IEEE P802.11
Wireless LANs

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| Unscheduled Power Save for DMG and other corrections |
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### ****Abstract****

Despite its significant potential, unscheduled power save in DMG is a poorly defined mechanism, specified through 13 lines of text in Section 10.2.6.2.2 (Power management mod e operation of a non-AP and non-PCP STA with no wakeup schedule). Unscheduled power save brings agility to power save, and in common deployment scenarios (the most common being the entire DTI made of a single CBAP) enables granular (sub-BI) power saving, in contrast with the scheduled power save, which operates at beacon interval granularity.

The existing text leaves many details to imagination. There is brief description of using the Power Management (PM) bit to signal a non-AP and non-PCP STA transition to power save (PS) mode to the AP or PCP of the network, but many questions are left unanswered:

* What kind of frame exchanges can be used for this signaling?
* What is the mechanism to exit unscheduled PS mode?
* How would other non-AP and non-PCP STAs know about a STA transition into or out of PS mode? This is significant since DMG STAs are allowed to directly transmit frames to each other.
* How do unscheduled and scheduled power save mechanisms coexist and complement each other?

This submission addresses the above questions and more. In particular, it enhances the unscheduled power save mechanism robustness and state integrity by drawing elements from power save in infrastructure BSS and IBSS networks. The complete unscheduled power save mechanism defined in this submission coexists with and complements the scheduled power save mechanism. It is centralized in the sense that it makes a non-PCP and non-AP transition into or out of PS mode subject to AP’s or PCP’s acknowledgement, but it also defines elements for faster state synchronization (avoiding the beacon interval latency) by allowing direct (peer to peer) signaling of the power management mode.

A few corrections to scheduled power save are also included.

This document resolves CID 6373, 6374, 6816.

All proposed edits are relative to Draft P802.11REVmc\_D4.2.

### ****Revision History****

Rev 0: Initial revision

Rev 1:

* PSIM renamed to UPSIM (unscheduled power save indication map)
* UPSIM limited to unscheduled power save mode
* Included tables where UPSIM element needs to be added
* Updates to the general/overview section (10.2.6.1) to clarify scheduled and unscheduled PS modes and their co-existence
* Clarify ATIM response rules when in unscheduled PS mode (no need to wake up)
* Added an example for ATIM response behavior

Rev 2:

* Allow PCP to use the unscheduled power save mechanism when associated with more than one STA
* Corrections to figure to reflect need for additional ATIM frame transsmissions
* Define PS mode as a management primitive instead of the reflection of the STA power state

*[Add a new UPSIM abbreviation.]*

**3.4 Abbreviations and acronyms**

...

UPSIM Unscheduled Power Save Indication Map

*[DTIM is undefined in DMG networks.]*

**6.3.2.2.2 Semantics of the service primitive**

The primitive parameters are as follows:

 MLME-POWERMGT.request(

 PowerManagementMode,

 ReceiveDTIMs

 )

|  |  |  |  |
| --- | --- | --- | --- |
| **Name** | **Type** | **Valid range** | **Description** |
| PowerManagementMode | Enumeration | ACTIVE,POWER\_SAVE | An enumerated type that describes the requested power management mode of the STA. |
| ReceiveDTIMs | Boolean | true, false | Non-DMG BSS: When true, this parameter causes the STA to awaken to receive all DTIM frames. When false, the STA is not required to awaken for every DTIM Beacon frame.DMG BSS: Not applicable |

*[Clarify the usage of the Power Management field in DMG.]*

**8.2.4.1.7 Power Management field**

The Power Management subfield is 1 bit in length and is used to indicate the power management mode of a STA. The value of this subfield is either reserved (as defined below) or remains constant in each frame from a particular STA within a frame exchange sequence (see Annex G). The value indicates the mode of the STA after the successful completion of the frame exchange sequence.

In an infrastructure BSS or PBSS, the following applies:

— The Power Management subfield is valid only in frame exchanges as described in 10.2.2.2 (STA power management modes) and 10.2.6 (Power management in a PBSS and DMG infrastructure BSS). In such exchanges, a value of 1 indicates that the STA will be in PS mode. A value of 0 indicates that the STA will be in active mode.

— The Power Management subfield is reserved in all Management frames transmitted by a STA to an AP or PCP with which it is not associated.

— The Power Management subfield is reserved in all frames transmitted by the AP.

In an IBSS, the Power Management subfield is valid only in frame exchanges as described in 10.2.3.4 (STA power state transitions). In such exchanges, a value of 1 indicates that the STA will be in PS mode. A value of 0 indicates that the STA will be in active mode.

In an MBSS, the Power Management subfield is valid only in frame exchanges as described per the mesh power management mode transitions rules in 13.14 (Power save in a mesh BSS).

*[Define a new information element, UPSIM (Unscheduled Power Save Indication Map), to communicate the power management mode of each DMG STA in unscheduled PS mode.]*

**8.4.2 Elements**

**8.4.2.1 General**

...

**Table 8-74—Element IDs**

|  |  |  |  |
| --- | --- | --- | --- |
| **Element** | **Element ID** | **Element ID Extension** | **Extensible** |
| UPSIM | <To be assigned, preferably in the 207-220 range> | N/A | Yes |

*[Add UPSIM element to Table 8-41 to indicate optional presence in DMG Beacon frames; add the element after “DMG Wakeup Schedule” element, which itself is missing and needs to be added after the “Awake Window” element, which is currently showing 15 in the Order column. The “DMG Wakeup Schedule” element addition is being proposed as part of resolution to #6057.]*

**Table 8-41—DMG Beacon frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| X (likely 17) | UPSIM | See 8.4.2.x (UPSIM element) |

*[Add UPSIM element to Table 8-408 to indicate optional presence in Announce frames; add the element after “DMG Wakeup Schedule” element, which itself is missing and needs to be added after the “Awake Window” element, which is currently showing 13 in the Order column. The “DMG Wakeup Schedule” element addition is being proposed as part of resolution to #6057.]*

**Table 8-41—DMG Beacon frame body**

|  |  |  |
| --- | --- | --- |
| **Order** | **Information** | **Notes** |
| X (likely 15) | UPSIM | See 8.4.2.x (UPSIM element) |

*[UPSIM element definition; element construction is based on an unscheduled power save indication virtual bitmap similar to the traffic indication virtual bitmap in the TIM element. Some text from the TIM element section (8.4.2.6) is reused.* ***We request to use the legacy (non-extended) IE format as the addition will be implemented by 802.11ad devices that may have had hard assumptions about IE format****.]*

**8.4.2.x UPSIM element**

The UPSIM element is defined as shown in Figure 8-xxx (UPSIM element format).

The Element ID and Length fields are defined in 8.4.2.1 (General).

The Length field for this element is constrained as described below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Element ID | Length | Flags | Partial Unscheduled Power Save Bitmap |
| Octets: | 1 | 1 | 1 | 0-32 |

**Figure 8-xxx—UPSIM element format**

The Flags field is defined in Figure 8-xxx (Flags field format).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | B0 | B1 | B2 | B3 B7 |
|  | PS PCP | PS Non-PCP | Reserved | Bitmap Offset |
| Bits: | 1 | 1 | 1 | 5 |

**Figure 8-xxx—Flags field format**

The PS PCP field is set to 1 if the PCP is in unscheduled PS mode at the time of UPSIM element transmission, and is set to 0 otherwise. The PS PCP field is set to 0 in infrastructure BSS. The PS Non-PCP field is set to 1 if all non-AP and non-PCP STAs are in unscheduled PS mode at the time of UPSIM element transmission, and is set to 0 otherwise. The Bitmap Offset field defines the octet offset into a virtual bitmap maintained by the AP or PCP, as described below.

The AP or PCP maintains an unscheduled power save indication virtual bitmap that is 256 bits in length and is organized into 32 octets such that bit number *N* (0 ≤ *N* ≤ 255) in the bitmap corresponds to bit number (*N* mod 8) in octet number ⎣*N* / 8⎦, where the low order bit of each octet is bit number 0, and the high order bit is bit number 7. Bit *N* in the bitmap is set to 1 if there is an associated DMG STA with AID equal to *N* and the STA is in unscheduled PS mode, and is set to 0 if there is no associated DMG STA with AID equal to *N* or the STA is not in unscheduled PS mode. Bit 0 is set to 0 in the infrastructure BSS. Bit 255 is set to 0.

The Partial Unscheduled Power Save Bitmap field is not present when bits numbered 1 to 254 of the unscheduled power save indication virtual bitmap all have the same value at the time of UPSIM element transmission. In this case, the Length field is set to 1 and the Bitmap Offset field is set to 0.

When there are two bits in the unscheduled power save indication virtual bitmap with numbers between 1 and 254 and different values, the Partial Unscheduled Power Save Bitmap field consists of octets numbered *N*1 to *N*2 of the unscheduled power save indication virtual bitmap, where *N*1 is the largest integer such that bits numbered 1 to (*N*1× 8) – 1 in the unscheduled power save indication virtual bitmap are all 0, and *N*2 is the smallest number such that bits numbered (*N*2 + 1) × 8 to 255 in the unscheduled power save indication virtual bitmap are all 0. In this case, the Length field is set to (*N*2 – *N*1) + 2 and the Bitmap Offset subfield is set to *N*1.

NOTE—The Partial Unscheduled Power Save Bitmap field does not need to include bit 0 of the unscheduleued power save indication virtual bitmap even if that bit is set.

*[NOTE: At some point Section 10.2.6 could see a better reorganization into scheduled and unscheduled PS modes, with non-AP STA behavior defined under each. The current organization, based on non-AP/non-PCP and PCP, results in small sections with similar text.]*

*[Revise the outdated Section 10.2.6.1 to reflect the changes to scheduled and unscheduled power save.]*

**10.2.6 Power management in a PBSS and DMG infrastructure BSS**

**10.2.6.1 General**

Power save mechanisms in this subclause enable non-AP STAs to sleep for one or more beacon intervals or for parts of a beacon interval.

The non-AP and non-PCP STA power save mechanisms defined in 10.2.6.2 (Non-AP and non-PCP STA power management mode) enable a non-AP and non-PCP STA to sleep after signaling the AP or PCP, or to sleep according to a periodic schedule that is negotiated with the AP or PCP. A non-AP and non-PCP STA my use both mechanisms in conjunction to increase its power save opportunity.

Similarly, the PCP power save mechanisms defined in 10.2.6.3 (PCP Power management mode) enable a PCP to sleep after signaling at least one non-AP and non-PCP STA, or to sleep according to a wakeup schedule that is available to all STAs associated with the PCP.

A DMG STA operates in one of two power states:

* Awake: STA is expected to transmit and receive DMG frames.
* Doze: STA is not expected to transmit and receive DMG frames.

The manner in which a DMG STA transitions between these two power states is determined by the STA’s power management mode:

* Active mode: The STA does not use any of the scheduled or unscheduled poswer save mechanisms defined in this subclause and operates in the awake state, except during time intervals that it determines it is not the target of any transmission by other STAs, where it may operate in doze state.
* Power Save (PS) mode: The STA uses at least one of the scheduled or unscheduled power save mechanisms defined in this subclause and switches between awake and the doze states.

For scheduled power save, the DMG Wakeup Schedule element (8.4.2.130 (DMG Wakeup Schedule element)) is used to communicate the sleep and wakeup pattern of a DMG STA, referred to as the STA wakeup schedule (WS). A STA wakeup schedule defines a periodic routine of cycling between a set of contiguous beacon intervals referred to as Awake BIs and a set of contiguous beacon intervals referred to as Doze BIs. The rules for alternating between awake and doze power states during Awake BIs and and Doze BIs are defined in 10.2.6.2.3 (Non-AP and non-PCP STA operation with a wakeup schedule) and 10.2.6.3.3 (PCP operation with a wakeup schedule). An overview of these rules is given in in Table 10-3 (Power states for an Awake BI) and Table 10-4 (Power states for a Doze BI).

A STA in PS mode that is following a wakeup schedule and has also exercised unscheduled power save shall follow the Doze BI rules in this subclause and shall follow the ATIM rules in 10.2.6.4 for a non-AP STA without wakup schedule.

...

*[The MLME-POWERMGT primitive behavior is missing details for unscheduled power save.]*

**10.2.6.2 Non-AP and non-PCP STA power management mode**

**10.2.6.2.1 General**

The power management mode of a non-AP and non-PCP STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive. Once the STA updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive indicating the result of the operation. While the STA is in PS mode it may exercise the unscheduled or scheduled power save mechanisms described in this section..

*[Simplify the section title and add missing behavior related to PM signaling into and out of PS mode.]*

**10.2.6.2.2 Non-AP and non-PCP STA operation without a wakeup schedule**

To change its power state without a wakeup schedule, a non-AP and non-PCP STA shall inform the AP or PCP by completing a successful frame exchange (as described in Annex G) that is initiated by the STA and that includes a Management frame, Extension frame or Data frame, and also an Ack or a BlockAck frame from the AP or PCP. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the STA in this exchange that contain a BU or are QoS Null frame indicate the power state that the STA shall adopt upon successful completion of the entire frame exchange. A non-AP and non-PCP STA shall not change its power state using a frame exchange that does not receive an Ack or BlockAck frame from the AP or PCP, or using a BlockAckReq frame.

A non-AP and non-PCP STA in doze state shall limit the frames it transmits to the following:

* A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from the AP or PCP, with the Power Management subfield in the Frame Control field of the frame set to 0, i.e., a frame to indicate the STA intent to transition out of unscheduled PS mode.
* An RTS, DMG CTS-to-self, Grant, SSW or SSW-Feedback frame

NOTE—A DMG STA in doze state may need to perform beamforming to restore its links with other DMG STAs.

As long as there is at least one STA that has entered doze state through the unscheduled power save mechanismun, the AP or PCP shall establish an awake window by transmitting an Awake Window element, and shall include a UPSIM element in every DMG Beacon and Announce frame it transmits. The AP or PCP may establish an awake window and/or include a UPSIM element in a DMG Beacon or Announce frame it transmits even if no STA is in doze state. The absence of a UPSIM element in a DMG Beacon or Announce frame is equivalent to presence of the UPSIM element in the frame with all bits of the Power Save Indication Bitmap field in the UPSIM element set to 0. The UPSIM element in every DMG Beacon or Announce frame transmitted by the AP or PCP shall indicate the power state of all STAs at the time of frame transmission.

NOTE—Transmitting a DMG Beacon frame with the Discovery Mode subfield set to 0, or an Announce frame, without including the UPSIM element in the frame, indicates that no STA is in unscheduled PS mode at the time of the frame transmission.

A non-AP and non-PCP STA may also indicate its power state to another non-AP and non-PCP STA through the Power Management subfield in the Frame Control field of any frame that contains all or part of a BU. The non-AP and non-PCP STA shall indicate its correct power state in the Frame Control field of any frame it transmits that contains all or part of a BU.

...

*[Expand 10.2.6.3 into unscheduled and scheduled subsections to align with 10.2.6.2.]*

**10.2.6.3 PCP power management mode**

**10.2.6.3.1 General**

The power management mode of a PCP is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request primitive. Once the PCP updates its power management mode, the MLME shall issue an MLME-POWERMGT.confirm primitive indicating the result of the operation. While the PCP is in PS mode it may exercise the unscheduled or scheduled power save mechanisms described in this section.

**10.2.6.3.2 PCP operation without a wakeup schedule**

To change its power state without a wakeup schedule, the PCP shall include a UPSIM element in or remove the UPSIM element from every DMG Beacon frame with the Discovery Mode subfield set to 0 or Announce frame that it transmits, and shall indicate its new power state in the UPSIM element if it is included in the frame

NOTE— The UPSIM element in a DMG Beacon frame with the Discovery Mode subfield set to 0, or in an Announce frame, includes the power state of the PCP at the time of the frame transmission. Transmitting a DMG Beacon frame with the Discovery Mode subfield set to 0 or an Announce frame, without including the UPSIM element in the frame, indicates that no STA (including the PCP) is in unscheduled PS mode at the time of the frame transmission.

Alternatively, to change its power state without a wakeup schedule, the PCP shall inform all associated STAs by completing a successful frame exchange (as described in Annex G) that is initiated by the PCP and that includes a Management frame, Extension frame or Data frame, and also an Ack or a BlockAck frame from the associated STA. The Power Management subfield(s) in the Frame Control field of the frame(s) sent by the PCP in this exchange that contain a BU or are QoS Null frame indicate the power state that the PCP shall adopt upon successful completion of the entire frame exchange. The PCP shall not change its power state using a frame exchange that does not receive an Ack or BlockAck frame from the associated STA, or using a BlockAckReq frame.

When attempting to enter doze state, the PCP shall not enter doze state unless it has received an Ack or BlockAck from each associated STA. When attempting to leave doze state, the PCP shall enter awake state as soon as it receives an Ack or BlockAck from one associated STA.

A PCP in doze state shall limit the frames it transmits to the following:

* A Management, Extension or Data frame that triggers an Ack or a BlockAck frame from a non-AP and non-PCP STA, with the Power Management subfield in the Frame Control field of the frame set to 0, i.e., a frame to indicate the PCP intent to transition out of unscheduled PS mode.
* An RTS, DMG CTS-to-self, Grant, SSW or SSW-Feedback frame

NOTE—A DMG STA in doze state may need to perform beamforming to restore its links with other DMG STAs.

The PCP shall present the correct power state in the Frame Control field of any frame it transmits to an associated STA that contains all or part of a BU.

**10.2.6.3.3 PCP operation with a wakeup schedule**

*[New section; move all text in the current Section 10.2.6.3 to this section.]*

*[After the move, delete the following sentence, which is a wrong leftover sentence from the approved -920- document).]*

…

To enter PPS mode, or to modify an established WS, the PCP announces a WS through a DMG Wakeup Schedule element (8.4.2.130 (DMG Wakeup Schedule element)) included in a DMG Beacon, Announce, or any Action frame.

…

**10.2.6.2.4 Non-AP and non-PCP STA operation with or without a wakeup schedule**

 *[AP or PCP responsibility to maintain the WS of all associated STAs to publish on demand is not clear.]*

…

In order for a STA to learn the WS of another STA within the BSS, the STA may send an Information Request frame to the other STA or to the AP or PCP as defined in 10.30.1 (Information Request and Response). The AP or PCP maintains a WS distribution table for the lifetime of the BSS, and upon receiving an Information Request frame that contains a request for the WS of a STA identified by the Subject Address field within the frame, shall add an entry to the WS distribution table made up of the STA that transmitted the Information Request frame (the requesting STA) and the STA identified by the Subject Address field within the Information Request frame (the target STA). If the AP or PCP moves the TBTT, changes the duration of the beacon interval, or resets the TSF, the AP or PCP shall transmit an unsolicited Information Response frame with the updated DMG Wakeup Schedule element to each requesting STA in the WS distribution table. If a target STA in the WS table changes its WS, the AP or PCP shall transmit an unsolicited Information Response frame with the updated DMG Wakeup Schedule element to each requesting STA in the WS table that has the corresponding target STA. When transmitting the DMG Wakeup Schedule element for a STA that is in PS mode, the transmitting STA shall use a value for the BI Start Time field that points to a TBTT that is earlier, but not more than 231 microseconds minus aDMGDWSValidPeriod earlier, than the TBTT of the beacon interval during which the BI Start Time field is transmitted, so that the receiving STA can correctly identify the power management mode of the STA the WS belongs to.

**10.2.6.4 ATIM frame usage for power management of non-AP STAs**

*[Awake window presence limited to CBAP allocations with broadcast Source AID and broast Destination AID. Also STAs in unscheduled PS mode are not required to wake up after they receive an ATIM frame during the awake window; i.e., control is left to the STS in unscheduled PS mode to retrieve its BUs, similar to U-APSD.]*

An awake window is present within the first CBAP of a beacon interval that is scheduled through the Extended Schedule element and has the Source AID and Destination AID fields in that Extended Schedule element equal to the broadcast AID, or in a CBAP that is scheduled through the CBAP Only field in the DMG Parameters field (8.4.1.46 (DMG Parameters field)) set to 1, for dot11MaxLostBeacons beacon intervals following the most recent transmission of the Awake Window element (8.4.2.136 (Awake Window element)) by the AP or PCP with the Awake Window Duration field set to a nonzero value.

NOTE—Transmission rules during the awake window are the same as the transmission rules for the CBAP that the awake window belongs to.

...

A STA that is in PS mode and following a wakeup schedule and has not performed unscheduled power save to enter doze state and receives an ATIM frame during the awake window shall be awake during allocations within the current beacon interval that have the Source AID equal to broadcast AID or have a Source AID that identifies a STA whose MAC address is equal to the TA field of the received ATIM frame, or during any DTI that is scheduled through the CBAP Only field in the DMG Parameters field (8.4.1.46 (DMG Parameters field)) set to 1. If a STA transmits an ATIM frame during the awake window, it shall attempt to deliver its BUs during allocations within the current beacon interval that have a Destination AID equal to broadcast AID or have a Destination AID that identifies a STA whose MAC address is equal to the RA field of the transmitted ATIM frame, or during any DTI that is scheduled through the CBAP Only field in the DMG Parameters field (8.4.1.46 (DMG Parameters field)) set to 1. A STA that receives or transmits an ATIM frame during the awake window may enter the doze state when it has successfully transmitted to and received from all corresponding peer STAs for this beacon interval a QoS Data frame with the EOSP subfield set to 1; otherwise it shall stay active until the end of the current BI. ATIM frame transmissions and MSDU transmissions follow the rules defined in 10.2.3.5 (ATIM frame and frame transmission).

NOTE—A STA that has performed unscheduled power save to enter doze state and receives an ATIM frame during an awake window can use the incoming traffic indication to exercise the unscheduled power save mechanism to leave doze state following the procedure in 10.2.6.2.2 (Non-AP and non-PCP operation without a wakeup schedule) or 10.2.6.3.2 (PCP operation without a wakeup schedule).

Figure 10-xxx (Example of ATIM frame response behavior in PS mode) illustrates an example of a DMG STA response to an ATIM frame. For illustration purposes the 5 beacon intervals shown in the figure are numbered from 0 to 4. The PCP is following a wakeup schedule, with 1 Awake BI out of every 4 beacon intervals. The non-PCP STA A is also following a wakeup schedule, with 1 Awake BI out of every 2 beacon intervals. In addition, STA A performs unscheduled power save during BI 0, and also during BI 2 through BI 4. STA A is required to stay awake during the following CBAP after receiving an ATIM frame in BI 2. An ATIM frame received during BI 4 however serves as a traffic indication and PCP will transmit frames to STA A only after STA A has performed unscheduled power save to leave doze state.



**Figure 10-xxx—Example of ATIM frame response behavior in PS mode**

*[Editorial – Following the capitalization preference discussion in the 802.11 maintenance group, change all instances of “Power Management mode” to “power management mode” (global change for DMG and non-DMG).]*