IEEE P802.11

Wireless Access Method and Physical Layer Specification

Text Updates to Section 6 from Sub-Group Work

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Abstract

This contains changes to Section 6 (formerly Section 5) letter ballot comments and submissions related to Section 6, as well as some inter–section consistency issues identified during the work of the sub–group. Note that there are also changes to Section 6 from the adoption of material from documents 95/140 and 95/150. At the close of this meeting, all D1 technical letter ballot comments identified as relating to section 5 (hence applicable to current section 6) have been addressed, with the resolution notes in document 95/173.

1. MAC Sub-layer Functional Description

In the following sections, the MAC functional description is presented. Section 6.1 introduces the architecture of the MAC sublayer, including the distributed coordination function, the point coordination function and their coexistence in an 802.11 LAN. Sections 6.2 and 6.3 expand on this introduction and provide a complete functional description of each. ~~Section 6.4 describes the security mechanisms within the MAC layer.~~ Sections 6.45 and 6.56 cover fragmentation and reassembly. Multirate support is addressed in Section 6.67. Section 6.78 reiterates the functional descriptions in the form of state machines.

1.1. MAC Architecture

The MAC is composed of several functional blocks: the MAC-LLC Service Interface, the MAC State Machines, the MAC Management State Machines and the MAC Management Information Base (MIB). The MAC-LLC Service Interface comprises the MAC Data Service and the MAC Management Service. These blocks perform the functions required to provide contention and contention-free access control on a variety of physical layers. The functions are provided without reliance upon particular data rates or physical layer characteristics. The MAC provides both distributed and point coordination functions and is able to support both asynchronous and time bounded service clases. Figure 6-1 illustrates the MAC architecture.

The MAC-LLC Service Interface shall accept MAC service requests from higher layer entities and shall distribute those requests to either the MAC Data Service or the MAC Management Service as appropriate. The MAC Data and MAC Management Services shall interpret the service requests and shall cause the appropriate signals to be generated to initiate actions in the state machines. The MAC-LLC Service Interface shall also accept indications from the state machines and provide those indications to higher layer entities. The particular service requests and indications are described in Section 3.2.

The MAC State Machine shall provide the sequencing required to provide the distributed coordination function. The MAC State Machine shall provide the protocol sequencing necessary to provide asynchronous communication service. The MAC State Machine shall provide the sequencing required to provide the point coordination function and the associated time-bounded and contention-free communication services. The implementation of the PCF portions of the MAC State Machine (and the associated Time-bounded and contention-free services) are optional . The MAC State Machine shall not interfere with time-bounded nor contention-free communications even if the optional point coordination function is not implemented.

The MAC Management State Machine shall provide the protocol sequencing required to provide the following services:

a) Association and re-association
b) Access to the MAC MIB
c) Timing synchronization
d) Power management
e) Authentication

The MAC MIB shall provide storage of and access to all of the information required to properly manage the MAC.

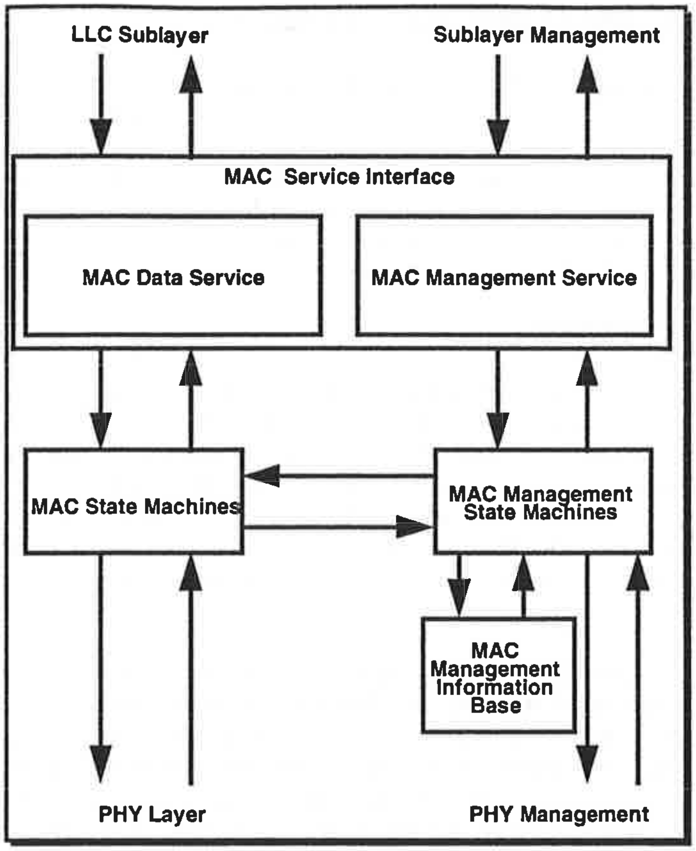

Figure 6-1: MAC Architecture Block Diagram

Viewed along a different axis, the MAC architecture can be described as shown in Figure 6-2 below as providing the point coordination function through the services of the distributed coordination function.

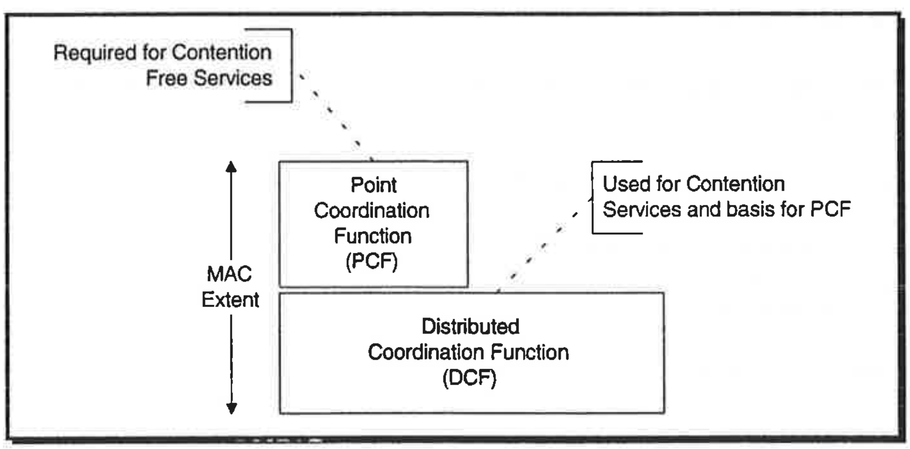

Figure 6-2: Alternative view of MAC architecture.

1.1.1. Distributed Coordination Function

The fundamental access method of the 802.11 MAC is a distributed coordination function known as carrier sense multiple access with collision avoidance, or CSMA/CA. The distributed coordination function shall be implemented in all stations. It is used within both ad hoc and infrastructure configurations.

A station wishing to transmit shall sense the medium to determine if another station is transmitting. If the medium is not busy, the transmission may proceed. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exist between contiguous frames. A transmitting station shall ensure that the medium is idle for the required duration before attempting to transmit. If the medium is sensed busy the station shall defer until the end of the current transmission. After deferral, the station shall select a random backoff interval and shall decrement the interval counter while the medium is free. A refinement of the method may be used under various circumstances to further minimize collisions - here the transmitting and receiving station exchange short control frames (**RTS** and **CTS** frames) prior to the data transmission. The details of CSMA/CA are described in Section 6.2. RTS/CTS exchanges are also presented in Section 6.2.

1.1.2.Point Coordination Function

The 802.11 MAC may also incorporate an optional access method described as a point coordination function, which is only usable on infrastructure networks. This optional access method shall be implemented on top of the distributed coordination function. This access method uses a point coordinator, which must operate at the access point of the BSS, to determine which station currently has the right to transmit. The operation is essentially that of polling with the point coordinator playing the role of the polling master. The operation of the Point Coordination Function may require additional coordination, not sepcified in this standard, to permit effiecent operation in cases where multiple Point-Coordinated BSSs are operating on the same channel in overlapping physical space.

The point-coordination function shall be built up from the distributed coordination function through the use of an access priority mechanism, aided by the virtual carrier sense mechanism. Different classes of traffic can be defined through the use of different values for IFS, thereby creating prioritized access to the medium for those classes with a shorter IFS. The point coordination function shall use an IFS that is smaller than the IFS for data frames transmitted via the distributed coordination function. The use of a smaller IFS implies that point-coordinated traffic shall have priority access to the medium.

The access priority provided by point-coordinated traffic may be utilized to create a **contention-free** access method. The priority access of the PIFS allows the point coordinator to "seize control" of the medium, at a time whenthe medium is free, by starting its transmission before the other stationsare allowed to begin their transmissions under the DCF access method. The point coordinator can then control the frame transmissions of the stations so as to eliminate contentionfor a limited period of time.

1.1.3.Coexistence of DCF and PCF

The distributed coordination function and the point coordination function shall coexist in a manner that permits both to operate concurrently in the same BSS. When a point coordinator is operating in a BSS, the two access methods alternate, with a contention-free period followed by a contention period. This is described in greater detail in Section 6.3.

1.1.4. Fragmentation/Reassembly Overview

The process of partitioning a MAC Service Data Unit (MSDU) into smaller MAC level frames, MAC Protocol Data Units (MPDUs), is defined as fragmentation. Fragmentation creates MPDUs smaller than the MSDU size to increase reliablity of successful transmission of the MSDU over a given PHY. Fragmentation accomplished at each immediate transmitter. The process of recombining MPDUs into a single MSDU is defined as reassembly. Reassembly is accomplished at each immediate recipient.

When a frame is received from the LLC with a MSDU size greater than aFragmentation_Threshold, the frame must be fragmented. The MSDU is divided into MPDUs. Each MPDU is a fragment with a frame body no larger than aFragmentation_Threshold. It is possible than any fragment may contain a frame body smaller than aFragmentation_Threshold~~Payload~~. An illustration of fragmentation is shown in Figure 6-3.

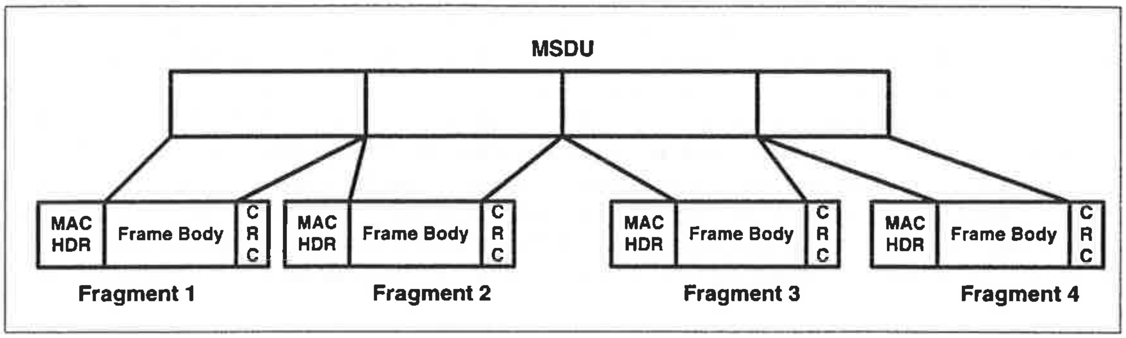

Figure 6-3: Fragmentation

1.1.5.MAC Data Service

The MAC Data Service shall translate MAC service requests from LLC into input signals utilized by the MAC State Machines. It shall also translate output signals from the MAC State Machines into service indications to LLC. The translations are given below.

The MA_UNITDATA~~DATA~~.request from LLC shall initiate one of the transmit cycles in the MAC State Machine. The psuedo-code below shall be used to translate this request into inputs to the MAC State Machine.

Tx_~~data_~~req = { ~~requested_~~service_class = async & length(MSDU) < aMax_Frame_Length~~>~~
~~RTS_threshold~~
& priority = contention~~-destination_address <> (broadcast | multicast)~~ }
~~Tx_multicast_req = { requested_service_class = async & destination_address = multicast }~~
Tx_CF~~unitdata~~_req = { ~~requested_~~service_class = async & length(MSDU) < aMax_Frame_Length & priority = contention-free ~~RTS_threshold~~}
SA = { aMAC_address }
DA = { destination_address }
MSDU_Length = { ~~Rate_factor * (~~length(MSDU) ~~+ Overhead)~~ }
~~Connection ID = integer. Note a value of zero is reserved for all asynchronous data requests~~

The MAC Data Service shall translate outputs from the MAC State Machine to MA_UNITDATA~~DATA~~.indication as shown in the following pseudo-code.

control = { type,control }
destination_address = { DA }
source_address = { SA }
routing_information = { null }
data~~MSDU~~ = { info_field }
reception_status = { ~~1~~(no_error | CRC_error | Format_error) }
service_class = asynchronous
~~Connection ID = integer. Note a value of zero is used when there is no connection.~~

1.2. Distributed Coordination Function

The basic medium access protocol is a Distributed Coordination Function (DCF) that allows for automatic medium sharing between compatible PHYs through the use of CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) and a random backoff time following a busy medium condition. In addition, all directed traffic uses immediate positive acknowledgements (ACK frame) where retransmission is scheduled by the sender if no ACK is received.

The CSMA/CA protocol is designed to reduce the collision probability between multiple stations accessing a medium, at the point where they would most likely occur. Just after the medium becomes free following a busy medium (as indicated by the CS function) is when the highest probability of a collision occurs. This is because multiple stations could have been waiting for the medium to become available again. This is the situation where a random backoff arrangement is needed to resolve medium contention conflicts.

Carrier Sense shall be performed both through physical and virtual mechanisms.

The virtual Carrier Sense mechanism is achieved by distributing medium busy reservation information through an exchange of special RTS and CTS (medium reservation) frames prior to the actual data frame. For stations & all AP's that do not initiate an RTS/CTS sequence, the duration information is also available in all data frames. The RTS and CTS frames contain a duration field that defines the period of time that the medium is to be reserved to transmit the actual data frame and the returning ACK. This information is distributed to all stations within detection range of both the transmitter and the receiver, so also to stations that are possibly "hidden" from the transmitter but not from the receiver. This scheme can only be used for directed frames. When multiple destiniations are addressed by broadcast/multicast frames, then this mechanism is not used.

It can also be viewed as a Collision Detection mechanism. Because the actual data frame is only transmitted when a proper CTS frame is received in response to the RTS frame, this results in a fast detection of a collision if it occurs on the RTS.

However the addition of these frames will result in extra overhead, which impacts short data frames. Also since all stations will likely be able to hear traffic from the AP but may not hear the traffic from all stations within a BSA.

However in situations where multiple BSS's utilizing the same channel do overlap, then the medium reservation mechanism will work accross the BSS boundaries, when RTS/CTS is also used for all traffic.

The use of the RTS/CTS mechanism is under control of aRTS_Threshold attribute. However in situations where multiple BSS's utilizing the same channel do overlap, then the medium reservation mechanism will work accross the BSS boundaries, when RTS/CTS is also used for all traffic.

This parameter is a manageable object and can be set on a per station basis. This mechanism allows stations to be configured to use RTS/CTS either always, never or only on frames longer then a specified payload length.

Although a station can be configured not to initiate RTS/CTS to transmit its frames, every station shall respond to the duration information in the MAC headers of receivedRTS/CTS frames to update its virtual Carrier Sense mechanism, and respond with a proper CTS frame in response to an addressed RTS frame.

The basic medium access protocol allows for stations supporting different set of rates to coexist, this is achieved by the fact that all stations are required to be able to receive any frame transmitted on a given Basic Rate Set, and must be able to transmit at (at least) one of these rates. All Multicast, Broadcast and Control frames (RTS, CTS and ACK) are always transmitted at one of this mandatory rates. This set of restrictions will assure that the Virtual Carrier Sense Mechanism described above will still work on multiple rate environments.

1.2.1. Physical Carrier Sense Mechanism

A physical carrier sense mechanism shall be provided by the PHY. See Section 98, Physical Service Specification for how this information is conveyed to the MAC. The details of carrier sense are provided in the individual PHY specification sections.

1.2.2. Virtual Carrier Sense Mechanism

A virtual carrier sense mechanism shall be provided by the MAC. This mechanism is referred to as the Net Allocation Vector (NAV). The NAV maintains a prediction of future traffic on the media based on duration information that is announced in RTS/CTS frames prior to the actual exchange of data. The duration information is also available in the MAC headers of all ~~data and Ack~~ frames sent during the contention period other than PS–Poll control frames. The mechanism for setting the NAV is described in 6.2.6.4

1.2.3. MAC-Level Acknowledgments

To allow detection of a lost or errored frame an ACK frame shall be returned to the source STA by the destination STA immediately following a successfully received frame. Success shall be determined by the calculation of a proper remainder for the CRC check defined in section 4.1.2.7.~~an identical CRC generated from the received frame and the FC field of the same frame~~. The gap between the received frame and the ACK frame shall be the SIFS. This technique is known as positive acknowledgement.

The following frame types shall be acknowledged with an ACK frame:

a) Data
b) PS–Poll
c) Management Requests
d) Management Responses

The lack of an ACK frame from a destination STA on any of the listed frame types shall indicate to the source STA that an error has occurred. Note however, that the destination STA may have received the frame correctly and the error has occurred in the ACK frame. This condition is~~shall be~~ indistinguishable from an error occurring in the initial frame.

1.2.4. Inter-Frame Space (IFS)

The time interval between frames is called the inter-frame space. A STA shall determine that the medium is free through the use of the carrier sense function for the interval specified. Three different IFS's are defined so as to provide a corresponding number of priority levels for access to the wireless media. The following three different IFSs are defined:

a) SIFS	Short Interframe Space
b) PIFS	PCF Interframe Space
c) DIFS	DCF Interframe Space

It should be noticed that the different IFSs are independent of the station bitrate, and are fixed per each PHY (even in multi-rate capable PHYs),

The IFS timings are defined as time gaps on the medium.~~The standard shall specify the relation of the relative PHY MIB parameters to achieve the specified timegaps as further specified in section 6.2.13.~~

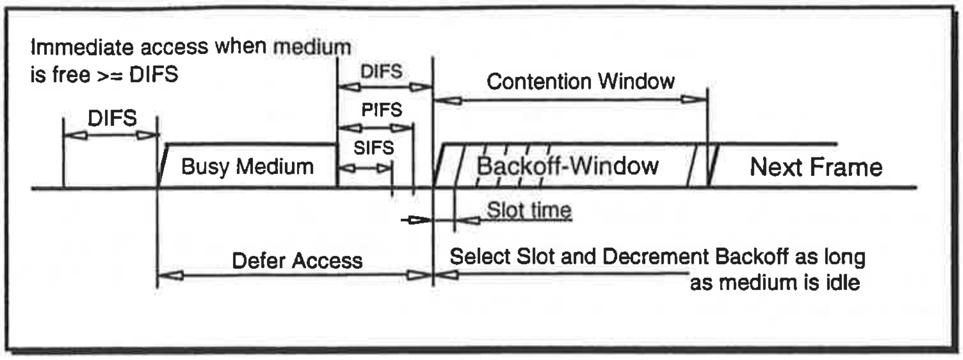

Figure 6-4: IFS Relations

1.2.4.1. Short-IFS (SIFS)

This inter-frame space shall be used for an- ACK frame, a CTS frame, a Data frame of a fragmented MSDU, and, by a STA responding to any polling as is used by the Point Coordination Function (PCF); and may be used by a point coordinator for any types of frames during the contention free period (See Section 6.3, Point Coordination Function). The SIFS is the time from the end of the last symbol of the previous frame to the begining of the first symbol of the pre-amble of the listed frame as seen at the air interface. The valid cases where the SIFS interval may or must beis used are listed in Frame Exchange Sequences found in section 4.43.

-The SIFS timing will be achieved when the transmission of the subsequent frame is started at the TxX_SIFS Slot boundary as specified in section 6.2.1113.

1.2.4.2. PCF-IFS (PIFS)

This PCF priority level shall be used only by the PCF to gain priority access to the medium at the startsend any of the Contention Free Period (CFP)- frames. The PCF shall be allowed to transmit contention free traffic after it detects the medium free at the Tx-PIFS slot boundary as defined in section 6.2.1113. This mustcan occur at the start of and during a CF-PeriodBurst-. The PCF may also transmit after it detects the medium free at the Tx-PIFS slot boundary after failing to receive an expected acknowledgement during a CF-Period.

1.2.4.3. DCF-IFS (DIFS)

The DCF priority level shall be used by the DCF to transmit data and managementasynchronous MPDUs. A STA using the DCF shall be allowed to transmit if it detects the medium to be free at the Tx_DIFS slot boundary as defined in section 6.2.1113, and its backoff time has expired.

1.2.5. Random Backoff Time

STA desiring to initiate transfer of data or managementasynchronous MPDUs shall utilize both the physical and virtual carrier sense functions to determine the state of the mediuma. If the mediuma is busy, the STA shall defer until after a DIFS gap is detected, and then generate a random backoff period for an additional deferral time before transmitting. This process resolves contention between multiple STA that have been deferring to the same eventMPDU occupying the medium.

Backoff Time = INT(CW * Random()) * Slot time

where:

CW = An integer between the values of MIB variables aCW_{min} and aCW_{max}
Random() = Pseudo random number between 0 and 1
Slot Time = The value of MIB variable aSlot_time~~Transmitter turn-on delay + medium propagation delay + medium busy detect response time (including MAC delay) and is PHY dependent~~.

The Contention Window (CW) parameter shall contain an initial value of aCW_{min} for every MPDU queued for transmission. The CW shall double at every retry until it reaches the value of aCW~~w~~max. The CW will remain at a value of aCWmax for the remaining of the retries. This is done to improve the stability of the access protocol under high load conditions. See Figure 6-5.

Suggested values are for: aCWmin=31, aCwmax = 255.~~,~~

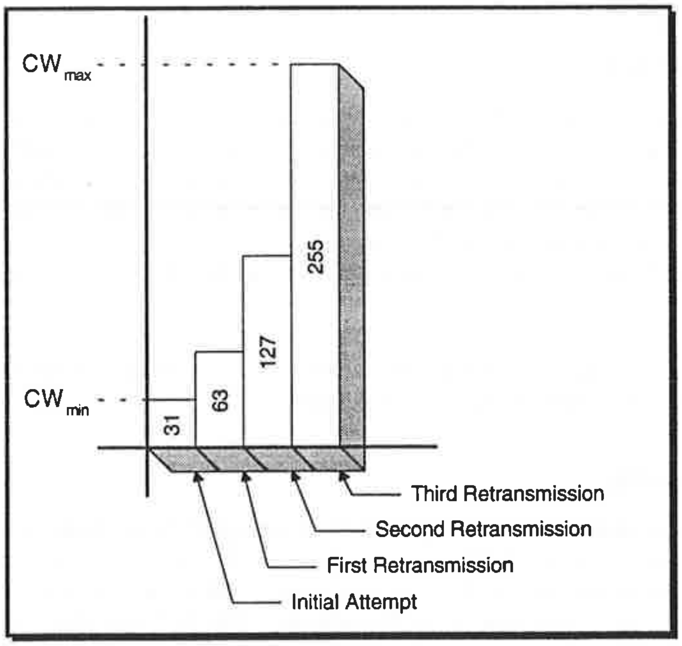

Figure 6-5: Exponential Increase of CW

aCWmin and aCWmax are MAC constants that should be fixed for all MAC implementations, because they effect the access fairness between stations.

1.2.6. DCF Access Procedure

The CSMA/CA access method is the foundation of the Distributed Coordination Function. The operational rules vary sligthly between Distributed Coordination Function and Point Coordination function.

1.2.6.1. Basic Access

Basic access refers to the core mechanism a STA uses to determine whether it has permission to transmit.

Both the Physical and Virtual Carrier Sense functions are used to determine the busy state of the medium. When either of them indicate a busy medium, the medium shall be considered busy. The opposite of a busy medium shall be known as a free medium.

A STA with a pending MPDU may transmit when it detects a free medium for greater than or equal to a DIFS time. This rule applies both when the BSS is using the DCF access method exclusively and when the

BSS is using the PCF access method, but the transmission is taking place during in the Contention Period~~Area~~.

If the medium is busy when a STA desires to initiate an RTS, Data, PS-Poll, or~~and~~ Management MPDU transfer, and only a DCF is being used to control access, the Random Backoff Time algorithm shall be followed.

Likewise, if the medium is busy when a STA desires to initiate an RTS, Data, PS-Poll, or~~and~~ Management MPDU transfer, and during the~~a~~ Contention Period while a PCF ~~portion of a Superframe~~ is active (See 6.3 Point Coordination Function~~PCF~~), the Random Backoff Time algorithm shall be followed.

The basic access mechanism is illustrated in the following diagram.

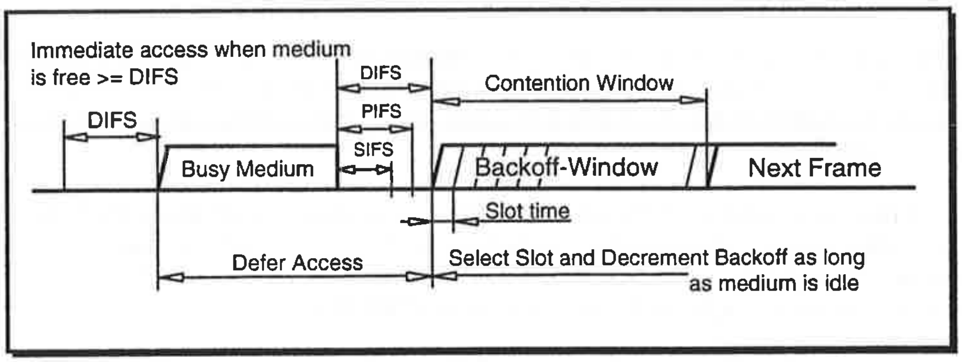

Figure 6-6: Basic Access Method

1.2.6.2. Backoff Procedure

The backoff procedure shall be followed whenever a STA desires to transfer an MPDU and finds the medium busy.

The backoff procedure consists of selecting a backoff time from the equation in Section 6.2.5 Random Backoff Time. The Backoff Timer shall decrement by slottime amount after every slottime, while the medium is free. The Backoff Timer shall be frozen while the medium is sensed busy. Decrementing the Backoff Timer shall resume whenever the medium is detected to be free at the Tx_DIFS slot boundary as defined in section 6.2.11~~13~~. Transmission shall commence whenever the Backoff Timer reaches zero.

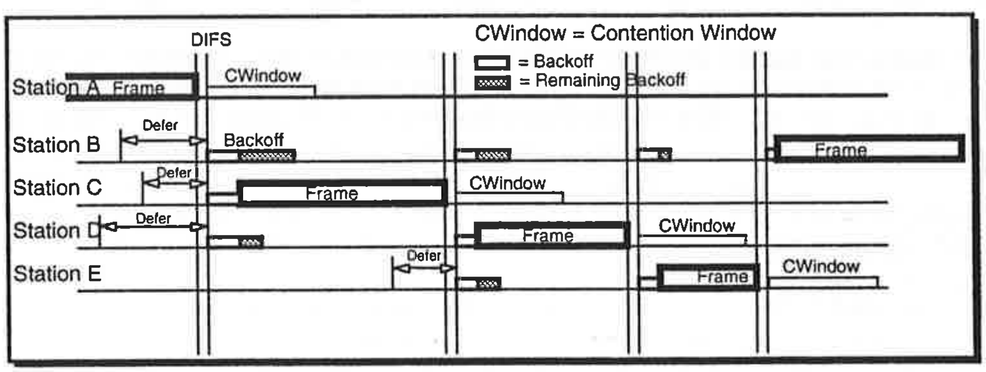

Figure 6-7: Backoff Procedure

A station that has just transmitted an MSDU and has another MSDU ready to transmit (queued), shall perform the backoff procedure. This requirement is intended to produce a level of fairness of access amongst STA to the medium.

The effect of this procedure is that when multiple stations are deferring and go into random backoff, then the station selecting the lowest delay through the random function will win the contention. The advantage of this approach is that stations that lost contention will defer again until after the next, and will then likely have a shorter backoff delay than new stations entering the backoff procedure for the first time. This method tends toward fair access on a first come, first served basis.

1.2.6.3. RTS/CTS Recovery Procedure and Retransmit Limits

Many circumstances may cause an error to occur in a RTS/CTS exchange.

For instance, CTS may not be returned after the RTS transmission. This can happen due to a collision with another RTS or a DATA frame, or due to interference during the RTS or CTS frame. It can however also be that CTS fails to be returned because the remote station has an active carrier sense condition, indicating a busy medium time period.

If after an RTS is transmitted, the CTS fails in any manner within a predetermined CTS_Timeout (T1), then a new RTS shall be generated while following the basic access rules for backoff. Since this pending transmission is a retransmission attempt, the CW shall be doubled as per the backoff rules. This process shall continue until the aRTS_Retry_Counter reaches an aRTS_Retry_Max limit.

<< REVIEWERS' NOTE: It appears that several MIB variables are needed, including one for CTS_Timeout and one for ACK_Window (probably better named ACK_Timeout) also separation of aRTS_Retry_Max and aData_Retry_Max from aRetry_Max, but this may be continued use of obsolete names rather than extra variables — we are not sure. >>

The same backoff mechanism shall be used when no ACK frame is received within a predetermined ACK_Window (T3) after a directed DATA frame has been transmitted. Since this pending transmission is a retransmission attempt the CW will be greater than one as per the backoff rules. This process shall continue until the aData_Retry_Counter reaches the aData_Retry_Max limit .

1.2.6.4. Setting the NAV Through Use of RTS/CTS Frames

In the absence of a PCF, reception of all frames other than PS–Poll ~~RTS and CTS, Data and ACK~~ frames are the events that shall set the NAV to a non-zero duration. Various conditions may reset the NAV.

All DCF frames other than PS–Poll ~~RTS and CTS~~ frames contain a Duration field based on the medium occupancy time of the MPDU from the end of the ~~RTS or CTS~~ frame until the end of the corresponding ACK frame. (See Section 4: ~~RTS and CTS Frame Structure~~.) All STA receiving these frame types with a valid FCS field, but with the exception of the station(s) that are~~is~~ addressed shall interpret the duration field in these frames, and maintain the Net Allocation Vector (NAV). Stations receiving such~~a~~ valid frames shall~~should~~ update their NAV with the information received in the Duration field. Updating the NAV only changes the current NAV~~, but only~~ when the new NAV value is greater then the current NAV value.

Maintenance of the NAV shall consist of an internal state accurate to 1 microsecond of the busy/free condition of the medium. Figure 6-8 indicates the NAV for stations that can hear the RTS frame, while other stations may only receive the CTS frame, resulting in the lower NAV bar as shown. Although the NAV effectively will "count-down" from a non-zero value, only the fact of whether the NAV is non-zero or zero~~not~~ is necessary for correct protocol operation.

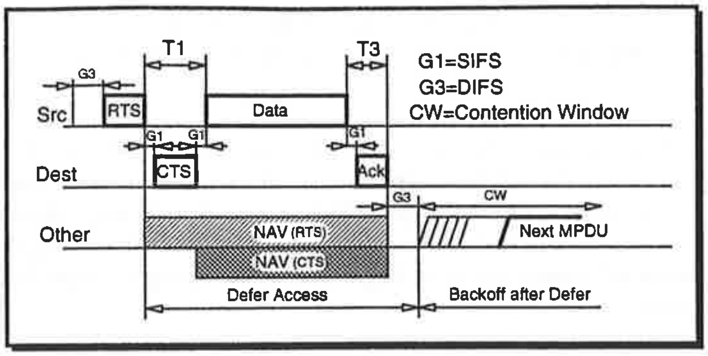

Figure 6-8: RTS/CTS/DATA/ACK MPDU

1.2.6.5. Control of the Channel

The Short Interframe Space (IFS) is used to provide an efficient MSDU delivery mechanism. Once a station has contended for the channel, it will maintain control of the channel until it has sent all the fragments of a MSDU, and received their corresponding Acks, or until it failed to receive an Ack for a specific fragment. After all fragments have been transmitted, the station will relinquish control of the channel.

Once the station has contended for the channel, it will continue to send fragments until either all fragments of a MSDU have been sent, an acknowledgment is not received, or the station can not send any additional fragments due to a dwell time boundary.

Figure 6-9 illustrates the transmission of a multiple fragment MSDU using the SIFS.

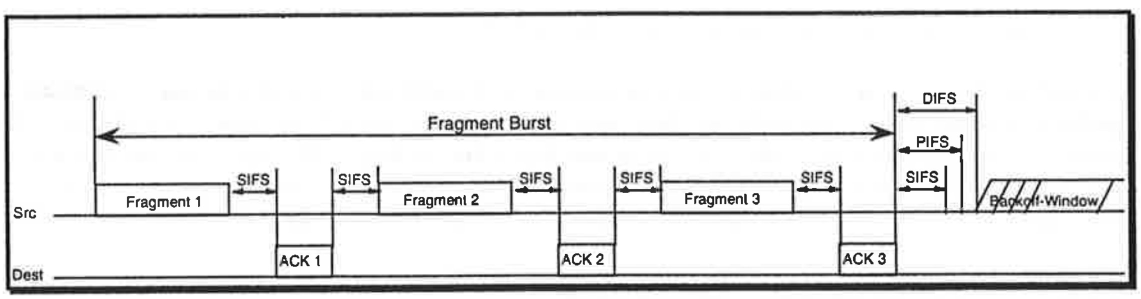

Figure 6-9: Transmission of a Multiple Fragment MSDU using IFS

The source station transmits a fragment then releases the channel and waits for an acknowledgment. When the source station releases the channel following its fragment, it will immediately monitor the channel for an acknowledgment frame from the destination station.

When the destination station has finished sending the acknowledgment, the SIFS following the acknowledgment is then reserved for the source station to continue (if necessary) with another fragment. The station sending the acknowledgment does not have permission to transmit on the channel immediately following the acknowledgment.

The process of sending multiple fragments after contending for the channel is defined as a fragment burst.

If the source station receives an acknowledgment but there is not enough time to transmit the next fragment and receive an acknowledgment due to an impending dwell boundary, it will contend for the channel at the beginning of the next dwell time.

If the source station does not receive an acknowledgment frame, it will attempt to retransmit according to the backoff algorithm. When the time arrives to retransmit the fragment, the source station will contend for access in the contention window.

After a station contends for the channel to retransmit a fragment of a MSDU, it will start with the last fragment that was not acknowledged. The destination station will receive the fragments in order since the source sends them one at a time, in order. It is possible however, that the destination station may receive duplicate fragments. This will occur if the destination station sends an acknowledgment and the source does not receive it. The source will resend the same fragment after executing the backoff algorithm and contending for the channel.

A station will transmit after the SIFS only under the following conditions during a fragment burst:

The station has just received a fragment that requires acknowledging.

The source station has received an acknowledgment to a previous fragment, has more fragment(s) for the same MSDU to transmit, and there is enough time left in the dwell time to send the next fragment & receive an acknowledgment.

The following rules also apply.

When a station has transmitted a frame other than a fragment, it shall not transmit on the channel following the acknowledgment for that frame, without going through a backoff.

When an MSDU has been succesfully delivered, and want to transmit a subsequent MSDU, then it should go through a backoff.

Only unacknowledged fragments are retransmitted.

If a multiple fragment MSDU does not require an acknowledgment (for example, a broadcast/multicast packet transmitted by the Access Point), the source station will transmit all fragments of the MSDU without releasing the channel as long as there is enough time left in the dwell time. If there is not, the station will transmit as many fragments as possible and recontend for the channel during the next dwell time. The spacing between fragments of a broadcast/multicast frame shall be equal to the SIFS period.

1.2.6.6. RTS/CTS Usage with Fragmentation

The following is a description of using RTS/CTS for the first fragment of a fragmented MSDU. RTS/CTS will also be used for retransmitted fragments if their size warrents it. The RTS/CTS frames define the duration of the first frame and acknowledgment. The duration field in the data and acknowledgment frames specifies the total duration of the next fragment and acknowledgment. This is illustrated in Figure 6-10.

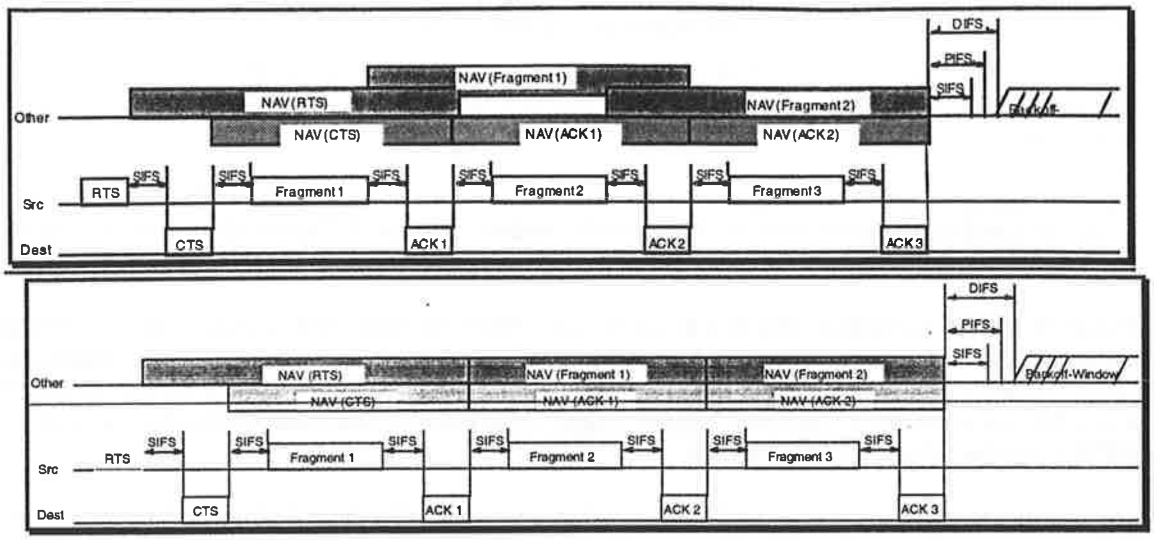

Figure 6-10: RTS/CTS with Fragmented MSDU

Each frame contains information that defines the duration of the next transmission. The RTS will update the NAV to indicate busy until the end of ACK 1. The CTS will also update the NAV to indicate busy until the end of ACK 1. Both Fragment 1 and ACK 1 will update the NAV to indicate busy until the end of ACK 2. This is done by using the duration field in the DATA and ACK frames. This will continue until the last Fragment and ACK which will have the duration set to zero. Each Fragment and ACK acts as a virtual RTS and CTS, therefore no RTS/CTS frame needs to be generated even though subsequent fragments are larger the aRTS_Threshold.

In the case where an acknowledgment is not received by the source station, the NAV will be marked busy for next frame exchange. This is the worst case situation. This is shown in Figure 6-11. If the acknowledgment is not sent by the destination station, stations that can only hear the destination station will not update their NAV and be free to access the channel. All stations that hear the source will be free to access the channel after the NAV from Frame 1 has expired.

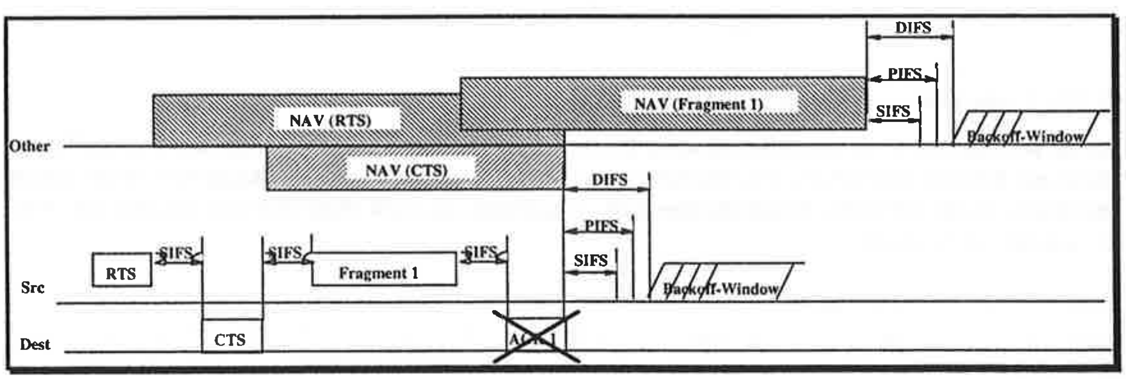

Figure 6-11: RTS / CTS with Transmitter Priority with Missed Acknowledgment

The source station must wait until the ACK timeout before attempting to contend for the channel after not receiving the acknowledgment.

1.2.7.Directed MPDU Transfer Procedure Using RTS/CTS

Figure 6-11 shows the Directed MPDU transfer procedure with the use of RTS/CTS. In certain circumstances the DATA frames will be preceded with an RTS and CTS frame exchange that include duration information.

STA shall use an RTS/CTS exchange for directed frames only when the length of the MPDU is greater than the length threshold indicated by the RTS_Threshold attribute. The aRTS_Threshold attribute shall be set to a MPDU length threshold in each STA.

The aRTS_Threshold attribute shall be a managed object within the MAC MIB, and its value can be set and retrieved by the MAC LME. The aRTS_Threshold attribute shall be constrained to range (0 ... Maximum MPDU Length). The value 0 shall be used to indicate that no MPDU shall be delivered without the use of RTS/CTS. Values of aRTS_Threshold ≥ aMax_Frame_LengthMDPU_Maximum shall indicate that all MPDUs shall be delivered with RTS/CTS.

The asynchronous payload frame (e.g. DATA) shall be transmitted after the end of the CTS frame and an SIFS gap period. No regard shall be give to the busy or free status of the medium.

1.2.7.1. Directed MPDU Transfer Procedure without RTS/CTS

Following the basic access mechanism, the source STA shall transmit the asynchronous payload frame (e.g. DATA). The destination STA shall follow the ACK Procedure.

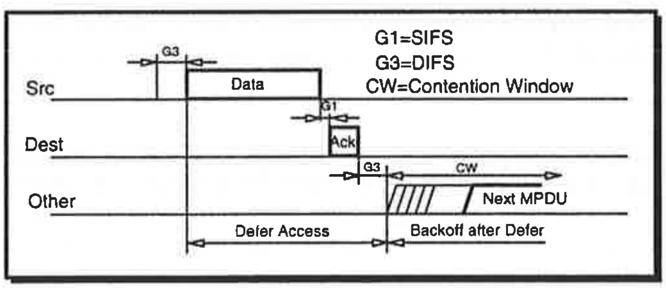

Figure 6-12: Directed Data/ACK MPDU

1.2.8.Broadcast and Multicast MPDU Transfer Procedure

In the absense of a PCF, when Broadcast or Multicast MPDUs are transferred from an AP to a STA, or from one STA to other STA's, only the basic access mechanism shall be used. Regardless of the length of the frame, no RTS/CTS exchange shall be used. In addition, no ACK shall be transmitted by any of the receipients of the frame.

Any Broadcast or Multicast MPDUs transferred from a STA with a To_DS bit set shall, in addition to conforming to the basic access mechanism of CSMA/CA, obey the rules for RTS/CTS exchange. In addition, the AP shall transmit an ACK frame in response just as if the MPDU were directed traffic.

Multicast MSDUs shall- be propagated throughout the ESS.

There is no MAC level recovery on Broadcast or Multicast frames except for those frames sent with the To_DS bit set. As a result the reliability of this traffic is reduced due to the increased probability of lost frames from interference or collisions.

1.2.9.ACK Procedure

Upon successful reception of a data or management frame with the ToAP bit set, an AP shall always generate an ACK frame. An ACK frame shall be transmitted by the destination STA which is not an AP whenever it successfully receives a unicast data frame or management frame,- but not if it receives a broadcast or multicast data frame. The transmission of the ACK frame shall commence after an SIFS period without regard to the busy/free state of the medium.

The Source STA shall wait an Ack_timeout amount of time without receiving an Ack frame before concluding that the MPDU failed.

This policy induces some probability that a pending frame in a neighboring BSA (using the same channel) could be corrupted by the generated ACK. However if no ACK is returned because a busy medium was detected, then it is guaranteed that the frame would be interpreted as in error due to the ACK timeout, resulting in a retransmission.

1.2.10. Duplicate Detection and Recovery

Since MAC-level acknowledgments and retransmissions are incorporated into the protocol, there is the possibility that a frame may be received more than once. Such duplicate frames shall be filtered out within the destination MAC.

Duplicate frame filtering is facilitated through the inclusion of a sequence control field~~dialog token~~ (consisting of a sequence number and fragment number) field within DATA and MANAGEMENT frames. MPDUs which are part of the same MSDU shall have the same sequence number, and different MSDUs will (with a very high probability) have a different sequence number.

The sequence number is generated by the transmitting station as an incrementing sequence of numbers.

The receiving station shall keep a cache of recently-received <source-address, sequence-number, fragment-number> tuples.

A destination STA shall reject a frame which has the RETRY bit set in the Frame Control ~~CONTROL~~ field as a duplicate if it receives one which matches the~~both~~ source-address, sequence-number and fragment-number of an entry in the cache-.

There is the small possibility that a frame will be improperly rejected due to such a match; however, this occurrence would be rare and would simply result in a lost frame similar to an FCS error in ethernet.

The Destination STA shall perform the ACK procedure even if the frame is subsequently rejected due to duplicate filtering.

1.2.11. DCF Timing Relations

This section formulates the relation between the IFS specifications as have been defined as time gaps on the medium, and the associated MIB variables that are provided per PHY.

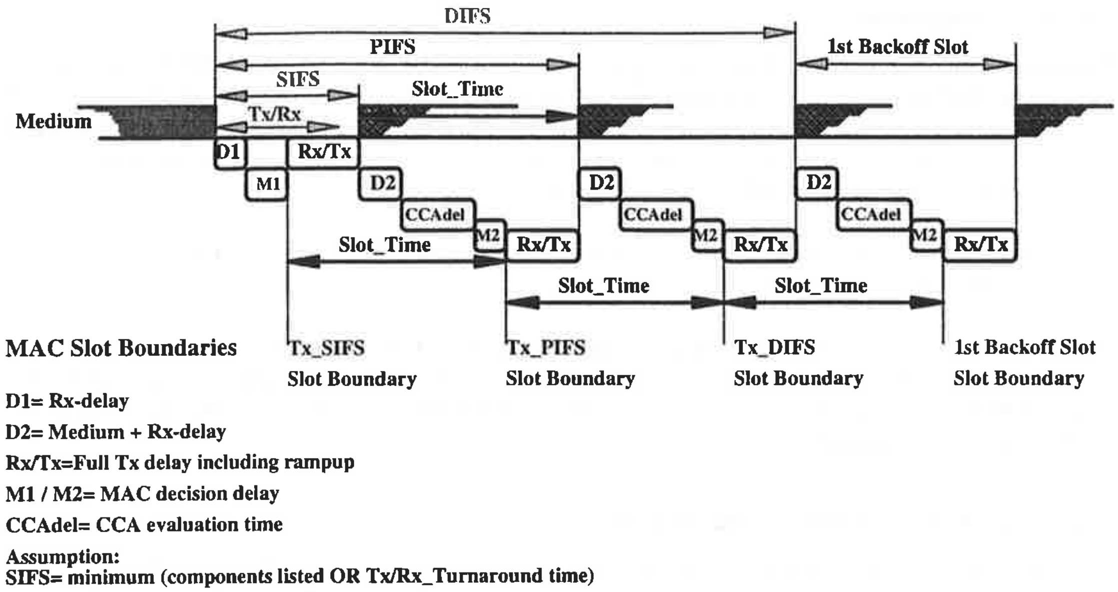

Figure 6-13

All timings are referenced to the end of the last symbol of a frame on the medium.

The SIFS, and Slot_Time are defined in the MIB, and are fixed per PHY.

SIFS is based on: Rx_Delay + MAC_Delay-1 + Rx/Tx_Delay.

Slot_Time is based on: Rx/Tx_Delay + Medium_Delay + Rx_Delay + CCA_Delay + MAC_Delay-2

The PIFS and DIFS are derived by the following equations, as illustrated in figure 6-13.

PIFS = SIFS + Slot_Time

DIFS = SIFS + 2 * Slot_Time

The Medium_Delay component is fixed at 1 usec.

Figure 6-13 illustrates the relation between the SIFS, PIFS and DIFS as they are measured on the medium and the different MAC Slot Boundaries Tx_SIFS, Tx_PIFS and Tx_DIFS. These Slot Boundaries define when the transmitter can be turned on by the MAC to meet the different IFS timings on the medium, after subsequent detection of the CCA result of the previous Slot_Time.

The following equations define the MAC Slot Boundaries, using parameters defined in the MIB, which are such that they compensate for implementation timing variations. The reference of these slot boundaries is again the end of the last symbol of the previous frame on the medium.

Tx_SIFS = SIFS - a Rx/Tx_Turnaround_Time (MIB variable)

Tx_PIFS = Tx_SIFS + Slot_Time

Tx_DIFS = Tx_SIFS + 2 * Slot_Time.

The tolerances are specified in the MIB, and will only apply to the SIFS specification, so that tolerances will not accumulate.

1.3. Point Coordination Function (thissection is replaced by text from 95/140, further updated by 95/150, however, edits relating to MIB consistency appear below because they were inadvertently omitted from 95/140)

The Point Coordination Function (PCF) provides Contention Free frame transfer. It is an option for a STA to be able to become the Point Coordinator(PC). All STA inherently obey the medium access rules of the PCF, because these rules are based on the DCF, with the Point Coordinator gaining priority access to the medium using a PCF IFS (PIFS) which is smaller than the DCF IFS (DIFS) usedby the DCF to access the medium. The operating characteristics of the PCF are such that all stations are able to operate properly in the presence of a BSS in which a Point Coordinator is operating, and, if associated with a point-coordinated BSS, are able to receive data frames sent under PCF control.. It is also an option for a station to be able to respond to a contention-free poll (CF-poll) received from a Point Coordinator. A station which is able to respond to CF-polls is referred to as being CF-Aware, and may request to be polled by an active Point Coordinator. When polled by the Point Coordinator, a CF-Aware station may transmit one frame to any destination (not just to the Point Coordinator), and may ÒpiggypackÓ the acknowledgement of a frame received from the Point Coordinator using particular data frame subtypes for this transmission. If the addressed recipient of a CF transmission is not CF-Aware, that station acknowledges the transmission using the DCF acknowledgement rules, and the Point Coordinator retains control of the medium by waiting the PIFS duration before resuming CF transfers.

When more than one point-coordinated BSS is operating on the same PHY channel in overlapping space, the potential exists for collisions between PCF transfer activities by the independent point coordinators. The rules under which multiple, overlapping point-coordinated BSSs can coexist are presented in section 6.3.3.3.As shown in Figure 6-2, the PCF is built on top of the CSMA/CA based DCF, by utilizing the access priority provisions provided by this scheme.An active Point Coordinator must be located at an AP, which restricts PCF operation to infrastructure networks. However, there is no requirement that a distribution system be attached to this AP, which permits a station capable of AP and PC functionality to be designated as the ÒAPÓ in an isolated BSS. PCF is activated at a PC---capable AP by setting the aCFP_Max_Duration managed object to a non--zero value.

1.3.1.Contention Free Period Structureand Timing

The PCF controls frame transfers during a Contention Free Period (CFP) . The CFP alternates with a Contention Period (CP), when the DCF controls frame transfers,as shown in Figure 6-14. Each CFP begins with a Beacon frame that contains a DTIM Element (hereafter referred to as a ÒDTIMÓ). The CFPs occur at a defined repetition rate, which is synchronized with the beacon interval as specified below.

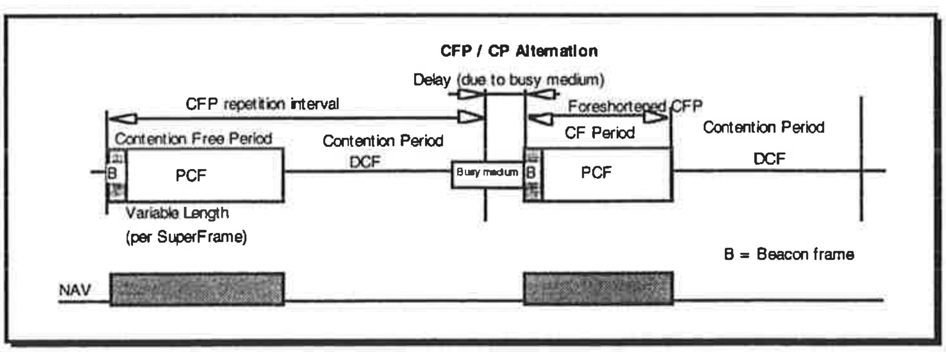

Figure 6-14: CFP / CP Alternation

The PC generates CFPs at the **Contention-Free Repetition Rate** (CFP-Rate), which shall be an integral number of DTIM intervals. The PC determines the CFP-Rate (depicted as a repetition interval in the illustrations below) to use from the aCFP_Rate managed object. This value, in units of beacon intervals, is communicated to other stations in the BSS in a field of the PCF Element of Beacon frames. The PCF Element is only present in Beacon frames transmitted by stations containing an active Point Coordinator.

<< NOTE: These references to milliseconds may not be enumerated in the 95/149r1 update list because of the co-pending update motions, but they do need to be updated to Kusec from the adoption of 95/149r1. >>

The length of the CFP is controlled by the PC, with maximum duration specified by the value of the aCFP_Max_Duration managed object at the PC. Neither the maximum duration nor the actual duration (signalled by transmission of a CF-End or CF-End+Ack frame by the PC) are constrained to be a multiple of the beacon interval. If the CFP-Rate is greater than the beacon interval, the PC shall transmit beacons at the appropriate times during the CFP (subject to delay due to traffic at the nominal times, as with all beacons). The PCF Element in all beacons at the start of, or within, a CFP contain a non-zero value in the CFP_Dur_Remaining field. This value, in units of milliseconds, specifies the maximum time from the transmission of this beacon to the end of this CFP. The value of the CFP_Dur_Remaining field is zero in beacons sent during the contention period. An example of these relationships is illustrated in figure 6-15, which shows a case where the CFP-Rate is 2 DTIM intervals, the DTIM interval is 3 beacon intervals, and the aCFP_Max_Duration is approximately 2.5 beacon intervals.

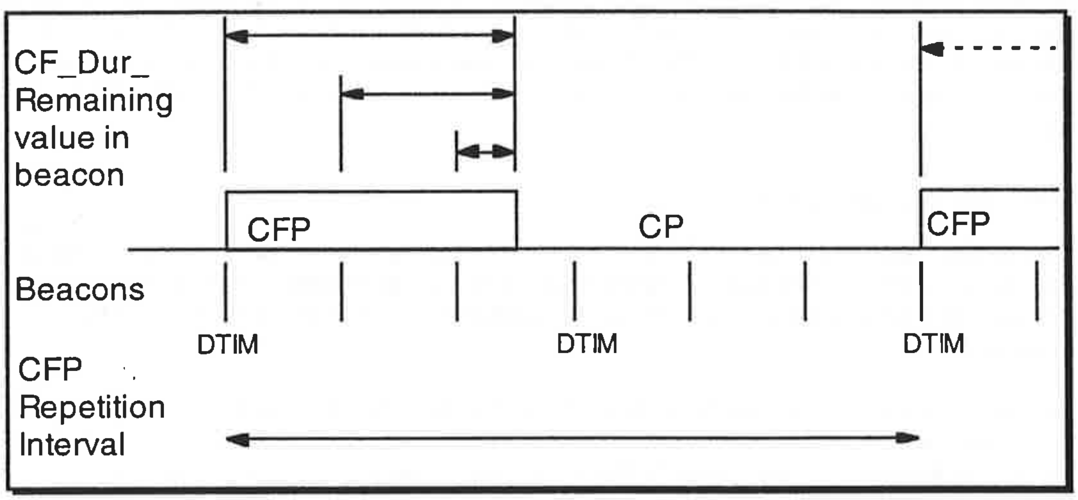

Figure 6-15: Beacons & Contention Free Periods

The PC may terminate any CFP at or before the aCFP_Max_Duration, based on available traffic and size of the polling list. Because the transmission of any beacon may be delayed due to a medium busy condition at the nominal beacon transmission time, a CFP may be foreshortened by the amount of the delay. In the case of a busy medium due to DCF traffic, the upper bound on this delay is the maximum aHandshake_Overhead~~RTS + CTS~~ + aM~~m~~ax_MPDU_Time + aACK_Time~~Ack~~ duration. In cases where the beacon transmission is delayed, the CFP_Dur_Remaining value in the beacon at the beginning of the CFP shall specify a time that causes the CFP to end no later than the nominal beacon transmission time plus the value of aCFP_Max_Duration. This is illustrated in figure 6-16.

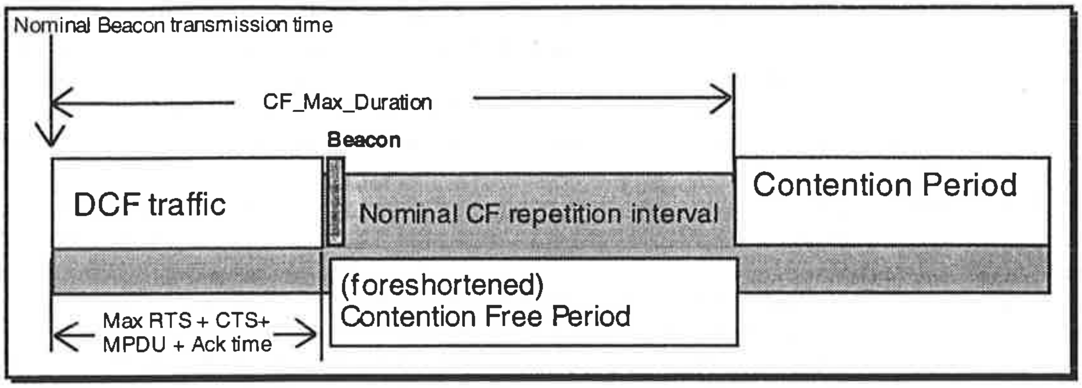

Figure 6-16: Example of Delayed Beacon and Foreshortened CFP

1.3.2.PCF Access Procedure

The contention free transfer protocol is based on a polling scheme controlled by a Point Coordinator operating at the AP of the BSS. The PC gains control of the medium at the beginning of the CFP and attempts to maintain control for the entire CFP by waiting a shorter time between transmissions than the stations using the DCF access procedure. Acknowledgement of frames sent during the Contention Free Period may be accomplished using Data+CF-Ack, CF-Ack, Data+CF-Poll+CF-Ack (only on frames transmitted by the PC), or CF-Ack+CF-Poll (only on frames transmitted by the PC) frames in cases where a data (or null) frame immediately follows the frame being acknowledged, thereby avoiding the overhead of separate Ack frames.

1.3.2.1. Fundamental Access

At the nominal beginning of each CFP, the PC shall sense the medium. When the medium is free (both CCA and NAV) for one PIFS interval, the PC shall transmit a beacon frame containing a PCF Element with CFP-Rate and CFP_Dur_Remaining fields set as specified above. A DTIM element is also required in this beacon frame.

After the initial beacon frame, the PC waits for the medium to be free (CCA only, not NAV) for one SIFS interval then transmits either a Data frame, a CF-Poll frame, a Data+CF-Poll frame, or a CF–End frame. If a null CFP is desired, a CF–End frame shall be transmitted immediately after the initial beacon.

Stations receiving error-free frames from the PC are expected to respond after an SIFS interval, in accordance with the transfer procedures defined in Section 6.3.3. If the recipient station is not CF-Aware, the response to receipt of an error-free Data frame is always an Ack frame.

1.3.2.2. NAV Operation During the Contention Free Period

Each station, except the station with the PC, shall preset it's NAV to the CF_Dur_Remaining value in the PCF Element of the beacon frame at the beginning of every CFP. This prevents stations from taking control of the medium during the CFP, which is especially important in cases where the CFP spans multiple medium-occupancy intervals, such as dwell periods of an FH PHY. This setting of the NAV also minimizes eliminates the risk of hidden stations sensing a DIFS gap during the CFP and possibly corrupting a transmission in progress.

The PC shall transmit a CF–End or CF-End+Ack frame at the end of each CF-Period. Receipt of either of these frames shall reset the NAV of all stations in the BSS.

1.3.3.PCF Transfer Procedure

Frame transfer under the PCF typically consists of alternating between frames sent from the AP/PC and frames sent to the AP/PC. During the CFP, the ordering of these transmissions, and the station allowed to transmit frames to the PC at any given point in time, is controlled by the PC. Figure 6-17 depicts a frame transfer during a typical CFP. The rules under which this frame transfer takes place are detailed in the following paragraphs.

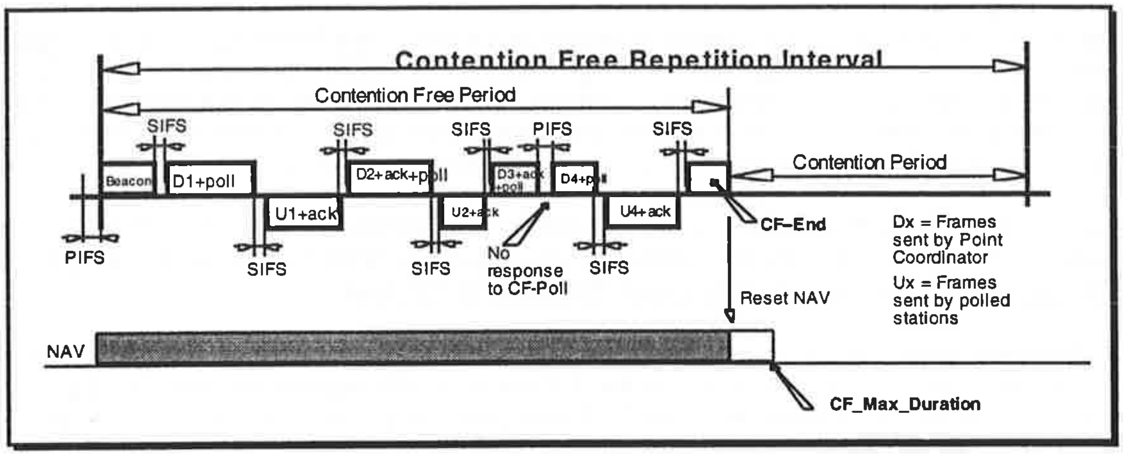

Figure 6-17: Example of PCF Frame Tranfser

1.3.3.1. PCF Transfers When the PCF Station is Transmitter or Recipient

The PC shall transmit frames between the beacon which starts of the CFP and the CF–End using the SIFS gap (CCA only, not NAV) except in cases where a transmission by another station is expected by the PC and an SIFS gap elapses without the receipt of the expected transmission. In such cases the PC shall send its next pending transmission a PIFS gap after the end of its last transmission. This permits the PC to retain control of the medium in cases where an expected response or acknowledgement does not occur. The PC may transmit any of the following frame types to CF-Aware stations:

Data, used when the addressed recipient is not being polled and there is nothing to acknowledge;

Data+CF-Ack, used when the addressed recipient is not being polled and the PC needs to acknowledge the receipt of a frame received from a CF-Aware station an SIFS interval before starting this transmission;

Data+CF-Poll, used when the addressed recipient is the next station to be permitted to transmit during this CFP and there is nothing to acknowledge;

Data+CF-Ack+CF-Poll, used when the addressed recipient is the next station to be permitted to transmit during this CFP and the PC needs to acknowledge the receipt of a frame received from a CF-Aware station an SIFS interval before starting this transmission;

CF-Poll (no data), used when the addressed recipient has no pending frames buffered at the AP, but is the next station to be permitted to transmit during this CFP and there is nothing to acknowledge;

CF-Ack+CF-Poll (no data), used when the addressed recipient has no pending frames buffered at the AP but is the next station to be permitted to transmit during this CFP and the PC needs to acknowledge the receipt of a frame from a CF-Aware station an SIFS interval before starting this transmission;

CF-Ack (no data), used when the addressed recipient has no pending frames buffered at the AP or insufficient time remains in the CFP to send the next pending frame, but the PC needs to acknowledge receipt of a frame from a CF-Aware station an SIFS interval before starting this transmission (useful when the next transmission by the PC is a management frame, such as a beacon); or

any management frame that is appropriate for the AP to send under the rules for that frame type.

The PC may transmit Data or management frames to non-CF-Aware, non-Power Save stations during the CFP. These stations acknowledge receipt with Ack frames after and SIFS gap, as with the DCF. The PC may also transmit broadcast or multicast frames during the CFP. Because the Beacon frame that initiates the CFP contains a DTIM Element, if there are associated stations using Power Save Mode, the broadcasts and multicasts buffered for such stations shall be sent immediately after the initial Beacon.

A CF-Poll bit in the Subtype field of these frames will allow the stations to send their (CF-Up) data if any. Stations shall respond to the CF-Poll immediately when a frame is queued, by sending this frame after an SIFS gap. This results in a burst of Contention Free traffic; the CF-Burst.

A CF-Aware station that receives a directed frame with any of data subtypes that include CF-Poll may transmit one data frame when the medium is free (CCA only) an SIFS gap after receiving the CF-Poll. CF-Aware stations ignore, but do not reset, their NAV when performing transmissions in response to a CF-Poll.

For frames that require MAC level acknowledgment, CF-Aware stations that received a CF-Poll (of any type) may perform this acknowledgment using the Data+CF-Ack subtype in the response to the CF-Poll. For example, the U1 frame in Figure 6-18 contains the acknowledgement to the preceding D1 frame. Also the D2 frame contains the acknowledgement to the preceding U1 frame. The PC may use the CF-Ack subtypes to acknowledge a received frame even if the Data frame sent with the CF-Ack subtype is addressed to a different station than the one being acknowledged. CF-Aware stations that are expecting an acknowledgement shall interpret the subtype of the frame (if any) sent by the PC an SIFS gap after that stationÕs transmission to the PC. If a frame that requires MAC level acknowledgement is received by a non-CF-Aware station, that station does not interpret the CF-Poll indication (if any), and acknowledges the frame by sending an Ack frame after an SIFS gap.

If a frame, transmitted during the CFP, requires MAC level acknowledgement and is not acknowledged, that frame is *not* retransmitted during the same CFP. The frame may be retried once, during a subsequent CFP, at the discretion of the PC or CF-Aware station.

The sizes of the frames may be variable, only bounded by the frame and/or fragment size limitations that apply for the BSS. If a CF-Aware station does not respond to a CF-Poll (of any type) within the SIFS gap following a transmission from the PC, or a non-CF-Aware station does not return the Ack frame within an SIFS gap following a transmission from the PC that requires acknowledgment, then the PC shall resume control and transmit its next frame after a PIFS gap from the end of the PCF's last transmission. or a non-CF-Aware station does not return the Ack frame within an SIFS gap following a transmission from the PC that requires acknowledgment,

A CF-Aware station must respond to a CF-Poll. If the station has no frame to send when polled, the response shall be a Null frame. If the station has no frame to send when polled, but an acknowledgment is required for the frame that conveyed the CF-Poll, the response shall be either a CF-Ack (no data) or an Ack frame. The null response is required to permit a 'no-traffic' situation to be distinguished from a collision between overlapping PCFs.

The the CFP ends when the CF_Max_Duration time has elapsed since the last Beacon or when the PC has no further frames to transmit nor stations to poll. In either case, the end of the CFP is signalled by the transmission of a CF-End by the PC. If there is a received frame which requires acknowledgement at the time the CF-End is to be transmitted, the PC transmits a CF-End+Ack frame instead. All stations of the BSS receiving a CF-End or CF-End+Ack reset their NAVs so they may attempt to transmit during the contention period.

1.3.3.2. PCF Transfers When the PCF Station is Neither Transmitter nor Recipient

A CF-Aware station, when transmitting in response to a CF-Poll (any type), may send a Data frame to any station in the BSS an SIFS gap after receiving the CF-Poll. If the addressed recipient of this transmission is not the AP, the Data frame is received and acknowledged according to the DCF rules for Data frames. This is illustrated in Figure 6-18. The PC resumes transmitting an SIFS gap after the Ack frame, if the PC hears the Ack, or a PIFS gap after the expected time for the Ack frame if the PC does not hear the Ack.

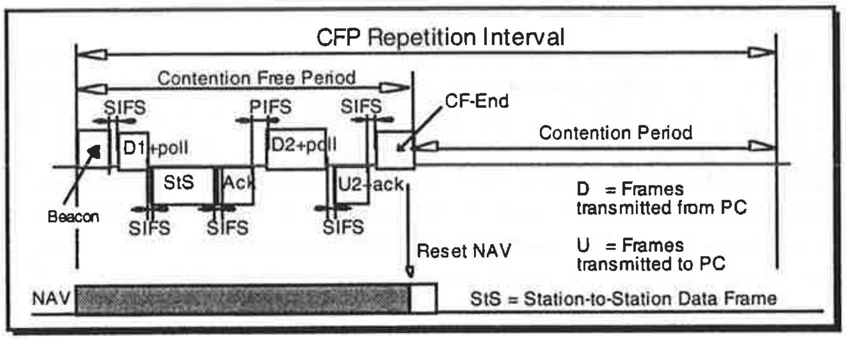

Figure 6-18: Station-to-Station Contention Free Transfer

1.3.3.3. Operation with Overlapping Point-Coordinated BSSs

Because the PCF operates without the CSMA/CA contention window randomization and backoff of the DCF, there is a risk of repeated collisions if multiple, overlapping BSSs are operating with PCF on the same PHY channel, and their CFP-Rates and beacon intervals are approximately equal. To minimize the risk of significant frame loss due to undetected collisions during contention free operation, transmissions of data an management frames during the CFP are only initiated when the medium is free (CCA only, NAV ignored) for the SIFS interval. This is in contrast to Ack frames, which are transmitted (under DCF or PCF) after the SIFS interval without regard to the state of the medium. In addition, whenever the PC has a Data and/or CF-Poll transmission go unacknowledged, the PC shall sense medium free (CCA only) for the PIFS interval, rather than the SIFS interval prior to its next transmission.

<< NOTE: Another reference to milliseconds appears below and needs to be changed to Kusec. >>

To further reduce the susceptibility to inter-PCF collisions, the PC shall require the medium be free for a random (over range of 1 to aCW_Mmin) number of slot times once every aMedium_Occupancy_Limit milliseconds during the CFP. This can only result in loss of control of the medium to overlapping BSS or hidden station traffic, because the stations in this BSS are prevented from transmitting by their NAVs. For operation of the PCF in conjunction with an FH PHY, aMedium_Occupancy_Limit shall be set equal to the dwell time. For operation in conjunction with other PHY types, when using a short aCFP_Max_Duration that does not require this extra protection against inter-PCF collisions, aMedium_Occupancy_Limit can be set equal to aCFP_Max_Duration. (The aMedium_Occupancy_Limit is also useful for compliance in regulatory domains that impose limits on continuous transmission time as part of a spectrum etiquette.)

1.3.3.4. CFP_Max_Duration Limit

The value of aCFP_Max_Duration shall be limited to allow coexistence between Contention and Contention Free traffic.

The minimum value for aCFP_Max_Duration, if the PCF is going to be used, is two times aMax_MPDU_Time plus the time required to send the initial Beacon frame and the CF-End frame of the CFP. This allows sufficient time for the AP to send one Data frame to a station, while polling that station, and for the polled station to respond with one Data frame.

The maximum value for aCFP_Max_Duration is the duration of aCFP_Rate minus aMax_MPDU_Time plus aHandshake_Overhead plus aACK_Time~~the time required for the RTS/CTS and Ack frames~~ associated with this MSDU when operating with a~~default size~~ contention window of aCW_Min. This allows sufficient time to send at least one contention-based Data frame.

1.3.3.5. Contention Free Usage Rules

A PC may send broadcast or multicast frames, and directed Data or management frames to any active station, as well as to CF-Aware Power Save stations. During the CFP, CF-aware stations shall acknowledge receipt of each Data+CF-Poll frame , Data+CF-Ack+CF-Poll frame, CF-Poll (no data) frame, or CF-Ack+CF-Poll frame using Data+CF-Ack or CF-Ack (no data) frames, sent after an SIFS–interval (CCA only, NAV ignored); and shall acknowledge the receipt of all other Data and management frames using ACK Control frames sent after an SIFS–interval (CCA and NAV ignored, as with all ACK frames). Non-CF-aware stations shall acknowledge receipt of (all) Data and management frames using ACK Control frames sent after an SIFS–interval (CCA and NAV ignored, as will all ACK frames). This non-CF-Aware operation is the same as these stations already do for DCF operation.

When polled by the PCF (Data+CF-Poll, Data+CF-Ack+CF-Poll, CF-Poll, or CF-Ack+CF-Poll) a CF-aware station may send one Data or managment frame to any destination. Such a frame directed to or through the PC station shall be acknowledged by the PC, using the CF-Ack indication (Data+CF-Ack, Data+CF-Ack+CF-Poll, CF-Ack, CF-Ack+CF-Poll, or CF-End+Ack) sent after an SIFS–interval. Such a frame directed to non–PCF stations shall be acknowledged using an ACK Control frame sent after an SIFS–interval. (This is the same as these stations already do.) A polled CF-aware station with neither a Data frame nor acknowledgement to send shall respond by transmitting a Null frame after an SIFS-interval.

The PC shall not issue CF-Polls if insufficient time remains in the current CFP to permit the polled station to transmit a Data frame containing a maximum–length MPDU.

1.3.4. Contention Free Service Types

The PCF provides a frame transfer mechanism, not a service class. This transfer mechanism may be used for delivery of asynchronous traffic (data and management frames) that would otherwise be sent in the contention period,and connection-oriented traffic, which may include Time-Bounded Services (TBS) as defined elsewhere in this standard.

1.3.5. Contention Free Polling List

The PC maintains a "polling list" for use in selecting stations that are eligible to recive CF-Polls during contention free periods. The polling list is used to force the polling of CF-Aware stations, whether or not the PC has no pending traffic to transmit to those stations. The polling list may be used to control the use of Data+CF-Poll and Data+CF-Ack+CF-Poll types for transmission of Data frames being sent to CF-Aware stations by the PC. The polling list is a *logical* construct, which is not exposed outside of the PCF. A minimum set of polling list maintenance techniques are required to ensure interoperability of arbitrary CF-Aware stations in BSSs controlled by arbitrary CF-Capable access points. APs may also implement additional polling list maintenance techniques which are outside the scope of this standard.

1.3.5.1. Polling List Processing

The PC shall send a CF-Poll to at least one station during each station begins when there are entries in the polling list. The PCF shall issue polls to stations whose entries on the polling list are for reasons other than time-bounded service connections in order by ascending SID value. If there is insufficient time to send CF-Polls to all such entries on the polling list during a particular CFP, the polling commences with the next such entry during the next CFP. The issuance of polls to stations whose entries on the polling list are for time-bounded service connections shall follow the rules applicable to the service class.

While time remains in the CFP, the PC may generate one or more CF-Polls to *any* stations on the polling list. While time remains in the CFP, the PC *may* send Data or Management frames to *any* stations.

In order to gain maximum efficiency from the contention free period, and the ability to piggyback acknowledgements on successor Data frames in the opposite direction, the PC should generally use Data+CF-Poll and Data+CF-Ack+CF-Poll types for each data frame transmitted while sufficient time for the potential response to the CF-Poll remains in the CFP. The PC may send multiple frames (with or without CF-Polls) to the same station during a single CFP, and may send multiple CF-Polls to a station in cases where time is available and the station indicates that More frames are available in the frame control field of a transmission in response to a CF-Poll.

1.3.5.2. ACFS Procedure

A station indicates its CF-Awareness during the Association process. If a station desires to change the PCF's record of CF-Awareness, that station must perform a Reassociation. During Association, a CF-Aware station may also request to be placed on the polling list for the duration of its association, or to never be placed on the polling list. The later is useful for CF-Aware stations that normally use Power Save Mode, permitting them to receive buffered traffic during the CFP (since they have to be awake to receive the DTIM that initiated the CFP), but not requiring them to stay awake to receive CF-Polls when they have no traffic to send.

Stations that establish connections are automatically placed on the polling list for the duration of each connection. Note that ony CF-Aware stations may establish connections, and that connection-based services are only available when a PC is operating in the BSS.

CF-Aware stations that are not on the polling list due to a static request during Association, and are not excluded from the polling list due to a static request during Association, may be dynamically placed on the polling list by the PC to handle bursts of frame transfer activity by that station. The PC monitors CF-aware station activity during both the Contention Free period and the contention period. When a CF-aware station placed on the polling list dynamically has not transmitted a Data frame in response to the number of successive CF-Polls indicated in aPoll_Inactivity, then the PCF may delete that station from the polling list. When a CF-aware station not on the polling list, but not excluded from the polling list, has transmitted any Data frames during the previous contention period, then the PC may add that station to the polling list. This is illustrated in Figure 6-19.

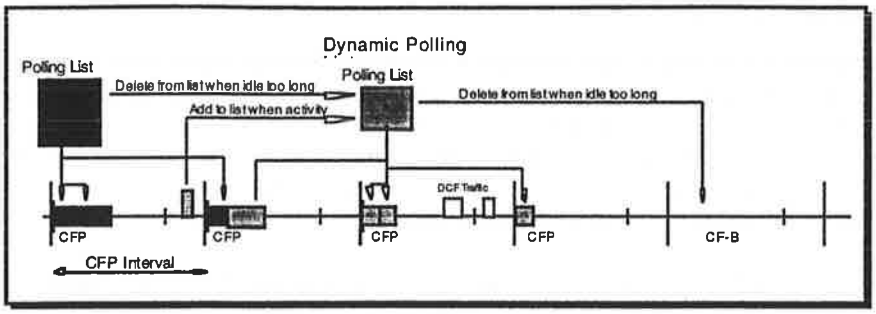

Figure 6-19: Dynamic Polling List Update Technique

1.3.6. Connection Management Frame Usage

Note: The incomplete definition of the connection service specification and the incomplete specification of the connection management frames prevents this section from being complete. These updates reflect letter ballot comments, and do not constitute an attempt to complete definition of the connection management frames nor their usage.

The contention free management frames are used in the following way.

1.3.6.1. STA Start Connection Request

Generated if the MAC user (of a station) makes a "Start Connection Request" when there is no outstanding request.

A station initiates a request for a connection to be established. The Payload must be included in this frame.

Receipt of this management frame will generate a "Start Connection Indication".

1.3.6.2. AP Start Connection Request

Generated if the MAC user (of an AP) makes a "Start Connection Request" when there is no outstanding request

An AP initiates a request for a connection to be established within the contention free period. The Payload and Connection ID must be included in this frame. The connection ID is the proposed connection ID that of the connection that will be established if this request is granted.

1.3.6.3. Grant Connection

After a Start Connection Request frame has been received the MAC shall reply with a “Grant Connection” frame which indicates the success or failure of the connection request.

If the requested connection is granted, the PC places an entry corresponding to that connection onto the polling list. If a station has multiple connections active, that station appears on the polling list multiple times. Only an access point may assign MAC connection numbers; so if a station is to grant a connection it must return the connection ID that was proposed by the access point. The MAC Connection ID must be included in this frame.

Transmitting or receiving this frame causes a Connection Granted Indication or a Connection Denied Indication..

1.3.6.4. End Connection

Either a station or an access point may initiate the end of a connection. When a node receives an End Connection frame it should stop using that connection, since the sending node will no longer maintain it. The MAC Connection ID must be included in this frame. When the connection is ended, the PC removes the entry corrresponding to that station from the polling list.

mentation

fragment and reassemble MSDUs, directed and multicast/broadcast. The primary reason for MSDU is that it is larger than the PHY is capable of sending in one MPDU. The nd reassembly mechanisms allows for fragments to be retransmitted.

l support the concurrent~~simultaneous~~ reception of a minimum of 6 MSDUs.

on design also allows for the characteristics of FH PHYs. For the purposes of this vell time' will refer to the duration of time spent on a single frequency in a FH system. H PHY the PHY will hop to the next frequency in the hop sequence at the end of the ne.

a fragment shall be an even number of octets for all fragments except the last. The payload all never be larger than aFragmentation_Threshold~~Payload~~. However, it may be less than _Threshold~~Payload~~.

be transmitted, the number of octets in the payload of the fragment shall be determined e at which the fragment is to be transmitted for the first time. Once a fragment is he first time, its contents shall be fixed until it is successfully delivered to the immediate .

ata octets in the payload of a fragment shall depend on the values of _Threshold, and may depend on the values of of the following three variables at the instant ssembled to be transmitted for the first time:

ragmentation_Threshold~~Payload~~
e time remaining in the current dwell time.
e number of octets in the MSDU that have not yet been transmitted for the first time.

of the channel will be lost at a dwell time boundary and the station will have to contend fter the dwell boundary, it is required that enough time be allowed for the acknowledgment be transmitted before the stations cross the dwell time boundary. Hence, if there is not aining in the dwell time to transmit a fragment with an aFragmentation_Threshold~~Payload~~ ber of octets in the payload may be reduced to the maximum number of octets that will nt plus the MAC acknowledgment to fit within the time remaining in the dwell time. This is 6-21 for an MSDU of 1500 octets.

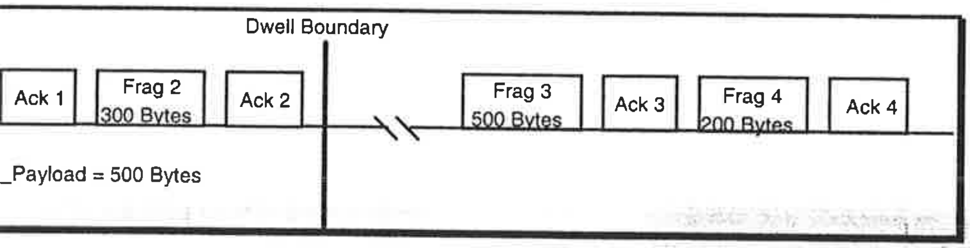

Figure 6-21: Fragmentation Near a Dwell Boundary

re 6-21, a 1500 octet MSDU is fragmented into four fragments with Threshold~~Payload~~ set at 500 octets. There is enough time left in the dwell to send two 500 octets and a second of 300 octets. After the dwell boundary, the rest of the MSDU is et fragment and one 200 octet fragment.

A station may elect not to adjust the size of the payload when approaching a dwell boundary. In this case, the station must wait until after the next dwell boundary to create and transmit a fragment with a aFragmentation_Threshold~~Payload~~ octet payload (provided there are at least aFragmentation_Threshold~~Payload~~ ~~more~~ octets remaining in the MSDU). A station must be capable of receiving fragments of varying size for a single MSDU.

If a fragment requires retransmission, its contents and length shall remain fixed for the lifetime of the MSDU at that station. In other words, after a fragment is transmitted once, contents or length of that fragment are not allowed to fluctuate to accommodate the dwell time boundaries. Let the fragmentation set refer to the contents and length of each of the fragments that make up the MSDU. The fragmentation set is created at a station as soon as transmissions of the fragments are attempted for the first time. The fragmentation set remains fixed for the lifetime of the packet at the transmitting station. This is shown in Figure 6-22.

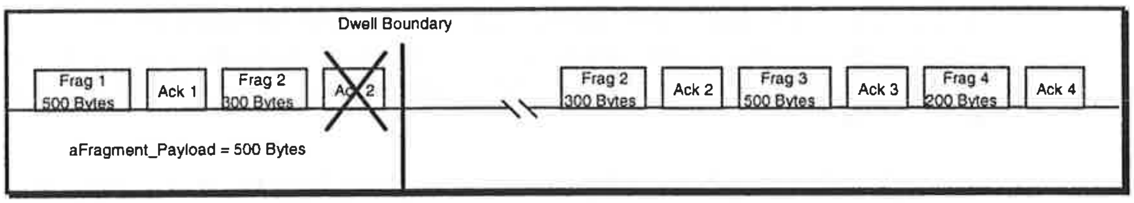

Figure 6-22: Fragmented MSDU with missed ACK Near a Dwell Boundary

In the example shown in Figure 6-22, the same 1500 octet MSDU is fragmented at the same point in the dwell time as in Figure 6-21 but the ACK for the second fragment is missed. After the dwell boundary, the fragment is retransmitted and the fragment size remains 300 octets.

Each fragment will contain a Sequence Control Field, which is comprised of a Sequence Number and Fragment Number. When a station is transmitting an MSDU, the Sequence Number will remain the same for all fragments of that MSDU. The fragments will be sent in order of lowest Fragment Number to highest Fragment Number, where the fragment number increases by one for each fragment. The Frame Control Field also contains a bit, the Last Fragment bit, that indicates the MPDU which constitutes the last (or only) fragment of the MSDU.

If, when retransmitting a fragment, there is not enough time remaining in the dwell time to allow transmission of the fragment plus the acknowledgment, the station shall wait until after the next dwell boundary before retransmitting that fragment.

The source station will maintain a aTransmit_MSDU_Timer attribute for each MSDU being transmitted. There is also an attribute, aMax_Transmit_MSDU_Lifetime, that specifies the maximum amount of time allowed to transmit a MSDU. The aTransmit_MSDU_Timer starts on the attempt to transmit the first fragment of the MSDU. If aTransmit_MSDU_Timer exceeds aMax_Transmit_MSDU_Lifetime than all remaining fragments are discarded by the source station and no attempt is made to complete transmission of the MSDU.

1.5. Reassembly

Each data fragment contains information to allow the complete MSDU to be reassembled from its constituent fragments. The header of each fragment contains the following information that is used by the destination station to reassemble the MSDU:

Frame Type (data, acknowledgment, etc.).

Source Address

Destination Address

Sequence Control Field: This field allows the destination station to check that all incoming fragments belong to the same MSDU, and the sequence in which the fragments should be reassembled. The Sequence Number within the Sequence Control Field remains the same for all fragments of an MSDU, while the Fragment Number within the Sequence Control Field increments for each fragment.

Last Fragment Indicator: Indicates to the destination station that this is the last fragment of the MSDU. Only the last or sole fragment of the MSDU will have this bit set to one. All other fragments of the MSDU will have this bit set to zero.

The destination station can reconstruct the MSDU by combining the fragments in order of Fragment Number portion of the Sequence Control Field. If the fragment with the last fragment bit set to one has not yet been received, then the destination station knows that the MSDU is not yet complete. As soon as the station receives the fragment with the last fragment bit set to one, the station knows that no more fragments will be received for the MSDU.

The destination station will maintain a aReceive_MSDU_Timer attribute for each MSDU being received. There is also an attribute, aMax_Receive_MSDU_Lifetime, that specifies the maximum amount of time allowed to receive a MSDU. The aReceive_MSDU_Timer starts on the reception of the first fragment of the MSDU. If aReceive_MSDU_Timer exceeds aMax_Receive_MSDU_Lifetime thean all received fragments of this MSDU are discarded by the destination station.

To properly reassemble MSDUspackets, a destination station must discard any duplicated fragments received. If a station receives a fragment with the same Source, Destination, and Sequence Control Field as a previous fragment, then the station must discard the duplicate fragment. However an acknowledge must be sent in response to a duplicate fragment of a directed MSDU.

1.6. Multirate Support

The following set of rules must be followed by all the stations to ensure coexistence and interoperability on MultiRate Capable PHYs.

All Control Frames (RTS, CTS and ACK) are transmitted on the aBSS_Basic_Rate_SetSTATION_BASIC_RATE (which as specified before belongs to the ESS_BASIC_RATE) so they will be understood by all the stations in the ESS.

All Multicast and Broadcast Frames are transmitted on the aBSS_Basic_Rate_SetSTATION_BASIC_RATE, regardless of their type.

Unicast Data and/or Management Frames are sent on any available transmit rate. The algorithm for selecting this rate is implementation dependent and is beyond the scope of this standard.

1.7. MAC State Machines (replaced from docuement 95/14, also there will be a 95/14r1 to reflect the name changes adopted from 95/38)

There are two distinct sets of state machines in the 802.11 MAC, the media access control state machines and the MAC management state machines. The media access control state machines implement the distributed, time-bounded and contention-free media access control protocols providing a frame-based communication channel. The MAC management state machines make use of this channel inoder to provide some if the required MAC management services.

1.7.1. General Notes to the State Machine Diagrams

The state machine diagrams on the following pages use the following conventions:

1. States are indicated by vertical bars that are labeled above the bar. The state labels are a descriptive title and a state number that includes a letter to indicate the identity of the state machine. For example, state C0 is in the control state machine, R0 is in the receive state machine and T0 is in the transmit state machine.

2. Transitions are indicated by horizontal bars that terminate in an arrowhead. A transition that is a loop that returns to the same state it leaves may include a short vertical bar as part of the transition. Any conditions that must be met in order to take a transition a listed above the transition. Actions that are taken only on particular transitions are listed below the transition. Transitions are labelled with a descriptive title and a letter indicating the state machine followed by two numbers that indicate the originating state and the terminating state. For example, C01 is the transition from state C0 to state C1 in the control state machine. If there is more than one transition between two states that would result in the same label for the transition, a letter is appended to each of the transition labels such that the new labels are unique. For example, R20a and R20b indicate two unique transitions from state R2 to state R0.

3. In addition to actions taken on transitions, actions may also be taken as part of a state. If this is the case, the actions to be taken in the state will be noted in the notes on a particular state machine that follow the state machine diagram.

1.7.2. Media Access Control State Machines

There are three state machines used to describe the asynchronous communication portion of the 802.11 MAC. The transmit state machine is a simple "data pump" that will forward data to the PHY after including the required MAC header and parameters and calculating the frame CRC. The receive state machine is a simple "data acceptor" that receives data from the PHY, checks this data for valid format and errors and indicates the type of frame received. The control state machine performs the major MAC protocol sequencing and error handling. In addition to the three state machines, there are resources supporting the operation of the state machines. These resources include the timer block and the NAV. The block diagram shows how these state machines communicate.

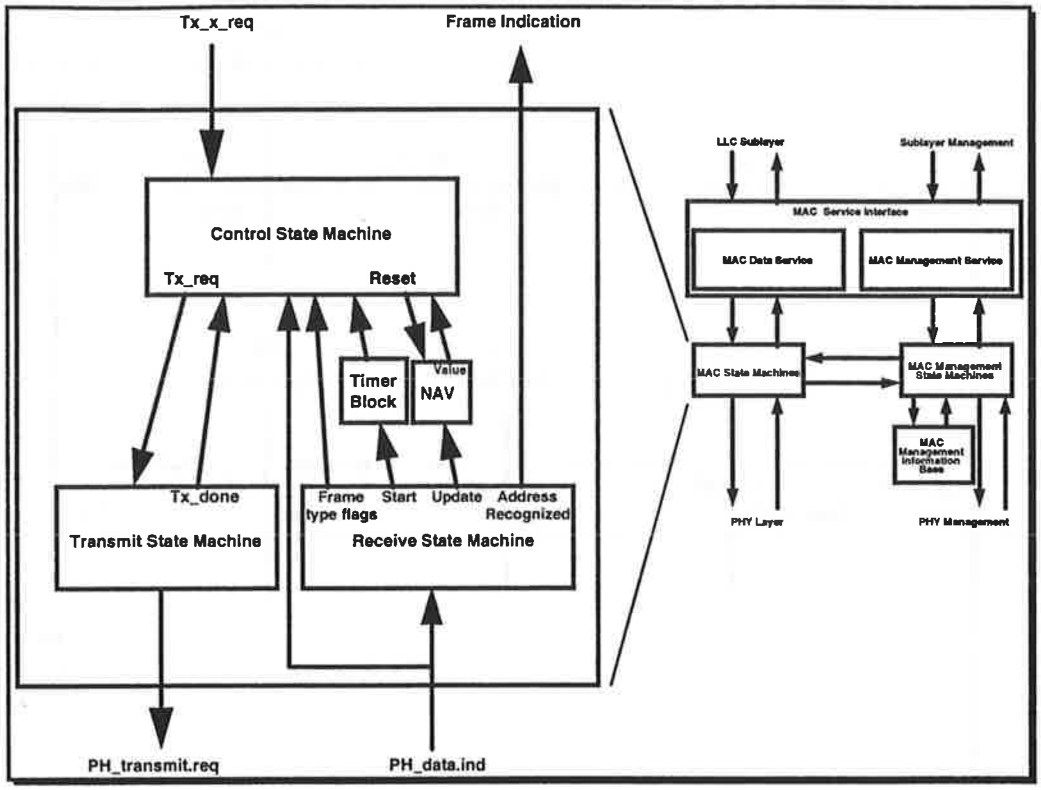

Figure 6-23: Media Access Control State Machines

1.7.2.1. Transmit State Machine

As can be seen in the transmit state machine diagram, this state machine is a simple, unconditional loop. The control state machine uses the service of the transmit state machine to form a valid frame and send it to the PHY. Upon leaving the idle state, the transmit state machine is guaranteed that the media is available and that there is a frame to be sent. The transmit state machine forms a complete, valid frame by prepending any PHY required preamble, a start delimiter, and a MAC header to the data (SDU) to be transmitted. It also appends a CRC and any PHY required end delimiter or postamble to complete the frame (MPDU). After sending the MPDU to the PHY via PH_data.indicate operations, the transmit state machine signals that it has completed its task.

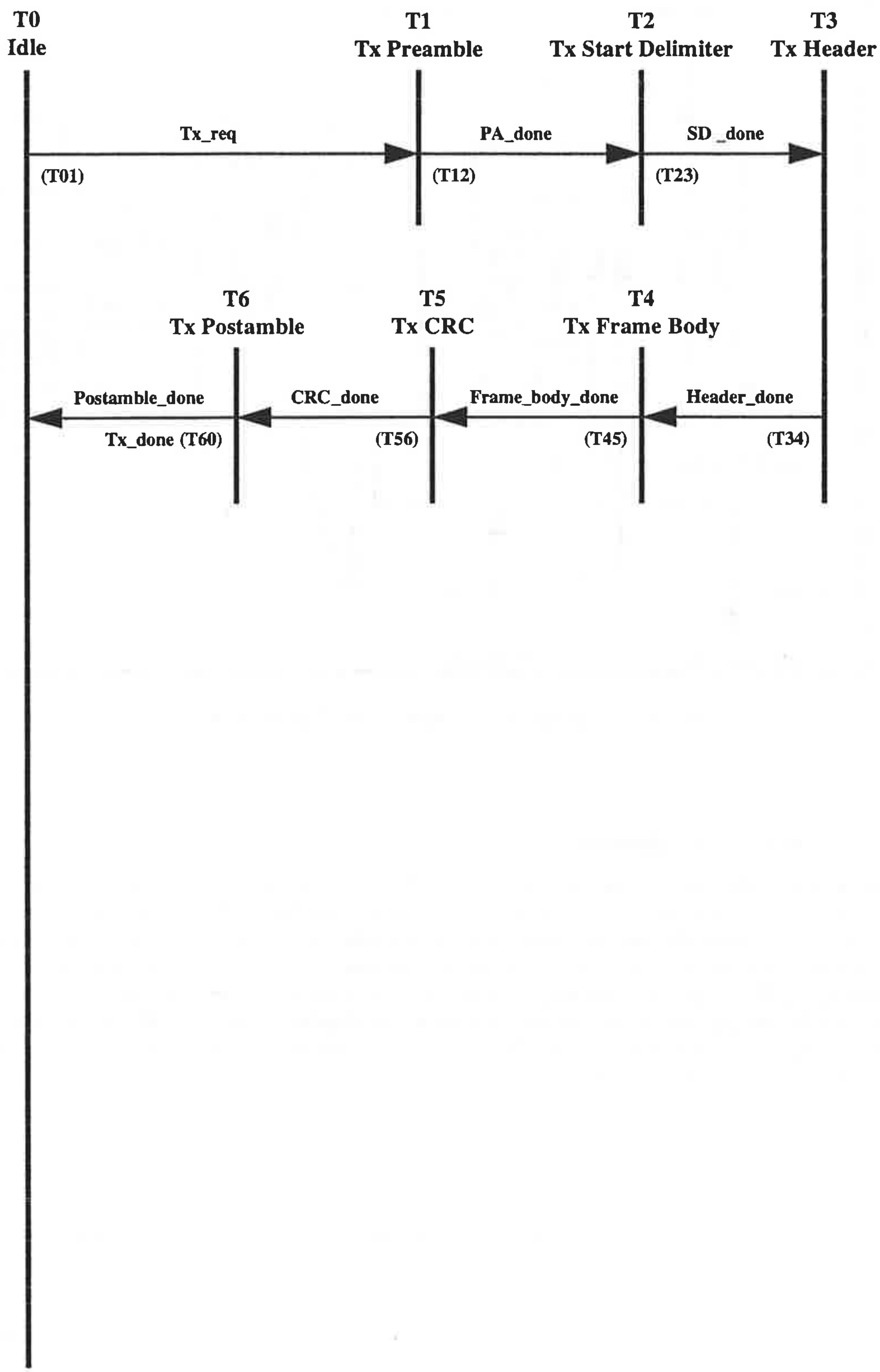

Figure 6-24: Transmit State Machine

Notes to the transmit state machine

State T0, Idle: The MAC transmitter shall enter this state upon initialization or after a transmission is concluded.
T01, Start_transmit: When a transmit request is received this transition shall be taken to begin a transmission.

State T1, Tx Preamble: In this state the transmit state machine shall cause the PHY-specific preamble to be transmitted. PA_done shall be set when the preamble has been transmitted.
T12, Send_start_delimiter: This transition shall be taken when the transmission of the preamble is complete.

State T2, Tx Start Delimiter: The state machine shall enter this state at the conclusion of the transmission of the preamble. In this state, the unique word that delimits the start of a frame shall be transmitted. At the conclusion of the transmission of the start delimiter, SD_done shall be set.
T23, Send_MAC_header: This transition shall be taken when the transmission of the start delimiter is complete.

State T3, Tx Header: In this state , the MAC header shall be assembled and transmitted. Bits in the Type, Control and MPDUID/ConnID fields shall be updated immediately before transmission. At the conclusion of the header transmission, Header_done shall be set.
T34, Send_frame_body: This transition shall be taken when the transmission of the MAC header is complete.

[T3 needs better definition of the fields to be updated immediately before transmission -Bob]
State T4, Tx Frame Body: In this state, the body of the MAC frame, if any, shall be transmitted. At the conclusion of the transmission of the frame body, or unconditionally if there is no frame body, Frame_body_done shall be set.
T45, Send_CRC: This transition shall be taken when the transmission of the frame body is complete.

State T5, Tx CRC: In this state the CRC shall be transmitted. At the conclusion of the transmission of the CRC, CRC_done shall be set.
T56, Send_postamble: This transition shall be taken when the transmission of the CRC is complete.

State T6, Tx Postamble: In this state, any required ending delimiter and PHY-specific trailer shall be transmitted. At the conclusion of the transmission of the postamble, Postamble_done shall be set.
T60, Transmit_complete: This transition shall be taken when the transmission of the postamble is complete. Tx_done shall be set.

1.7.2.2. Receive State Machine

The receive state machine is almost as simple as the transmit state machine. The receive state machine remains idle until the PHY indicates that a frame is being received. When the PHY signals that a start delimiter has been received, the receive state machine takes the transition to the state that processes the frame body. If no errors are detected and a valid frame type is received, the exit from this state is solely dependent on the frame type received. Based on the frame type, the next state is chosen such that the proper actions required by each frame type are accomplished. Most of the states chosen based on the frame type have two exit paths. One path is chosen to indicate to the control state machine that additional protocol actions are required. The other path is chosen if there is no protocol action required by the control state machine.

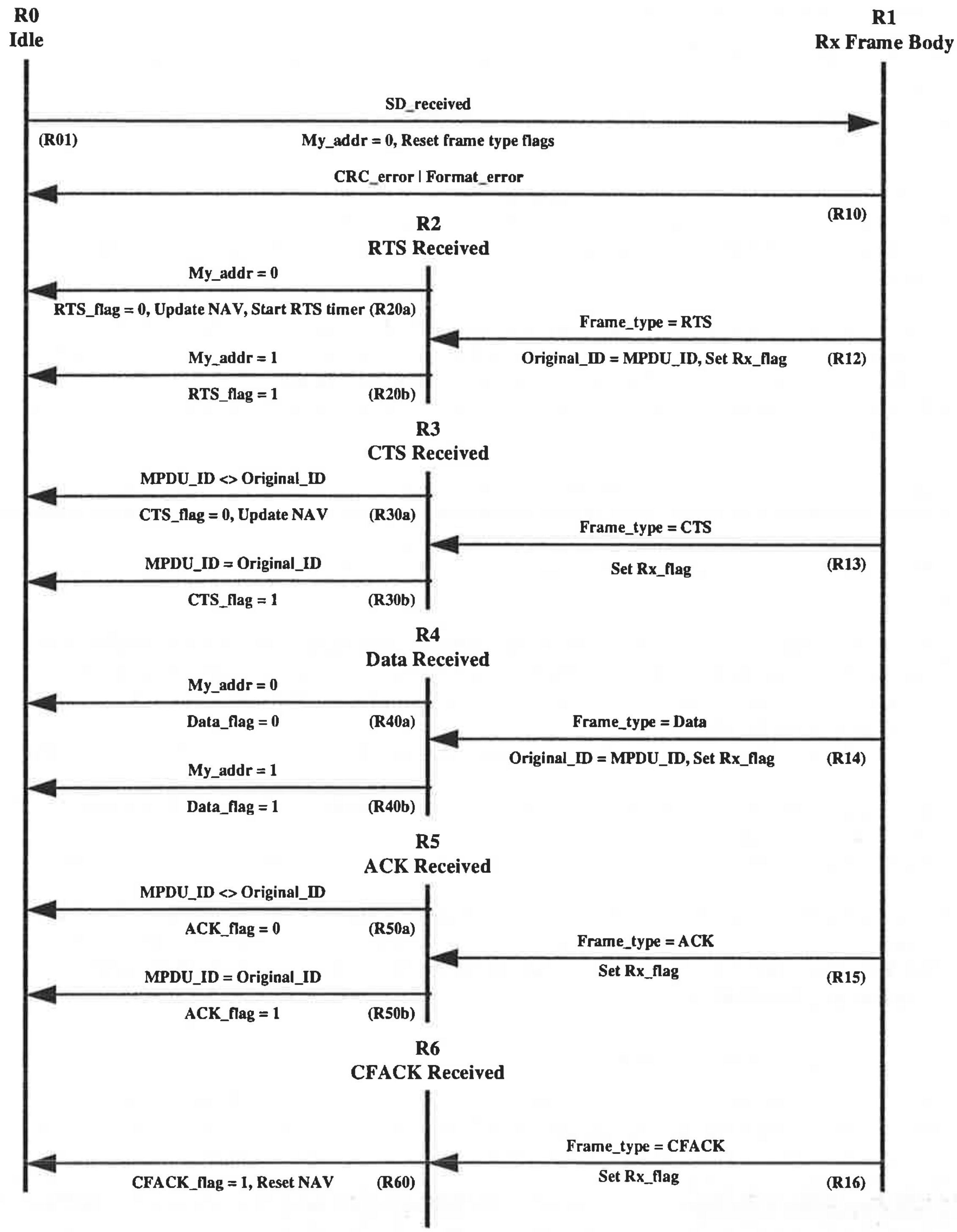

Figure 6-25: Receive State Machine

Notes to the receive state machine

State R0, Idle: This state shall be entered whenever the MAC receiver is initialized. In this state the receiver awaits the receipt of the start delimiter.
R01, Start_Receive: If a start delimiter is received from the PHY, a transition to state R1 shall occur. The address recognized flag and error detected flag shall be cleared. The CRC accumulator shall be cleared in preparation for receiving a frame. My_addr and the frame type flags shall be cleared.

State R1, Rx Frame Body: This state shall be entered when a valid start delimiter is detected. In this state the incoming frame shall be checked for valid format, correct CRC, valid network identifier and correct MPDU_ID as appropriate for the frame type. Based upon the frame type received, the appropriate exit shall be chosen. If the frame is uniquely addressed to this station, My_addr shall be set.
R10, Frame_error: If there is an error in the frame format or the frame contains a CRC error, this transition shall be taken to return the receiver to the Idle state. The error flag shall be set.
R12, Received_RTS: When the frame is valid and the frame type is RTS, this transition shall be taken. Original_ID shall be set to MPDU_ID. Rx_flag shall be set.
R13, Received_CTS: When the frame is valid and the frame type is CTS, this transition shall be taken.. Rx_flag shall be set.
R14a, Received_Data: When the frame is valid and the frame type is Data, this transition shall be taken.. Rx_flag shall be set.
R14b, Received_Unitdata: When the frame is valid and the frame type is Unitdata, this transition shall be taken. Original_ID shall be set to MPDU_ID.. Rx_flag shall be set.
R15, Received_ACK: When the frame is valid and the frame type is ACK, this transition shall be taken.. Rx_flag shall be set.

State R2, RTS Received: This state shall be entered when a valid RTS frame is received. In this state the actions appropriate to receipt of an RTS frame shall be taken.
R20a, Other_RTS: This transition shall be taken when the RTS receipt actions are complete and My_addr is not set. The NAV shall be updated with the value in the Length field of the frame plus the value of RTS_time_offset. The RTS_flag shall be reset. The RTS timer shall be initialized and started.
R20b, RTS_complete: This transition shall be taken when the RTS receipt actions are complete and My_addr is set. The RTS_flag shall be set.

State R3, CTS Received: This state shall be entered when a valid CTS frame is received. In this state the actions appropriate to receipt of a CTS frame shall be taken. The CTS timer shall be stopped.
R30a, Other_CTS: This transition shall be taken when the CTS receipt actions are complete and the MPDU_ID is not equal to the Original_ID. The NAV shall be updated with the value in the Length field of the frame plus the value of CTS_time_offset. The CTS_flag shall be reset.
R30b, CTS_complete: This transition shall be taken when the CTS receipt actions are complete and the MPDU_ID is equal to the Original_ID. The CTS_flag shall be set.

State R4, Data Received: This state shall be entered when a valid Data or Unitdata frame is received. In this state the actions appropriate to receipt of a Data or Unitdata frame shall be taken. If the destination address received is contained in the set of this station's destination addresses and the To_AP bit is not set in the control field, the address recognized flag shall be set and the frame shall be passed to the LLC entity.
R40a, Other_Data: This transition shall be taken when the data receipt actions are complete and My_addr is not set. The data_flag shall be reset.
R40b, Data_complete: This transition shall be taken when the data receipt actions are complete and My_addr is set. The data_flag shall be set.

State R5, ACK Received: This state shall be entered when a valid ACK frame is received. In this state, the actions appropriate to the receipt of an ACK frame shall be taken.
R50a, Other_ACK: This transition shall be taken when the ACK receipt actions are complete and the MPDU_ID is not equal to the Original_ID. The ACK_flag shall be reset. The NAV shall be updated to

indicate that the network is now free.
R50b, ACK_complete: This transition shall be taken when the ACK receipt actions are complete and the MDPU_ID is equal to the Original_ID. The ACK_flag shall be set.

State R6, CFACK Received: This state shall be entered when a valid CFACK frame is received.
R60, CFACK_complete: This transition shall be taken when the CFACK receipt actions are complete. The NAV shall be reset. The CFACK_flag shall be set.

1.7.2.3. Control State Machine

The control state machine is a combination of several simple loops. The largest loop consists of states C0, C1, C2 C3 and C4. This is the loop used to transmit a frame with the RTS/CTS handshake. There are two conditional exits from this loop; one exit is used when CTS is not received in response to RTS, the other is used when an ACK is not received after transmitting the data frame. This loop may also be entered in the middle, at state C3, in order to transmit a Unitdata frame, i.e., a data frame without the RTS/CTS handshake. When either of the conditional exits from this loop is taken or if a transmission is attempted while the media is not free, a path is entered that calculates a backoff interval and initiates the backoff period. The remainder of the state machine is a set of four short loops that handle the responses to receipt of RTS frames, data frames, expiration of the backoff period and the lack of CTS response to an RTS addressed to another station.

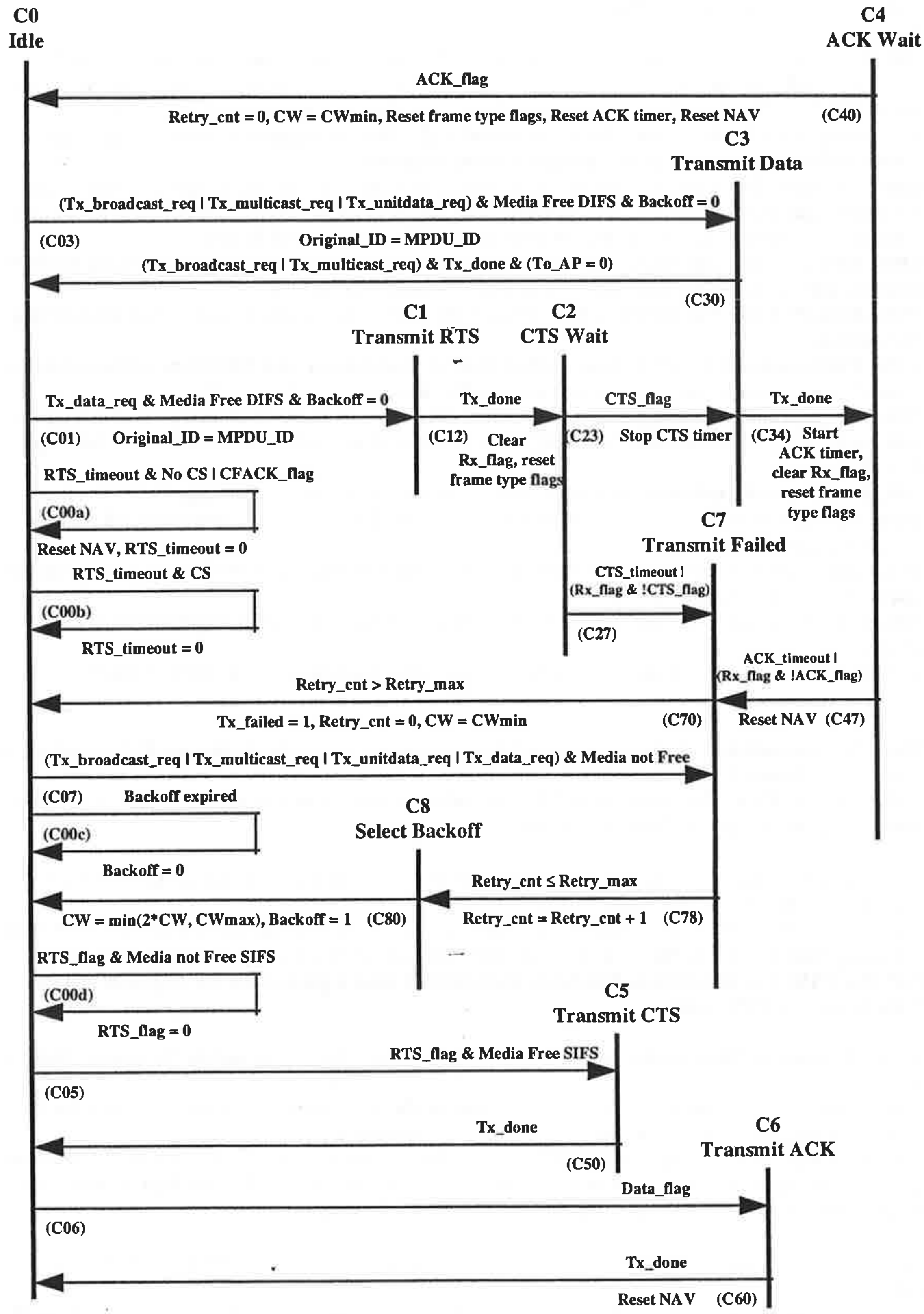

Figure 6-26: Control State Machine

Notes to the control state machine

State C0, Idle: The control state machine shall enter this state upon initialization and after any of the following conditions: receipt of ACK after a successful transmission, exceeding the maximum retry count during transmission, after a backoff interval has been computed, after transmitting a CTS and after transmitting an ACK. In this state, the backoff interval shall be counted down while the media is free. While in a backoff interval, transmit requests shall be postponed.
C00a, No_Data: This transition shall be taken when the RTS timer expires due to not receiving a data frame that corresponds to the RTS frame or due to the receipt of a CFACK frame signalling the end of a contention-free period. The NAV shall be reset and the RTS_timeout shall be reset.
C00b, RTS_timeout_and_busy: This transition shall be taken when the RTS timer expires and the PHY indicates activity on the medium. The RTS timeout condition shall be reset.
C00c, Backoff_done: This transition shall be taken when the backoff interval expires. The Backoff flag shall be reset.
C00d, Can't_respond_to_RTS: This transition shall be taken when a valid RTS frame addressed to this station has been received and a response is not possible because the media is not free.
C01, Start_transmit_handshake: This transition shall be taken when the MAC is requested to transmit with the full RTS, CTS handshake, the MAC is not in a backoff interval and the media is free for longer than DIFS.
C03, Start_transmit_unitdata: This transition shall be taken when the MAC is requested to transmit a unitdata frame, a multicast frame or a broadcast frame, the media is free longer than DIFS and the MAC is not in a backoff interval.
C05, Send_CTS: This transition shall be taken when a valid RTS frame addressed to this station is received and the media is free longer than SIFS.
C06, Send_ACK: This transition shall be taken when a valid data frame addressed to this station is received.
C07, Media_busy: This transition shall be taken when a transmit data request is received and the media is busy.

State C1, Transmit RTS: In this state , a valid RTS frame addressed to the destination shall be formed and passed to the Transmit state machine. The Tx_req shall be set.
C12, Wait_for_CTS: This transition shall be taken when the transmission of the RTS frame is complete. The Rx_flag and frame type flags shall be reset.

State C2, CTS Wait: This state shall be entered after an RTS frame has been transmitted. The CTS timeout timer shall be initialized and started.
C23, Send_data: This transition shall be taken when a valid CTS frame that matched the MPDUID of the previously transmitted RTS has been received. The CTS timer and CTS_timeout shall be reset.
C27, No_CTS: This transition shall be taken when the CTS timer expires or the Rx_flag is set and the frame type is not CTS_frame.

State C3, Transmit Data: In this state, the MAC data frame shall be formed and the Tx_request shall be set.
C30, Multicast_sent: This transition shall be taken when the transmission of a broadcast or multicast frame is complete and the frame is not to be forwarded by an access point.
C34, Wait_for_ACK: This transition shall be taken when the transmission of the data frame is complete and the frame was not a multicast or broadcast frame sent to an AP. The ACK timer shall be initialized and started. The Rx_flag and frame type flags shall be reset.

State C4, ACK Wait: This state shall be entered while waiting for an ACK response to a transmitted data frame.
C40, End_transmit_handshake: This transition shall be taken when a valid ACK frame that matches the MPDUID of the previously transmitted RTS has been received. Retry_cnt and the frame type flags shall be reset and CW set to CWmin. The ACK timer shall be reset. The NAV shall be reset.

C47, No_ACK: This transition shall be taken when the ACK timer expires or the Rx_flag is set and the frame type is not ACK_frame. The NAV shall be reset.

State C5, Transmit CTS: In this state, the control state machine shall respond to an RTS frame directed to this station. A CTS frame shall be formed and passed to the Transmit state machine. The Tx_req shall be set.
C50, CTS_complete: This transition shall be taken when the CTS frame has been transmitted.

State C6, Transmit ACK: In this state, the control state machine shall respond to the successful receipt of a data frame. An ACK frame shall be formed and passed to the Transmit state machine. The Tx_req shall be set.
C60, ACK_complete: This transition shall be taken when the transmission of the ACK frame is complete. The NAV shall be reset.

State C7, Transmit Failed: In this state, the control state machine shall react to a failure in the handshake required for data transmission or to a request to transmit while the medium is not free.
C70, Transmission_failure: This transition shall be taken when the maximum number of retry attempts has been exhausted. Tx_failed shall be set. Retry_cnt shall be reset. CW shall be set to CWmin.
C78, Try_again: This transition shall be taken when the maximum number of retry attempts has not been exhausted. The Retry_cnt shall be incremented.

State C8, Select Backoff: In this state a backoff interval shall be calculated by multiplying a random number uniformly distributed between zero and one by the product of the contention window parameter (CW) and the slot time.
C80, Wait_for_Backoff: This transition shall be taken when the backoff interval is computed. The CW shall be doubled and limited by CWmax. The backoff flag shall be set.

1.7.3. MAC Management State Machines