Proposed text for Section 7.1 based on responses to Draft D1 Letter Ballot processed at March 1995 Meeting

Phil Belanger

Xircom, Inc.
2041 Landings Drive
Mountain View, CA
94043

Greg Ennis

Symbol Technologies
2145 Hamilton Ave
San Jose, CA 95125

Bob O'Hara

Advanced Micro
Devices
One AMD Place
Sunnyvale, CA 94088

Chris Zegelin

Symbol Technologies
2145 Hamilton Ave
San Jose, CA 95125

Abstract: This paper presents the changes to section 7.1 in the Draft Standard P802.11/D1 as a result of the Response to Draft D1 Letter Ballot processed at the March 1995 Meeting as shown in the companion Document P802.11-95/71. Not all Letter Ballot comments were processed at the March 1995 Meeting.

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

7. MAC Layer Management Entity

7.1. Synchronization

All nodes within a single BSS shall be synchronized to a common clock using the mechanisms defined in this section.

7.1.1. Basic Approach

All stations shall maintain a local Synchronization Timer. A Timing Synchronization Function (TSF) keeps the timers for all stations in the same BSS synchronized.

7.1.1.1. TSF for Infrastructure Networks

In an infrastructure network, the AP shall be the timing master and shall perform the Timing Synchronization Function. To synchronize the other stations in a BSS, the AP shall periodically transmit special frames called Beacons that contain a copy of its Synchronization Timer. Receiving stations shall always accept the timing information in Beacons sent from the AP servicing their BSS. If the station's Synchronization Timer is different from the timestamp in the received Beacon, they shall set their local timer to the received timestamp value.

Beacons shall be generated for transmission by the AP once every a~~MACMGT_~~Beacon_Interval time units.

7.1.1.2. TSF for Ad Hoc Networks

The Timing Synchronization Function in an ad hoc network is implemented via a distributed algorithm that is performed by all of the members of the BSS. All stations in the BSS shall transmit Beacons according to an algorithm to be specified below. Stations receiving a Beacon from another station in the same BSS shall adjust their Synchronization Timers towards the Beacon's timestamp value in a manner to be specified below.

~~Timing synchronization shall be maintained in an ad hoc network by adjusting a synchronized timing reference to be the average of itself and any time stamp received from another station within the same ad hoc network.~~

~~NOTE: The timers for all synchronized stations in a BSS will typically converge to the same value over a short period of time.~~ It is permitted that a station within an ad-hoc BSS may scan for a better BSS within the same ESS. Within an ad-hoc network, all Beacon~~beacons~~ and probe-responses carry a TSF time element. A station receiving such a frame from another BSS with the same ESS ID will compare the TSF time with its own TSF time. If the TSF time of the received frame is later than its own TSF time, it will adopt the BSS-ID, channel synchronization information and TSF time contained in that received frame.

7.1.2. Maintaining Synchronization

Each station shall maintain a ~~free-running~~ TSF timer with modulus 2e64~~TSFTIMERMOD~~ counting in increments of microseconds. Stations expect to receive Beacons at a nominal rate. The interval between Beacons is defined by the a~~MACMGT_~~Beacon_Interval parameter of the station. ~~If the time interval between received Beacons exceeds MACMGT_Beacon_Interval, the station shall act as described in Clause XXX.~~ A station sending a Beacon~~beacon~~ shall set the value of the Beacon~~beacon~~'s timestamp so that it equals the value of the station's TSF timer at the time that the first MAC bit of the Beacon~~beacon~~ is transmitted to the PHY.

7.1.2.1. Beacon Generation in Infrastructure Networks

The access point shall define the timing for the entire BSS by transmitting Beacons according to the a~~MACMGT-~~Beacon_Interval parameter within the AP. This defines a series of Target Beacon Transmission Times (TBTTs) exactly a~~MACMGT-~~Beacon_Interval time units apart, time zero is defined to be a TBTT. At each TBTT, the AP shall schedule a Beacon as the next frame for transmission. If the medium is sensed to be unavailable, the AP shall delay the actual transmission of a Beacon according to the CSMA medium access rules specified in Section 5.

NOTE: Though the transmission of a Beacon may be delayed because of CSMA deferrals, subsequent Beacons will be scheduled at the nominal beacon interval. This is shown in Figure 7-1

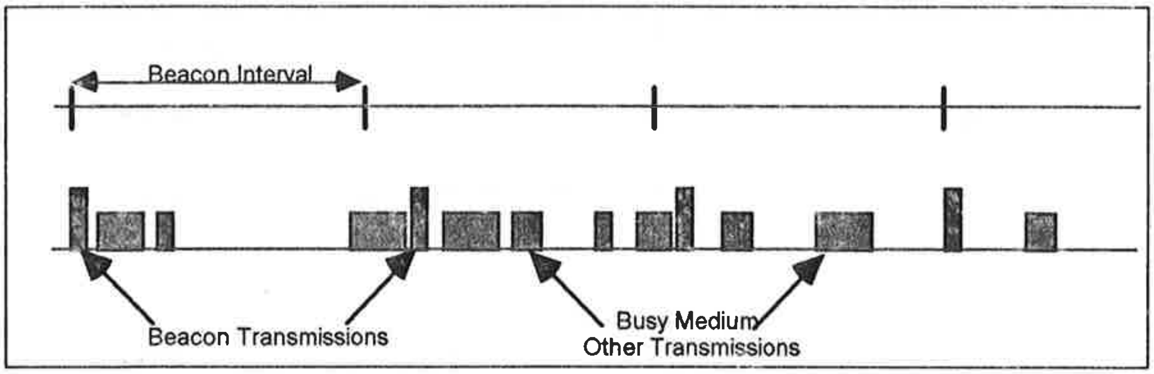

Figure 7-1 — Beacon transmission on a busy network.

7.1.2.2. Beacon Generation in Ad Hoc Networks

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

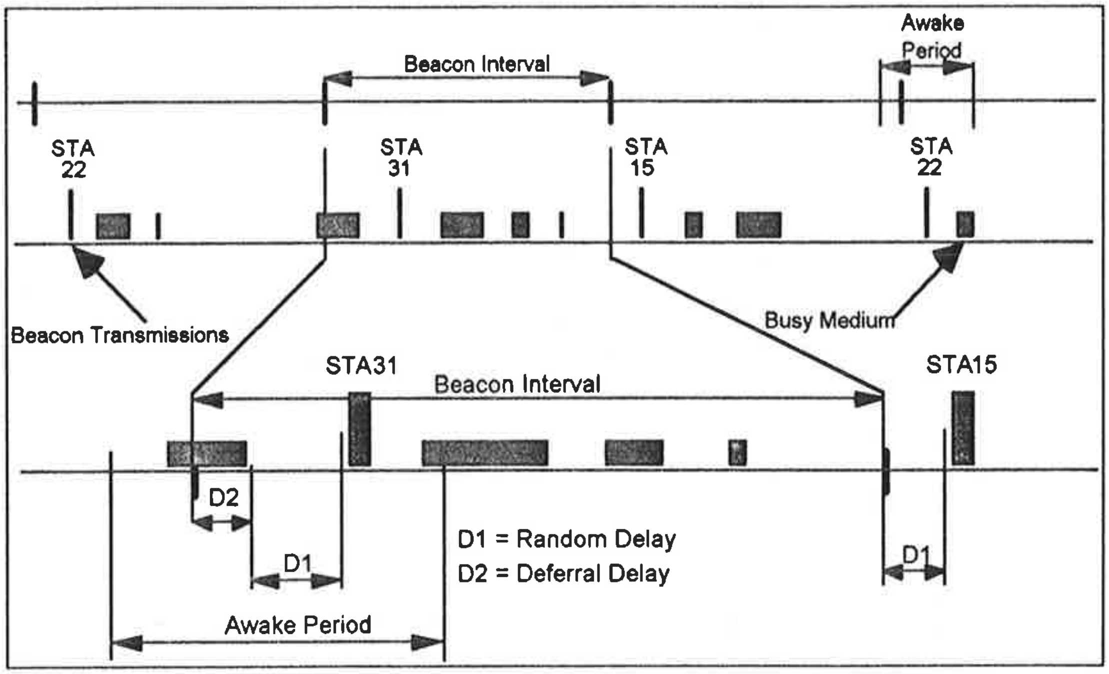

Figure 7-2 — Beacon transmission in an Ad Hoc network.

The randomized Beacon generation delay uses the same algorithm as the Access Backoff Procedure that stations use when they attempt to transmit and find the network busy. However, the Beacon transmission random delay shall be incurred even if the network is idle when the Beacon transmission is first attempted. This is shown in Figure 7-2. The Beacon transmission will always occur during the Awake Period of stations that are operating in a low power mode. This is described in more detail in Section 76.2.

7.1.2.3. Synchronization Beacon Content

A synchronization Beacon contains a message header and the following required elements:

> **Timestamp** — a 32 bit field containing the TSF timer MOD 2^{31} (in microseconds) and a Boolean flag SYNC which is 1 if the station sending the Beacon is synchronized (MACMGT_Sync_State = Syncronized). An AP is always synchronized. Stations are always initially unsynchronized and shall transmit SYNC = 0 until they become synchronized with the BSS.

> **Beacon interval** — a 24 bit field containing the time in microseconds between Beacons.

Beacons are sent to the broadcast destination address and contain the NID of the sending station. Section 6.2 defines other elements which must also be included within an AP-generated Beacon under certain circumstances.

7.1.2.4. Synchronization Timer Accuracy

The TSF timer has a resolution of microseconds. The Beacon's timestamp field shall not be filled in until after the CSMA deferral on the Beacon transmission. The start of the MAC frame is used as the timing reference. The timestamp value in the Beacon frame is the value of the TSFfree-running synchronization timer at the instant that the first bit of the MAC frame is transmitted to the PHYStart Frame Delimiter (SFD) is transmitted.

Upon receiving a Beacon BSS with a valid CRC and BSS-ID, a Station shall update its TSF timer according to the following algorithm: The received timestamp value shall beis adjusted by adding an amount equal to the receiving station's delay through its local PHY components plus the time since the first MAC bit was received at the MAC/PHY interface. In the case of an infrastructure BSS, the station's TSF timer shallis then be set to the adjusted value of the timestamp. In the case of an ad hoc BSS, the station's TSF timer shall beis set to the value of the adjusted received timestamp, if the value of the adjusted timestamp is greater than the value of the station's TSF timer. The accuracy of the TSF timer shall be +/- 0.01%.

7.1.3. Acquiring Synchronization, Scanning

A Station shall perform a scan whenever its aMACMGT_Scan_State variable is SCAN.

A Station shall operate in either a Passive Scanning mode or an Active Scanning mode depending on the current value of the system variable aMACMGT_Scan_Mode, which can take the values PASSIVE or ACTIVE.

7.1.3.1. Passive Scanning

If a Station's aMACMGT_Scan_Mode variable is PASSIVE, the station shallwill listen to each channel scanned (for a maximum duration aMACMGT_Passive_Scan_Duration, until a valid Beacon is heard with the correct BSS-ID. It will then leave the SCAN state.

7.1.3.2. Active Scanning

Active scanning involves the generation of Probe frames and the subsequent processing of received Probe Response Frames. The details of the active scanning procedures are described belowin Sections 7.1.3.3, 7.1.3.4, and 7.1.3.5.

Probes shall be sent to the broadcast address and have an NID with a specific ESSID.

Probe Responses are shall be sent to the source of the Probe as directed messages and contain an NID matching the Probe. A Probe Response also contains the following elements:

Timestamp

Source NID — a 24 bit field containing the NID of the sending station. The NID in the header always matches the NID received in the Probe.

7.1.3.2.1. Sending a Probe Response

Stations receiving probes shall respond with a probe response only if the ESSID is the broadcast ESSID or if the ESSID matches the specific ESSID of the station. Probe responses shall be sent as directed messages to the address of the station that generated the probe. The probe response shall be sent using normal frame transmission rules. An access point shall respond to all probes meeting the criteria above. In an ad hoc network, the station that generated the last Beaconbeacon shall respond to a probe. Stations responding to Probes shall follow these rules.

a) Always send a Probe Response as a directed message.
b) Always defer and do a Backoff before sending a Probe Response even on the first transmission attempt.

In a network there shall be at least one node that is awake at any given time to respond to probes. The station that sent the most recent Beaconbeacon shall remain awake and shall be the only station to respond to Probes until a Beaconbeacon frame is received. If the station is an access point, it shall always respond to probes. In an ad hoc network probe responses shall be sent by the station that sent the last beacon.

7.1.3.2.1.1. Scanning for Infrastructure Networks

APs are always in Sync (MACMGT_Sync_State = Sync) and always respond to Probes.

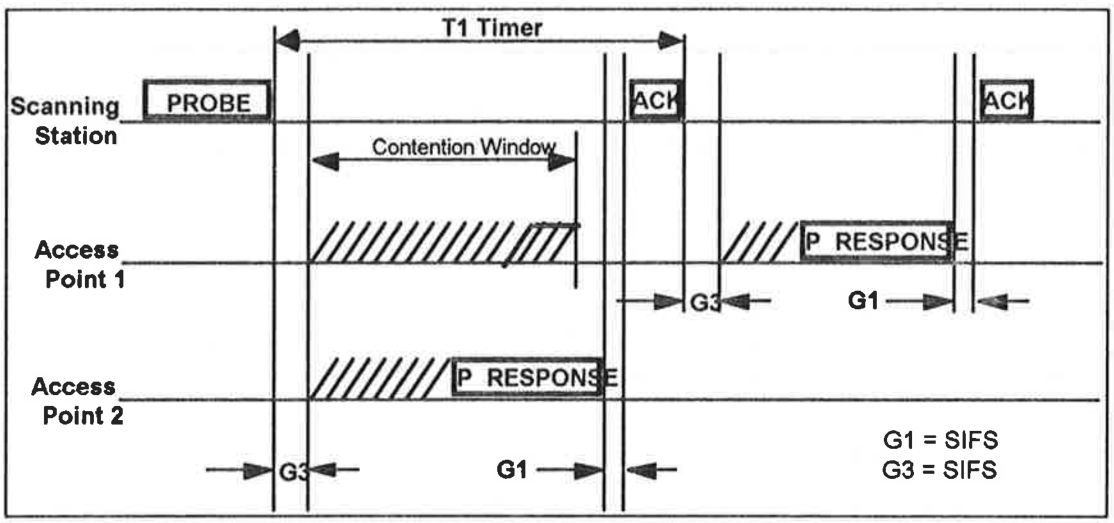

Figure 7-3 — Multiple APs responding to a Probe.

An actively scanning station shall take the following actions to find any AP belonging to a certain ESS :

a) CSMA defer
b) Send Probe with Broadcast Destination, Specific ESSID, and Broadcast BSSID
c) Start T1 timer
d) If receive energy within T1 then start T2
   Else If hear nothing within T1
      then clear NAV
   Scan next channel.
e) When T2 expires, process all received Probe Responses.
f) Clear NAV and Scan next channel.

7.1.3.2.2. Active Scanning Procedurefor an Existing Ad Hoc Network

A station using active scanning shall use the following procedure.

~~A new station attempting to join an existing ad hoc network shall actively scan using the following procedure:~~

For each channel to be scanned:

- a) wait until CCA indicates the medium is clear
- b) Send Probe with Broadcast Destination, ESSID, and broadcast BSSID
- c) Start Probe_Timer_1
- d) If CCA indicates activity prior to expiration of Probe_Timer_1
  then start Probe_Timer_2
  Else If CCA indicates no activity before the expiration of Probe_Timer_1
  then Clear NAV, Scan next channel.
- e) When Probe_Timer_2 expires, process all received Probe Responses.
- f) Clear NAV and Scan next channel. ~~a) CSMA defer~~
- ~~b) Send Probe with Broadcast Destination, Specific ESSID, and Specific BSSID~~
- ~~c) Start T1 timer~~
- ~~d) If receive energy within T1~~
  ~~then start T2~~
  ~~Else If hear nothing within T1~~
  ~~then Clear NAV~~
  ~~Scan next channel.~~
- ~~e) When T2 expires, process all received Probe Responses.~~
- ~~f) Clear NAV and Scan next channel.~~

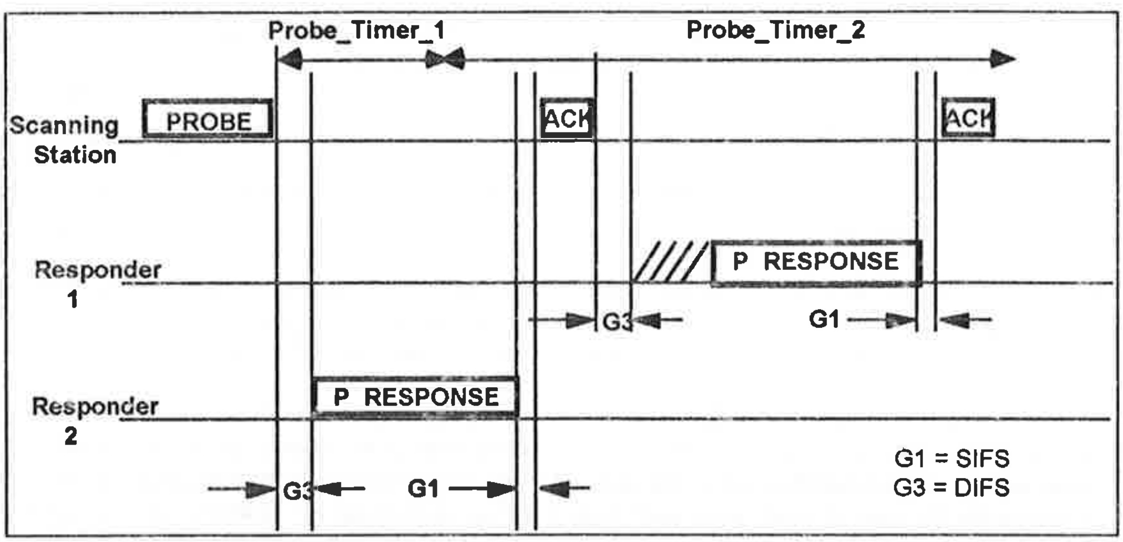

Figure 7-4~~4-7~~ - Probe Response

7.1.3.3. Initializing or Synchronizing with a BSS~~an Ad Hoc Network~~

An access point shall select a BSSID, select channel synchronization information, select a beacon interval, initialize its TSF timer, and begin transmitting Beacons.

Stations which are not access points shall:

- a) Scan for the presence of an existing BSS with a specific ESSID
- b) If a BSS with the specific ESSID is found, adopt the BSSID, channel synchronization information, TSF timer value of the BSS.

Else if the ESSID designates an ad hoc network, select an ad hoc BSSID, select channel synchronization, select a beacon interval, initialize and start the TSF timer, and begin transmitting Beacons.

Else indicate failure to find a network matching the ESSID.

~~The procedure for starting an ad hoc network is as follows:~~

a) ~~Scan (BSSID = specific) for T5 seconds~~
b) ~~If hear something then JoinNet~~
c) ~~else StartNet~~
d) ~~Stay active (don't go into low power mode) for T3 seconds~~

~~JoinNet is the process described above as scanning for an ad hoc network. StartNet causes the station to establish the initial timing reference for the ad hoc network. The station shall set its MACMGT_Sync_State variable to "Synced" and begin sending Beacons at the expected intervals. Stations following the same process slightly later than the first station will find the first station during the long Scan in step 1.~~

7.1.4. Adjusting Station Timers and Coalescing

In the infrastructure network, stations shall always adopt the timer in a Beacon or Probe Response coming from the AP in their BSS.

In an ad hoc network, a station shall always adopt the information in the contents of a Beacon or probe response frame when those frames contain a matching ESSID and the value of the time stamp is greater than the station's TSF timer. A station may return to its previous BSS, if any, and transmit a Beacon with the newly adopted information.

~~In the infrastructure case, Stations shall always adopt the timer in a Beacon or Probe Response coming from the AP in their BSS.~~

~~In an ad hoc network, a station shall determine whether to adopt the timer from an incoming Beacon or Probe Response, or to adjust its own timer in the direction of the timestamp received, using MACMGT_Sync_State and MACMGT_Weight variables as described in this section.~~

~~When a station first enters a network, it shall be unsynchronized (its MACMGT_Sync_State variable is 0). After a station has heard a suitable number of Beacons from other stations that are synchronized and the timestamp in the Beacons matches the station's timer, it shall change to the synchronized state. If a station adopts the timer of an AP or a synchronized station, it shall change its state to synchronized.~~

~~The timer adjustment rules are as follows:~~

~~If the receiving station is unsynchronized:~~
~~if receive Beacon or Probe Response with SYNC = 1 then adopt timestamp~~
~~if receive Probe Response with SYNC = 0 AdjustTimer~~
~~If the receiving station is synchronized:~~
~~if receive Beacon or Probe Response with SYNC = 1 then~~
~~if the difference between the timers is above a threshold Coalesce~~
~~else AdjustTimer~~
~~if receive Probe Response with SYNC = 0 ignore~~

~~AdjustTimer uses the Weight value in the Beacon or Probe Response to determine how much to adjust the station timer. If an incoming Beacon contains a Weight that is greater than the station Weight, the station timer is adjusted by a large amount towards the timestamp contained in the Beacon. By contrast if he~~

station weight is greater, then the station timer is adjusted by a small amount. Details of this algorithm are to be specified.

The Coalesce operation is for further study.

7.1.5. Timing Synchronization for Frequency Hopping PHYs

NOTE: This section only pertains to stations using a Frequency Hopped PHY.

The TSF described here provides a mechanism for stations in a frequency hopping system to synchronize their transitions from one channel to another (their hops). Every station shall maintain a table of all of the hopping sequences that are used in the system. All of the stations in a BSS shall use the same hopping sequence. There is a function (to be specified) that maps from BSSID to a particular entry in the hopping sequence table. This shall be used to select the hopping sequence for a BSS. Every frame contains the BSSID, so a new station joining a BSS shall determine the hopping sequence from any received frame. Since it knows the channel on which it is receiving, the station shall determine which hop in the sequence is the current hop and the channel to use for the next hop. Each Beacon and probe response includes the channel synchronization information necessary to determine the hop pattern and timing for the BSS.

Stations shall use their TSFTIMER to time the aMACMGT_Dwell_Interval. The aDwell_Interval is the length of time that stations will stay on each frequency in their hopping sequence. Once stations are synchronized, they have the same TSFTIMER value. The TSFTIMER shall be a 31 bit value measured in microseconds. In a frequency hopping system, the maximum value of the TSFTIMER shall be the number of microseconds it takes to complete one hopping sequence — MACMGT_Dwell_Interval * #Hops.

Stations in the BSS shall tune to the next frequency in the hopping sequence whenever:

[TSFTIMER + aDwell_Offset] MOD aMACMGT_Dwell_Interval = 0

The time remaining in the current hop is:

MACMGT_Dwell_Interval - (TSFTIMER MOD MACMGT_Dwell_Interval).