IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: Proposed Revisions to Section 7.1, 7.2, and 7.3 of P802.11/D1.1

Many authors participated in the creation of these proposed changes.

Abstract: This paper presents the changes to section 7.1, 7.2, and 7.3 to address a large number of letter ballot comments..

Action: Adopt the changes in this paper to replace the relevent portions of Section 7.1, 7.2, and 7.3 of P802.11/D1.1.

7. MAC Layer Management Entity

7.1. Synchronization

7.1.1. Basic Approach

7.1.1.1. TSF for Infrastructure Networks

In an infrastructure network, the AP shall be the timing master and shall perform the Timing Synchronization Function. The AP shall initialize the TSF timer such that simultaneously started APs are not synchronized. To synchronize the other stations in a BSS, the AP shall periodically transmit special frames called Beacons that contain a copy of its Synchronization Timer. Receiving stations shall always accept the timing information in Beacons sent from the AP servicing their BSS. If the station's Synchronization Timer is different from the timestamp in the received Beacon, they shall set their local timer to the received timestamp value.

Beacons shall be generated for transmission by the AP once every aBeacon_Interval time units.

7.1.2. Maintaining Synchronization

7.1.2.1. Beacon Generation in Infrastructure Networks

7.1.2.2. Beacon Generation in Ad Hoc Networks

Beacon generation in an ad hoc network is distributed. All members of the BSS participate in Beacon generation. Each station shall maintain its own TSF timer which is used for aBeacon_Interval timing. This defines a series of Target Beacon Transmission Times (TBTTs) exactly aBeacon_Interval time units apart, time zero is defined to be a TBTT. At each TBTT the station shall 1) ~~save the timestamp from the most recently received Beacon, 2)~~ calculate a random delay, 2~~3~~) wait for the period of the random delay, 3~~4~~) if no Beacon has arrived during the delay period, send a Beacon~~one, go to step 1, otherwise 5) go to step 2~~. See Figure 7-2.

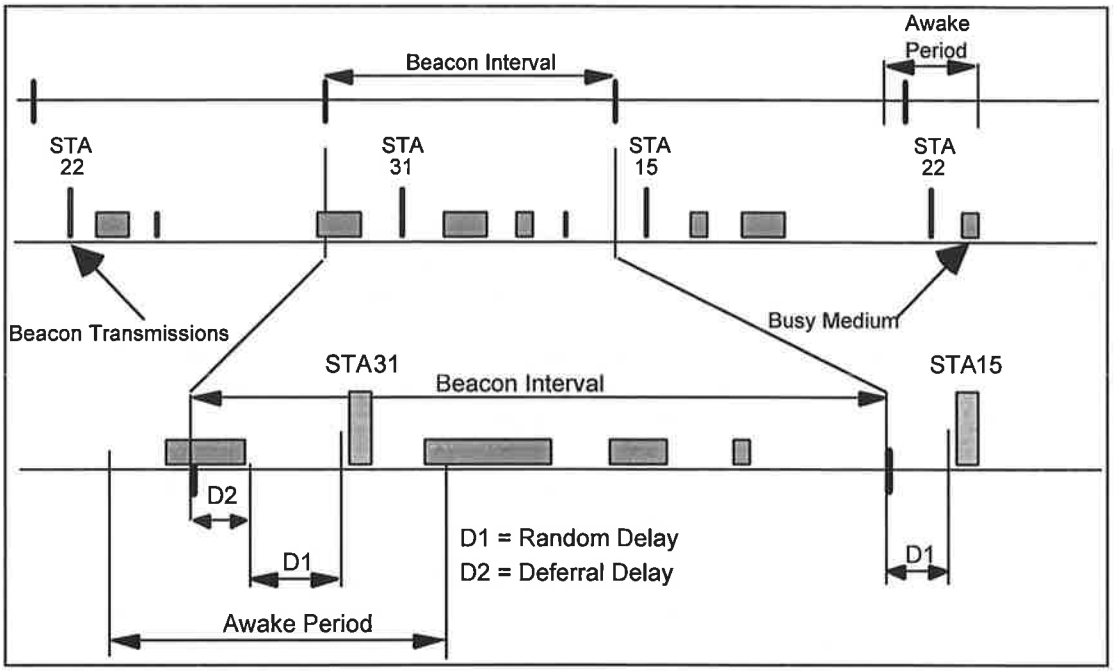

Figure 7-2 — Beacon transmission in an Ad Hoc network.

The Beacon transmission will always occur during the Awake Period of stations that are operating in a low power mode. This is described in more detail in Section 7.2.

7.2. Power Management

7.2.1. Power Management in an Infrastructure Network~~Mode~~

7.2.1.1. Overview

Stations changing power management mode shall inform the AP of this fact (via the Power Management bits within transmitted frames). The AP shall not arbitrarily transmit frames to station operating in a power saving mode, but shall buffer frames and only transmit them at designated times.

The stations which currently have buffered frames within the AP are identified in a **Traffic Indication Map (TIM)**, which shall be included as an element within all Beacons generated by the AP. A station shall determine that a frame is buffered for it by receiving and interpreting a TIM.

Stations operating in power save modes shall periodically listen for Beacon~~beacons~~, as determined by the Station's **a~~MACMGT~~_Listen_Interval** parameter.

Upon determining that a frame is currently buffered in the AP, a Station operating in the **Power Save Polling** mode (PSP) shall transmit a short Poll frame to the AP, which will respond with the corresponding buffered frame. ~~Stations operating in the **Power Save Non-Polling** mode (PSNP) shall listen for certain specific TIMs (called **Delivery TIMs, or DTIMs**) after which the AP shall deliver their buffered frames without waiting for a poll.~~ If any station in its BSS is in power saving mode, the AP shall buffer all broadcast and multicast frames and~~Broadcast or multicast frames shall be~~ delivered them to all stations following a~~the DTIM~~**Delivery TIM** (DTIM) transmissions.

A station shall remain in its current power management mode until it informs the AP of a power management mode change via a successful frame exchange. Power management mode shall not change during any single frame exchange sequence, as described in section 4.3.

7.2.1.2. Station Power Management Modes

A station ~~transceiver~~ can be in two~~three~~ different power states:

> ~~**Transmit**: Transmitter is turned on.~~
>
> **Awake**: Station~~Receiver~~ is fully powered.
>
> **Doze**: Station~~Transceiver~~ is not able to transmit or receive and consumes very low power. Some circuitry (such as~~like~~ timers) may still be active.

The manner in which a station ~~commands its transceiver to~~ transitions between~~among~~ these two~~three~~ power states shall be~~is~~ determined by the station's Power Management Mode (a~~MACMGT~~_Power_Management_Mode). ~~Stations which always leave their receiver on are said to operate in a *Continuous Active Mode* (i.e., MACMGT_Power_Management_Mode = CAM). Such a station will likely achieve the highest level of performance. A Station which has its receiver on temporarily is said to operate in *Temporary Active Mode*. Ordinarily a station which wishes to conserve power will operate in either the *Power Save Nonpolling* or *Power Save Polling* mode.~~ These modes are summarized in the table below.

~~Continuous~~ Active ~~-~~Mode ~~or CAM~~ or AM	Station may receive frames at any time, no AP buffering of frames. In Active Mode, a station shall be in the Awake state. A station on the polling list of a PCF shall be in Active Mode for the duration of the contention free period.
~~Temporary Active Mode or TAM~~	~~Similar to CAM mode but temporary, no AP buffering~~
~~Power Save Non Polling or PSNP~~	~~Station listens to all DTIMs and keeps its receiver on if DTIM indicates a frame is buffered. AP transmits buffered frame without waiting for a poll after the DTIM is transmitted.~~
Power ~~-~~Save ~~-~~Polling or PSP	Station listens to selected TIMs (based upon its aListen_Interval) and polls the AP if the TIM indicates a frame is buffered for that station (except for broadcasts). The AP shall ~~only~~ transmits buffered unicast frames only in response to a poll. In PSP mode, a station shall be in the Doze state and shall enter the Awake state to listen for selected TIMs and to transmit.

~~Transitions between any of the major modes identified in the table require that the AP be informed.~~To change power management modes, a station shall inform the AP through a successful frame exchange initiated by the station.

7.2.1.3. Access Point TIM Transmissions

The TIM will identify the stations for which traffic is pending and buffered in the AP. This information is coded in a *virtual bitmap*, as described in Section 4. In addition the TIM~~it~~ contains an indication whether Broadcast/m~~M~~ulticast traffic is pending. ~~This information is coded in a *virtual bitmap*, as described in Section 4.~~ Every station is assigned a Station ID code (SID) by the AP as part of the association process (see Section 7~~6~~.3). SID 0 (zero) shall be reserved to indicate the presence of buffered broadcast/multicast frames. The AP shall identify those stations for which frames are buffered by setting bits in the TIM's virtual bitmap that~~which~~ correspond to the appropriate SIDs.

7.2.1.4. TIM Types

Two different TIM types are distinguished: ~~(ordinary)~~ TIM~~,~~ and DTIM~~, which stands for Delivery TIM~~. ~~Immediately a~~After a DTIM, the AP shall send out the stored Broadcast/Multicast frames using normal frame transmission rules~~, and all the frames stored (only those announced in the DTIM) for stations operating in the PSNP mode~~.

The AP shall transmit TIMs with every Beacon. Every a~~MACMGT~~ DTIM_Interval, a TIM of type "DTIM" is transmitted within a Beacon rather than an ordinary TIM.

The following figure illustrates the AP and station activity under the assumption that a DTIM is transmitted once every three TIMs.

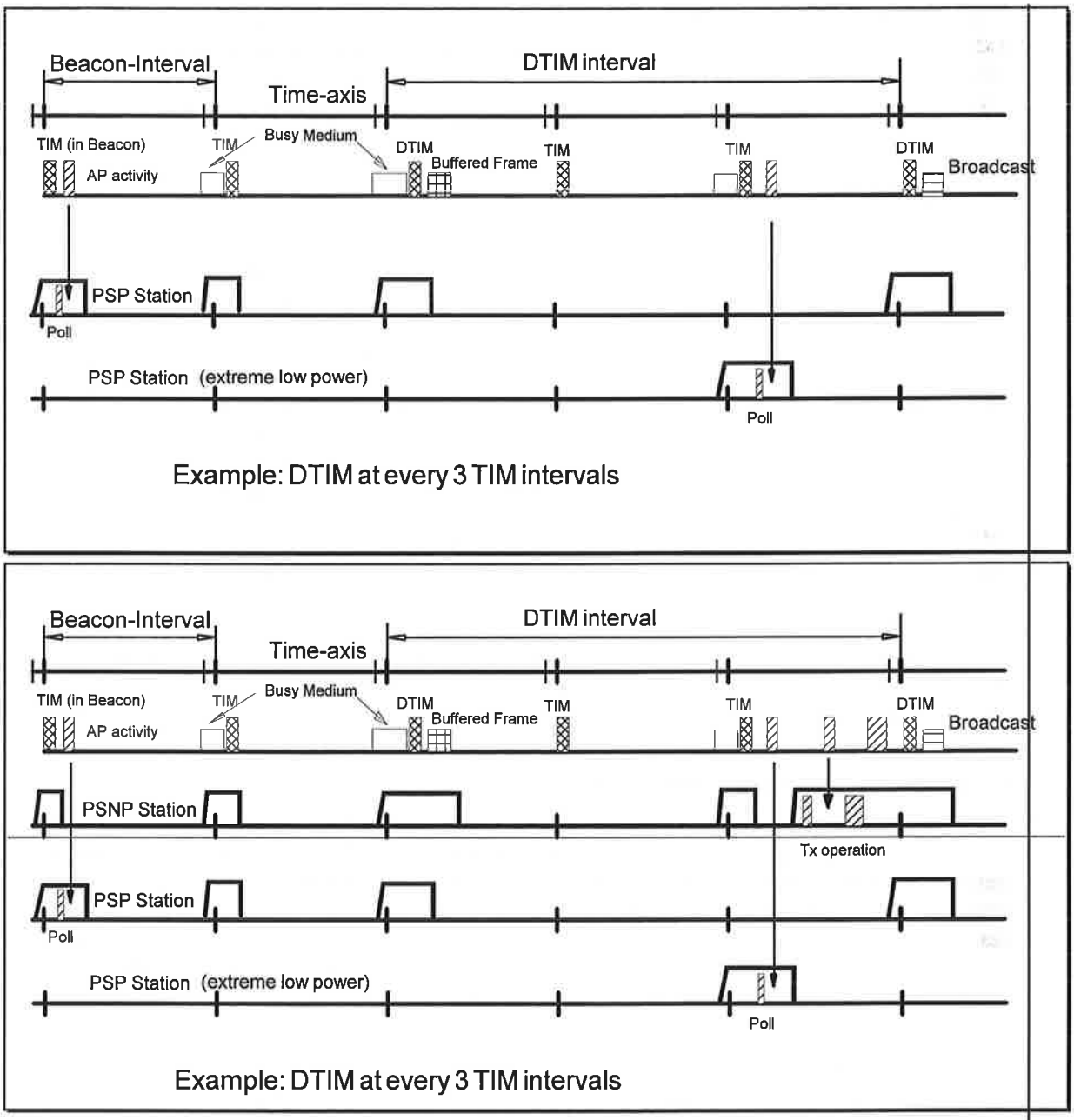

Figure 7-5: Infrastructure Power Management Operation (No PCF Operating)

7.2.1.5. Access Point Operation During the Contention Period

Access Points shall maintain a Power Management status for each currently associated~~per~~ station that indicates in which Power Management mode the station is currently operating. An AP shall, depending on the Power Management mode of the station, buffer the frame destined to the station temporarily. No~~All~~ frames received for stations operating in the Active~~CAM or TAM~~ mode shall ~~not~~ be buffered~~, but are directly forwarded~~. ~~The station Power Management operational modes are indicated in the header of each frame transmitted to the AP. Stations can dynamically change modes, and shall indicate this in the frames transmitted to the AP.~~

a) Frames destined for~~to PSNP and~~ PSP stations shall be temporarily buffered in the AP.
b) Frames destined to stations in the Active~~CAM or TAM~~ mode shall be directly transmitted.
c) At every Beacon Interval, the AP shall assemble the virtual bitmap containing the buffer status per destination for stations in the PSP~~ and PSNP~~ modes, and shall send this out in the TIM field of the Beacon. The bit for SID 0 (zero) shall be set ~~A Broadcast indication shall be included~~ whenever b~~B~~roadcast or multicast traffic is buffered.
d) All Broadcast/Multicast frames shall be buffered if any associated stations are in PSP mode.
e) After every DTIM, the AP shall transmit all~~the~~ buffered broadcast/multicast frames~~, and the frames destined for stations in the PSNP mode~~.
f) Buffered frames for stations in the PSP mode shall be forwarded to the station after a Poll has been received from that station.
g) An AP shall have an aging function to delete pending traffic when it was buffered for an excessive time period. ~~The maximum age of a buffered item will depend on the Power Management mode (PSNP or PSP) of the station, or as further negotiated by the station at association time.~~
h) Whenever an AP is informed that a station changes to the Active~~TAM~~ M~~m~~ode, then the AP shall send buffered frames (if any exist) to that station immediately.

7.2.1.6. Access Point Operation During the Contention Free Period

Access Points shall maintain a Power Management status for each currently associated CF Aware station that indicates in which Power Management mode the station is currently operating. An AP shall, for stations in PSP Mode, buffer the frame destined to the station temporarily.

a) Frames destined for PSP stations shall be temporarily buffered in the AP.
b) Frames destined to stations in the Active mode shall be transmitted as defined in Section 5.
c) Prior to every Contention Free Period, the AP shall assemble the virtual bitmap containing the buffer status per destination for stations in the PSP mode, set the bits in the virtual bitmap for stations the Point Coordinator is intending to poll in this Contention Free Period, and shall send this out in the TIM field of the DTIM. The bit for SID 0 (zero) shall be set whenever broadcast or multicast traffic is buffered.
d) Buffered frames for stations in the PSP mode shall be forwarded to the CF Aware stations under control of the Point Coordinator.
e) An AP shall have an aging function to delete pending traffic when it was buffered for an excessive time period.

~~7.2.1.6.1. Receive Operation for Stations in PSNP Mode~~

~~Stations in PSNP mode shall operate as follows to receive a frame from the AP:~~

~~a) Stations shall wake up so as to receive every DTIM and shall decode the virtual bitmap.~~
~~b) Whenever traffic is pending (either unicast or broadcast), then the station shall stay awake after the DTIM to receive the buffered frames.~~
~~c) Whenever the "More" bit in the frame header indicates that more data is pending, the station shall stay awake until all buffered frames are received.~~
~~d) Whenever no traffic is pending the Stations shall go into the Doze state again, scheduled to wake up at the next DTIM.~~

7.2.1.7. Receive Operation for Stations in PSP Mode During the Contention Period

Stations in PSP mode shall operate as follows to receive a frame from the AP when not participating in the contention free period:

a) Stations shall wake-up so as to receive the next scheduled Beacon after Listen Interval from the last received Beacon.

b) ~~Whenever traffic is pending (no broadcast), then the station shall issue a Poll to retrieve the buffered frame.~~When a station detects that the bit corresponding to its SID is set in the TIM, the station shall issue a Poll to retrieve the buffered frame. If more than one bit is set in the TIM, the Poll shall be transmitted after a random delay.

c) If the Power Management~~"More"~~ bits in the received frame indicates that more traffic for that station is buffered, the station shall Poll until no more frames are buffered for that station.

d) To receive broadcast frames, the station shall wake up so as to receive every DTIM.

7.2.1.8. Receive Operation for Stations in PSP Mode During the Contention Free Period

Stations in PSP mode that are associated as CF Aware shall operate as follows to receive a frame from the AP during the contention free period:

a) Stations shall wake-up so as to receive the next scheduled DTIM.

b) When a station detects that the bit corresponding to its SID is set in the DTIM, the station shall remain awake for the duration of the contention free period to receive the frame(s) buffered for it in the AP or until a frame is received with the Power Management bits indicating no further traffic is buffered.

c) If the Power Management bits in the received frame indicate that more traffic for that station is buffered and the contention free period ends, the station may send a Poll to the AP to request the delivery of additional buffered frames.

~~7.2.1.8.1. PSNP and PSP Station Transmitter Operation~~

~~Stations operating in the PSP and PSNP mode shall operate as follows whenever a user data frame is passed down to the MAC for transmission:~~

~~If the transceiver's state is not "Doze" then MPDU transmission is accomplished as described in Section 5.~~

~~If the transceiver's state is "Doze", then the transceiver is powered on and placed into "Awake" state. The normal CSMA transmission rules of Section 5 then apply.~~

~~7.2.1.8.2. Stations operating in the TAM Mode~~

~~a) An AP shall transmit all buffered frames for a TAM station immediately after the station has indicated a mode change to the TAM mode to the AP.~~

~~b) An AP shall send incoming frames for stations in the TAM mode without any buffering.~~

~~c) A station shall switch to the TAM mode under control of a "MACMGT_Transmit_Holdover" parameter, which indicates how long a station stays awake after every transmission.~~

~~d) Whenever the MACMGT_Transmit_Holdover value is non zero, then the station will change to the TAM mode, and remains in this mode under control of a "Transmit_Holdover" Timer.~~

~~e) When this timer expires, then the station shall transmit a frame indicating the mode change back to its original mode to the AP, and goes into the Doze state. This frame is a NULL frame unless another data frame is scheduled for transmission.~~

7.2.1.9. Stations Operating in the Active~~CAM~~ Mode

Stations operating in this mode shall have their transceivers activated continuously, so they do not need to interpret the traffic announcement part of the Beacon~~beacon~~s.

~~7.2.2. Power Management in an Ad Hoc Network~~

~~This section specifies the power management mechanisms for ad hoc networks.~~

7.2.2.1. 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 (in a short transmission) by the transmitter. A power conserving station need only listen for these announcements (called Ad Hoc TIMs, or *ATIMs*) 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 mode, then the transmitting station first transmits an ATIM frame in a predetermined window in which all the stations operating in a power save mode are awake. In the case that a short frame is to be transmitted, then the frame itself is transmitted.

ATIM frames are only addressed to the destination station of the subsequent frame.

The estimated power saving state of another station shall be based on the power management information transmitted by that station and additional information available locally (such as history of failed transmission attempts) which may be deemed relevant.

7.2.2.2. Frame Reception with Power Conservation

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

a) The transceiver shall change to the "Awake" state at a predetermined "wake-up_window" time, triggered by the Beacon_Interval timer.
b) The transceiver shall stay in the "Awake" state for a predetermined interval, unless an ATIM frame addressed to this station (Station address or multicast) is received.
c) If the station receives an ATIM frame, then the station shall remain in the Awake state until it receives a subsequent Data frame.

This is illustrated in the following figure.

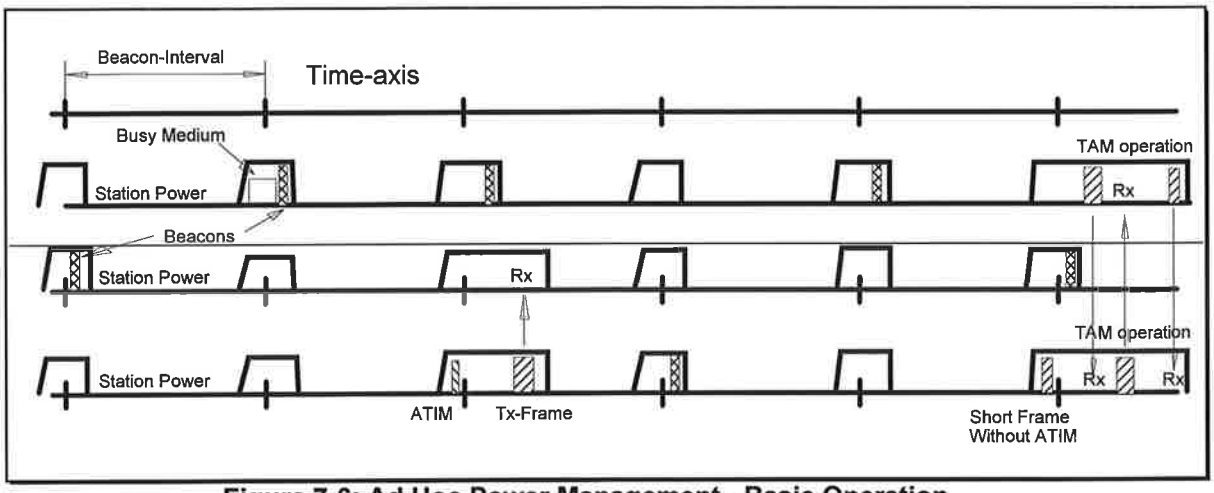

Figure 7-6: Ad Hoc Power Management - Basic Operation

7.2.2.3. Frame Transmission

Each station shall monitor the power-management status of the other stations with which it needs to exchange frames. This is determined by examining the power-management bits within the frames generated by the other stations.

To transmit a frame, a station shall perform the following steps:

~~a) If the destination station is operating in the CAM (or TAM) mode, then the station shall transmit the frame using the normal CSMA/CA transmit rules.~~

~~b) If the destination station is not operating in the CAM or TAM mode, the transmitting station shall wait until its TFS Timer indicates a station awake status, which is some time (awake_Window) before the next Beacon frame is scheduled to arrive.~~

~~c) Then the transmitting station shall transmit an ATIM frame to the destination station, which shall be Acked by the destination station.~~

~~d) The actual Data frame shall be sent when the awake period has elapsed.~~

~~e) The contents of the transmitted ATIM are identical to the header of the Data frame, with the appropriate Type field set to indicate a ATIM.~~

7.3. Association and Reassociation

This section defines how a station associates and reassociates with an access point.

7.3.1. Station Association Procedures

A station shall associate with an access point via the following procedure:

a) The station shall transmit a ASSOCIATION Request frame to an access point. ~~of type Request including the Associate element and the Previous AP Address element. This is transmitted using normal CSMA/CA procedures and requires an acknowledgment. The station shall start timer AWAIT_ASSO_RESPONSE with value MAC.await_asso_response_timeout.~~

b) If ~~no acknowledgment is received,~~transmission fails, ~~the association attempt has failed. T~~the station shall scan for a different access point with which to attempt association.

~~c) If the AWAIT_ASSO_RESPONSE timer expires, the association attempt has failed. The station shall scan for a different access point with which to attempt association.~~

c~~d~~) If an ASSOCIATION Response~~RESPONSE~~ frame is received ~~with the Associate element~~with status value of "successful", ~~the station shall cancel timer AWAIT_ASSO_RESPONSE. The station shall accept the new MIB values passed to it as elements within the RESPONSE frame. The station is now associated with the access~~ the station is now associated with the access point.

d) If an ASSOCIATION Response frame is received with status value of "failed", the station shall scan for a different access point with which to attempt association.

7.3.2. Access Point Association Procedures

An access point shall operate as follows in order to support the association of stations.

a) Whenever an ASSOCIATION Request~~REQUEST~~ frame is received from a station, ~~with an Associate element is received from a station~~, the access point shall transmit a ASSOCIATION response with a status value of "successful" or "failed". If the status value is "successful", the assigned ~~a~~ Station ID to the station is included in the response, ~~and shall transmit a RESPONSE frame with an Associate element back to the station. The RESPONSE frame shall include the Timestamp, Station ID, DTIM Period, and Beacon Interval elements~~.

b) When the ASSOCIATION Response with a status value of "successful"~~RESPONSE~~ frame is acknowledged by the station, the station is considered to be associated with this access point.

c) The AP shall~~shall~~ inform the Disribution System of ~~other access points regarding~~ the ~~new~~ association.

7.3.3. Station Reassociation Procedures

A station shall reassociate with an access point via the following procedure:

a) The station shall transmit a REASSOCIATION Request frame to an access point.

b) If transmission fails, the station shall scan for a different access point with which to attempt reassociation.

c) If an REASSOCIATION Responseframe is received with status value of "successful", the station is now associated with the access point.

d) If an REASSOCIATION Response frame is received with status value of "failed", the station shall scan for a different access point with which to attempt reassociation.

7.3.4. Access Point Reassociation Procedures

An access point shall operate as follows in order to support the reassociation of stations.

a) Whenever an REASSOCIATION Request frame is received from a station, , the access point shall transmit a REASSOCIATION response with a status value of "successful" or "failed". If the status value is "successful", the assigned Station ID to the station is included in the response..

b) When the REASSOCIATION Response with a status value of "successful" frame is acknowledged by the station, the station is considered to be associated with this access point.

c) The AP shall inform the Disribution System of the reassociation.