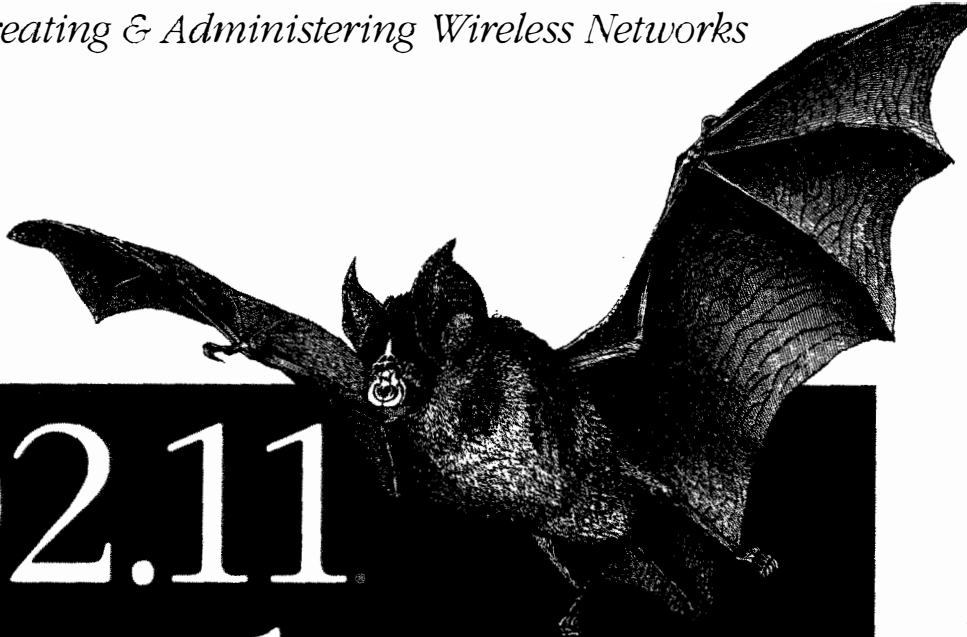


2nd Edition

Covers 802.11a, g, n & i

Creating & Administering Wireless Networks



802.11[®] Wireless Networks

The Definitive Guide



O'REILLY[®]

Matthew S. Gast
SCT Exhibit 2024
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SECOND EDITION

802.11[®] Wireless Networks: The Definitive Guide

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802.11® Wireless Networks: The Definitive Guide, Second Edition

by Matthew Gast

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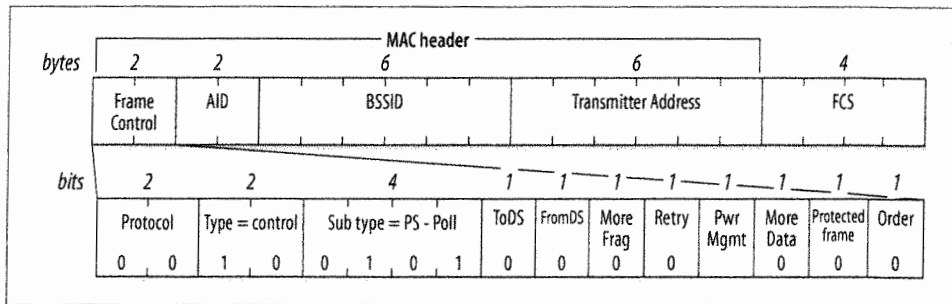


Figure 4-19. PS-Poll frame

Association ID (AID)

Instead of a Duration field, the PS-Poll frame uses the third and fourth bytes in the MAC header for the association ID. This is a numeric value assigned by the access point to identify the association. Including this ID in the frame allows the access point to find any frames buffered for the now-awakened mobile station.

Address 1: BSSID

This field contains the BSSID of the BSS created by the access point that the sender is currently associated with.

Address 2: Transmitter Address

This is the address of the sender of the PS-Poll frame.

The PS-Poll frame does not include duration information to update the NAV. However, all stations receiving a PS-Poll frame update the NAV by the short interframe space plus the amount of time required to transmit an ACK. The automatic NAV update allows the access point to transmit an ACK with a small probability of collision with a mobile station.

Association ID (AID)

In the PS-Poll frame, the Duration/ID field is an association ID rather than a value used by the virtual carrier-sensing function. When mobile stations associate with an access point, the access point assigns a value called the Association ID (AID) from the range 1-2,007. The AID is used for a variety of purposes that appear throughout this book.

Management Frames

Management is a large component of the 802.11 specification. Several different types of management frames are used to provide services that are simple on a wired network. Establishing the identity of a network station is easy on a wired network because network connections require dragging wires from a central location to the new workstation. In many cases, patch panels in the wiring closet are used to speed up installation,

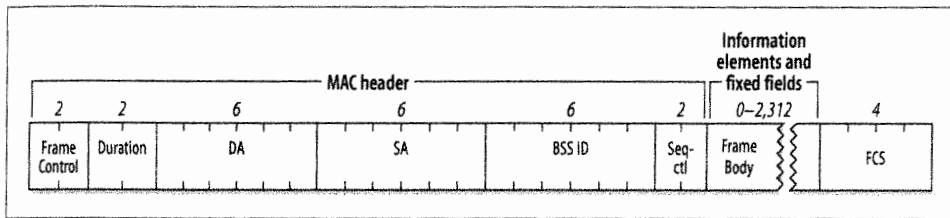


Figure 4-20. Generic management frame

but the essential point remains: new network connections can be authenticated by a personal visit when the new connection is brought up.

Wireless networks must create management features to provide similar functionality. 802.11 breaks the procedure up into three components. Mobile stations in search of connectivity must first locate a compatible wireless network to use for access. With wired networks, this step typically involves finding the appropriate data jack on the wall. Next, the network must authenticate mobile stations to establish that the authenticated identity is allowed to connect to the network. The wired-network equivalent is provided by the network itself. If signals cannot leave the wire, obtaining physical access is at least something of an authentication process. Finally, mobile stations must associate with an access point to gain access to the wired backbone, a step equivalent to plugging the cable into a wired network.

The Structure of Management Frames

802.11 management frames share the structure shown in Figure 4-20. The MAC header is the same in all management frames; it does not depend on the frame subtype. Management frames use *information elements*, little chunks of data with a numerical label, to communicate information to other systems.

Address fields

As with all other frames, the first address field is used for the frame's destination address. Some management frames are used to maintain properties within a single BSS. To limit the effect of broadcast and multicast management frames, stations are required to inspect the BSSID after receiving a management frame, though not all implementations perform BSSID filtering. Only broadcast and multicast frames from the BSSID that a station is currently associated with are passed to MAC management layers. The one exception to this rule is Beacon frames, which are used to announce the existence of an 802.11 network.

BSSIDs are assigned in the familiar manner. Access points use the MAC address of the wireless network interface as the BSSID. Mobile stations adopt the BSSID of the access point they are currently associated with. Stations in an IBSS use the randomly generated BSSID from the BSS creation. One exception to the rule: frames sent by the mobile

station seeking a specific network may use the BSSID of the network they are seeking, or they may use the broadcast BSSID to find all networks in the vicinity.

Duration calculations

Management frames use the Duration field in the same manner that other frames do:

1. Any frames transmitted in the contention-free period set the duration to 32,768.
2. Frames transmitted during the contention-based access periods using only the DCF use the Duration field to block access to the medium to allow any atomic frame exchanges to complete.
 - a. If the frame is a broadcast or multicast (the destination address is a group address), the duration is 0. Broadcast and multicast frames are not acknowledged, so the NAV is not needed to block access to the medium.
 - b. If a nonfinal fragment is part of a multiframe exchange, the duration is set to the number of microseconds taken up by three SIFS intervals plus the next fragment and its acknowledgment.
 - c. Final fragments use a duration that is the time required for one acknowledgment plus one SIFS.

Frame body

Management frames are quite flexible. Most of the data contained in the frame body uses fixed-length fields called *fixed fields* and variable-length fields called *information elements*. Information elements are blobs of data of varying size. Each data blob is tagged with a type number and a size, and it is understood that an information element of a certain type has its data field interpreted in a certain way. New information elements can be defined by newer revisions to the 802.11 specification; implementations that predate the revisions can ignore newer elements. Old implementations depend on backward-compatible hardware and frequently can't join networks based on the newer standards. Fortunately, new options usually can be easily turned off for compatibility.

This section presents the fixed fields and information elements as building blocks and shows how the building blocks are assembled into management frames. 802.11 mandates the order in which information elements appear, but not all elements are mandatory. This book shows all the frame building blocks in the specified order, and the discussion of each subtype notes which elements are rare and which are mutually exclusive.

Fixed-Length Management Frame Components

10 fixed-length fields may appear in management frames. Fixed-length fields are often referred to simply as *fields* to distinguish them from the variable-length information elements. Fields do not have a header to distinguish them from other parts of the frame

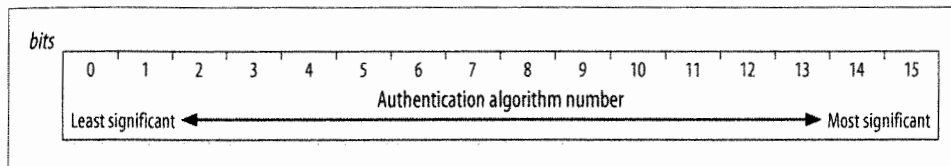


Figure 4-21. Authentication Algorithm Number field

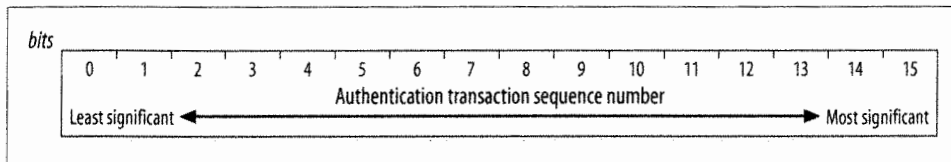


Figure 4-22. Authentication Transaction Sequence Number field

body. Because they have a fixed length and appear in a known order, fields can be delimited without using a field header.

Authentication Algorithm Number

Two bytes are used for the Authentication Algorithm Number field, which are shown in Figure 4-21. This field identifies the type of authentication used in the initial 802.11-level authentication process before association occurs. 802.1X authentication occurs after association, and is not assigned an algorithm number. (The authentication process is discussed more thoroughly in Chapter 8.) The values permitted for this field are shown in Table 4-3. Only two values are currently defined. Other values are reserved for future standardization work.

Table 4-3. Values of the Authentication Algorithm Number field

Value	Meaning
0	Open System authentication (typically used with 802.1X authentication)
1	Shared Key authentication (deprecated by 802.11i)
2-65,535	Reserved

Authentication Transaction Sequence Number

Authentication is a multistep process that consists of a challenge from the access point and a response from the mobile station attempting to associate. The Authentication Transaction Sequence Number, shown in Figure 4-22, is a two-byte field used to track progress through the authentication exchange. It takes values from 1 to 65,535; it is never set to 0. Use of this field is discussed in Chapter 8.

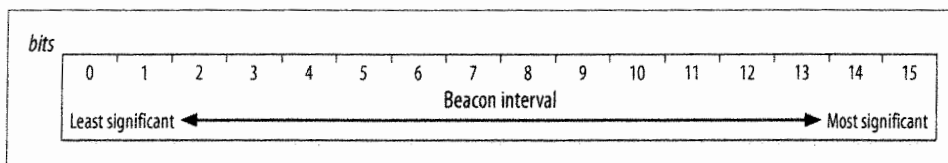


Figure 4-23. Beacon Interval field

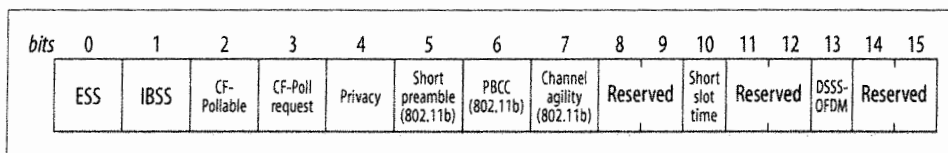


Figure 4-24. Capability Information field

Beacon interval

Beacon transmissions announce the existence of an 802.11 network at regular intervals. Beacon frames carry information about the BSS parameters and the frames buffered by access points, so mobile stations must listen to Beacons. The Beacon Interval, shown in Figure 4-23, is a 16-bit field set to the number of *time units* between Beacon transmissions. One time unit, which is often abbreviated TU, is 1,024 microseconds (ms), which is about 1 millisecond.³ Time units may also be called kilo-microseconds in various documentation (Kms or kms). It is common for the Beacon interval to be set to 100 time units, which corresponds to an interval between Beacon transmissions of approximately 100 milliseconds or 0.1 seconds.

Capability Information

The 16-bit Capability Information field (Figure 4-24) is used in Beacon transmissions to advertise the network's capabilities. Capability Information is also used in Probe Request and Probe Response frames. In this field, each bit is used as a flag to advertise a particular function of the network. Stations use the capability advertisement to determine whether they can support all the features in the BSS. Stations that do not implement all the features in the capability advertisement are not allowed to join.

ESS/IBSS

These two bits are mutually exclusive. Access points set the ESS field to 1 and the IBSS field to 0 to indicate that the access point is part of an infrastructure network. Stations in an IBSS set the ESS field to 0 and the IBSS field to 1.

3. Kilo-microseconds are an odd blend of the powers-of-2 used in computing for the kilo, and the more common 1/1,000 for micro. Presumably, the International Bureau of Weights and Measures would protest the mangling of the traditional form of the prefixes.

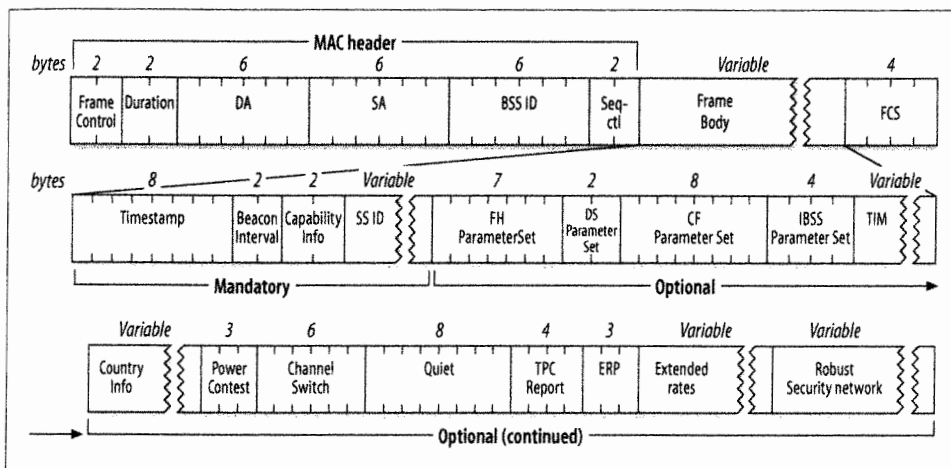


Figure 4-51. Beacon frame

Types of Management Frames

The fixed fields and information elements are used in the body of management frames to convey information. Several types of management frames exist and are used for various link-layer maintenance functions.

Beacon

Beacon frames announce the existence of a network and are an important part of many network maintenance tasks. They are transmitted at regular intervals to allow mobile stations to find and identify a network, as well as match parameters for joining the network. In an infrastructure network, the access point is responsible for transmitting Beacon frames. The area in which Beacon frames appear defines the basic service area. All communication in an infrastructure network is done through an access point, so stations on the network must be close enough to hear the Beacons.

Figure 4-51 shows most the fields that can be used in a Beacon frame in the order in which they appear. Not all of the elements are present in all Beacons. Optional fields are present only when there is a reason for them to be used. The FH and DS Parameter Sets are used only when the underlying physical layer is based on frequency hopping or direct-sequence techniques. Only one physical layer can be in use at any point, so the FH and DS Parameter Sets are mutually exclusive.

The CF Parameter Set is used only in frames generated by access points that support the PCF, which is optional. The TIM element is used only in Beacons generated by access points, because only access points perform frame buffering. If the Country-specific frequency hopping extensions were to be present, they would follow the Country information element. Frequency hopping networks are much less common now,

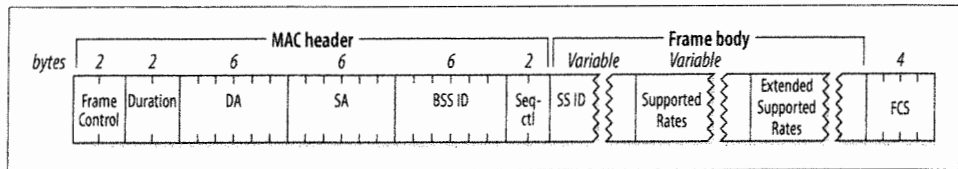


Figure 4-52. Probe Request frame

though, so I omit the frequency hopping extensions for simplicity. Likewise, the IBSS DFS element occur between the Quiet and TPC Report elements, were it to appear.

Probe Request

Mobile stations use Probe Request frames to scan an area for existing 802.11 networks. The format of the Probe Request frame is shown in Figure 4-52. All fields are mandatory.

A Probe Request frame contains two fields: the SSID and the rates supported by the mobile station. Stations that receive Probe Requests use the information to determine whether the mobile station can join the network. To make a happy union, the mobile station must support all the data rates required by the network and must want to join the network identified by the SSID. This may be set to the SSID of a specific network or set to join any compatible network. Drivers that allow cards to join any network use the broadcast SSID in Probe Requests.

Probe Response

If a Probe Request encounters a network with compatible parameters, the network sends a Probe Response frame. The station that sent the last Beacon is responsible for responding to incoming probes. In infrastructure networks, this station is the access point. In an IBSS, responsibility for Beacon transmission is distributed. After a station transmits a Beacon, it assumes responsibility for sending Probe Response frames for the next Beacon interval. The format of the Probe Response frame is shown in Figure 4-53. Some of the fields in the frame are mutually exclusive; the same rules apply to Probe Response frames as to Beacon frames.

The Probe Response frame carries all the parameters in a Beacon frame, which enables mobile stations to match parameters and join the network. Probe Response frames can safely leave out the TIM element because stations sending probes are not yet associated and thus would not need to know which associations have buffered frames waiting at the access point.

IBSS announcement traffic indication map (ATIM)

IBSSs have no access points and therefore cannot rely on access points for buffering. When a station in an IBSS has buffered frames for a receiver in low-power mode, it sends an ATIM frame during the delivery period to notify the recipient it has buffered data. See Figure 4-54.

Roaming is sometimes given yet another meaning, referring to the process of moving a network session from one network (say, an 802.11 wireless LAN) to another disparate network (say, a 3G mobile telephone network). The IEEE has started another working group to define roaming operations to move network sessions and state between different types of IEEE 802 networks.

Power Conservation

The major advantage of wireless networks is that network access does not require nodes to be in any particular location. To take full advantage of mobility, nothing can constrain the location of a node, including the availability of electrical power. Mobility therefore implies that most mobile devices can run on batteries. But battery power is a scarce resource; batteries can run only so long before they need to be recharged. Requiring mobile users to return frequently to commercial power is inconvenient, to say the least. Many wireless applications require long battery life without sacrificing network connectivity.

As with any other network interface, powering down the transceiver can lead to great power savings in wireless networks. When the transceiver is off, it is said to be *sleeping*, *dozing*, or in *powersaving mode* (PS). When the transceiver is on, it is said to be *awake*, *active*, or simply *on*. Power conservation in 802.11 is achieved by minimizing the time spent in the latter stage and maximizing the time in the former. 802.11 accomplishes this without sacrificing connectivity.

Power Management in Infrastructure Networks

Power management can achieve the greatest savings in infrastructure networks. All traffic for mobile stations must go through access points, so they are an ideal location to buffer traffic. Most traffic can be buffered. The standard forbids buffering frames that require in-order delivery and have Order bit set because buffer implementations could possibly re-order frames. There is no need to work on a distributed buffer system that must be implemented on every station; the bulk of the work is left to the access point. By definition, access points are aware of the location of mobile stations, and a mobile station can communicate its power management state to its access point. Furthermore, access points must remain active at all times; it is assumed that they have access to continuous power. Combining these two facts allows access points to play a key role in power management on infrastructure networks.

Access points have two power management-related tasks. First, because an access point knows the power management state of every station that has associated with it, it can determine whether a frame should be delivered to the wireless network because the station is active or buffered because the station is asleep. But buffering frames alone does not enable mobile stations to pick up the data waiting for them. An access point's second task is to announce periodically which stations have frames waiting for them.

The periodic announcement of buffer status also helps to contribute to the power savings in infrastructure networks. Powering up a receiver to listen to the buffer status requires far less power than periodically transmitting polling frames. Stations only need to power up the transmitter to transmit polling frames after being informed that there is a reason to expend the energy.

Power management is designed around the needs of the battery-powered mobile stations. Mobile stations can sleep for extended periods to avoid using the wireless network interface. Part of the association request is the Listen Interval parameter, the number of Beacon periods for which the mobile station may choose to sleep. Longer listen intervals require more buffer space on the access point; therefore, the Listen Interval is one of the key parameters used in estimating the resources required to support an association. The Listen Interval is a contract with the access point. In agreeing to buffer any frames while the mobile station is sleeping, the access point agrees to wait for at least the listen interval before discarding frames. If a mobile station fails to check for waiting frames after each listen interval, they may be discarded without notification.

Unicast frame buffering and delivery using the Traffic Indication Map (TIM)

When frames are buffered, the destination node's Association ID (AID) provides the logical link between the frame and its destination. Each AID is logically connected to frames buffered for the mobile station that is assigned that AID. Multicast and broadcast frames are buffered and linked to an AID of zero. Delivery of buffered multicast and broadcast frames is treated in the next section.

Buffering is only half the battle. If stations never pick up their buffered frames, saving the frames is a rather pointless exercise. To inform stations that frames are buffered, access points periodically assemble a traffic indication map (TIM) and transmit it in Beacon frames. The TIM is a virtual bitmap composed of 2,008 bits; offsets are used so that the access point needs to transmit only a small portion of the virtual bitmap. This conserves network capacity when only a few stations have buffered data. Each bit in the TIM corresponds to a particular AID; setting the bit indicates that the access point has buffered unicast frames for the station with the AID corresponding to the bit position.

Mobile stations must wake up and enter the active mode to listen for Beacon frames to receive the TIM. By examining the TIM, a station can determine if the access point has buffered traffic on its behalf. To retrieve buffered frames, mobile stations use PS-Poll Control frames. When multiple stations have buffered frames, all stations with buffered data must use the random backoff algorithm before transmitting the PS-Poll.

Each PS-Poll frame is used to retrieve one buffered frame. That frame must be positively acknowledged before it is removed from the buffer. Positive acknowledgment is required to keep a second, retried PS-Poll from acting as an implicit acknowledgment. Figure 8-12 illustrates the process.

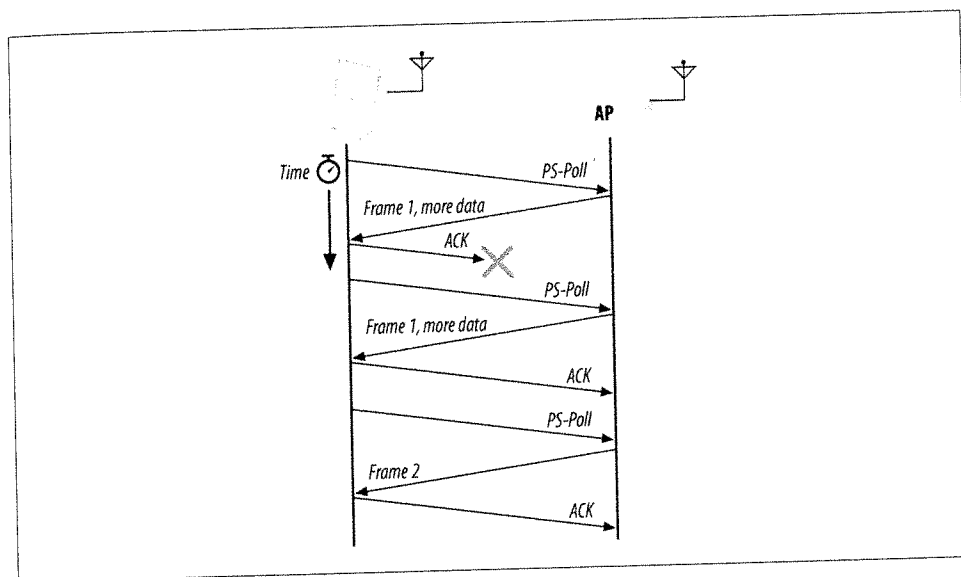


Figure 8-12. PS-Poll frame retrieval

If multiple frames are buffered for a mobile station, then the More Data bit in the Frame Control field is set to 1. Mobile stations can then issue additional PS-Poll requests to the access point until the More Data bit is set to 0, though no time constraint is imposed by the standard.

After transmitting the PS-Poll, a mobile station must remain awake until either the polling transaction has concluded or the bit corresponding to its AID is no longer set in the TIM. The reason for the first case is obvious: the mobile station has successfully polled the access point; part of that transaction was a notification that the mobile station will be returning to a sleeping mode. The second case allows the mobile station to return to a power conservation mode if the access point discards the buffered frame. Once all the traffic buffered for a station is delivered or discarded, the station can resume sleeping.

The buffering and delivery process is illustrated in Figure 8-13, which shows the medium as it appears to an access point and two associated powersaving stations. The hash marks on the timeline represent the beacon interval. Every beacon interval, the access point transmits a Beacon frame with a TIM information element. (This figure is somewhat simplified. A special kind of TIM is used to deliver multicast traffic; it will be described in the next section.) Station 1 has a listen interval of 2, so it must wake up to receive every other TIM, while station 2 has a listen interval of 3, so it wakes up to process every third TIM. The lines above the station base lines indicate the ramp-up process of the receiver to listen for the TIM.

At the first beacon interval, there are frames buffered for station 1. No frames are buffered for station 2, though, so it can immediately return to sleep. At the second beacon interval, the TIM indicates that there are buffered frames for stations 1 and 2, although

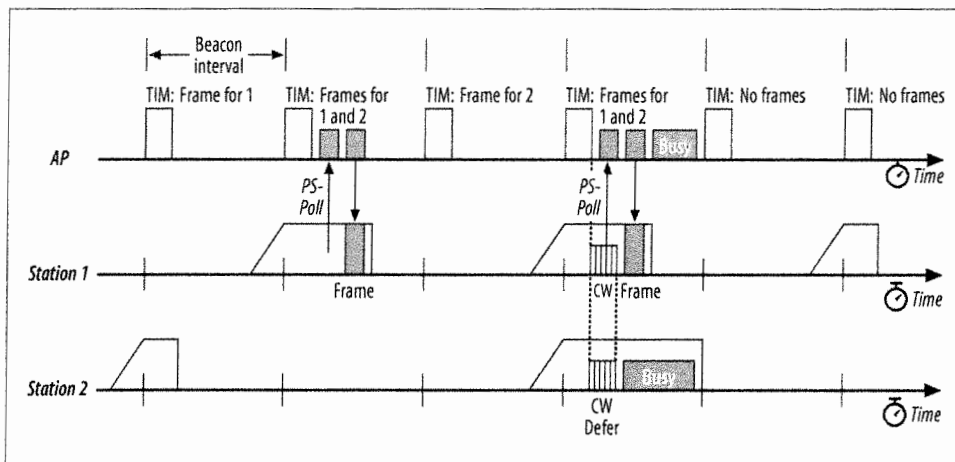


Figure 8-13. Buffered frame retrieval process

only station 1 woke up to listen to the TIM. Station 1 issues a PS-Poll and receives the frame in response. At the conclusion of the exchange, station 1 returns to sleep. Both stations are asleep during the third beacon. At the fourth beacon, both wake up to listen to the TIM, which indicates that there are frames buffered for both.

Both station 1 and station 2 prepare to transmit PS-Poll frames after the expiration of a contention window countdown, as described in Chapter 3. Station 1 wins because its random delay was shorter. Station 1 issues a PS-Poll and receives its buffered frame in response. During the transmission, station 2 defers. If, at the end of that frame transmission, a third station, which is not illustrated, seizes the medium for transmission, station 2 must continue to stay awake until the next TIM. If the access point has run out of buffer space and has discarded the buffered frame for station 2, the TIM at the fifth beacon indicates that no frames are buffered, and station 2 can finally return to a low-power mode.

Stations may switch from a power conservation mode to active mode at any time. It is common for laptop computers to operate with full power to all peripherals when connected to AC power and conserve power only when using the battery. If a mobile station switches to the active mode from a sleeping mode, frames can be transmitted without waiting for a PS-Poll. PS-Poll frames indicate that a powersaving mobile station has temporarily switched to an active mode and is ready to receive a buffered frame. By definition, active stations have transceivers operating continuously. After a switch to active mode, the access point can assume that the receiver is operational, even without receiving explicit notification to that effect.

Access points must retain frames long enough for mobile stations to pick them up, but buffer memory is a finite resource. 802.11 mandates that access points use an *aging function* to determine when buffered frames are old enough to be discarded. The standard leaves a great deal to the discretion of the developer because it specifies only one

constraint. Mobile stations depend on access points to buffer traffic for at least the listen interval specified with the association, and the standard forbids the aging function from discarding frames before the listen interval has elapsed. Beyond that, however, there is a great deal of latitude for vendors to develop different buffer management routines.

Delivering multicast and broadcast frames: the Delivery TIM (DTIM)

Frames with a group address cannot be delivered using a polling algorithm because they are, by definition, addressed to a group. Therefore, 802.11 incorporates a mechanism for buffering and delivering broadcast and multicast frames. Buffering is identical to the unicast case, except that frames are buffered whenever any station associated with the access point is sleeping. Buffered broadcast and multicast frames are saved using AID 0. Access points indicate whether any broadcast or multicast frames are buffered by setting the first bit in the TIM; this bit corresponds to AID 0.

Each BSS has a parameter called the DTIM Period. TIMs are transmitted with every Beacon. At a fixed number of Beacon intervals, a special type of TIM, a Delivery Traffic Indication Map (DTIM), is sent. The TIM element in Beacon frames contains a counter that counts down to the next DTIM; this counter is zero in a DTIM frame. Buffered broadcast and multicast traffic is transmitted after a DTIM Beacon. Multiple buffered frames are transmitted in sequence; the More Data bit in the Frame Control field indicates that more frames must be transmitted. Normal channel acquisition rules apply to the transmission of buffered frames. The access point may choose to defer the processing of incoming PS-Poll frames until the frames in the broadcast and multicast transmission buffers have been transmitted.

Figure 8-14 shows an access point and one associated station. The DTIM interval of the access point is set to 3, so every third TIM is a DTIM. Station 1 is operating in a sleep mode with a listen interval of 3. It will wake up on every third beacon to receive buffered broadcast and multicast frames. After a DTIM frame is transmitted, the buffered broadcast and multicast frames are transmitted, followed by any PS-Poll exchanges with associated stations. At the second beacon interval, only broadcast and multicast frames are present in the buffer, and they are transmitted to the BSS. At the fifth beacon interval, a frame has also been buffered for station 1. It can monitor the map in the DTIM and send a PS-Poll after the transmission of buffered broadcast and multicast frames has concluded.

To receive broadcast and multicast frames, a mobile station must be awake for DTIM transmissions. Nothing in the specification, however, keeps powersaving stations in infrastructure networks from waking up to listen to DTIM frames. Some products that implement powersaving modes will attempt to align their awakenings with DTIM transmissions. If the system administrator determines that battery life is more important than receiving broadcast and multicast frames, a station can be configured to sleep for its listen period without regard to DTIM transmissions. Some documentation may

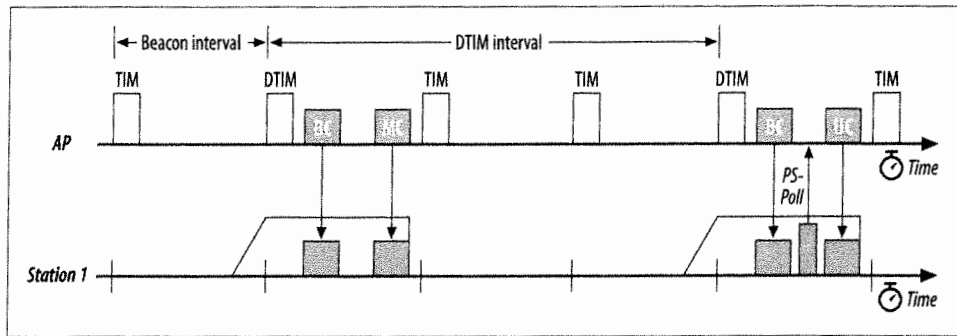


Figure 8-14. Multicast and broadcast buffer transmission after DTIMs

refer to this as *extremely low power*, *ultra powersaving mode*, *deep sleep*, or something similar.

Several products allow configuration of the DTIM interval. Lengthening the DTIM interval allows mobile stations to sleep for longer periods and maximizes battery life at the expense of timely delivery. Shorter DTIM intervals emphasize quick delivery at the expense of more frequent power-up and power-down cycles. You can use a longer DTIM when battery life is at a premium and delivery of broadcast and multicast frames is not important. Whether this is appropriate depends on the applications you are using and how they react to long link-layer delays.

IBSS Power Management

Power management in an IBSS is not as efficient as power management in an infrastructure network. In an IBSS, far more of the burden is placed on the sender to ensure that the receiver is active. Receivers must also be more available and cannot sleep for the same lengths of time as in infrastructure networks.

As in infrastructure networks, power management in independent networks is based on traffic indication messages. Independent networks must use a distributed system because there is no logical central coordinator. Stations in an independent network use *announcement traffic indication messages* (ATIMs), which are sometimes called *ad hoc traffic indication messages*, to preempt other stations from sleeping. All stations in an IBSS listen for ATIM frames during specified periods after Beacon transmissions.

If a station has buffered data for another station, it can send an ATIM frame as notification. In effect, the ATIM frame is a message to keep the transceiver on because there is pending data. Stations that do not receive ATIM frames are free to conserve power. In Figure 8-15 (a), station A has buffered a frame for station C, so it sends a unicast ATIM frame to station C during the ATIM transmission window, which has the effect of notifying station C that it should not enter powersaving mode. Station B, however, is free to power down its wireless interface. Figure 8-15 (b) shows a multicast ATIM

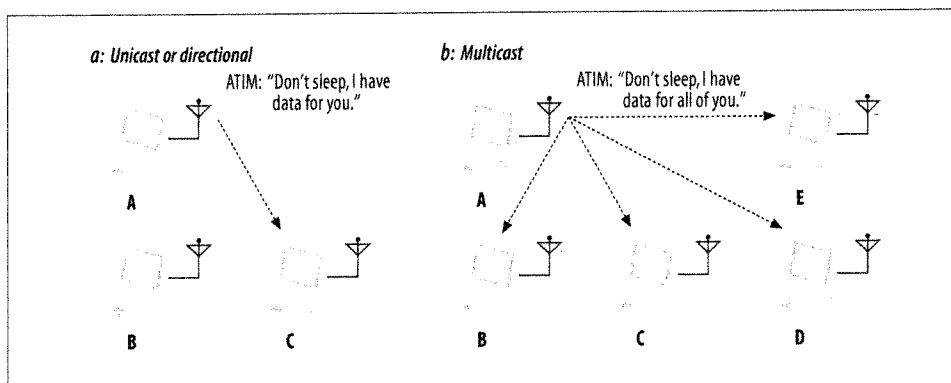


Figure 8-15. ATIM usage

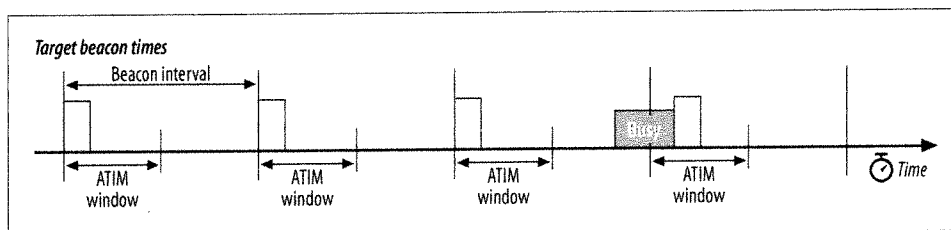


Figure 8-16. ATIM window

frame in use. This frame can be used to notify an entire group of stations to avoid entering low-power modes.

A time window called the *ATIM window* follows the Beacon transmission. This window is the period during which nodes must remain active. No stations are permitted to power down their wireless interfaces during the ATIM window. It starts at the time when the beacon is expected and ends after a period specified when the IBSS is created. If the beacon is delayed due to a traffic overrun, the usable portion of the ATIM window shrinks by the same amount.

The ATIM window is the only IBSS-specific parameter required to create an IBSS. Setting it to 0 avoids using any power management. Figure 8-16 illustrates the ATIM window and its relation to the beacon interval. In the figure, the fourth beacon is delayed due to a busy medium. The ATIM window remains constant, starting at the target beacon interval and extending the length of the ATIM window. The usable period of the ATIM window shrinks by the length of the delay in beacon transmission.

To monitor the entire ATIM window, stations must wake up before the target beacon transmission. Four situations are possible: the station has transmitted an ATIM, received an ATIM, neither transmitted nor received, or both transmitted and received. Stations that transmit ATIM frames must not sleep. Transmitting an ATIM indicates an intent to transmit buffered traffic and thus an intent to stay active. Stations to which

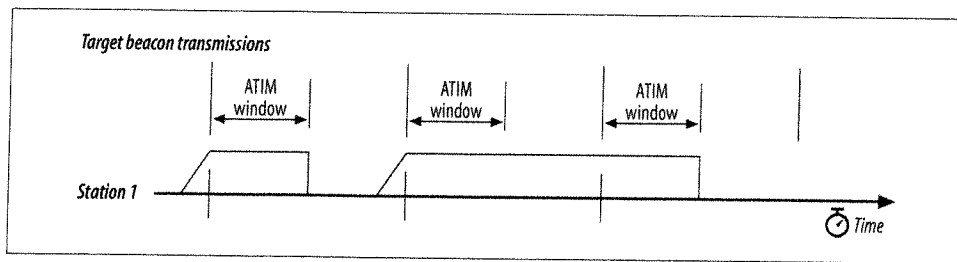


Figure 8-17. ATIM effects on powersaving modes

ATIM frames are addressed must also avoid sleeping so they can receive any frames transmitted by the ATIM's sender. If a station both transmits and receives ATIM frames, it stays up. A station is permitted to sleep only if it neither transmits nor receives an ATIM. When a station stays up due to ATIM traffic, it remains active until the conclusion of the *next* ATIM window, as shown in Figure 8-17. In the figure, the station goes active for the first ATIM window. If it does not send or receive any ATIM frames, it sleeps at the end of the ATIM window. If it sends or receives an ATIM frame, as in the second ATIM window, the station stays active until the conclusion of the third ATIM window.

Only certain control and management frames can be transmitted during the ATIM window: Beacons, RTS, CTS, ACK, and, of course, ATIM frames. Transmission takes place according to the rules of the DCF. ATIM frames may be transmitted only during the ATIM window because stations may be sleeping outside the ATIM window. Sending an ATIM frame is useless if other stations in the IBSS are sleeping. In the same vein, acknowledgments are required for unicast ATIM frames because that is the only guarantee that the ATIM was received and that the frame destination will be active for the remainder of the beacon interval. Acknowledgments are not required for multicast ATIM frames because multicast frames cannot be efficiently acknowledged by a large group of stations. If all potential recipients of an ATIM frame were required to acknowledge it, the mass of acknowledgments could potentially interrupt network service.

Buffered broadcast and multicast frames are transmitted after the conclusion of the ATIM window, subject to DCF constraints. Following the transmission of broadcast and multicast frames, a station may attempt to transmit unicast frames that were announced with an ATIM and for which an acknowledgment was received. Following all transmissions announced with an ATIM, stations may transmit unbuffered frames to other stations that are known to be active. Stations are active if they have transmitted the Beacon, an ATIM, or are not capable of sleeping. If contention is severe enough to prevent a station from sending the buffered frame it announced with an ATIM, the station must reannounce the transmission with an ATIM at the start of the next ATIM window.

Figure 8-18 illustrates several of these rules. In the first beacon interval, the first station transmits a multicast ATIM to stations 2, 3, and 4. Multicast ATIM frames need not

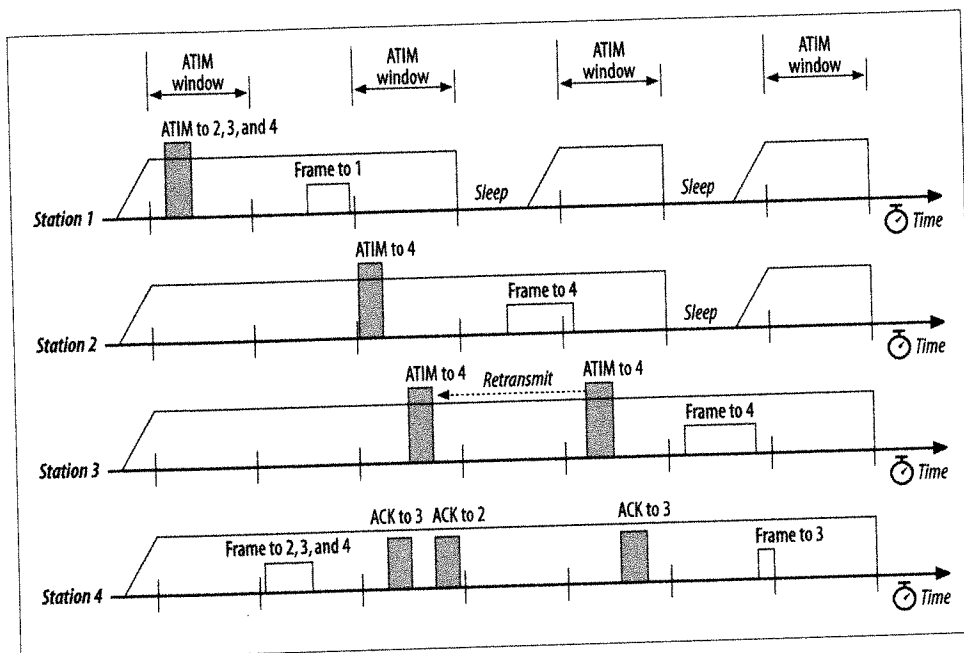


Figure 8-18. Effect of ATIM on powersaving modes in an IBSS network

be acknowledged, but the transmission of the ATIM means that all stations must remain active until the conclusion of the next. When the ATIM window ends, station 1 can transmit its multicast frame to the other three stations. After doing so, station 4 can take advantage of the remaining time before the beacon to transmit a frame to station 1. It was not cleared with an ATIM, but it is known to be active.

In the second beacon interval, stations 2 and 3 have both buffered a frame for station 4, so each transmits an ATIM. Station 4 acknowledges both. At the conclusion of the ATIM window, station 1 has neither transmitted nor received an ATIM and can enter a low-power state until the next beacon interval. However, station 2's frame is extremely long and robs station 3 of the opportunity to transmit its frame.

Station 3 still has a buffered frame for station 4 when the third beacon interval opens. It therefore retransmits its ATIM frame to station 4, which is acknowledged. Station 2 is not involved in any ATIM exchanges and can enter a low-power state when the ATIM window ends. At that time, no broadcast or multicast frames have been buffered, and the ATIM-cleared frame from station 3 to station 4 can be transmitted. After the frame from 3 to 4 is transmitted, station 4 can again take advantage of the remaining time before the beacon frame to transmit a frame of its own to station 3, which is known to be active because of the ATIM exchange.

Stations are responsible for maintaining sufficient memory to buffer frames, but the buffer size must be traded off against the use of that memory for other purposes. The standard allows a station in an independent network to discard frames that have been

buffered for an “excessive” amount of time, but the algorithm used to make that determination is beyond the scope of the standard. The only requirement placed on any buffer management function is that it retain frames for at least one beacon period.

Timer Synchronization

Like other wireless network technologies, 802.11 depends a great deal on the distribution of timing information to all the nodes. It is especially important in frequency-hopping networks because all stations on the network must change frequency channels in a coordinated pattern. Timing information is also used by the medium reservation mechanisms.

In addition to local station timing, each station in a basic service area maintains a copy of the *timing synchronization function* (TSF), which is a local timer synchronized with the TSF of every other station in the basic service area. The TSF is based on a 1-MHz clock and “ticks” in microseconds. Beacon frames are used to periodically announce the value of the TSF to other stations in the network. The “now” in a timestamp is when the first bit of the timestamp hits the PHY for transmission.

Infrastructure Timing Synchronization

The ease of power management in an infrastructure network is based on the use of access points as central coordinators for data distribution and power management functions. Timing in infrastructure networks is quite similar. Access points are responsible for maintaining the TSF time, and any stations associated with an access point must simply accept the access point’s TSF as valid.

When access points prepare to transmit a Beacon frame, the access point timer is copied into the Beacon’s timestamp field. Stations associated with an access point accept the timing value in any received Beacons, but they may add a small offset to the received timing value to account for local processing by the antenna and transceiver. Associated stations maintain local TSF timers so they can miss a Beacon frame and still remain roughly synchronized with the global TSF. The wireless medium is expected to be noisy, and Beacon frames are unacknowledged. Therefore, missing a Beacon here and there is to be expected, and the local TSF timer mitigates against the occasional loss of Beacon frames.

To assist active scanning stations in matching parameters with the BSS, timing values are also distributed in Probe Response frames. When a station finds a network by scanning, it saves the timestamp from the Beacon or Probe Response and the value of the local timer when it was received. To match the local timer to the network timer, a station then takes the timestamp in the received network advertisement and adds the number of microseconds since it was received. Figure 8-19 illustrates this process.

802.11 Wireless Networks: The Definitive Guide



Using a wireless network is a liberating experience. But underneath the experience lies a complex protocol, and even more complex issues arise when your data isn't limited to traveling on physical wires. How do you structure your network so mobile users can move around effectively? How do you extend wireless coverage so it's available everywhere you need it? What kinds of security issues do wireless networks raise? How do you tune your network for optimal performance? How do you provide enough capacity to support the users you expect initially, and how do you deal with the problems that arise as more users join the network?

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