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**IEEE P802.11**  
**Wireless LANs**

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**Criteria and method for detection using Antenna Selection**  
**Diversity**

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**Date:** July 5, 1999

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**Abstract**

This document discusses the issues involved in the detection of the short symbol sequence and then provides an algorithm as to how it can be achieved. It shows that if AGC adjustment can be made in one short symbol then it is possible to use antenna diversity selection with two antennas. It also shows through an algorithm that a robust receiver can be built which will ensure that the system is failsafe even if the signal could not be collected in both the antennas.

Whenever a packet is transmitted, the receiver should detect the transmission through the first short symbol and then should acquire AGC and make a diversity selection in the first 8  $\mu$ s or 10 short symbols. The selection of the antenna in part also determines if the packet has been received without any errors. Thus, the antenna selection process determines the packet loss rate, throughput and the total transmission delay.

For simplicity we will assume that there are no collisions. A packet can be lost in several ways. It could be lost through a missed detection, a successful detection in which the packet has errors after error-correction, or the cost associated due to a false alarm. Here, we define a false alarm as the case when the presence of signal is "detected" even though there is no actual signal.

We will defer the first two considerations to a later discussion and now consider the case when there might be false alarms. A false alarm usually sets the decoder into a "busy" mode and start performing several functions. As these functions are being performed, the receiver might determine that there has been a false alarm and switch back to the "standby" mode. If the receiver has received no packet during the period in which the receiver is in the "busy" mode, then there will not be any cost associated due to the false alarm.

However, if a packet has been received during the "busy" mode, the receiver in the false alarm might allow the packet go undetected contributing to the loss of a packet. A false alarm effects a loss of packet if the detector goes into a mode where no further detection is performed or when it assumes that the long symbol will follow exactly after 10 short symbols. However, if we allow continuous monitoring of the channel and if the long symbol transition is detected directly independent of the number of short symbols that are detected, we can avoid any cost associated with the "busy" mode that originates due to a false alarm. If the long symbol transition goes undetected, then this situation becomes just another missed detection. Thus we can conclude that the cost associated with a pure false alarm is zero.

Having concluded that the effect of false alarms can be disregarded, let us consider the probability of a loss of a packet. For now, We assume that there is only one antenna. A packet is considered lost if the detection of the packet is missed or if the packet contains errors. Thus,

$$\Pr [\text{a packet lost}] = P_M + (1 - P_M) \Pr [\text{Frame in Error} | \text{Frame is detected}] \quad (1)$$

where  $P_M$  is the probability of a missed detection. The probability,  $\Pr [\text{Frame in Error} | \text{Frame is detected}]$  which depends on the channel, convolutional coding and the interleaver can be determined based on simulations. Now, we focus on the missed detections. A missed detection is considered to occur when the presence of the signal is either

not detected totally or not detected early enough so that certain key functions could not be performed during the reception of the short symbols or when the transition to the long symbols is not detected.

The functions that need to be performed during the short symbol reception (either directly or on the buffered signal) are AGC, diversity selection if there are multiple number of antennas, coarse frequency offset estimation and timing synchronization. Coarse frequency estimation and timing synchronization can be reasonably performed only with the establishment of the AGC. Thus it is important that the AGC has been established first. The frequency offset estimation and timing synchronization can be performed in at most two short symbol duration. Under the assumption that the AGC settling time is one short symbol, while using one antenna, we need to be able to detect the signal within at least 7 short symbols. Assuming a nominal operating SNR of 8 dB, in AWGN channel, the probability of a missed detection during a short symbol is about  $10^{-4}$ , while in a flat-fading Rayleigh channel, it is about  $10^{-2}$ . Since there are at least 7 short symbols during which the signal needs to be detected, the probability of a missed detection during short symbol is  $10^{-28}$  in the AWGN channel and  $10^{-14}$  in a flat fading channel. Even when the gain adjustment is increased to 3 short symbols, the worst-case scenario of the probability of a missed detection is  $10^{-10}$ . Thus the first term in (1) can be neglected and hence a missed detection is very unlikely to happen in the case of a single antenna and can be disregarded.

For the case of multiple antennas, (1) needs to be modified. For example, for the case of two antennas, the probability of losing a packet is,

$$\begin{aligned} \text{Pr [a packet lost]} = & \text{Pr [Missed detection on both antennas]} \\ & + \text{Pr [Antenna 1 is used for detection]} \text{Pr [Frame in Error | Antenna 1 is used for detection]} \\ & + \text{Pr [Antenna 2 is used for detection]} \text{Pr [Frame in Error | Antenna 2 is used for detection]} \end{aligned} \quad (2)$$

Note that, in the above equation, the last two terms on the right hand side do consider the situation in which the signal is detected by only one antenna. In formulating (2), we have disregarded the effect of false alarms. The first term in (2) is analogous to the first term in (1). As before, a signal is deemed missed if either the signal is not detected or if the signal is detected, but not all functions (such as AGC, coarse frequency synchronization and timing synchronization) are performed. In order to minimize the probability of a miss, the functions that need to be performed during the reception of the short symbols should be done in a timely manner. When the receiver is on a standby mode, the receiver will alternate between the two antennas with signal collection on each antenna lasting for the duration of one short symbol. This also means that the receiver should wait for at most one short symbol before it starts detecting the signal (and get ready to perform the associated functions). When a signal is detected, the receiver needs as before, three to five symbols to establish AGC and synchronization (if need be, with the use of only one antenna). In either case, there are at least five symbols during which the presence of the signal needs to be detected. Thus the probability of a miss by two antennas is same as for one antenna and can be disregarded. Finally, the first multiplicative term in the second additive term in (2) (as well as the first multiplicative term in the third additive term) depends on the signal level on the antenna with respect to the signal level on the other antenna and/or the timeline (which will be explained later). This as well as the second multiplicative terms can be again determined through simulations.

Having established both missed detections and false alarms are unlikely, we now proceed to establish the requirements for the antenna selection diversity with two antennas. As described before, we need two symbols to detect the presence of the signal. In addition, for each antenna, we need two symbols for the signal collection and at least one more for the AGC adjustment. One extra short symbol also needs to be assigned for switching from one antenna to another. Thus at least 8 short symbols are needed for AGC and synchronization. This completes the available ten short symbols. This shows that any timeline that will be used will be very tight for the employment of antenna selection diversity. However, whatever sequence of operations we might employ, the probability of losing a packet due to the missed detection of the signal is very low and can be neglected.

Noting all the comments above, the receiver can minimize the false alarms and missed detections by employing the following sequence of steps:

- 1) Set  $E \leftarrow 0$ ,  $E_{old} \leftarrow 0$ ,  $F \leftarrow 0$ .  $E$  and  $E_{old}$  are used for measuring the energy while  $F$  is a flag that will be used further.
- 2) Start monitoring the channel by switching on to Antenna A.
- 3) Integrate for the duration of one short symbol (perhaps through an envelope detection or a correlator) and save the result in  $E$ .
- 4) Compare  $E$  with a threshold  $T_1$ . If  $E < T_1$ , go to step 12.

- 5) Perform AGC. Collect the signal through a correlator and save the result in E. Perform coarse frequency estimation and timing synchronization.
- 6) Compare with another threshold  $T_2$ . If  $E < T_2$ , go to step 12.
- 7) Store the parameters determined in step 5.
- 8) Check F. If F is 0, go to step 14.
- 9) Compare E and  $E_{old}$ . If  $E < E_{old}$ , go to step 10.
- 10) Use the current antenna and get ready for detecting the long symbol.
- 11) Switch the antenna and go to step 10.
- 12) Check F. If F is 1, go to step 11.
- 13) Set  $E \leftarrow 0$ . Switch Antenna and go to step 3.
- 14) Set  $F_{old} \leftarrow 1$ ,  $E_{old} \leftarrow E$ . Switch Antenna and go to step 3.

$T_1$  and  $T_2$  are two thresholds that can be determined through experimentation. It can be seen that the above algorithm will reduce both false alarm and missed detections by a great deal. Also, it can be easily seen that the above algorithm is highly fault-tolerant and will ensure that the packet is not dropped even if it is detected by one antenna.

Fig. 1 shows the algorithm in the form of a flow chart.

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