IEEE 802.11
Wireless Access Method and Physical Layer Specifications

Title: **Preamble and MAC Header to Support Hop Acquisition for a Frequency Hopped PHY**

Authors: Jerry Socci and Ken Ju
National Semiconductor
Wireless Networking
Santa Clara, Ca 95052
Phone: 408-721-5590
Fax: 408-721-4115
Email: socci@berlioz.nsc.com

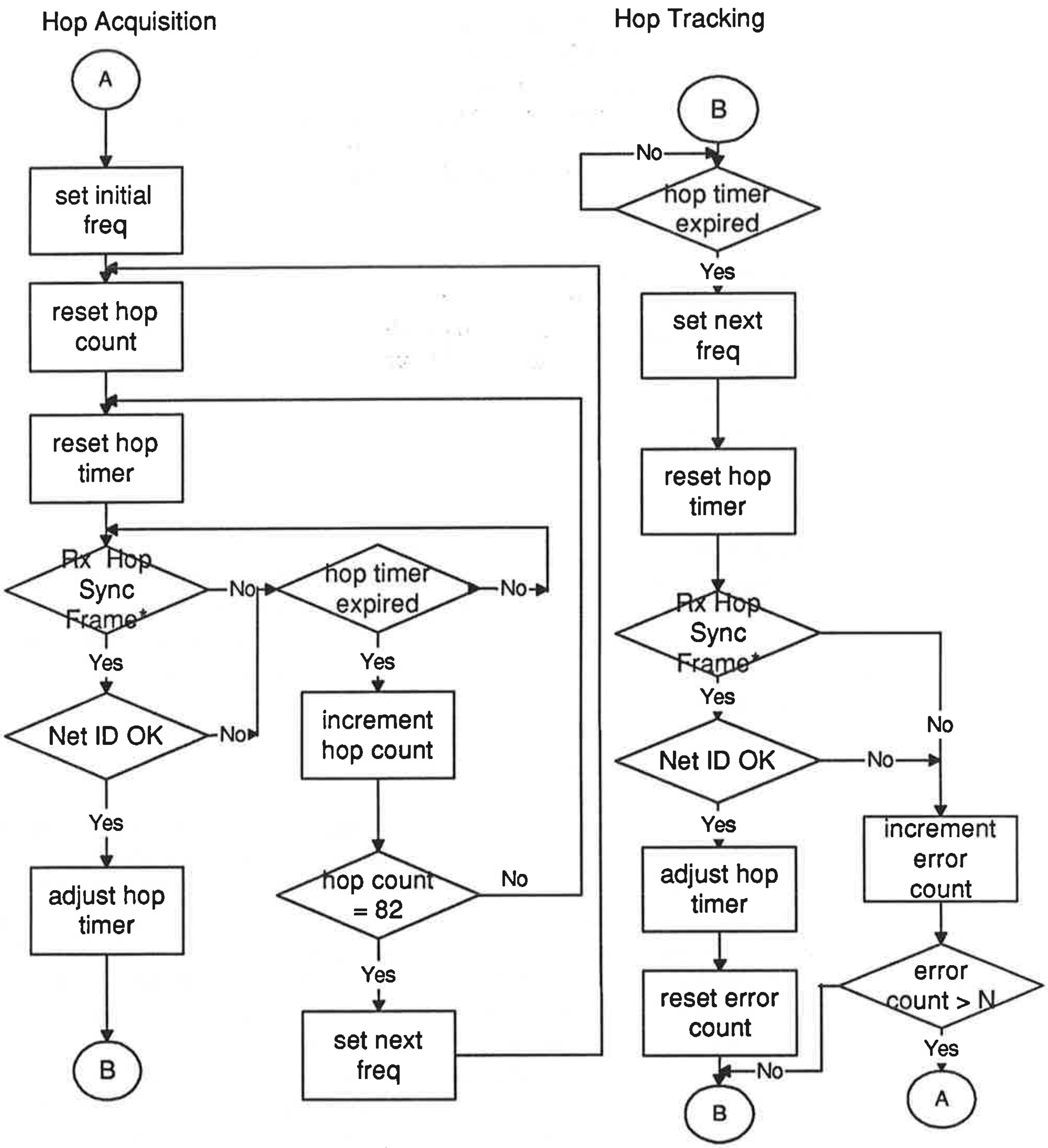
Abstract

This paper is intended to address Issue 24.11, "How will Hopping synchronization, acquisition and tracking be accomplished in the Frequency Hopping (FH) and their terms defined?" The requirements for the MAC header to support hop acquisition and timing are investigated.
A preamble suitable for a frequency hopped radio is also presented. The preamble should support carrier detection/antenna diversity selection, baseband dc offset adjustment, and symbol timing recovery and unique word detection.

1. Frequency Hop Acquisition and Timing

This paper is intended to address Issue 24.11, "How will Hopping synchronization, acquisition and tracking be accomplished in the Frequency Hopping (FH) and their terms defined?"
A flowchart that outlines a method to perform hop synchronization and tracking with an access point present is shown in Figure 1. The purpose of this flowchart is to show a possible approach to perform frequency hop acquisition and timing. The access point serves the function of sending a header or announce frame at the start of the next hop. Assuming the mobile has no concept of time relative to the hop time prior to acquisition then any of the 81 frequencies is equally likely. A possible search strategy is to stay on one of the frequencies and wait until either the signal is detected or for 81 hop durations. If no signal is detected in 81 hop durations then switch to a new frequency. The next frequency in the hop pattern is a good choice, assuming the hop patterns are selected so that consecutive hops have a minimum frequency separation based on the coherence bandwidth of the channel. Using this method the dwell time at a single frequency is 81*hop time = 4.05 seconds for a 50 ms hop time. The average time is half of the maximum time.

After hop acquisition has occured then frequency and hop time tracking needs to be maintained. As a minimum the MAC header needs to contain the next frequency. It is desirable to use fixed length hop times otherwise, the time to next hop would also be necessary.



* includes valid unique word detection

Figure 1 Frequency Hop Acquisition and Tracking

Instead of just the next frequency it is desirable to provide either a frequency table number or the next N frequencies where, for example N = 4. This allows a mobile to maintain synchronization even if a number of hops are missed. Skipping a certain frequency in the hop pattern to avoid a band of interference can be implemented for either scheme. If a frequency table number is used then the frequency to be skipped needs to be transmitted, preferably at least N hops ahead of time. If only the next N frequencies are transmitted then skipping certain frequencies can be done easily.

2. Preamble Length and Structure

A previous submission [1] presented a preamble suitable for a frequency hopped radio. In particular, estimates were given for performing the functions of carrier detection/antenna diversity selection, baseband dc offset adjustment and symbol timing recovery. This submission updates those results. The estimate for the time to perform carrier detection/antenna diversity is increased and time is included in the preamble for unique word detection since this function is more properly a PHY function. The preamble updated time estimates are:

o carrier detection/antenna diversity selection- 58 symbols worst case
o baseband dc offset adjustment- 8 symbols
o symbol timing recovery- 12 symbols
o unique word detection- 24 symbols

The estimates for baseband dc offset adjustment and the symbol timing recovery are the same as the previous submission. The carrier detection/antenna diversity selection is based on performing a correlation with a known pattern (a 1010... pattern) rather than a form of energy detection. The correlation with the known pattern should be more robust against interference. The total preamble length is 102 symbols which includes 24 symbols for unique word detection. Binary data at a rate of 1 Mbps is assumed so a symbol time is 1 microsecond. Figure 2 shows a timeline for the worst case receiver acquisition.

The unique word performance is presented in Appendix A. The unique word length of 24 bits provides a false alarm probability of less than 0.001 for a search of 1000 symbols (this is a conservative assumption since a false alarm should only cause a problem if it occurs during approximately the 100 symbols before the start of the true preamble) and a miss probability of less than 0.001 for a bit error rate of 10^{-5}.

The structure of the preamble, exclusive of the unique word, is recommended to be a 1010... pattern. There are two main advantages to this pattern which are it provides maximum transitions for symbol synchronization and it has no inherent dc component. The format of the unique word is not specified at this time. However, it is desirable for the unique word not to have a dc component.

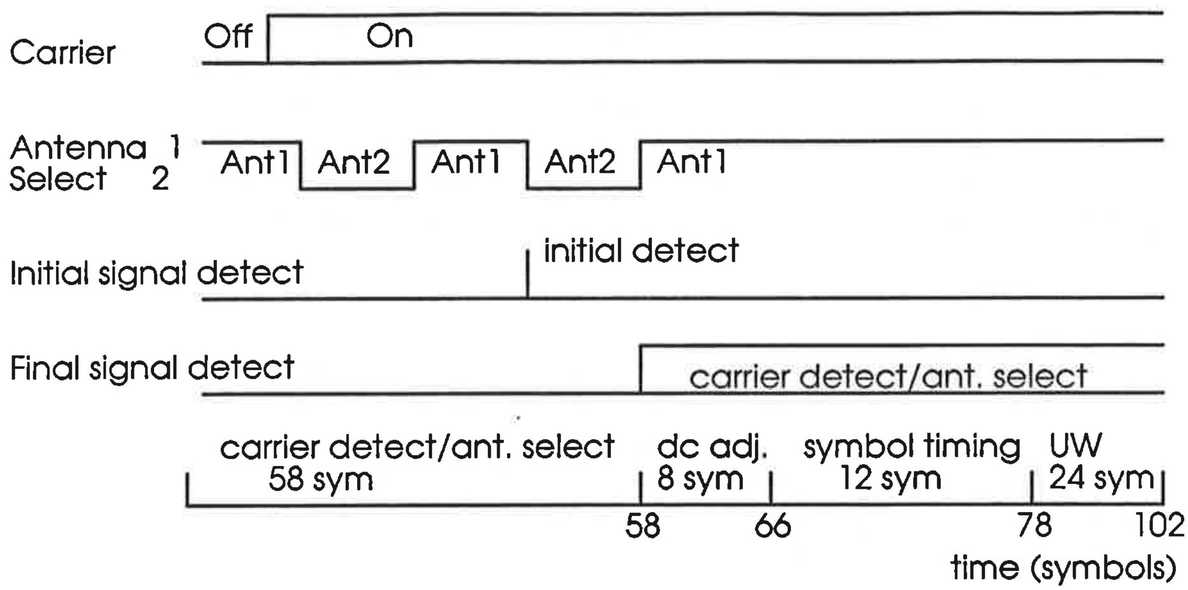


Figure 2 Preamble Timeline

Conclusion

A possible method to perform frequency acquisition and tracking was presented. This served to identify the requirements of the MAC header for frequency hop acquisition and timing. As a minimum the MAC header needs to contain the next frequency. It is desirable to use fixed length hop times otherwise, the time to next hop would also be necessary.

A preamble suitable for a frequency hopped radio has been presented. The preamble length is 102 symbols which includes 24 symbols for unique word detection. This allows for the following receiver functions:

o carrier detection/antenna diversity selection- 58 symbols worst case
o baseband dc offset adjustment- 8 symbols
o symbol timing recovery- 12 symbols
o unique word detection- 24 symbols

The structure of the preamble is 78 symbols of an alternating 1010... pattern followed by 24 bits of unique word. The format of the unique word is not specified at this time.

References

[1] Socci, Jerry, "Preamble Length Considerations for a Frequency Hopped Phy", Doc IEEE P802.11-93/72, May 1993.

Appendix A-Unique Word False Alarm Probability and Miss Probability

Unique Word Detection
Assume the following:
N = length of the unique word
p = bit error probability
E = # of allowed errors in the unique word detection

The probability of missing the unique word, Pmiss, is given by:

$$Pmiss = 1 - \sum_{i=0}^{E} \left(\frac{N!}{i!(N-i)!} \right) p^{i} (1-p)^{N-i}$$

A miss probability less than 0.001 seems reasonable based on an assumed packet error rate of 0.01.

Unique Word False Alarm Probability
The false alarm probability, F, on a per trial basis is given by:

$$F = 2^{-N} \left[\sum_{i=0}^{E} \left(\frac{N!}{i!(N-i)!} \right) \right]$$

If we assume a search over a 1000 symbols then the total false alarm probability = 1000*F. For a total false alarm probability of 0.001 then $F = 10^{-6}$.

Results are tabulated for E=0 and E=1. The length of the unique word needs to be on the order of 20 to 24 bits. E=1 and N=24 gives somewhat better overall performance than E=0 and N=20.

Table A-1 Unique Word Performance for a Bit Error Probability of 10^{-5}

Errors Allowed in Unique Word Detection	E = 0			E = 1	
length of unique word, N	False Alarm Probability, F (per trial)	Probability of a Miss		False Alarm Probability, F (per trial)	Probability of a Miss
16	1.5E-5	1.6E-4		2.6E-4	1.2E-8
18	3.8E-6	1.8E-4		7.3E-5	1.5E-8
20	9.5E-7	2.0E-4		2.0E-5	1.9E-8
22	2.4E-7	2.2E-4		5.4E-6	2.3E-8
24	6.0E-8	2.4E-4		1.5E-6	2.8E-8
26	1.5E-8	2.6E-4		4.0E-7	3.3E-8
28	3.7E-9	2.8E-4		1.1E-7	3.8E-8
30	9.3E-10	3.0E-4		2.9E-8	4.4E-8