IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: **Power Management in an Ad Hoc Network**

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Abstract: This submission provides ad hoc network power management text for the draft standard.

Introduction

The May 1995 letter ballot removed power management for ad hoc networks. A number of members were not in agreement with this action, but realised that additional work was necessary in order to define a practical scheme. This submission provides additional text for draft D2 that defines a new power management scheme for ad hoc networks.

The support of ad-hoc networks within the standard is an important feature, allowing a number of users to create a network to share data without pre-planning. Considering the typical scenarios where ad-hoc networks may be deployed - meeting rooms, conferences and airport lounges - participants will often be using battery powered notebook computing devices. Minimising battery drain will be important in these applications and power management is thus essential in ad-hoc networks.

This revision incorpoarates changes from the July and August 1995 meetings to Rick's original proposal.

Action

Adopt the text presented in this document into the draft standard.

8.2.2. Power Management in an Independent BSS

This section specifies the power management mechanism for use within an independent BSS.

8.2.2.1. Basic Approach

The basic approach is similar to the infrastructure case in that the stations are synchronized, and frames which are to be transmitted to a power conserving station are first announced during a period when all stations are awake. The announcement is done via an Ad Hoc Traffic Indication Message (ATIM). A power conserving station ~~need only~~ listens for these announcements to determine if its receiver must be left on.

When a frame is to be transmitted to a destination station that is in a Power Save (PS) mode, the transmitting station first transmits an ATIM frame during the ATIM Window, in which all the stations including those operating in a Power Save (PS) mode are awake. The ATIM Window is defined as a specific period of time following a beacon during which only ATIM frames can be transmitted. ATIMs are randomized after the beacon using the backoff procedure. ATIMs are acknowledged. If a station receives an ATIM frame during the ATIM Window, it will acknowledge the ATIM and stay awake for the entire Beacon Interval waiting for the announced frame(s) to be received. If a Station does not receive an ATIM, it can go back to PS Mode after the end of the ATIM Window. Frames annouced by ATIMs are randomized after the ATIM Window using the backoff procedure. If a station transmitting the ATIM does not receive an acknowledgement, the station will execute the backoff procedure for retransmission of the ATIM.

It is possible that an ATIM can be received from more that one station and that a station that receives an ATIM may receive more than a single frame from the transmitting station. ATIM frames are only addressed to the destination station of the frame.

An ATIM will have a destination address of broadcast/multicast for broadcast/multicast frames. All stations will remain awake if they receive an ATIM with a broadcast/multicast destination address.

After the ATIM Interval, the frames are transmitted using the DCF Access procedure.

The following figure illustrates the basic power save operation.

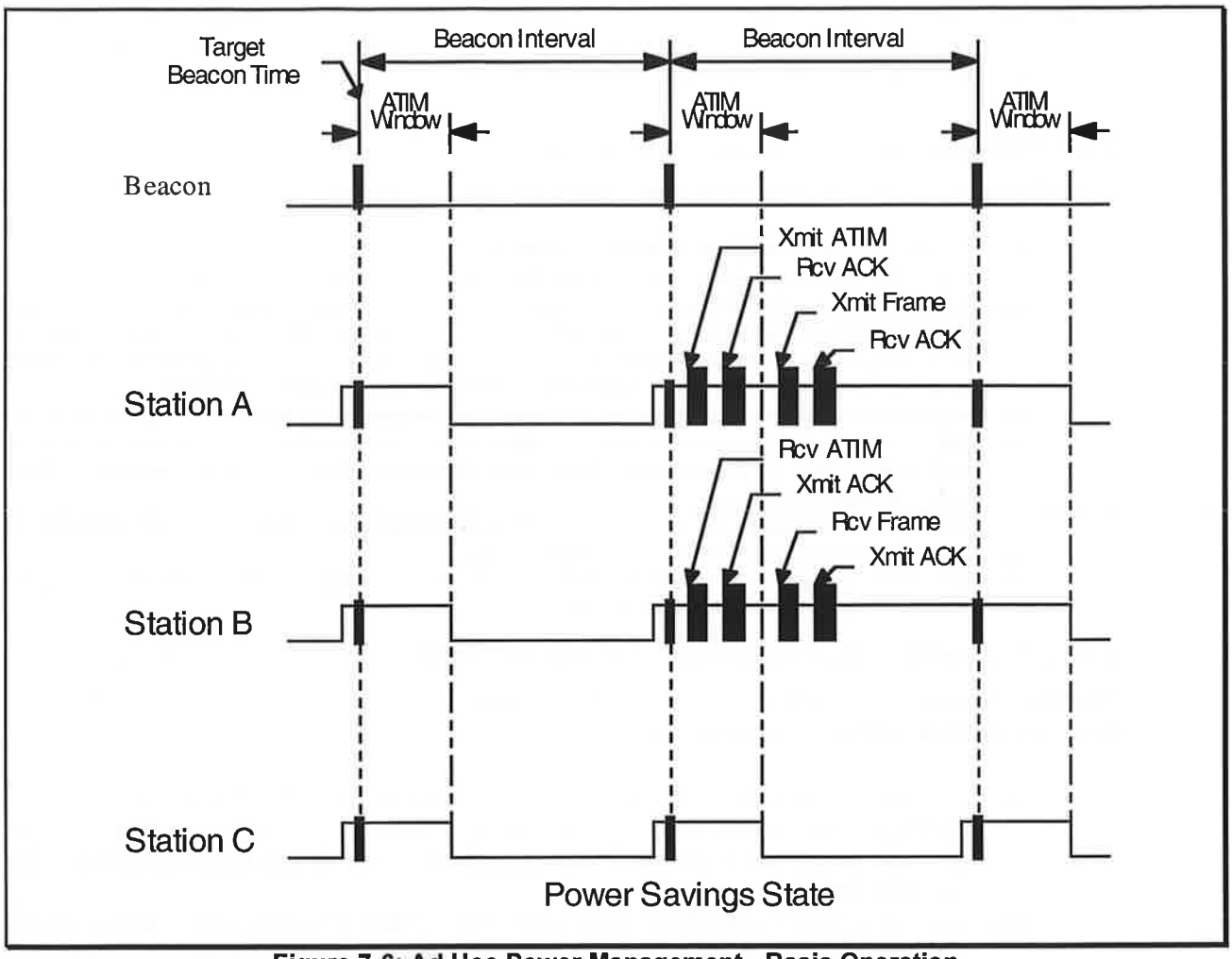

Figure 7-6: Ad Hoc Power Management - Basic Operation

The estimated power saving state of another station can be based on the power management information transmitted by that station and additional information available locally such as history of failed transmission attempts. The use of RTS/CTS in an ad hoc network can reduce the length of transmissions to a station that is in Power Save mode. If a RTS is sent and a CTS is not received, the transmitting station can assume that the destination station is Power Save mode. The method of estimating the power management state of other stations in the IBSS is outside the scope of this standard.

~~8.2.2.2. Power Management State Estimation~~

~~Each station must estimate the power management state of station with which it needs to exchange frames. This can be done in one of four ways.~~

~~1) A station can monitor the Power Management bits within the frames generated by other stations in the network. A station that intends on using PS mode must indicate that in all frames transmitted.~~
~~2) A station can transmit the frame when received from the LLC and assume the destination station is in PS mode if an Ack is not received.~~
~~3) A station can use RTS/CTS to transmit a frame. If a CTS is not received, the destination station can be assumed to be in PS mode.~~
~~4) A station can always assume all other stations are operating in PS Mode. In this case, the station will always transmit an ATIM in the ATIM Window before transmitting a frame~~

~~A station will transmit a frame when received from the LLC to the destination station if the destination station is assumed not to be in PS mode and it is not during an ATIM interval.~~

~~If RTS/CTS is used, the destination station will be assumed to be in PS mode and the frame will be buffered if a CTS is not received. If RTS/CTS is not being used, the destination station will be assumed to be in PS mode and the frame will be buffered if an Ack is not received.~~

~~8.2.2.3. ATIM Window and Beacon Transmission~~

~~The following procedure is used to receive and transmit beacons and transmit ATIM frames:~~

~~a) Station shall wake up prior to Target Beacon Time.~~
~~Target Beacon Time is defined as: [TSFTIMER]MODaBeacon_Interval = 0~~
~~b) The length of the ATIM window is defined in the Ad Hoc Parameters Set element in the Beacon. A station that receives a beacon will update its aATIM_Window MIB variable with the value contained in the beacon. A station that transmits a beacon will use the value of the aATIM_Window MIB variable for the ATIM Window parameter in the Ad Hoc Parameter Set element.~~
~~c) Station receives/transmits a Beacon. The procedure for generating Beacons is defined in Section 8.1.~~
~~d) After a Beacon is received/transmitted, a station may transmit ATIMs for all buffered frames until the end of the ATIM Window using the DCF Access Procedure. ATIMs are randomized after the beacon using the backoff procedure~~
~~End of ATIM Window is defined as: [TSFTIMER]MODaBeacon_Interval – aATIM_Window = 0~~
~~e) ATIMs are acknowledged by the receiving station.~~
~~f) If a station has an ATIM to transmit and is unable to do so before the end of the ATIM Window, it must wait until the next ATIM Window.~~

8.2.2.2 Initialisation of power management within an IBSS

The following procedure shall be used to initialise power management within a new IBSS, or to learn about the power management being used within an existing IBSS.

a) A STA joining an existing IBSS by the procedure in subclause 8.1.3.3 shall replace its aATIM_Window MIB attribute with the value contained in the ATIM Window field of the ATIM Parameter Set element within the Beacon, or Probe Response Management frame received during the scan procedure.
b) A STA creating a new IBSS by the procedure in subclause 8.1.3.3 shall set the value of the ATIM Window field of the ATIM Parameter set element within the Beacon Management frames transmitted to the value of its aATIM_Window MIB attribute.
c) The start of the ATIM Window shall be the Target Beacon Transmission Time, defined in subclause 8.1.2.2.. The end of the ATIM Window shall be defined as [TSFTIMER]MODaBeacon_Interval – aATIM_Window=0.
d) The ATIM Window period shall be static during the lifetime of the IBSS.
e) An ATIM Window value of zero shall indicate that power management is not in use within the IBSS.

8.2.2.3 STA Power State Transitions

A STA may enter power save mode iff the value of the ATIM Window in use within the IBSS is greater than zero. A STA shall set the Power Management subfield in the Frame Control field of frames that it transmits according to the procedure in subclause 4.1.2.1.7. A station in active mode may use either of the Active Mode codes defined.

A STA in power save mode shall transition between awake and doze states according to the following rules:

a) If a STA is operating in power save mode it shall enter the awake state prior to each Target Beacon Transmission Time.
b) If a STA receives a directed ATIM Management frame containing its individual address, or a multicast ATIM Management frame during the ATIM Window it shall remain in the awake state until the end of the next ATIM Window..
c) If a STA transmits an ATIM Management frame it shall remain in the awake state until the end of the next ATIM Window regardless of whether an acknowledgement is received for the ATIM.

d) If the STA has not transmitted an ATIM and does not receive either a directed ATIM Management frame containing its individual address, or a multicast ATIM management frame during the ATIM Window, it may return to the doze state following the end of the current ATIM Window.

8.2.2.4. ATIM and Frame Transmission

If power management is in use within an IBSS, all STAs shall buffer frames for stations that are known to be in power save mode. The estimation of the power management state of stations within the IBSS is outside the scope of this standard. Frames to STAs in active mode may be sent at any valid time.

a) Following the reception or transmission of the Beacon and during the ATIM Window, the STA shall transmit a directed ATIM Management frame to each STA for which it has one or more buffered unicast frames. If the STA has one or more multicast frames buffered it shall transmit a multicast ATIM frame.
b) All STAs shall use the backoff procedure defined in subclause 6.2.6.2 for transmission of the first ATIM following the Beacon. All remaining ATIMs shall be transmitted using the conventional DCF access procedure.
c) ATIM Management frames shall only be transmitted during the ATIM Window.
d) A STA shall not transmit frame types other than Beacon and ATIM Management frames during the ATIM Window.
e) Directed ATIM Management Frames shall be acknowledged. If no acknowldgement is received the ATIM shall be retransmitted using the conventional DCF access procedure. Multicast ATIM Management frames shall not be acknowledged.
f) If an STA is unable to transmit an ATIM during the ATIM Window, for example due to contention with other STAs, the STA shall retain the buffered frame(s) and attempt to transmit the ATIM during the next ATIM Window.
g) Immediately following the ATIM Window, a STA shall begin transmission of buffered frames to STAs for which a valid acknowledgement for a transmitted ATIM frame was received. All STAs shall use the backoff procedure defined in subclause 6.2.6.2 for transmission of the first frame following the Beacon. All remaining frames shall be transmitted using the conventional DCF access procedure.
h) A buffered MSDU may be transmitted using fragmentation. If an MSDU has been partially transmitted when the next beacon frame is sent, the STA shall retain the buffered frame and announce the remaing fragments by transmitting an ATIM during the next ATIM Window.
i) If an STA is unable to transmit a buffered frame during the beacon interval in which it was announced, for example due to contention with other STAs, the STA shall retain the buffered frame and announce the frame again by transmitting an ATIM during the next ATIM Window.
j) Following the transmission of all buffered frames, an STA may transmit frames without announcement to STAs that are known to be in the awake state for the current beacon interval due to an appropriate ATIM having been successfully transmitted or received.

~~8.2.2.4. ATIM and Frame Transmission~~

~~A station that has frames buffered for a station that is assumed to be in PS mode shall operate as follows:~~

~~a) The station will send an ATIM during the ATIM Window. ATIMs are randomized after the beacon using the backoff procedure~~
~~b) Only ATIMs and their associated acknowledgments shall be transmitted during the ATIM Window. ATIMs can only be transmitted during the ATIM Window.~~
~~c) Following the ATIM Window, the station will transmit the announced. Announced frames are randomized ater the ATIM Window using the backoff procedure.~~
~~d) The station transmitting the ATIM will remain awake for the entire Beacon Interval.~~
~~e) Buffered frames may be fragmented.~~

~~f) If more than one frame is buffered for a given station, multiple frames can be transmitted using the DCF Access procedure. A frame will indicate if more frames are buffered via the Power Management bits.~~

~~A frame that is in the process of backoff will be considered a buffered frame for the purpose of ad hoc power management. In other words, an ATIM will be transmitted every ATIM Window until the frame is successfully delivered or times out, even if the frame may not be transmitted during the beacon interval because it is in the process of backoff.~~

~~A fragmented frame that has outstanding fragments will also be considered a buffered frame for the purpose of ad hoc power management.~~

~~8.2.2.5. Receive Operation for PS Mode~~

~~A station which wishes to conserve power in ad hoc mode shall operate as follows:~~

~~a) Stations shall wake up prior to Target Beacon Time.~~
~~b) The station will remain awake for the duration of the ATIM Window.~~
~~c) If an ATIM addressed to the station is not received, the station may go back to Power Save mode at the end of the ATIM Window.~~
~~d) If the station receives an ATIM frame, it will acknowledge the ATIM and the station shall remain awake for the entire Beacon Interval to receive the subsequent announced frame/s.~~

Author's Note: The following changes should be made in Section 5.

5.2.3.1. BEACON Frame Format

The Frame Body of a Management frame of Subtype Beacon shall contain the following information:

Order	Information	Note
1	Timestamp	
2	Beacon Interval	
3	Regulatory Domain	
4	Capability Information	
5	ESS ID	
6	Supported Rates	
7	FH Parameter Set	1
8	CF Parameter Set	2
9	Ad Hoc Parameter Set	3
10	DTIM	
11	TIM	

Notes:

1 The FH Parameter Set information shall be mandatory only within Beacon Frames generated by STAs using Frequency Hopping Physical Layers

2 The CF Parameter Set information shall be mandatory only within Beacon Frames generated by APs supporting a PCF

3 The Ad Hoc Parameter information set shall be mandatory only within Beacon Frames generated by STAs in an Ad Hoc Network

5.2.3.2 Ad Hoc Traffic Indicator Message (ATIM) Frame Format

The Frame Body Shall be Null.

5.2.3.9. Probe Response Frame Format

The Frame Body of a Management frame of Subtype Probe Response shall contain the following information:

Order	Information	Note
1	Timestamp	
2	Beacon Interval	
3	Regulatory Domain	
4	Capability Information	
5	ESS ID	
6	Supported Rates	
7	FH Parameter Set	1
8	CF Parameter Set	2
9	Ad Hoc Parameter Set	3

Notes:

1 The FH Parameter Set information shall be mandatory only within Probe Response Frames generated by STAs using Frequency Hopping Physical Layers

2 The CF Parameter Set information shall be mandatory only within Probe Response Frames generated by APs supporting a PCF

3 The Ad Hoc Parameter set information shall be mandatory only within Probe Response Frames generated by STAs in an Ad Hoc Network

5.4.2 Information Elements

Elements are defined to have a common general format consisting of a one-octet Element ID field, a one octet length field and a variable-length element-specific information field. Each element is assigned a unique Element ID as defined in this specification. The length field shall specify the number of octets in the information field.

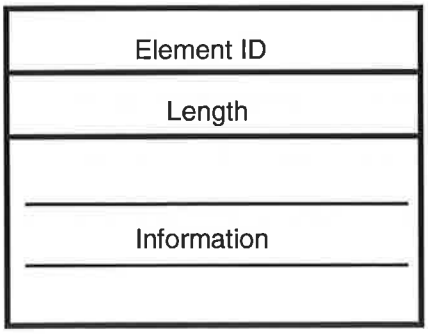

Figure 5-13, Element Format

The set of valid elements is defined below.

Information Element	Element ID
ESSID	0
Supported Rates	1
FH Parameter Set	2
CF Parameter Set	3
DTIM	4
TIM	5
Challenge Text	6
Ad Hoc Parameter Set	7

5.4.2.9 Ad Hoc Parameter Set

The Ad Hoc Parameter Set element shall contain the set of parameters necessary to support an Ad Hoc Network. The information Field shall contain ATIM Window parameter.

Element ID	1 octet
Length	1 octet
ATIMWindow	4 octets

The ATIM Window field shall be 4 octets in length and contain the ATIM Window length in μs.

Author's Note: The following MIB Variable should be added to Section 8.4.

8.4.X.X.X aATIM_Window

ATIM_Window ATTRIBUTE
WITH APPROPRIATE SYNTAX
integer
BEHAVIOUR
"The ATIM Window shall indicate the time in microseconds of the ATIM window in an Ad Hoc Network. The ATIM Window defines the period of time that ATIM frames can be sent to Power Save mode Stations in an Ad Hoc network. The ATIM window begins at the Target Beacon Time.
REGISTER AS
{ iso(1) member-body(2) us(840) ieee802dot11(xxxx) SMT(x) attribute(x) atim_window(x) };