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Wireless Access Method and Physical Layer Specification

Packet Length Issues Based on RF Media Considerations

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Abstract

The issue of selection of PDU length is critical to the finalization of the 802.11 standard. It is generally agreed that characteristics of the 2.4 GHz channel place unique constraints on the problem of reliable data transfer. In the absence of an agreed-upon channel model for the RF medium, the committee must rely extensively on the diverse experiences of various members to formulate a recommendation. The inputs on selected topics provided here are the result of Norand's experiences developing wireless products, and some recent experimentation with 2.4 GHz propagation.

Introduction

The PHY group has been instructed to develop and deliver a recommendation for maximum PDU length within the 2.4 GHz RF channel. There are a number factors that must be considered in making this decision -- requirements of the PAR, structure of the MAC, and expected characteristics of the channel. This paper provides input on selected topics in these three categories.

Bursty vs. AWGN Limited Channels

Recent contributions, as well as earlier papers, have addressed some of the issues of PDU length selection. In discussions within the full working group channel characteristics have been commonly simplified to discussions of channel bit error rate. While this is a useful treatment in an AWGN limited case, it is an inadequate view of real indoor radio channels. A more appropriate model, particularly at signal levels in the interesting region within 30 dB of receiver sensitivity, is to treat the channel as bursty. In this view periods of generally acceptable channel BER are interspersed with "events" during which BER may be (on a probabilistic basis) unacceptable. If events are predictable, maximum PDU lengths can be determined, based on the length of intervals between events.

Microwave Oven Interference

Microwave ovens have previously been discussed as a burst interference source with periodicity of 8 milliseconds, with the implication that PDU length should be short enough to fit in the gaps. They have also been characterized as being partial band jammers [2]. Figures 1 through 4 in the companion document 802.11-94/94a show received energy in selected portions of the band for a commercial oven.

These measurements were obtained by using an HP8561B spectrum analyzer as a tuned receiver (zero span) with 2 MHz RBW, and 1 MHz VBW. Because of limitations with digital storage capabilities of the spectrum analyzer at the sweep rate of interest, the XY display output from the analyzer was captured using a slaved digital oscilloscope. Results were captured at 10 MHz frequency increments, over the range of 2350 to 2550 MHz. A calibrated circular patch antenna at three meters was used for this testing, with the setup calibrated by generator substitution with a second, log periodic antenna. The results indicate substantial wide band emissions from the oven during magnetron turn-on and turn-off, indicating that extreme caution is necessary in applying a partial band jammer model to the microwave oven. The composite energy vs. time plot in figure 5 of 94/94a provides a single graphical representation of this result.

Effects of Mobility

Support of mobile devices is a requirement of the 802.11 PAR. A standard view of the indoor channel is that of a three-dimensional standing wave pattern with features varying at increments of $\lambda/4$ or greater. A mobile device moving through this environment samples the standing wave pattern at a rate determined by its velocity. There are differing views on the degree of change that can be expected over a quarter wavelength distance. A stationary device within the standing wave pattern is subject to much slower variations that are primarily attributed to movement reflectors and absorbers in the RF environment.

Using $\lambda/4$ as a maximum distance to be traversed during the course of packet, maximum packet duration can be predicted as function of station velocity.

Velocity			
mph	**m/s**	**Time d = $\lambda/4$**	**Example**
20	8.94	3.3 ms	
10	4.47	6.7 ms	Industrial Vehicle
5	2.23	13.4 ms	Fast Walk
3	1.34	22 ms	Rumba
1	.44	67 ms	Waltz

In the US, 10 mph is an effective limit, based upon OSHA safety restrictions.

Some Measured Results

Recent work in the area of antenna diversity has led to experimentation with diversity selection algorithms [4]. While the results of this testing have not been fully reduced and analyzed, a byproduct of that work is interesting anecdotal experience with the 2.4 GHz channel.

Test Set Up

A single channel 2.4 GHz GMSK system at 250 KBPS was used for this testing. A test bed consisting of two breadboard transceivers, each with dual-antenna diversity were employed, one in a stationary location, one as a battery powered mobile unit on a push cart. A simple "ping pong" protocol with the mobile unit initiating either 3 ms or 8 ms packets, and the stationary unit echoing any packets successfully received. Packets successful received by the mobile station were logged, and tagged according to the antenna selected for reception.

Stationary Testing

After testing an obstructed path, in a fringe area with high pedestrian traffic, it was noted that there was frequent antenna switching even with the mobile unit in a stationary position. The unit was positioned to provide an average signal strength of 10 dB above sensitivity. The system was re configured to use a variant of the best antenna algorithm of Doc. 94/93, using only an RSSI based selection criterion with 6 dB hysteresis. Three millisecond packets were used. Under these conditions the average period on a given antenna was three to four packet exchanges, or 18 - 24 ms, and about one in six packets were dropped.

Mobile Testing

Mobile testing was conducted using both 3 ms and 8 ms packets, with and without diversity. Testing was conducted along an obstructed office hallway from a point with average signal levels approximately 20 dB above sensitivity, to the point at which reliable reception was no longer possible (round-trip packet success rate < 1/20). The cart was pushed at a normal walking rate, with antennas mounted on PVC pipe at a height of 60 inches. Baseline (non-diversity) results were as follows.

a) For 8 ms packets, the round-trip packet success rate while in motion, was about 35% in the strong signal region, falling off to near zero, well before the point at which stationary communications were no longer possible. However, the one way (mobile to stationary) success rate was close to 85% in the strong signal area, degrading to 25% near the coverage limit.

b) For 3 ms packets, the one way and round-trip packet success rates were about 90 % and 75% respectfully in the strong signal areas, degrading to 35% and 30% as the fringe was reached.

This was not a controlled test of successful delivery vs. packet length, but a test intended to allow comparison of diversity vs. non-diversity implementations. Other factors may have contributed to the poor results for longer packets. However, there is a strong case for considering motion to be a large contributor.

Transmission Intervals

This paper has discussed two types of periodic events that are factors in the PDU length decision. Microwave oven interference sets a window of 8 ms. This window represents an absolute interference source that pulses asynchronously with respect to PDU generation. Because of its asynchronous nature, PDU's of lengths near the quiet time between pulses will tend to experience interference in "aloha" fashion--i.e., high probability of collision. Clearly the microwave problem dictates PDUs substantially shorter than 8ms.

The station mobility aspect sets a calculated window of 6.7 ms assuming a maximum station velocity of 10 mph. Unlike the microwave case, this window begins synchronously with the start of transmission.

Consideration of MAC Handshaking

The Foundation MAC includes a variety of data exchange structures. In recommending PDU length to the full working group, consideration of these structures is appropriate. In selecting a PDU length, it is desirable to consider a length definition that contemplates channel access and acknowledgment. The two methods within the MAC for delivery of Unicast data are Data/ACK and RTS/CTS/Data/ACK.

The FH PHY currently adds 112 symbols of overhead to each transmission for ramp-up, preamble, start of frame, and ramp down. Assuming an approximate payload of 12 octets at 1 MBPS for RTS, CTS, and ACK frames, implies a duration of about 220 μs for each. For RTS/CTS/data ACK the PHY overhead contributes about 730 μs of overhead, effectively reducing the ability to transfer MAC payload during an available transmission interval. For example, for the microwave oven interference case, a full RTS/CTS/data ACK sequence must be completed during the time the magnetron is off. The data/ACK structure carries about 330 μs of overhead. The addition of the overhead for RTS/CTS may have potential benefit in the MAC for reduction in collisions, as well as a less publicized, (and perhaps more controversial) potential benefit as a channel sounding mechanism during operation in fringe areas.

Recommendations

On the basis of mobility and microwave oven interference considerations, a maximum PDU size of 3 ms is recommended. With maximum overhead considered, this provides a transmission duration of 50% of the microwave oven window.

Ongoing Work

Norand is involved in more extensive channel modelling activities in conjunction with our diversity work. Additionally, efforts are underway to analyze the effects of mobility using the

NTIA office data [5] as an independently derived channel model data base. The later, will hopefully be the subject of a future contribution.

References

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