Preamble for Frequency Hopping PHY

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Abstract

In this submission we propose a packet structure for a frequency hopping PHY which includes the preamble, a postamble and the associated whitener. The preamble considers the symbols required for antenna diversity selection, symbol timing recovery and preamble validation to open the data gate to the MAC layer. Frame synchronization is not part of the preamble as it is included in the MAC frame. [1]

Introduction

The purpose of the preamble is to allow the receiver to perform antenna diversity selection, clock and data recovery, and this without any prior knowledge of the timing at which a data packet will hit the receiver. Generally a preamble is made of synch bits from which clock synchronization is extracted, followed by a unique word sequence to prepare the PHY to provide data to the MAC, and eventually to prepare itself for a specific data rate / coding indicated by this incoming sequence. In wireless environment before performing the actual clock and bit recovery there is a need to perform an additional task where the receiver selects sequentially between two different antenna patterns (antenna diversity selection). At the end of the packet a postamble is included to allow the system to prepare itself for the next packet by making sure that the radio enters in the search preamble mode.

Operating sequences

Turn on sequence

During the interval that the MAC layer initiates the transmission and the actual MAC frame, synchronizing signals for proper conditioning at the receiving transceiver must be generated by the transmitting transceiver. These are signals to establish carrier detection, timing synchronization and whitener initialization. The sequences for all data rates are divided into two segments:

- Timing acquisition, antenna diversity/Receive Signal Strength Indication (RSSI)/preamble validation.
- codeword synchronization sequence

Preamble format

Clock recovery

Clock recovery must be achieved before synchronization and frame detection is attempted or erroneous bit boundaries will cause false detect. Clock recovery will measure the phase difference between a bit edge and a receiver synchronous clock. Several bit edges are required to correct from errors due to bit jitter. Therefore to achieve this bit synchronization as quickly as possible a pattern with the highest number of transitions is the most suitable, the 101010... pattern satisfy this requirement and has already been proven in systems such as PMR, DECT,..., with the drawback that it does not provide any indication of the preamble timing. This drawback is exploited in the fact that this repeating bit synchronizing sequence aids in capturing of the preamble, and in addition this sequence is not likely to occur in the data sequence if the data are whitened.

Based on [2] if we consider a bit error rate of 10^{-5} this means an acknowledgement packet (100 bits) error rate of 10^{-3}, and as the miss probability should be significantly less than the packet error rate and therefore 16 independent samples are required.

The other important problem is false detection which may result in missed packet if a real packet arrive while processing a false one. Considering that on average a LAN is loaded only at 10% (to absorb peek traffic) there will be long periods with light traffic and therefore with a lot of idle which will be prone for false detection. Therefore by choosing a trial length of 16 with a miss probability better than 10^{-3} the probability of false detection becomes better than 10^{-7} which provide a good protection.

In addition if one adds the time required for settling due to switching between antenna pattern, and some house keeping for decision process this lead to an overall single view time of 20 SI.

Antenna selection

The assumption is that a repeating synch pattern is used and that consecutive antenna measurements on a single receiver are made. Then antenna selection will consist basically in making the choice between the highest received signal power between the two antennas, while checking the coherence of the received preamble. This process requires in worst case 4 views as indicated in [2]:

1. first view: the receiver is on the good antenna but did not have enough time to get a valid information.
2. second view: the receiver has switched to the bad antenna so it does not detect any valid signal.
3. third view: the receiver detects a good preamble
4. Fourth view: the receiver has switched to the bad antenna

carrier detector

Signal validation is performed simultaneously with antenna selection and clock recovery and allow to determine whether the received symbols are part of preamble, or spurious or data signal from an other collocated network. Synchronously with that digital process a RSSI measurement is performed to validate the received level associated with each antenna.

Codeword synchronisation sequence

A PHY codeword synchronization sequence identifies the boundary between the preamble and the MAC frame. Minimizing false synchronization requires that the codeword be unique: a bit pattern with low cross correlation will have few comparisons with bit streams of other LAN or its own data.

As with co-located networks the radio will inevitably forward pseudo packets to the upper layer, which are not for that station, or which are truncated packets which emulate the beginning of a packet.

It is clearly impossible to reserve one character for synchronization in a binary system, so this unique word is taken to be a sequence of binary digits with a sharply peaked autocorrelation function.

Based on the decoding of a unique word which has good autocorrelation properties in the preamble this will allow to perform a first level of packet filtering at PHY layer.

This unique sequence is based on the output of a shift register corresponding to $h(x) = X^4 + X + 1$

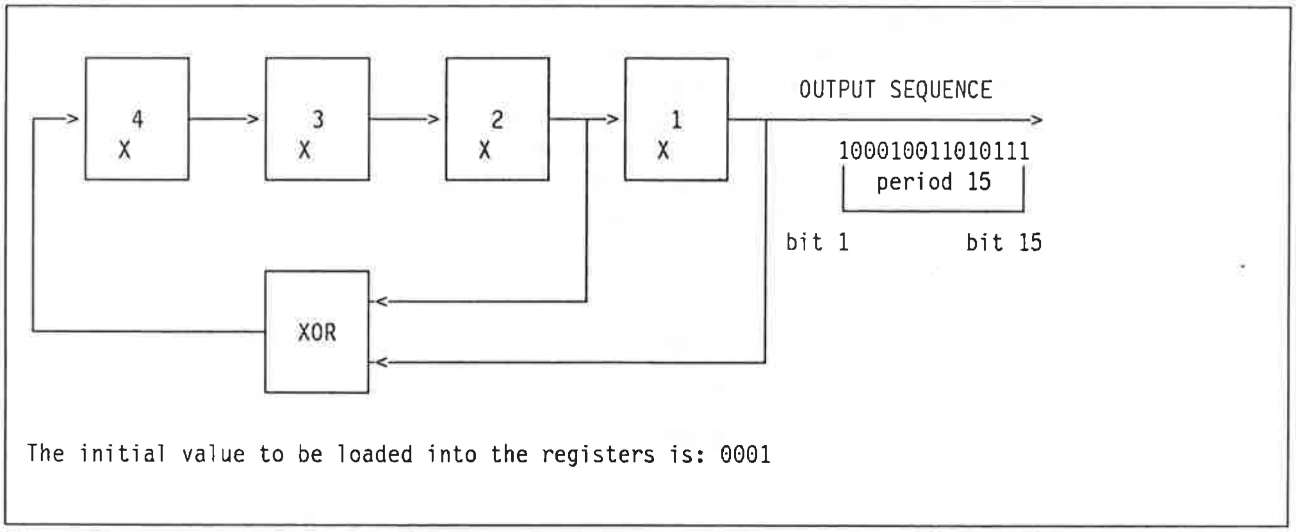

Figure 1. Unique turn on sequence implementation

The Pseudo Noise sequence generated has an autocorrelation function of:

$\rho(0) = 1$ and $\rho(\tau) = -1/N = -1/15$

However this system performs just a first level of filtering and therefore an additional one is required . But in order to keep the transmitted spectrum as narrow as possible, techniques such the one used for 802.3 and 802.5 where Manchester code violations are used to avoid confusion between frame delimiter and real data or control information cannot be used. Therefore the frame recognition at MAC layer is based on unique words which cannot occur in the data part of the frame, this technique is known as bit insertion, which avoid any sequence of more than 5 contiguous 1s to occur in the data stream.

This function can be considered as a valid data detector. Same codeword has been used in the past as control channel codeword synchronisation sequence in [3].

Summary of preamble structure

The 80 bit segment 1 is used for antenna diversity selection, clock synchronization, and RSSI measurement, while the 16 bit segment 2 is used for packet synchronization.
MAC frame synchronization is achieved through the start delimiter byte which is part of the MAC layer function and which is a unique word which does not occur in the user data.

Table 1. Summary of template for turn on sequence

	segment 1	segment 2	segment 3
type of line signal	Continuous alternating bit 1 and 0	Codeword synchronization sequence	Frame synchronization part of MAC layer
number of symbol interval	80 SI	16 SI	8 bits

Turn off sequence

The detection of the termination of transmission can be made on the basis of received signal strength, invalid bit clock, timeout on maximum packet length or other radio signal conditions, but it might be more safe to append some kind of unique postamble to secure the end of transmission. The most obvious solution is that after recognizing the unique end delimiter it becomes possible to recognize an abort sequence which means unambiguously the end of packet transmission.
The signal emitted at the end of a MAC frame is divided into two segments as shown in table 2.

Table 2. Summary of template for turn off sequence

	segment 1	segment 2
type of line signal	End delimiter (MAC Frame)	idles or aborts *
Duration	8 bits	8 bits
Note: (*) abort = 01111111 and idle = 11111111		

Overall packet structure

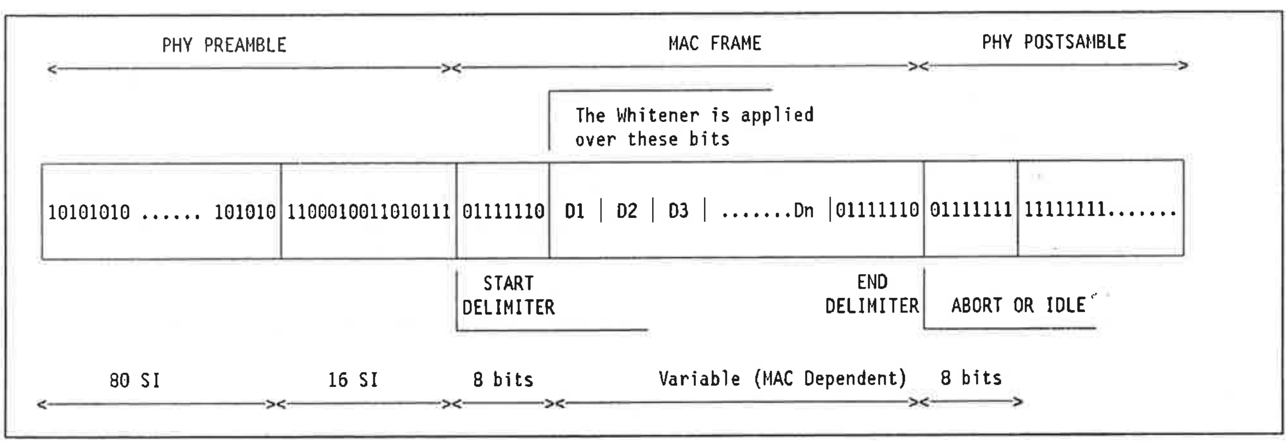

Figure 2. Air packet structure

Whitener algorithm

As the data sequence may exhibit binary "one" string length of 6 and uncontrollable string length of binary "zero" it is mandatory to include a whitener in the data string to preclude such a long sequence of 1 or 0, in order to avoid clock synchronization problems. This whitener is based on maximum length (pseudo-noise) sequence sequence generation. The circuit must satisfy the following pseudorandomness properties:

1. In any segment of length 2^{n-1} ones and 2^{n-1} -1 zeros.
2. In any segment of PN sequence with a length 2^{n}-1:
   - one half of the maximum string of consecutive identical symbols have a length of 1,
   - one quarter have a length of 2,
   - one eight have a length of 3
   - ....

   In each case the maximal string of consecutive zeros is equal to the number of maximal consecutive string of ones.
3. It satisfy the periodic autocorrelation requirement of a PN sequence

As the PN sequence is deterministic and that both PN generators can be synchronized when the same sequence is added modulo-2 to the sequence at hand at both transmitter and receiver the scrambling operation is achieved.

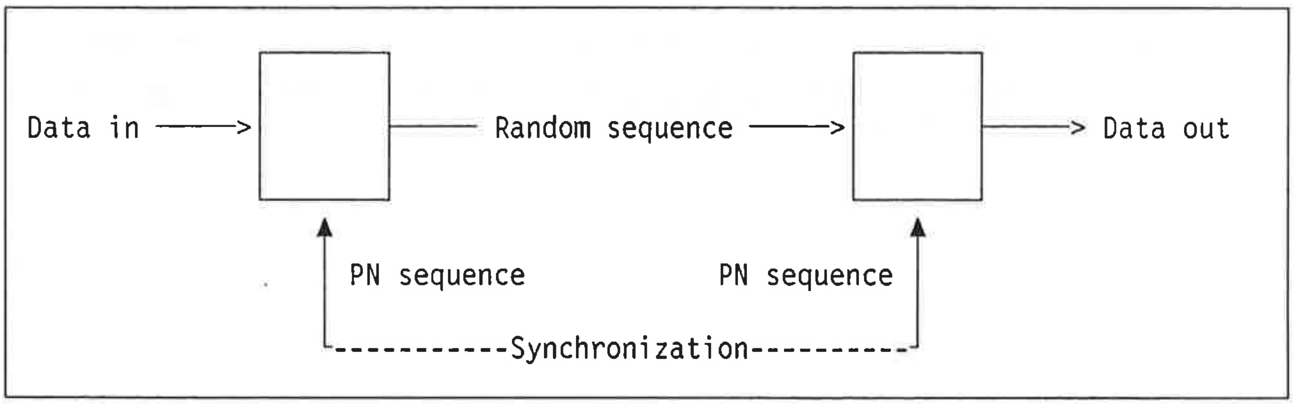

Figure 3. Whitener principle

A Whitener having the generating polynomial $X^{11} + X^{9} + 1$ shall be included into the transmitter. The data shall be effectively added modulo 2 to the generating polynomial in such a way that the output data sequence is :

$$D_s = \overline{X0} + Do \quad \overline{X1} + D1 \quad \overline{X2} + D2 \quad \overline{X3} + D3 \ ....$$

where

- Di: is the data sequence applied to the whitener
- + : denotes modulo 2 addition
- Xi: is the output sequence of the whitener

The length of the whitener is in line with the packet length under consideration at MAC level. In order to minimize the retransmission probability it will wise to limit the payload to 256 bytes.

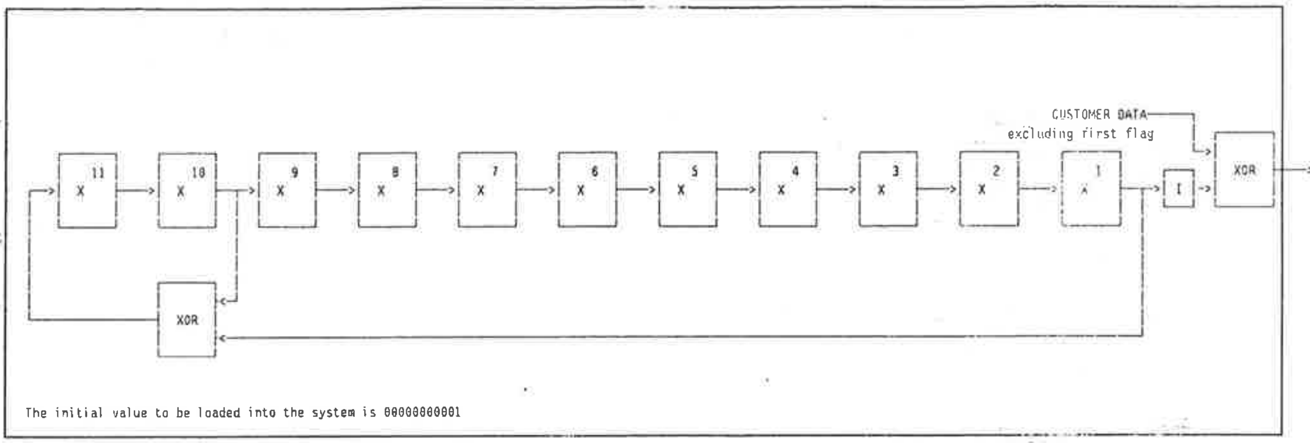

Figure 4. Withener possible implementation

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[1] F. Bauchot, *MAC to MAC interface* , IEEE P802.11/93-61

[2] J. Socci, *Preamble Length considerations for a Frequency Hopper PHY* , IEEE P802.11/93/72.

[3] MPT 1327 - A Signaling Standard, for Trunked Private Land Mobile Radio Systems. Department of Trade and Industry. London 1988.