IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: **Frame Windowing at the MAC Layer**

Motorola, Inc
Wireless Data Group
50 E. Commerce Drive
Schaumburg, Illinois 60173

Presented by: Rick White
Tel: 1-708-576-7878
Fax: 1-708-576-7907
Email: rick_white@wes.mot.com

Abstract: Frame windowing is defined as sending multiple data frames and receiving a single ACK. Frame windowing at the MAC layer allows better utilization of the radio channel and reduced delay. Windowing is especially beneficial when fragmentation is used. This paper addresses 20.7, "Will the MAC support windowing (allowing multi-packets with single acknowledge (ACK))?".

Introduction

Frame windowing is defined as sending multiple data frames and receiving a single ACK. The source station will maintain priority of the media while transmitting data frames in the window. The number of frames in the window will be programmable. Windowing will only be supported for asynchronous traffic. In the case of the Foundation MAC, the author would like to add windowing. When used with fragmentation, whole MAC Service Data Units (MSDU) can be fragmented into multiple data frames and sent with minimal delay. For a multiple fragment MSDU, the sending device would only have to contend for the channel for the first data frame of each MSDU. Windowing has equal benefits for both frequency hopping and direct sequence PHYs.

Windowing

Windowing is used in most of today's network protocols. It provides a technique that allows the transmission of data with reduced overhead. It allows the transmission of multiple frames with a single acknowledgment. It also provides for selective retransmission. If multiple frames are transmitted but all are not received by the destination, the destination can indicate which frames were correctly received and the source only needs to retransmit the missing frames.

Windowing also reduces the effect of delay introduced in a network. When using a request-reply protocol, the data throughput is greatly influence by the delay from the time that a request is sent to the time a reply is received. In a wireless network, a large portion of the round-trip delay is determine by delay in the wireless portion of the network connection. The delay is not only due to the lower bits rates of the wireless LAN but also the contention problem. It an ethernet environment, a station knows if there was a collision during the header of the packet due to the fact that a station can detect collisions. In the 802.11 wireless LAN, a station will only know if there was a collision if it does not receive an acknowledgment from the destination station.

If a station can only transmit one data frame each time it contends for the channel, the end-to-end delay of a multiple date frame transfer will increase. In order to reduce this delay, windowing can be used to allow a station to transmit more than one data frame after it has contended for the channel. In a radio environment it is better to send smaller frames from both a bit error rate perspective and also from a hidden station perspective. A station that sends multiple small data frames has a better chance of getting the frames to the destination station then sending one large data frame.

Windowing is especially beneficial when fragmentation is used at the MAC layer. It allows data frames of a fragmented MSDU to be transferred back-to-back without introducing any significant additional delay. Once the transmitting station has contended for the channel, it can send multiple data frames of the same MSDU without contending for the channel again. The transmitting station may use multiple windows to send a fragmented MSDU depending on the maximum size of the window. The destination station will send one acknowledgment for each window indicating which data frames were received without error.

Windowing is beneficial for both Frequency Hopping and Direct Sequence systems since bit error rates and transmission delays are similar.

Implementation of Windowing

The Foundation MAC provides three different accesses priorities which are distinguished using different values for the minimum silence period. They are described in [1] and restated here. Figure 1 shows the three Inter Frame Spaces (IFS). The three priorities are Short Inter Frame Space (SIFS), Point Coordination Function Inter Frame Space (PIFS) and Distributed Coordination Function Inter Frame Space (DIFS).

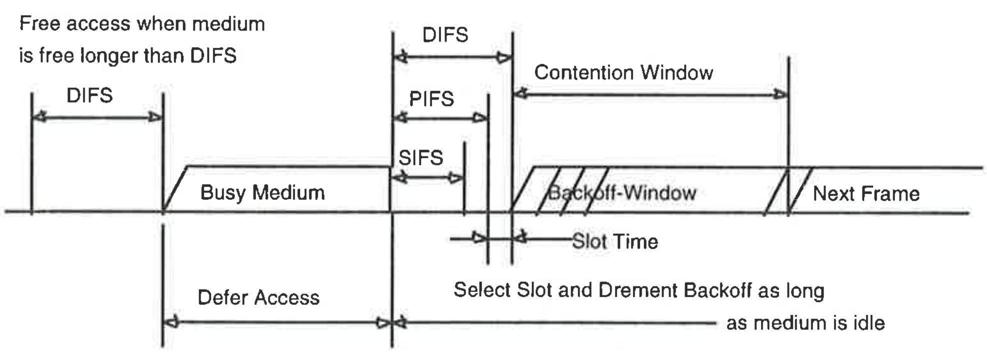

Figure 1: Foundation CSMA/CA Access Method

Short Priority

This priority level is used for all immediate response actions. This priority levels used for an Ack frame, immediately following a received frame, a CTS frame immediately following a received RTS frame, and by a station responding to any polling as is used by the Point Coordination Function (PCF). The corresponding interframe space is called the Short IFS, or SIFS.

PCF Priority

This priority level is used by the PCF in the AP to send any of the Contention Free Period (CFP) frames. The AP will send the next-in-line queued CFP frame after it finds the medium free for the period PIFS (PCF Interframe Space), during a CFP-Burst .

DCF Priority

The DCF priority is used by the Distributed Coordination Function to transmit Asynchronous frames in the Contention Period. Asynchronous stations that want to start transmission of an RTS frame, or a DATA frame (without the RTS/CTS option), will monitor the medium for at least a time DIFS (DCF Inter Frame Space) of silence, after the NAV and the CS function indicates a free medium. When the medium was found busy, then the DFWMAC will defer until an DIFS is detected, and then a random access backoff procedure is started.

Implementation of Windowing in the Foundation MAC

An implementation of windowing was described in [2]. This paper described an approach that added a new priority slot for the transmitter. This approach has been modified so that no new priority slots need to be added to the Foundation MAC. A brief description of this approach was given in [3].

Windowing is used in conjunction with fragmentation to provide a efficient MSDU delivery mechanism. Once a station has contended for the channel, it can maintain control of the channel until it has sent all of the data frames of a MSDU. After all frames have been transmitted, the station will relinquish control of the channel. It is not necessary for a station to transmit all frames in a single window (only requiring one acknowledgment) but the frames can be broken into several windows. The source station will maintain control of the channel for the entire series of windows. This can be looked at as if the source transmitted the entire MSDU without fragmentation but with fragmentation the entire MSDU will not have to be retransmitted if there is an error, only the frame(s) with the error.

When a transmitting station has another data frame to send following it's current data frame and all the rules for transmission that are described below are satisfied, the station can transmit another frame following the current frame. This is illustrated in Figure 2.

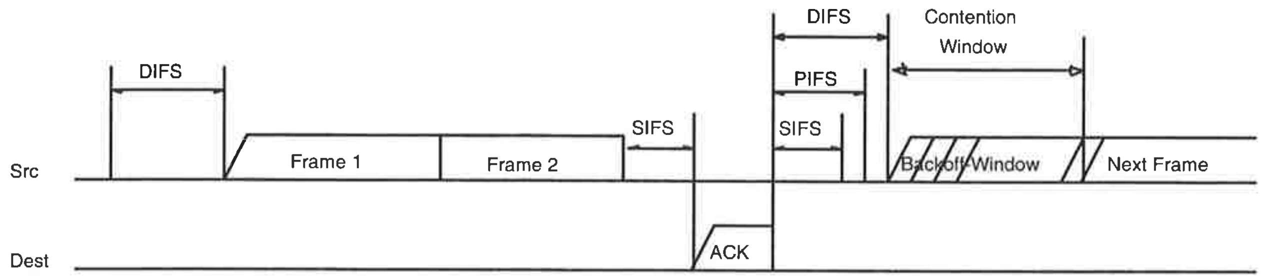

Figure 2: Multiple Data Frame Window with ACK

The source station transmits the second frame following the first. Both are complete frames with full radio header, MAC header, and CRC. The destination station will respond with an ACK following a SIFS. If the frame window was three, the source would send three frames back to back and the SIFS would occur after the third frame and the destination would respond with an ACK.

The device transmits some number (the frame window size) of data frames and then release the channel and waits for an acknowledgment. The variable *frame_window_size* determines the maximum number of data frames a station may transmit before waiting for an ACK. A station must release the channel before reaching the frame window size if no more data frames need transmitting. The station should release the channel to allow an acknowledgment to be transmitted.

When a source station releases the channel following its data frames, it will immediately turn its radio around and monitor the channel for an acknowledgment frame from the destination station. When the destination station hears the channel idle for SIFS, it must then transmit an acknowledgment frame to the source 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 more frames. The station sending the acknowledgment does not have permission to transmit on the channel immediately following the acknowledgment. Figure 3 illustrates multiple windows between two stations.

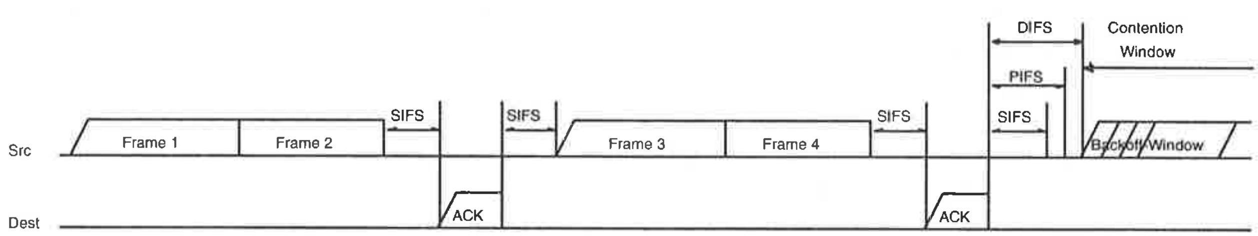

Figure 3: Multiple Window Operation

The acknowledgment frame following a window of data frames contains information to define which of the frames were received without error. Only one of the frames in a window needs to be received in order for a acknowledgment to be transmitted. This implies that a data frame(s) that contained errors are not acknowledged due to the absence on a positive acknowledgment in the acknowledgment frame. The source station needs only to retransmit packets that were not acknowledged.

A data frame that is not acknowledged will be retransmitted in the next window for the MSDU. If there are no other data frames to be transmitted other than the data frames requiring retransmission, a 'new' window will be generated. The 'new' window will follow after the SIFS of the acknowledgment frame of the previous window. A window of frames will only execute the backoff algorithm if no acknowledgment frame is received.

If the source station does not receive an acknowledgment frame, the source station will attempt to retransmit the data frame(s) at a later time (according to the backoff algorithm). When the time arrives to retransmit the data frame(s), the source station will contend for access in the contention window.

To summarize the above discussion, a station may transmit immediately following its own transmission when the following conditions are all satisfied:

- The station has just finished transmitting a data frame.
- The station has previously transmitted at least one data frame of a MSDU and more data frames require transmission.
- The number of consecutive data frames that may be transmitted (without waiting for an acknowledgment) has not exceeded the *frame_window_size*.

A station will transmit after the SIFS only under the following conditions (for windowing):

- The station has just received a frame that requires acknowledging and the SIFS is detected idle.
- The source station has received an acknowledgment to a previous window and has more data frame(s) for the same MSDU to transmit.

The following guidelines also apply.

- A transmitting station with permission to transmit following its own transmission need not turn its radio around to sense the channel. The station can simply continue in transmit mode and start transmitting the next frame as soon as the current frame is finished. At the end of the SIFS, other stations will hear a busy channel as required.
- When a station has transmitted a frame other than a data frame, it does not have priority to transmit on the channel following that packet.
- When a MSDU has been successfully delivered, the device does not have priority to transmit on the channel following the last acknowledgment of the last data frame.
- Only unacknowledged data frames need to be retransmitted.

Note that none of the above conditions require the destination station to be concerned with the value of *frame_window_size*.

If a multi-frame MSDU does not require an acknowledgment (for example, a broadcast/multicast packet transmitted by the Access Point), the source station will transmit all frames of the MSDU without releasing the channel. The source station will ignore the frame window rule and continue with all frames of the MSDU until the MSDU is complete.

Conclusion

The author believes that windowing is beneficial and can be built upon the Foundation MAC by adding the next level of detail to the draft standard.

Therefore the following motions are to be made:

> Move that Issue 20.7 be closed with a recommendation of yes, the MAC will support windowing.

> Move that windowing be implemented using the approach defined in this paper as a foundation.

References

[1] Wim Diepstraten - NCR, Greg Ennis - Symbol Technologies, & Phil Belanger - Xircom, "DFWMAC - Distributed Foundation Wireless Medium Access Control", Doc IEEE P802.11-93/190 Nov. 1993.

[2] Rick White - Motorola, et al, "A Complete Description of Frame Prioritization in a CSMA/CA MAC Protocol", Doc IEEE P802.11-93/208 Nov. 1993.

[3] Mark Demange - Motorola, et al, "Packet Fragmentation", Doc IEEE P802.11-94/37 March. 1994.