IEEE 802.11
Wireless Access Methods and Physical Layer Specifications

TITLE: Making Sense Out of MAC and PHY Timing Specifications

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Introduction

At the January meeting we spent some time discussing the MAC and PHY timing. The standard today basis the MAC timing as a function of events at the air interface. Although this may be the only place to test compliance to the standard, documenting the standard from the air interface is not the best way to write the standard. This contribution attempts to document the timing in the standard from the view that each MAC sublayer is a peer-to-peer entity

1.0 Introduction

One of the best things a WLAN standard document can do is attempt to describe the function of the LAN in terms that implementors can understand. This paper will propose text for both the MAC and PHY MIBs to better document the timing functions needed to be maintained at both the MAC and PHY sublayers in order to insure interpretability among manufacturers.

1.1 MAC View

In order to keep the MAC and PHY independent in terms of one MAC for many PHYs, it is reasonable to document the MAC in such a way that a minimum amount of PHY variables require consideration. Figure 1 shows the proposed format for documenting the MAC and PHY timing. The upper half of figure 1 shows the "MAC's View of the World". As this view moves in time, it starts with the end of a packet reception. When every MAC entity receiving this packet accepts the last octet from their local PHY entities, they each have a common reference point for setting time equal to zero on a peer-to-peer basis. Two things about this point that need to be addressed.

- This point is slightly skewed between the transmitting entity and all receiving nodes do to PHY timings, propagation delays and implementation differences.
- This point is slightly skewed between receiving nodes due to possible difference in implementations.

These two issues can probably be resolved within less than 1 usec of each implementation and this fact will be demonstrated later in this document. For now, lets continue the "MAC's View of the World" discussion. Assuming that all nodes can use this reference point as time zero, they each will start an SIFS timer. This timer value will essentially determine the beginning of the slot periods. As you can see, the MAC timing for implementing the 802.11 protocol in the "MAC's View of the World" is based solely on timing slots, once the start of the first slot is reached. The first slot is called the SIFS slot. This is the slot a MAC entity must use to send any protocol frames required to be sent in the SIFS slot such as an ACK. When the SIFS timer expires, indicating the start of the SIFS slot, the MAC entity who is going to use the SIFS slot needs to send a PHY_TXSTART.req to the PHY. This will start the PHY transmit state machine and guarantee the PHY will get a signal onto the air before the slot timer expires and prevent another MAC entity from taking the next slot. Any MAC entity not using the SIFS slot will start its slot timer.

Whenever the MAC's slot timer expires, it does the following:

```
if (Does the MAC have something to send?)
        begin
        if (Proper Slot?)
                begin
                if ( CCA==IDLE )
                        send PHY_TXSTART.req;
                else Execute Backoff Algorithm;
                end
        end
else Reset Slot timer
```

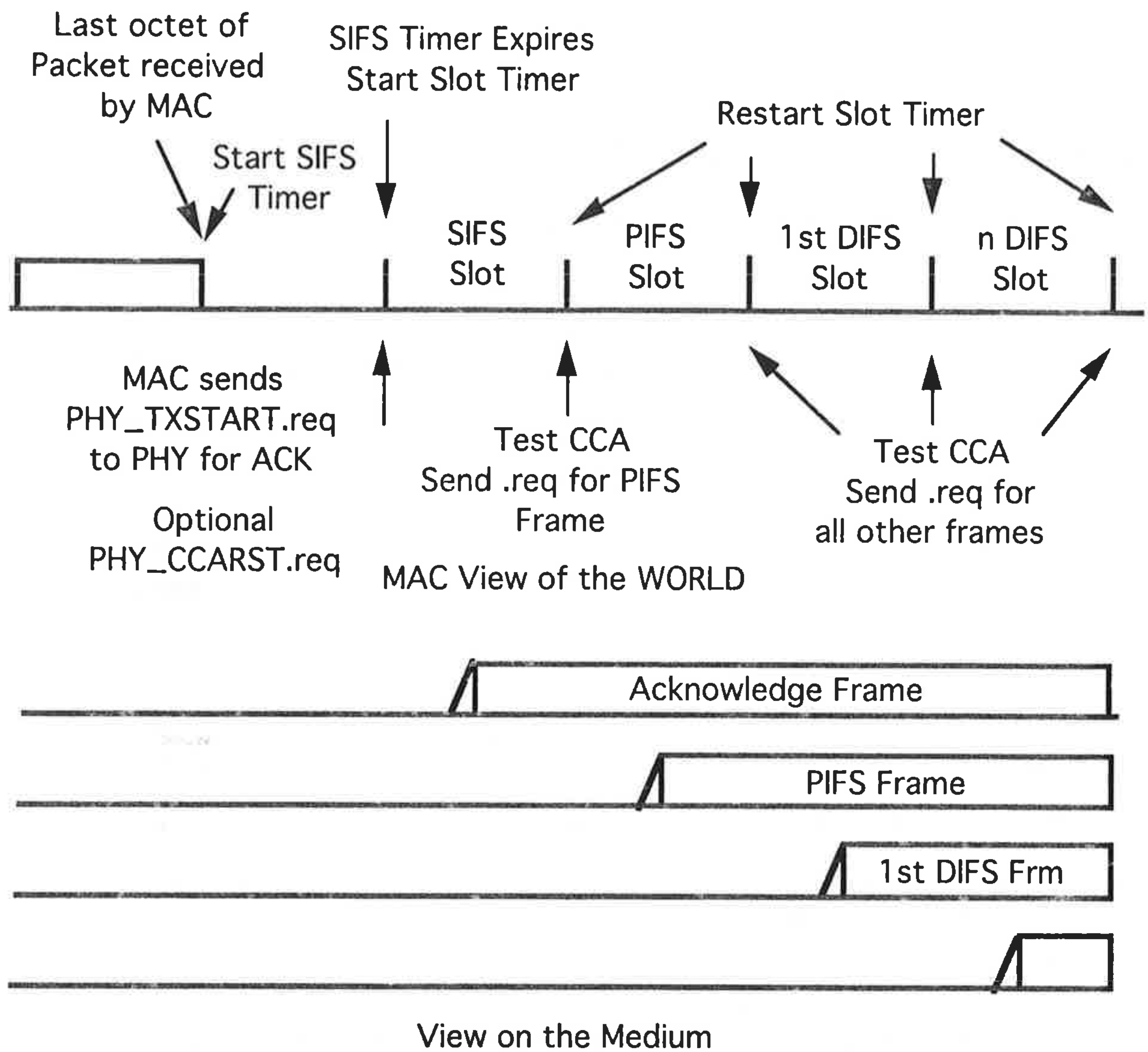


Figure 1

2.0 Determining the SIFS Timer for Receiving Station

First, a nominal value for the SIFS timer (SIFS_Time) must be defined. The SIFS_Time, since it defines the start of the MAC slots, must be sufficient in time to allow the transmitting node and all receiving nodes time to prepare for the possible use of the first slot. We define this term to be MAC_SIFS_Delay. Since the only way to set a reference point between all nodes involves receiving data, the delay from the media to the MAC must also be considered. We will select a nominal time for this delay and call it the RX_Data_Delay. Figure 2 show the terms involved in determining the RX_Data_Delay for the FHSS PHY. These parameters and timings may vary with each 802.11 PHY and each PHY will be responsible for setting these parameters for a compliant implementation. For the purposes of discussion, we will use the FHSS PHY as an example. The FHSS PHY would use the following terms to define the nominal RX_Data_Delay:

- RX_RF_Delay This is the delay from receiving a bit on the antenna to handing the bit/octet to the Receiver PLCP
- RX_PLCP_Delay This term represents the delay from the data entering the PLCP to the time an octet is turned over to the MAC.

The RX_Data_Delay is now defined as:

RX_Data_Delay = RX_RF_Delay + RX_PLCP_Delay

Now each PHY will have to set a nominal value for these timings. These nominal values are basically agreements among all implementor that, given today's technology, a reasonable implementation can met these timings. It does not restrict or force implementors to use these timings, it just establishes a baseline. In the case of the FHSS PHY, we might set these values as follows:

- RX_RF_Delay	4.0 usec.
- RX_PLCP_Delay	4.0 usec.

The RX_Data_Delay is now

RX_Data_Delay = 4.0 + 4.0 = 8.0 usec.

This is now the nominal RX_Data_Delay for the FHSS. This now sets one of the baseline parameters for determining the SIFS_Time. The next parameter is the responsibility of the MAC people. They might set the MAC_SIFS_Delay to consider implementations doing processing in software. Its value might be

MAC_SIFS_DELAY 40.0 USEC

In the case where the implementor designed to the exact nominal parameters, the SIFS_Time for a receiving node (SIFS_Rcvr_Time) would be:

SIFS_Rcvr_Time = MAC_SIFS_Delay = 40.0 usec

Since timing for RX_Data_Delay may be different from the nominal value due to implementation requirements, a delta factor is required called SIFS_Rcvr_Delta. This figure represents the difference between the nominal implementation and the actual. It is as follows:

SIFS_Rcvr_Delta = RX_Data_Delay - (Implementor's RX_Data_Delay)

This field then is used by the MAC to calculate the SIFS_Time for a particular implementation. It is as follows:

SIFS_Rcvr_Time = MAC_SIFS_Delay + SIFS_Rcvr_Delta

2.1 Determining the SIFS Timer for a Transmitting Station

The equation for calculating the SIFS_Time (SIFS_Xmtr_Time) that a transmitting station would use to start the slot timer is similar to the calculations in section 2.0 except that the transmitting node must consider the time it takes to get a bit from the MAC onto the air. This parameter is defined as TX_Data_Delay. Once again, for the purposes of discussion, we will use the FHSS PHY as an example. The FHSS PHY would use the following terms to define the nominal TX_Data_Delay:

- TX_PLCP_Delay This term represents the delay from data being handed off from the MAC to the PLCP to the time a bit is delivered to the RF section of the radio.
- TX_RF_Delay This is the delay in the RF section from receiving a bit from the PLCP to getting the bit onto the medium

The TX_Data_Delay is now defined as:

TX_Data_Delay = TX_RF_Delay + TX_PLCP_Delay

Once again, each PHY will have to set a nominal value for these timings. In the case of the FHSS PHY, we might set these values as follows:

- TX_RF_Delay 1.0 usec.
- TX_PLCP_Delay 1.0 usec.

The TX_Data_Delay is now

TX_Data_Delay = 1.0 + 1.0 = 2.0 usec.

This is now the nominal TX_Data_Delay for the FHSS. This now sets the baseline parameters for determining the SIFS_Xmtr_Time. The nominal equation for the SIFS_Xmtr_Time is as follows:

= TX_Data_Delay + Air_Prpg_Time + RX_Data_Delay + MAC_SIFS_Delay

where

Air_Prpg_Time = 1.0 usec. Air propagation Delay specified at Jan Meeting.
RX_Data_Delay = 8.0 usec. From earlier discussion.
MAC_SIFS_Delay = 40.0 usec. From earlier Discussion.
TX_Data_Delay = 3.0 usec.

= 2.0 + 1.0 + 8.0 + 40.0 = 51.0 usec Nominal

For an actual implementation, the calculation needs to consider the difference between the nominal value and the actual implementation values. As with the receiver, a delta factor is required called SIFS_Xmtr_Delta. This figure represents the difference between the nominal transmitter implementation and the actual. It is as follows:

SIFS_Xmtr_Delta = TX_Data_Delay - (Implementor's TX_Data_Delay)

Considering this delta in the equation, the new equation for the SIFS_Xmtr_Time is as follows:

SIFS_Xmtr_Time = TX_Data_Delay + Air_Prpg_Time + RX_Data_Delay + MAC_SIFS_Delay + SIFS_Xmtr_Delta

2.2 Slot Time Calculation

A similar exercise exists for calculating the PHY layer slot time (PHY_Slot_Time). The PHY_Slot_Time should be made up of three values. Figure 2 shows these values. They are defined as follows:

- RxTx_Turnaround_Time This parameter represents the maximum time a PHY layer implementation can use to covert a PHY_TXSTART.req to the first bit on the medium.
- Air_Prpg_Time This value represents the maximum delay in medium between a transmitter and a receiver.
- CCA_Assessment_Time This parameter represents the amount of time a PHY implementation must use to assess whether the medium is busy or idle.

Once again, we will use the FHSS PHY as an example for the calculating these figures. In the FHSS PHY, we have agreed that the equation for determining the RxTx_Turnaround_Time is as follows:

RxTx_Turnaround_Time = TX_Data_Delay + RxTx_Swtch_Time + Ramp_ON_Time

where

TX_Data_Delay = 2.0 usec	From previous discussion
RxTx_Swtch_Time = 10.0 usec	From FHSS PHY Spec
Ramp_ON_Time = 8.0 usec	From FHSS PHY Spec

= 2.0 + 10.0 + 8.0 = 20.0 usec.

From previous discussions, the Air_Prpg_Time is 1.0 usec. Now we need to discuss the CCA_Assessment_Time. The CCA_Assessment_Time is made up of at least two items in the FHSS PHY. These two items are as follows:

- RX_RF_Delay This is the delay from receiving a bit on the antenna to handing the bit/octet to the Receiver PLCP.
- PLCP_CCA_Assmnt_Time This is the time allocated to the PLCP to make a CCA determination. This timing has no real solid method of determination. In the FHSS PHY we have set this period to 25 usec. We have said that in 16 usec the PLCP CCA state machine should be able to detect a preamble 90% of the time.

The slot time calculation is not implementation specific, it is made up of nominal values and represents agreements between implementators for reasonable implementation. The PHY_Slot_Time calculation therefore is as follows:

PHY_Slot_Time = RxTx_Turnaround_Time + Air_Prpg_Time + CCA_Assessment_Time

For the FHSS PHY, this is

= 20.0 + 1.0 + 4.0 + 25.0 = 50 usec

Implementations that have smaller actual implementation values for RxTx_Turnaround_Time are basically better implementations but perfectly acceptable in this MAC/PHY timing. Implementations which have lower RX_RF_Delay are also better implementations in that they can use some of that time for better PLCP_CCA_Assmnt_Time. But implementations which have longer RX_RF_Delay times must sacrifice some of their PLPC_CCA_Assmnt_Time to make up for the lost time in the RF portion of their implementation.

3.0 Summary

The MAC needs the following PHY MIB parameter to determine slot time.

PHY_Slot_Time

The PHYs should calculate PHY_Slot_Time using these three parameters

PHY_Slot_Time = RxTx_Turnaround_Time + Air_Prpg_Time + CCA_Assessment_Time

The MAC needs two SIFS times:

SIFS_Rcvr_Time
SIFS_Xmtr_Time

These times are calculated as follows

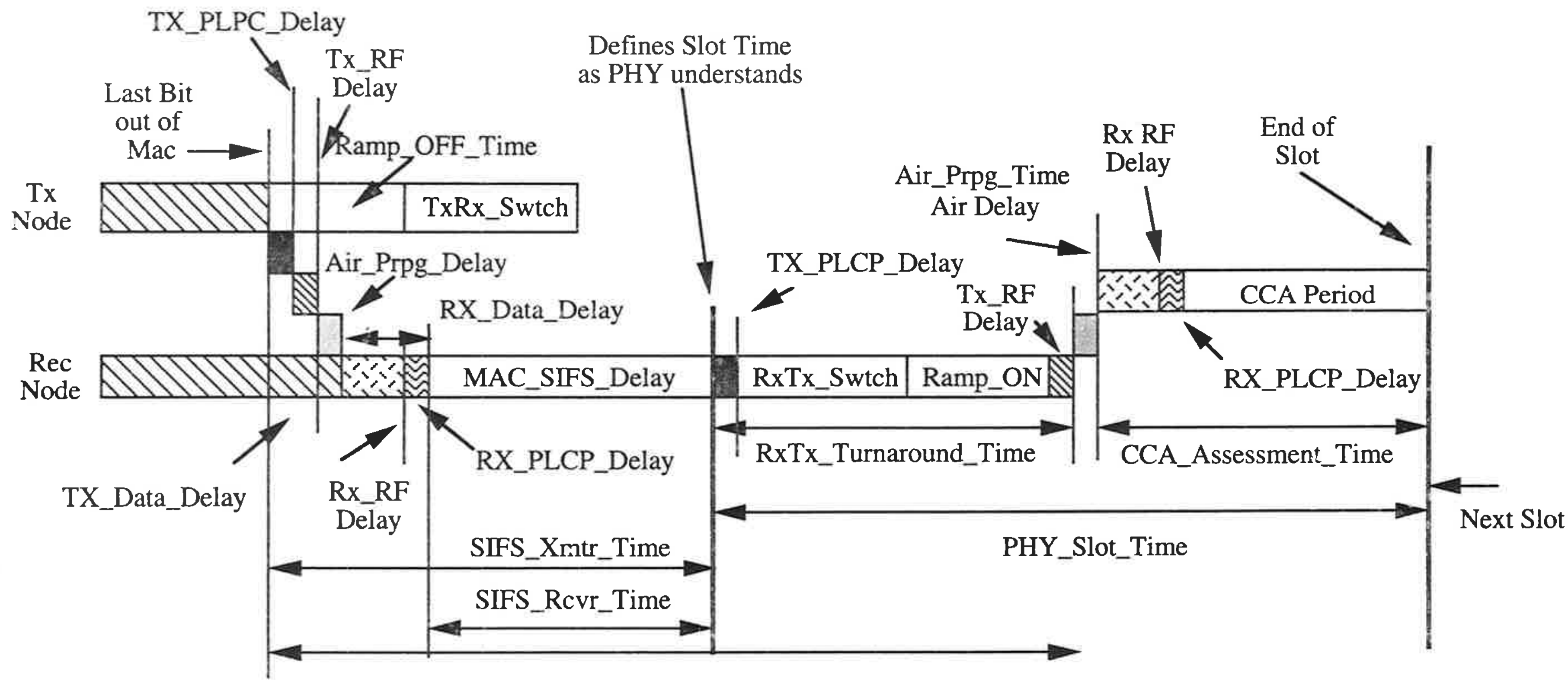
SIFS_Rcvr_Time = MAC_SIFS_Delay + SIFS_Rcvr_Delta
SIFS_Xmtr_Time = TX_Data_Delay + Air_Prpg_Time + RX_Data_Delay + MAC_SIFS_Delay + SIFS_Xmtr_Delta

where

MAC_SIFS_Delay	is argued in the MAC group for a value
SIFS_Rcvr_Delta	is calculate by the implementor

and

TX_Data_Delay	nominal number PHY Specified
Air_Prpg_Time	set by committee
RX_Data_Delay	nominal number PHY Specified
SIFS_Xmtr_Delta	is calculate by the implementor



FHSS PHY Timing Attributes
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