IEEE 802.11
Wireless Access Methods and Physical Layer Specifications

TITLE: Preamble for Supporting a Data Transport Protocol for a Frequency Hopping Spread Spectrum RF WLAN

DATE: Nov. 8-12th,1993

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Introduction

The design and development of a preamble is probably one of the most critical and difficult portions of any wireless LAN (WLAN) implementation. It must take into consideration a number of the important attributes such as clock recovery and synchronization, as well as, meet some of the timing requirements the overall protocol might require. The following paper details the implementation of the preamble used to support the data transport protocol for a frequency hopping RF spread spectrum WLAN designed to operate in an interference laden environment.

1.0 Preamble Functions

The preamble has two important functions within the overall operations of the data transport protocol. These two functions are:

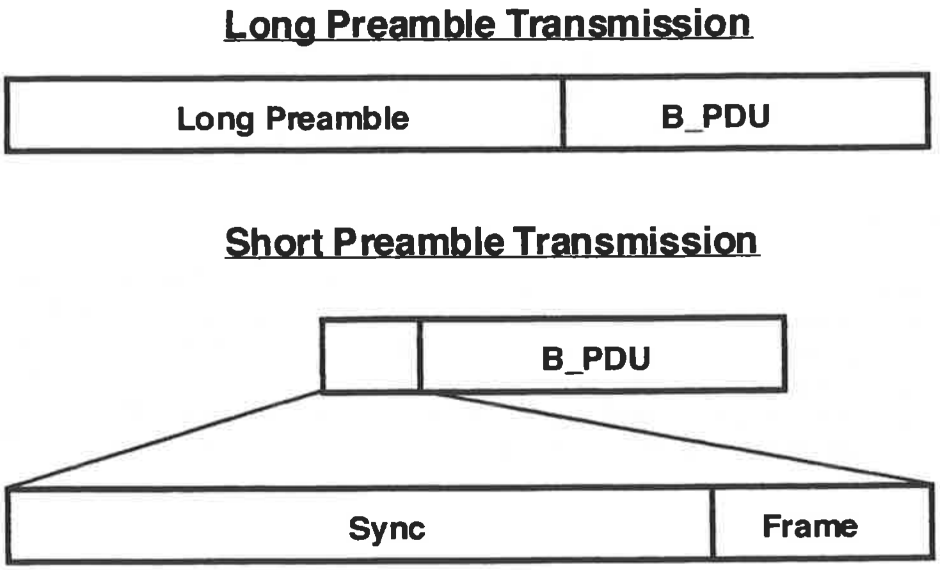
- Synchronization

- Protocol Timing

Synchronization is a term used to describe the functions the preamble provides for recovering data within each burst of the data transport protocol. Protocol Timing is a function the preamble provides for recovering multiple bursts within the transmission of a packet in the data transport protocol.

2.0 Preamble Construction

Figure 1.0 shows the data transport protocol as having two types of preambles. One type is called a long preamble and precedes the first three bursts of each packet transmission. The second type is a short preamble which precedes the last two bursts of each packet transmission.



B_PDU Preambles

Fig. 1.0

As shown in Figure 1.0, the preamble is made up of two data fields: SYNC and FRAME. The SYNC field is composed of multiple SYNC symbols while the FRAME field consists of a single FRAME symbol. The FRAME field is the same for both the long and short preambles. The SYNC field for long and short preambles use the same SYNC symbol but differ in the number of SYNC symbols each contain. This number is determined by the Protocol Timing.

3.0 The SYNC Field Synchronization Functions

As stated previously, the SYNC field in both types of preambles consists of multiple occurrences of the SYNC symbol. This string of SYNC symbols is used to provide support for the following synchronization functions.

- Data Clock Recovery
- Data Alignment
- Auto-Correlation
- Cross-Correlation

The primary concern of the SYNC field is to provide a pattern for the receiver which can be used to quickly achieve clock and data recovery. It is also desirable that this field provide some means of alignment relative to the FRAME symbol and data bytes to follow. In addition, the SYNC symbol should have some auto and cross correlation features relative to other LANs which might also operate in this spectrum.

3.1 Clock and Data Recovery

One of the most important functions of the SYNC field is to aide the receiver in acquiring the data clock, thus recovering the data transmission. Clock and data recovery circuits can be simplified if the following conditions are present in the SYNC field

- High number of transitions
- DC Balanced
- Phasing Information

It is important for any clock recovery circuitry to have a SYNC field with a high density of transitions. This will decrease the time it takes to start clock recovery and increase the opportunities to maintain and/or adjust any type of phase lock loop circuitry.

In addition to transitions, it desirable to develop a SYNC symbol or combination of SYNC symbols which are DC balanced. This requires designing a SYNC field that causes the output of the transceiver to be in the "1" state for the same length of time it is in a "0" state.

3.2 Data Alignment

One of the reasons for developing a small SYNC symbol to define the SYNC field is that state machines which operate on blocks of bits rather than long strings of bits are easier to implement. For example, it is easier to look for 5 consecutive occurrences of a 4 bit pattern rather than a single occurrence of a 20 bit pattern. In addition, once data alignment has been established within the SYNC field the same block processing applies equally as well to detecting the FRAME symbol and the following data fields.

3.3 Auto-correlation and Cross-correlation

Auto-correlation and cross-correlation are functions which must be considered when selecting a SYNC field. Auto-correlation refers to the number of times the SYNC symbol matches a copy of itself as it is shifted in time. This helps prevent false syncing in an error environment and enhances clock recovery. For example, a SYNC symbol such a 101010b has poor auto-correlation characteristics because as it is shifted in time, every other shift matches itself.

Cross-correlation refers to how closely sync symbols of another protocol might match. A low cross-correlation refers to a large Hamming distance between one sync symbol and all other known WLANs. This is useful not only in distinguishing one WLAN protocol from another, but also reduces the clock and data recovery circuitry's susceptibility to random noise, ie. making noise look like data. In the wireless environment, when considering effects such as multi-path, clock and data recovery circuitry must be able to tolerate noise and jitter within the data stream. This has a tendency to make noise appear as data and vice-a-versa. High auto-correlation and low cross-correlation characteristics help reduce this phenomena and should be taken into consideration when selecting a synchronization symbol.

4.0 FRAMING Symbol

The data transport protocol uses the FRAME symbol to delineate the preamble field from the beginning of the B_PDU. The FRAME symbol is actually made up of three parts which are: SYNCBAR, SYNC and SYNCBAR. SYNCBAR is the inversion of the SYNC symbol. SYNCBAR is used to delineate the FRAME symbol from the SYNC field by presenting the framing circuitry with a pattern highly uncorrelated with the SYNC symbol.

5.0 Synchronization and Framing Strategy

The synchronization and framing strategy for the data transport protocol is taken from a system approach to implementing the wireless LAN protocol. Obviously, preambles cannot satisfy all of the previously discussed requirements, and therefore some tradeoffs must be made.

First of all, our synchronization strategy is based upon the fact that prior to receiving the first burst of any packet the transmitting node is asynchronous with regards to any receiving node. The preamble must provide the synchronization features required to synchronize the transmitting node to the receiving node. These features include the following:

- Detecting the presence of Data or Noise
- Data Clock Recovery
- Frame and Byte Alignment

It is important to the protocol timing, when in asynchronous mode, that the clock and data recovery circuitry be able to look at the signal present on a given channel and determine quickly whether it is noise or data. When clock recovery begins, a timer is started to monitor the length of the time synchronization process. If clock and data cannot be recovered before the timer expires, the signal is determined to be noise, and the clock recovery mechanism reports no SYNC or data to the protocol state machine. The protocol state machine continues to SCAN. If clock recovery is successful, and thus data bits are detected, the SYNC state machine begins to function. The SYNC state machine has the following states.

- HUNT
- Pre-SYNC
- SYNC
- FRAME

HUNT: The HUNT state is looking for any occurrence of the SYNC symbol. If a SYNC symbol is detected, the SYNC state machine procedes to the Pre-SYNC state. If this state was entered via the Pre-SYNC or SYNC state, the HUNT state will restart the synchronization timer.

Pre-SYNC: The Pre-SYNC state is entered when one SYNC symbol has been detected. If three consecutive occurrences of the SYNC symbol have been detected, the SYNC state machine will advance to the SYNC state. If a SYNC symbol is found with two or more bits in error, or two SYNC symbols are found with single bit errors, the Pre-SYNC state will revert back to HUNT. If a SYNC symbol is found with a single bit error, the Pre-SYNC state machine will require another SYNC symbol to be detected prior to advancing to the SYNC state.

SYNC: When the SYNC state has been entered, at least 3 or 4 SYNC symbols have been successfully detected. When entering this state, the SYNC state machine will disable the timer it started when synchronization began. It will remain in this state until a SYNCBAR symbol is detected, two or more bit errors occur in a SYNC symbol, or the preamble timer expires.

FRAME: The FRAME state is entered when a SYNCBAR symbol is detected. This FRAME state will then look for a SYNC symbol followed by another SYNCBAR symbol. If the FRAME field is detected, the SYNC state machine will terminate and return a positive FRAME indication to the protocol state machine. This will result in the further processing of a B_PDU.

If the synchronization timer expires before entering the FRAME state, the synchronization process will terminate. If the synchronization process has detected valid data but no SYNC or FRAME symbols, the SYNC state machine will return a BUSY indication. If no valid data was ever detected (ie. data meeting the bit template), the SYNC state machine will return a CLEAR CHANNEL indication.

5.1 SYNC and FRAME Symbols

The SYNC symbol is a five bit data pattern. The FRAME symbol is a 15 bit data pattern implemented as SYNC/SYNCBAR/SYNC. These bit patterns are described below:

The SYNC symbol is	11010b
The SYNCBAR symbol is	00101b
The FRAME symbol is	001011101000101b

6.0 Preamble Protocol Timing

The preamble for the data transport protocol plays an important part in recovering an individual burst and all the following bursts for a given packet. This feature is the direct result of the preamble protocol timing. All nodes within a WLAN are basically asynchronous to one another until a node begins transmitting. Providing there is no interference, each listening node will lock up to the transmitting node's preamble when they SCAN the first channel. Since all nodes are asynchronous, they can be on any of the first three channels at any instant of time. The preamble timing considers this when determining the number of SYNC symbols in a long preamble's SYNC field. The preamble timing was derived from a worst case consideration of the following parameters:

- Transmitter ramp-on time
- Diversity Timing & Clock Recovery Channel 1
- SCAN Channel 2
- SCAN Channel 3
- SCAN Channel 1

The transmitter ramp-on time, which is included with each burst transmission, is 4.0 μsec. long and is implemented with the modulation turned-off. This is done to reduce the amount of AM spectrum component splatter and AM-to-PM conversion splatter that would occur if modulation was present as the carrier was varying in amplitude.

The diversity timing per SCAN is assumed to be 16.0 μsec. This timing is based upon the length of time to sample the RSSI value on the antenna in use, switch to the second antenna, build up RSSI energy, sample the second antenna, compare the samples and choose the best antenna. If the best antenna was the first antenna, a switch back to that antenna must be made and allowance made for the data delay time through the transceiver. Since we use the diversity function to overcome multipath, we can use this time to allow the receiver to perform DC offset correction. This function can be performed satisfactorily in a 16.0 μsec. time period.

Clock recovery timing is based on 36 bit times (36.0 μsec. assuming a 1.0 MHz bit clock) to allow for clock and data recovery and synchronization acquisition if SYNC is present. Scanning a channel requires the following times:

• Hop Time	80.0 μsec.
• Diversity Time	16.0 μsec.
• Clock Recovery Time	36.0 μsec.

The SCAN time for any channel [assuming a 1.0 MHz clock] is 132.0 μsec. The time to SCAN 3 channels is three times this or 396.0 μsec. Included in the long preamble timing is the additional time required for one more diversity and synchronization attempt for a total of 448.0 μsec. Therefore, the following applies to the number of SYNC symbols in a long preamble:

$$448.0\ \mu\text{sec} / 5\ \mu\text{sec/symbol} = 89.6 \text{ or } 90 \text{ whole symbols}$$

The long preamble consists of 90 SYNC symbols plus 1 FRAME symbol for a total of 93 symbols (465 bits).

Short Preambles: Short preambles are applied to bursts that no longer require burst synchronization between the transmitter and receiver. Their timing is:

- Diversity Timing 16.0 μsec.
- Clock Recovery Timing 36.0 μsec.

Short preambles are determined as follows:

52.0 μsec. / 5 μsec./symbol = 10.4 or 11 whole symbols

The short preamble consists of 11 SYNC symbols plus 1 FRAME symbol for a total of 14 symbols (70 bits).

The final piece of the preamble is the length field. This 32 bit field (16 bits for the length field and 16 bits for the BCH field) is error protected and used to delimit the length of each burst of data sent over the medium. If a receieving node does not correctly receive the length field, it will throw away that burst of data and perform one of two actions. If the receiver has already received one valid burst of data, then it performs an erasure delay and hops to the next frequency for reception of the next burst. If it has not received a valid burst of data yet, then it reverts back into the SCAN mode of operation.

Figure 2.0 illustrates the typical preamble length associated with a transceiver pair that have achieved burst synchronization. This length is 103 bit periods or 103 μsecs for a 1.0 Mbps system implementation:

4 bits	16 bits	36 bits	15 bits	32 bits
Ramp	Diversity	Sync	Frame	Length/BCH

Fig. 2.0

7.0 Conclusions

Synchronization and preamble timing both play an important role in the successful operation of the data transport protocol. There is always a concern as to whether the chosen synchronization method is rigorous enough to succeed in environments where different WLANs are operating with various forms of interference. This interference might cause false SYNC and FRAME detection which will degrade the overall throughput of the WLAN system.

In a system where the receiving and transmitting nodes are asynchronous, the synchronization and framing mechanisms are only the first line of defense used to protect the system against false synchronization. This is why our system implementation employs the error protected length field and additional FEC associated with each burst transmission.