description Document (SDD).

Proposed SDD Text

[Section] Enhanced Power Saving

[Subsection] Wake-up Signal

Wake-up signal is a physical layer signal that is easy to demodulate and detect. The wake-up signal provides a mechanism such that mobile stations in stand-by mode do not need to turn on their entire baseband circuits in every MS paging listening interval unless the BS intends to deliver paging messages or system updates to them. The wake-up signal associated with a certain idle mode MS shall precede its designated paging listening interval, which requires demodulation and decoding of the FCH, the DL-MAP, and the data burst. An idle MS, before entering its paging listening interval, shall first detect if there is a wake-up signal directed towards it. If there is no wake-up signal for the MS, it returns to the idle mode and turns off its receiver unit until next paging cycle. Only after the wake-up is detected, then the MS activates its entire chain of demodulator and decoders for FCH, DL-MAP and data bursts.

The wake-up signal is sent to targeted MS's one or a few frames before the actual MOB_PAG-ADV message, or before a DCD/UCD change or other system messages.

The wake-up signal can be embedded at a specific location in the DL data region without ambiguity. In the TDD mode, the wake-up signal can be located in the TTG, where the active users are transitioning from the receive mode to the transmit mode, while the standby users are not required to transmit. In the FDD mode, the wake-up signal can be located in the transmission gaps between two consecutive frames. The wake-up signal can be a single-tone or multiple-tone waveform. The wake-up signal may apply fractional frequency-time usage of the OFDMA symbol to match the available residual resources. The MS should be identified effectively by matching its MAC ID hash into the space of wake-up signals.

Detailed Description of Proposed Wake-up Signal

Enhanced Power Saving Requirement

The proposed wake-up signal reduces idle-mode MS's operation in paging listening intervals from full demodulation/decoding of preamble, FCH, DL-MAP and data bursts down to simple signal detection. The saved power over time extends MS battery life.

Backward Compatibility Requirement

The proposed wake-up signal only occupies un-used resources in an OFDMA frame specified in WirelessMAN OFDMA Reference Systems. It is transparent to legacy mobile stations.

Idle Mode MS Operation in WirelessMAN-OFDMA Reference Systems

The current paging process in MS idle mode is illustrated in Figure 1, which shows the relationship between paging cycles, paging offset, BS paging interval and OFDMA frame. The time axis is divided into paging cycles. The MS paging listening interval occurs once every cycle and its location is determined by the paging offset. The paging message may span over several frames and a MS may need to demodulate all of them to read the entire message.

An idle mode MS in the WirelessMAN-OFDMA Reference Systems, as specified in [2] and [3], "*shall scan, decode the DCD and DL-MAP, and synchronize on the DL for the preferred BS in time for the MS to begin decoding any BS Broadcast Paging message during the entire BS paging interval*". That is, the MS needs to periodically turn on the entire demodulator-and-decoder baseband unit during its idle period even when there are no paging messages for it and no system configuration changes/updates. However, the following operations are still required. The MS first synchronizes with the preamble and reads the FCH. It then reads the DL-MAP to look for the location and the format of the broadcast CID. If the DL-MAP shows a broadcast CID, the MS shall demodulate that burst to see if there is a BS Broadcast Paging message (MOB_PAG-ADV). Most of the time, there will be no paging information or no actions required for the MS (Action Code 0b00). During each paging interval, the MS has to be fully awake for 2 to 5 frames [1]. The processing of FCH, DL-MAP, and the data burst will invoke the entire receiver baseband unit, hence drains the MS battery over time. On the BS side, periodically sending MOB_PAG-ADV messages with Action Code 0b00 also wastes downlink capacity.

In addition to MOB_PAG-ADV messages, changes in channel descriptors (DCD or UCD) or broadcast system updates trigger idle MS's to stay on for updating the system parameters or reading other coming messages.

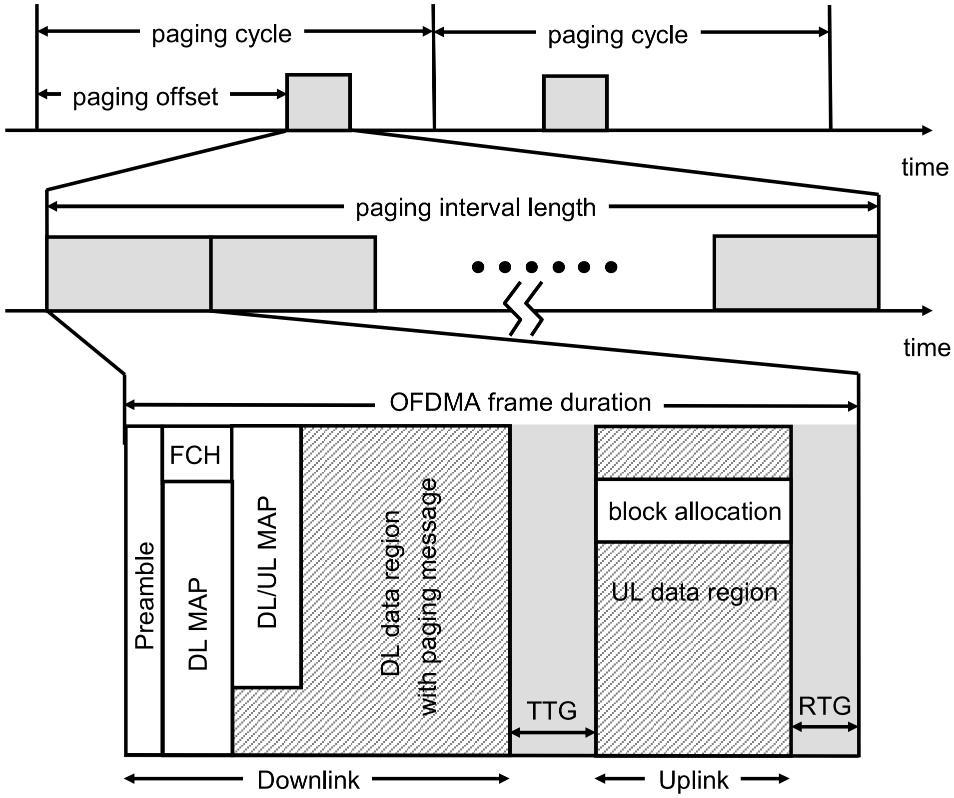

Figure 1: Paging process and OFDMA structure in 802.16

Proposed Wake-up Signal for 802.16m OFDMA Idle Mode

The proposed wake-up signal precedes the paging message or system updates to activate relevant idle MS's decoder only when necessary and prevent irrelevant MS's from wasting power in decoding paging messages that require no actions from those MS's.

The wake-up signal must be detected by the MS without reading FCH and DL-MAP. Therefore it must have a pre-determined location in a frame.

For TDD frames, the DL and UL subframes are separated by a BS transmit-to-receive transition gap (TTG) and a BS receive-to-transmit gap (RTG). The TTG serves for two purposes: the first is to reduce the interference in the beginning of a UL subframe caused by long propagation of DL subframes from other cells, and the second is to allow far users to advance their timing for synchronized UL transmission. The typical TTG value is on the order of 100□sec, such as specified in the WirelessMAN OFDMA Reference System [2][3]. Most DL signals from other cells become negligible after such a long propagation. The far users, except the receive-to-transmit switching time, also need to compensate their UL propagation delays by advancing their transmit timing. This illustrated in Figure 2. From each MS, the TTG should be larger than the sum of receiver-transmitter switching time and DL/UL propagation delays seen at its location. But for idle mode users, they can detect the wake-up signal during this period since there is no need to prepare for uplink transmission right after the TTG. Therefore, the DL subframe can be prolonged into the TTG to include wake-up signals, which only the idle users listen to and the active users treat as non-existent, as long as the interference to the uplink is maintained below an acceptable level. On the other hand, RTG allows the UL signal to fade before the next DL subframe takes place such that strong interference from near-by MS to the DL reception can be avoided. In the WirelessMAN

OFDMA Reference Systems [2][3], the RTG value is either 60μs or 74.4μs, which roughly corresponds to 18km or 22km in distance. In many deployment scenarios, the MS signal will be negligible long before such distances and there will be room at the end of RTG without interference. Therefore, the wake-up signal can be inserted right before the next preamble in the RTG.

In systems with a DL/UL ratio resulting in any un-used OFDMA symbols after dividing the subframes into slots, the wake-up signal can be inserted those un-used OFDMA symbols as well.

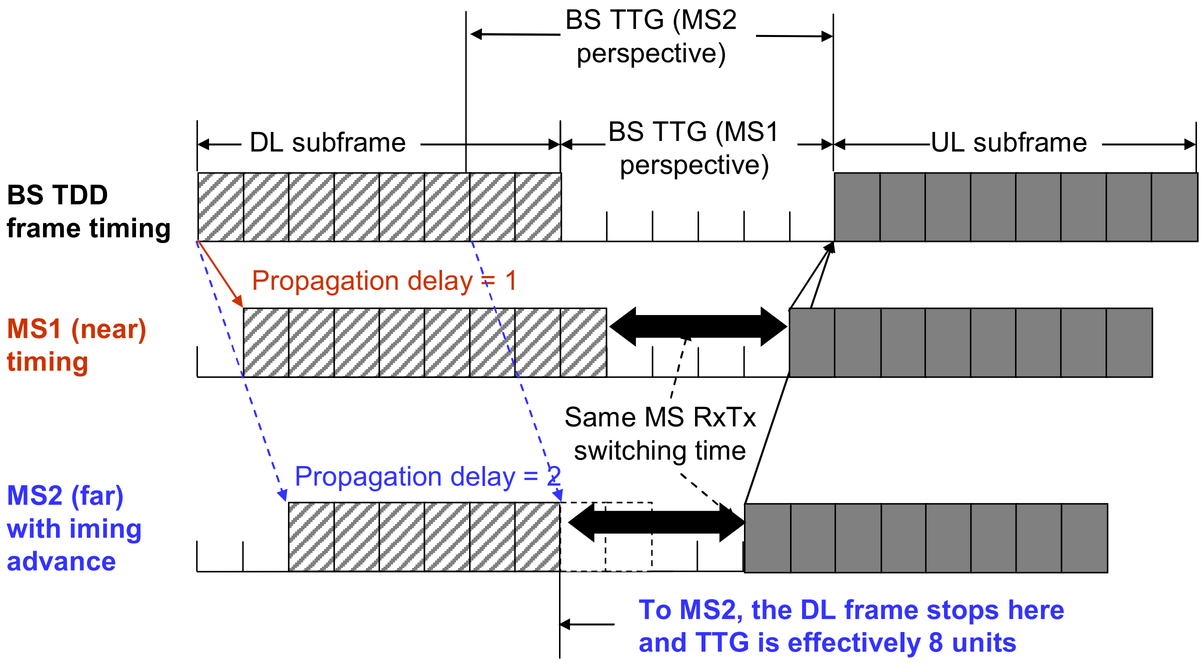

Figure 2: Timing Advance in TDD

The format of wake-up signal shall satisfy the fundamental requirement of being received by simple detection. The wake-up signal may consist of a single or multiple OFDMA subcarriers. The subsets of wake-up signal subcarriers can be modulated with or without signature sequences and hopping patterns during the detection window. The duration of the wake-up signal, when inserted in the transition gaps, can be reduced by only including a subset of evenly spaced subcarriers. This is explained by Figure 3 through Figure 5. In Figure 3, the subcarriers of an OFDMA symbol are illustrated for frequencies $1/T_{base}=f_{base}$, $2f_{base}$, , etc. up to $6f_{base}$, where T_{base} is the useful OFDM symbol duration and its reciprocal is called the base frequency.

As can be seen, the period for the frequency $2f_{base}$ is half of that for f_{base}; the period for the frequency $3f_{base}$ is one third of that for f_{base}, etc. Hence, using, for example, every other subcarrier starting with $2f_{base}$ will reduce the wake-up OFDMA symbol duration to half. This is illustrated in Figure 4, which shows the wake-up signal with 1/2 OFDM symbol duration based on integer multiples of $2f_{base}$. Following the same principle, using only every third subcarrier $3f_{base}$, $6f_{base}$, $9f_{base}$ etc., will reduce the wake-up symbol duration to one third. This is illustrated in Figure 5, which shows the wake-up signal with 1/3 OFDM symbol duration based on integer multiples of $3f_{base}$. As a general rule, using subcarriers whose frequencies are integer multiples of the Nth harmonic of the base frequency, $1/T_{base}$, the wake-up signal transmitted symbol duration can be effectively shortened to 1/N of the useful OFDM symbol duration, i.e., $1/N \cdot T_{base}$. At the receiver side, the same FFT module for demodulating other OFDMA symbols of T_{base} duration can be used by simply padding zeros outside the shortened T_{base}/N wake-up signal duration to perform detection. At the transmitter side, only the first 1/N of the N_{FFT} samples are converted from digital to analogue waveform for RF transmission. No new hardware is required to send or detect this type of wake-up signal.

As explained, the proposed fractional frequency-time space usage can accommodate the newly inserted wake-up signals in the TDD transition gaps or the gaps between FDD frames. The advantage of this approach is that the same FFT circuit can be used at the base station transmitter, while the mobile terminal's receiver can apply the same preamble detector, over a fractional symbol time window. The wake-up signal, when being sent with fractional symbol duration, might have coverage issues because of shorter symbol time to accumulate energy. A combination of multiple fractional-symbol-time wake-up signals over multiple frames that are dedicated to the same recipient(s) can be used to improve the coverage.

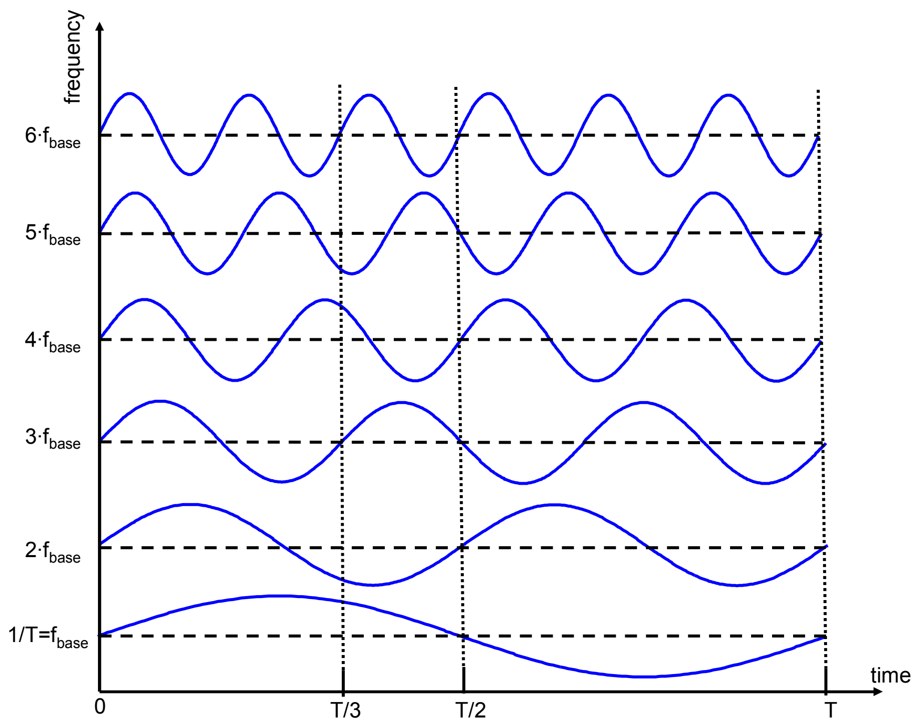

Figure 3: Relationship of Useful OFDM Symbol Time, Base Frequency, and Harmonics

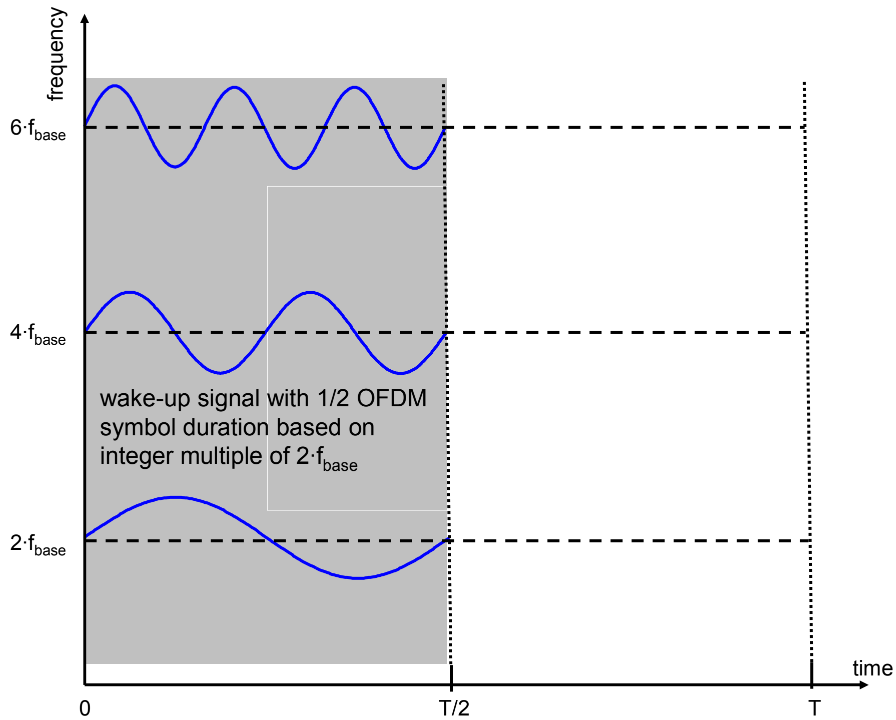

Figure 4: Even Integer Multiple of Base Frequency for Wake-Up Signal

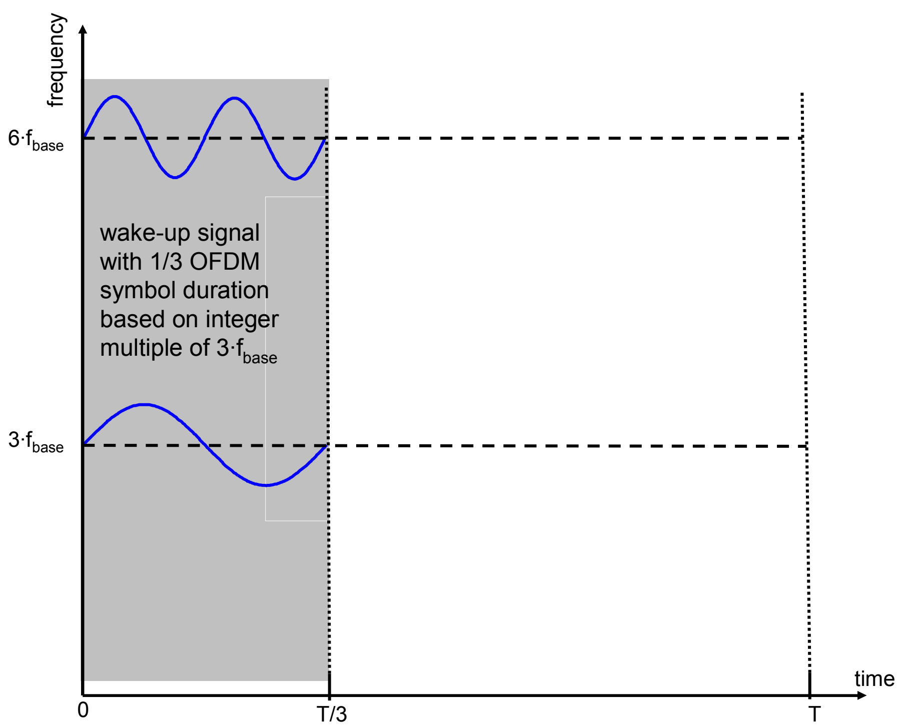

Figure 5: Integer Multiple of 3x Base Frequency for Wake-up Signal

In the BS broadcast paging message, the MS identifies its paging instruction by the “MS MAC Address hash” field. The required wake-up signal space for mapping MS ID’s can be reduced by dividing hashed MAC addresses by signaling groups.

Conclusions

This contribution addresses the enhanced power saving requirement as specified in [1] and proposes a wake-up signal before the broadcast paging message to reduce MS power consumption during the idle mode. We recommend that this wake-up signal proposal be adopted in the enhanced power saving section of the System Description Document.

References

[1] IEEE 802.16 Broadband Wireless Access Working Group, "IEEE 802.16m System Requirements", IEEE 802.16m-07/002r4, Oct 19, 2007.

[2] IEEE Std 802.16e-2005 and IEEE Std 802.16 Cor2/D3, "IEEE Standard for local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in License Bands,"

[3] WiMAX Forum™ Mobile System Profile, Release 1.0 Approved Specification (Revision 1.4.0: 2007-05-02)