IEEE 802.11
802 LAN Access Method for Wireless Physical Medium

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AUTHOR: Chandos A. Rypinski,
Chief Technical Officer
LACE, Inc.
655 Redwood Highway #340
Mill Valley, CA 94954 USA
Tel: +01 415 389 6659
Fax: +01 415 389 6746
E-m: rypinski@netcom.com

TITLE: RECOMMENDATION: The 2.4 GHz PHY Can't Be Frequency Hopping But Can Be Direct Sequence

SUMMARY

The main reasons why the FH PHY should not be an 802.11 recognized PHY are:

- ✖ The 1/1.4 Mbps gross transfer rate is inadequate for competent 802 LAN services requiring a low error-rate PHY. The shortfall is further increased by losses from excess deferral, unavoided contention and interference from lack of an area coverage plan.
- ✖ The FH PHY is inherently a narrow band modulation, which in a Rayleigh fading environment, will have a bit error rate floor that makes mandatory strong forward error correction using about 50% of the available capacity.
- ✖ There is no possible satisfactory PHY level channel assessment (CA) function. Only energy detection with time weighting is potentially fast enough. "Busy lock-out" or pure Aloha operation from high detection threshholds are the predictable consequences.
- ✖ The advantage of a second try on a new frequency after a failure on a first try is small or nonexistent because of the inherent large time delay before the second try can be made and completed.
- ✖ The channelization feature of the FH PHY is required for parallel capacity increase and for isolation of contiguous coverages. However, simultaneously used channels at different frequencies in the same band will be **mixed in each transmitter power amplifier** creating spurious signals at multiples of the difference frequencies removed from the transmitter carrier frequency (for transmitters without a unilateralization device in the antenna port). With numbers of simultaneously used transmitters in a small area, many false indications of activity will result from these intermodulation products.

(continued)

- ✖ The frequencing hopping PHY layer now defined cannot effectively be integrated with a MAC layer, and even assuming that it could be, will not render a functionally responsive integration of packet and connection-type services or a commercially adequate packet service alone.
- ✖ Radio cost, battery drain and size are less for a single channel PHY.
- ✖ Only a single channel PHY will enable extension of the traditional 802 philosophy of maximizing peak transfer rate within the available radio spectrum.

A motion to eliminate this PHY from further consideration will be introduced by this Committee Member at the current 802.11 meeting.

The arguments relevant to this question are given in brief form in the body of this contribution.

RECOMMENDATION:

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Table of Contents

Page

Recommendation:

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ARGUMENTS

Given:

The FH and the DS PHY are both defined acceptable by the FCC in §15.247 for use in the 2.4 GHz ISM band. The present DS PHY will provide a 1 or 1.4 Mbps transfer rate from an occupied bandwidth of 75-80 MHz one MHZ at a time, and the proposed DS PHY will use a 22 Mcps chipping rate for a 2 Mbps transfer rate. It is assumed that the DS PHY can be scaled to higher rates and occupied bandwidth if useful or necessary.

The offered arguments are sorted into groups: 1) 802.11 plenary issues, 2) joint MAC-PHY issues, and 3) pure PHY issues.

802 PLENARY ISSUES

PRO FH

1. The achievable transfer rate of 1 or 1.4 Mbps is sufficient for useful LAN and voice services.

Rebuttal PRO FH

1r. The minimum transfer rate for a duplex single station with integrated services was argued in 802.9 during its first year. Major Companies thought duplex 2.048 and 2.56 Mbps were sufficient. After two years of discussion and the formation of a high-rate PHY subgroup, the rates chosen were 4.096 and 20.540 Mbps. *Rates of 1 or 1.4 Mbps are simply unserviceable for mixed LAN and connection type services.*

LAN at 1 Mbps was recognized in 802.3 as 1Base5 (AT&T "StarLAN), and it has disappeared as a product. Similarly, PCNet at 2.0 Mbps (IBM and Sytek) was offered without much acceptance a few years ago when the threshhold of usefulness was much lower than now.

This transfer rate is too low for reasonable support of the true connection-type services associated with multi-media and telecom extended applications.

<u>Conclusion:</u> A 1 or 1.4 Mbps medium transfer rate is non-responsive to IEEE 802.11 Functional Requirements for integrated services, and is commercially inadequate for LAN only products. This conclusion is true for an error free medium before considering the uncertainties of radio and the FH NB modulation which greatly increase transfer rate requirements for a given throughput.

CON FH

2. The FH PHY is counter to traditional LAN values which emphasize a single high-rate medium with low-average/high-peak traffic capability. FH inherently divides an 80 MHz bandwidth into a number of parallel 1 MHz (low rate) channels used

simultaneously. The peak capacity of each channel is far below the potential of the 80 MHz bandwidth the system will occupy.

3. The FH PHY is counter to closed issues and 802.11 Functional Requirements

a) The channelization in this PHY is inadequate for providing all supported services over 100% of a coverage area.

b) The channelization function in this PHY is unique allowable only in the two higher USA ISM bands. It cannot be used in any of the narrower, new 1.9 GHz frequency bands. This PHY will preclude a common MAC for other available radio frequencies.

PRO DS PHY

4. The single channel PHY in general, and the DS PHY in particular are consistent with traditional 802 values which emphasize maximization of peak transfer rate and minimization of access delay and occupancy time. Each user has access to the transfer rate of the entire bandwidth allocation rather than a fraction of it.

5. Radio cost, battery drain and size are less for a single channel PHY.

JOINT 802.11 MAC/PHY ISSUES

PRO FH

5. The interference resistance properties of this PHY are superior because if there is interference on one particular frequency, the message may be successfully transferred on another.

6. By using various random patterns for the hopping sequence, different hopping sequences may be used by different groups with only occasional collisions. The different sequences can be considered as virtual channels usable for continuous area coverage.

Rebuttal PRO FH

5r. Given, that if the use of a first used frequency is unsuccessful, the second used frequency is then successful; the nominal time delay between opportunities will be one hop duration plus one channel switching time. With presently chosen parameters, this interval is at least a "superframe" duration of 25 milliseconds and may be a hundred milliseconds or more. *Recovery from the second transmission, if it is successful, is outside of the target transfer delay limits.*

The probability that the next selected channel is free of interference depends on the sum of the number of other hopping patterns that coexist in the coverage plus the degree of unrelated narrowband use of the band. There will be frequent cases of potential collision on retry, which must then be resolved by the MAC function.

If it is assumed that the active patterns are actually in use a small fraction of the time, it is possible to argue that pattern contention is improbable. However, this possibility should be evaluated with the system operated near its maximum rated capacity. Otherwise breakdown may occur only at times of peak traffic.

With current proposals for hopping patterns, and without coordination of different hopping patterns, the probability of channel contention is quite high with all channels in use.

This is without considering what may be happening from further unrelated interferers. Using conventional narrow band modulations, the signal-to-interference ratio necessary for capture by the stronger signal considering fading will be in the range of 12-18 dB. This large required margin reduces the probability that the stronger signal will be successful when there is a collision.

Conclusion: *The recovery mechanism of using retransmission after one or more frequency hops adds unacceptable time delay, and even then is decreasingly useful as channel use increases. This form of error recovery is unique to this PHY.*

6r. The assumption might be that the channelization capability with FH can be used as a method of frequency reuse. The existence of a channelized medium is not a frequency reuse plan. Unorganized use of multiple channels does not assure that all of any given building area has coverage and access. (This reason alone makes the FH PHY and DFWMAC non-responsive to 802.11 Functional Requirements).

Overlapping coverage can be resolved by capacity sharing, whether organized or random. Unorganized systems can always operate if unbounded transfer delays and reduced medium utilization are accepted. If a worst case access delay is a design parameter, there is considerable art in maximizing capacity for channelized systems.

In cellular terms, the reuse factor is likely to require 36 to 200 channels to cover an areas without a gap. An organized plan greatly reduces this number. If unorganized FH can produce 25 virtual channels, the performance would be quite poor with all of them running in a common area like one floor of a large building.

CON FH

7. Adding the CA function (Carrier-presence Assessment) to either the PHY or the associated MAC will not result in an adequate solution.

The first error is that channel energy observed at a station receiver is an unreliable indicator of receiving conditions at a destination station. The advantage of energy detection is that it is quick to reach a conclusion. Adding refinements, such as adaptive reference level, requires time-weighted judgements and/or dependence on message content.

Some proposals require the MAC to consider the content of received messages to classify the source or received signals and appraise the future time use of the channel. This is an intractable problem, which will cause the MAC to be unique to this PHY. *If the station MAC is required to use message content as a modification of the channel idle function for CSMA, the time delay introduced will be unacceptable. If this function is unique to FH, the choice of the PHY will cause the MAC to be non-responsive to an 802.11 Functional Requirement that the MAC be usable with multiple PHYs.*

8. Since single channel PHYs are inevitable, the MAC will really be two or more MACs to cover both FH and single channel. This partitioning is in addition to the MAC

partitioning to handle contention and reservation services. The difficulty in obtaining a fault-free protocol could be seriously underestimated.

9. Adding the channel pattern selection to a MAC, will associate the MAC with a particular method of frequency reuse management not particularly understood or planned in the DFWMAC. Properly, the MAC should not know anything about channel pattern selection except distinguishing that a particular received sequence is/is_not part of the defined group. Placing channel selection in the PHY, means that coordination with other channel patterns to provide a DAMA function is impossible.

PRO DS

10. DS is a single-channel PHY. All such PHYs are interchangeable with a common MAC. The need for channel pattern and selection in the MAC is avoided.

11. If used, the energy form of the CA function with DS is less vulnerable to false indications than with FH since it may detect energy in both the radio and information bandwidth and since the signal-to-interference ratio required is lower..

12. The DS PHY can be multiplied to higher transfer rates by simple scaling until the available bandwidth is used and further by increased symbol coding. The present and potential peak transfer rate is octaves above that of the FH PHY.

802.11 PHY GROUP ISSUES

PRO FH

13. The alternative DS PHY has been tried and found unsatisfactory by some suppliers, though it is one of the two currently accepted candidate PHYs for 802.11.

14. The necessary components for frequency synthesis, narrow band modulation, amplification and demodulation already exist using well known and "safe" technology.

Rebuttal PRO FH

13r. The unacceptable DS PHYs have generally used methods where the receiver output is logic level at the chip rate, and with correlators implemented as binary logic. Then *the threshhold noise bandwidth and interference susceptibility is the bandwidth of the chipping rate.* The processing gain is not obtained against interference strong enough to degrade the radio chip rate output.

These disadvantages are not present if the correlator is linear and analog operated at a level of 30-50 db above that received from the antenna and 60 dB below logic level. For this definition, the noise bandwidth of the information is obtained at correlation, and it is maintained for interference stronger than the signal which does not drive the correlator out of its linear range.

With linear correlation at minimal level above the noise threshold, the noise bandwidth of the receiver system will be that of the transferred information. This ratio is true for comparisons when equal channel modulations are used for narrowband and for chipping.

14r. Experience suggests that a new volume market will develop its own components using knowledge, but not the pieces, of the prior art. The constraints of prior art built into Standards may prevent economical solutions. The importance of existing parts is great for those who want to go to market immediately, but building a Standard around these parts can be very unfortunate for the functional value of the resulting equipment.

CON FH

15. The narrowband modulations proposed for FH will have an excessive error rate from time dispersion at signal levels far above threshhold.[1] Generally, forward error correcting codes and a higher order of receiver space diversity is required to obtain satisfactory error rates.

A narrowband modulation, particularly one using quadrature phase, will require considerable overhead in channel coding,[2] protocol, buffering of delayed transmissions and analog radio cost relative to DS with appropriate properties yielding greater fade resistance.

The same narrowband modulation is equally well applied to the chipping rate of the DS system for the same incentives. The use of DS will enable greatly reduced preamble length by deleting pattern discovery considerations and by *enabling much faster bit and frame delimiting acquisition.*

16. Intermodulation in simultaneously used transmitters is a major cause of spurous signals when many transmitters are densely packed. The potential for crowding of different hopping patterns in a common coverage area is overestimated, particularly when the CA function uses energy detection. Each active transmitter connected to an antenna generates spurious signals at multiples of the differences between the transmitter carrier and received signals. Unless a circulator is interposed between the antenna and a class C power amplifier, that amplifier acts like a low-loss mixer using the transmitted signal as a local oscillator for combining with strong received signals. The remodulated and reradiated signals will further confuse both energy and content decoding CA functions.

17. The time lost to overhead for pattern and bit clock acquisition in adverse context and for delay in channel changing is a significant degradation of the channel potential.

PRO DS

18. Direct sequence spreading is a single channel PHY. The spreading reduces the effects of fading including the ratio of desired/undesired signal level for correct demodulation of cochannel signals. With linear decorrelation at the receiver, the noise bandwidth will closer to that of the information than with the simpler narrowband radios.

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1 "Table 3. Bit Error Probabilities for Binary Orthogonal Signaling, Slow Non-selective fading, and Noncoherent Demodulator," Reference Data for Radio Engineers Seventh Edition, H. W. Sams Co., pg 24-23 (shows BER for Rayleigh, Rician and nonfaded channels for 4-20 $(E_b/N_o)_{dB}$)

2 "Wireless Access Methods and Physical Layer Specifications," E. Geiger, Apple Computer Inc., IEEE P802.11-93/104

Provided that an interfering signal is not strong enough to exceed the linear range of the correlator and its energy content is less than 3 dB above the desired signal, it is unlikely to cause material impairment. Certain clever circuits may increase this discrimination for signals of unlike spectrum.

19. Bit clock acquisition with DS may be accurately performed in a few bits rather than a much longer part of the 100 bits provided for the preamble in FH.

20. Radio cost is probably lower than for FH PHY. Much of radio cost is due to precision of filters and frequency control elements, a function of fractional bandwidth. A radio with a channel bandwidth of 25 MHz may be 25 times less precise than one with a bandwidth of 1 MHz. The high bandwidth radio will have 14 dB less overall gain which shows in diminished shielding and bypassing function.

21. A radio that must operate at the same time in the same space as many other like type radios must have much more dynamic range and higher overload points than the alternative single channel radio. The radios in one space operate sequentially at a much higher rate and lower channel time occupancy. For a single channel radio, the overload considerations are based not on other users within the same group but on more distant unrelated users.

22. Channelized systems cannot go both ways. The capacity advantage shown in previous comparisons results from using most of the channels at the same time. If it is argued that the simultaneous use is improbable, or if it is technically unfeasible, *the paper capacity advantage of FH shrinks to a disadvantage.*

RECOMMENDATION

- A radio without channelization is the simpler, more economical and the highest capacity and functionality. With a single channel radio, the time sharing can be better managed whether done with logic or with analog energy measurements.
- The FH PHY requires a MAC that is specific to this PHY and much more complex than necessary, and which would not be used in any other circumstance.
- The PHY must be single channel to have any generality, and it should be designed for the highest possible transfer rate. A minimum being a scaling of the present proposed DS PHY to 4 Mbps.

Passage of a motion terminating further effort of the FH PHY and expanding effort on the DS PHY in the context of the 2.4 GHz band would bring 802.11 closer to something which will meet the needs of both users and most suppliers.

Chandos A. Rypinski, voting member