IEEE 802.11
802 LAN Access Method for Wireless Physical Medium

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TITLE: **NECESSARY PHY LAYER ALTERNATIVES FOR ET BAND AND FOR "HIPERLAN"**

SUMMARY AND CONCLUSIONS

The present PHYs under development by the PHY group address the needs of and optimizes for spontaneous, autonomous groups. The result is unlikely to be useful for any public network compatible connection type service or for LAN comparable interactive communication.

It is necessary and desirable to have parallel effort on two additional sets of premises:

ETSI HIPERLAN and 5.85 GHz ISM bands

Premise: To provide high transfer rate and capacity/hectare services supporting bandwidth-on-demand connection-type and connectionless services consistent with business in-building needs.

ET band 1.85-1.99 GHz

Premise: 1910-1990 and 1850-1910+1930-1990 all with fully utilized 5/10/20 MHz bandwidth, and an attempt at common air-interface for licensed and unlicensed services consistent with voice and data service in-building or in semi-public or public places.

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PURPOSE

There is no US standards entity working on a radio air-interface for high megabit transfer rates, though that is clearly a mission for IEEE 802.11. In particular, this service should be defined as a transport of ATM cells to the user to attain technical flexibility to deal with either packet data or bandwidth-on-demand connection type services with equal efficiency. Because underlying inter-building and inter-city segments of a portion of this communication is essential, there is a public network compatibility consideration also present.

The need for nomadic function is particularly strongly advocated in 802.11. It is *not true* that this function for ad hoc autonomous groups precludes infrastructure based solutions for high capacity and function or makes unnecessary links to outside networks. Nomadic operation, apart from ad hoc groups, will require access to service provider facilities.

There is motivation for maximizing commonalities between LAN and licensed services:

a) to enable the user of a portable computer with wireless attachment to operate both on and off of his home premises within coverage of public or private infrastructure.

b) to enable a Company or a service provider to use a single infrastructure for both LAN data and connection-type service.

c) to absorb the cordless PBX function into a technology enabling a common instrument for local and public access for both telephone and portable computer stations.

It may be recognized that the need of the lower frequency services is qualitatively the same but with lower capacity and a much smaller range of services. Nonetheless, it would be economically desirable to have protocol commonality for high and lower capacity services in different bands.

In terms of frequencies, Table I (following page) lists obvious possibilities for wireless LAN systems including those which might be dually used for public telephone service. The use of all of these bands should be considered.

Considering the needs for portable computer access to LAN communication, the question now addressed is whether within these bands a useful level of commonality can be found so that many portable computers can be used in both resident (place of business) and external premises (including hotels, convention centers airports) and in some intensively used outdoor environments. It is probable that the breadth of services in licensed or service provider bands may be much less than in an exclusively premises area band, but it should be far more than what is possible with analog modems over voice channels.

Two further types of PHYs are required:

ETSI HIPERLAN and 5.85 GHz ISM bands

Premise: To provide high transfer rate and capacity/hectare services supporting bandwidth-on-demand connection-type and connectionless services consistent with business in-building needs.

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TABLE I -- POSSIBLE LAN FREQUENCY BANDS

Frequency band -- GHz	Modulation Type/Rate	Station Xfr rate	Reach/path/ directivity	Infrastructure Access-points	Capacity/ hectare	Note reference
1.85/1.93 LIC dplx BW = 10/10 MHz	8 x 0.5 Mbps after anti-fade	16 x 32 kbps	20 meters low obstruct corner ant	infrastructure repeater access-point	25 Mbps/ha	1.
1.92 UL ET BW = 10 MHz	8 Mbps after anti-fade	8 x 1 Mbps	20 meters low obstruct corner ant	infrastructure repeater access-point	50 Mbps/ha	2.
2.4 ISM BW = 83 MHz	1 Mbps FHSS -- 25 patterns	0.93 Mbps	20 meters low obstruct omni ant	spontaneous autonomous systems	12 Mbps/ha	3.
2.4 ISM BW = 83 MHz	3 x 2 Mbps DSSS -- 1 code	2.0 Mbps	20 meters low obstruct omni ant	spontaneous autonomous systems	8.4 Mbps/ha	4.
5.25 ETSI BW = 150 MHz	16 Mbps DSSS-7 c/s 4 codes	16 Mbps	20 meters low obstruct corner ant	infrastructure repeater access-point	250 Mbps/ha	5.
5.85 ISM BW = 133 MHz	16 Mbps DSSS-7 c/s 4 codes	16 Mbps	20 meters low obstruct corner ant	infrastructure repeater access-point	250 Mbps/ha	6.

Notes

1. Prospective unlicensed emerging technology band split into two 10 MHz segments for narrow band and packet data services respectively.
2. Prospective licensed band probably to be segmented in 2 x 10 MHz duplex allocation following the practice for licensed incumbents. Likely technology is frequency division for reuse and time division for site channelization. Spread spectrum alternatives are sure to emerge. Capacity based on wideband techniques modified for narrowband. Summary technical descriptions of short-reach telephone systems may be found in TR45.4/92.06.23.22.[1]
3. 802.11 proposed frequency hopping PHY[2].
4. 802.11 proposed LBT DS SS PHY[2].
5. Frequency band proposed by ETSI RES10[3] "Hiperlan" now allocated for aeronautical microwave landing systems. Technology shown is an example only.
6. 5.85 GHz ISM band using example technology proposed to 802.11.

G. All estimates normalize technology to available frequency space. The capacity estimates for 1, 2 are not based on assumptions consistent with the others with respect to overhead needed for error avoidance.

DESCRIPTION OF PROPOSED NEW PHY LAYERS

Two new PHYs are described below which should be concurrently introduced with the 2.4 GHz PHY which might be selected. It is apparent that the resulting three PHYs all start from substantially different initial assumptions. None will meet the primary need that is defined for the others. While advocates of any one of these might prefer that PHY to be the first and only one approved by 802, that is an unrealistic hope. This is particularly the case for three definitions on the market need.

Only one of these proposals has any serious hope of being practically compatible for both service provider and private systems within one small equipment.

Accordingly, 802.11 is requested to consider expanding the PHY group mission to include the two further types described following.

Proposed PHY Description -- ETSI "HIPERLAN" and 5.85 GHz ISM bands

For context 5. and 6. from Table I, it is now proposed that a PHY be defined for high Mbps/hectare LAN service including bandwidth-on-demand connection type service. This PHY could be *that necessary for full service ATM cell relay to/from the user.*

This PHY can be capable of autonomous peer-to-peer services. Because of the high transfer rate, the channel occupancy will be a fraction of that of other plans emphasizing this service. Operating in a pure "Aloha" mode with limited length segments, this factor alone would lead to the simplest and highest capacity result for that service definition. Because of the higher frequency, propagation would be more contained by wall type obstacles, but shadow filling might be better because increased reflection and smaller usable aperture dimensions for windows. But this is not the primary intent.

> The primary intent is to use the infrastructure and existing wiring to minimize radio cost and function with short distance transmission paths, and thereby provide very high capacity and transfer rate. The question is not whether to use infrastructure, but how to provide infrastructure at minimum cost and maximal functional advantage.

This must be optimized for large numbers of users operating over a wide area. The transfer rates must support all commonly used communication services now and in the predictable near future. This particularly applies to wideband connections necessary for video services that will be used in the "multi-media" applications.

Proposed PHY Description -- ET band

For context 1. and 2. from Table I, it is now proposed that a PHY be defined that operates in a 10 MHz bandwidth and which is scalable to half and double bandwidths. The protocol should support both the simplex and duplex or two-frequency operating modes. At least two different optimizations are necessary for voice and packet services.

This is written before the anticipated September 23 (1993) decisions of the FCC (90-314). Assuming adoption of 1910-20 and 1920-30 MHz bands operating within the constraints of the WINForum Etiquette (just filed in the last revision with the FCC), two modes would be necessary for narrow band voice and for packet data. It is further likely that public systems in the 1850-1910 and 1930-1990 MHz bands will use a 5 or 10 MHz bandwidth with a duplex separation of 80 MHz for compatibility that would ease transition into incumbent microwave licensee space. It is quite possible that a radio with 10 MHz separated frequency steps could operate in any of these bands, provided that they all used an identical, similar digital modulation.

It is now proposed that definition of a wireless LAN making maximum use of 10 MHz bandwidth simplex or duplex is useful and a major step toward commonality between private and provider systems with both packet data and voice services.

Since a technical solution to fading for an unspread narrowband channel seems inevitably necessary, these frequencies provide the incentives for finding it. Existing contributions[4] suggest that a signaling rate of at least 12 Mbps may be obtained in the 10 MHz channel. Sufficient improvement on the basic channel might be developed by some combination of the following techniques:

a) Multiple narrowly directive antennas at the access-point with combining type diversity (not selection).

b) Embedded strong forward error correction channel coding combined with short segments implementing cell relay.

c) Redundant coverage of station transmitters, and repeated or sequential transmissions to stations from different sources.

d) Smart and timely retransmission of failed segment transfers.

Comparison of Capacity and Premises for Three PHYs

An approximate comparison of system capacity for the proposed PHYs and a few others is shown in the Table below. The capacities presented are very rough approximations for the voice-based systems since they are normalized for a 10 MHz frequency space. They do not include anti-fade measures beyond those in the prototype system.

The effect of the cell size on this measure of capacity is much more significant than fine points of transmission technology. Inherently, all large area cover telephone systems show up poorly.

Table II -- Capacity/hectare for Various PHYs

System type	Capacity--Mbps/hectare
ETSI HIPERLAN:	500-1000
5.8 GHz ISM band (93-6):	2 x 125-250
5.8 GHz ISM band (91-7[6]):	2 x 4
2.4 GHz FH (40 m reach):	0.1-3
2.4 GHz DS (40 m reach):	0.5-2
1.91-.92 DQPSK NB+diversity (20 m reach):	1-3
1.92-93 GSM[1] variant (70 m reach):	.0022-.009
Qualcomm CDMA SS[1] (.5 mi reach):	<.01

Note: The methodology used for the capacity estimate was given in IEEE 802.11-93/101.

802.11 Proposed Frequency Hopping PHY

The proposed FH SS PHY[2] now before 802.11 will not come within an order of magnitude of the necessary capacity and transfer rate. This due to some combination of causes including the following:

a) Excessive emphasis on ad hoc autonomous mode losing the radio propagation advantages in reach and reduction in multipath available from use of a shared privileged antenna.

b) Use of frequency hopping preserving the disadvantages of narrow band systems with respect to Rayleigh fading.

c) Use of frequency hopping which does not provide in the limit as much capacity as if the available channels were used parallel without hopping.

c) Use of a frequency band where interference is a certainty in urban areas making a significant performance loss inevitable. The modulation is optimized against unrelated interferers where high capacity systems must be optimized for resistance to interference from other stations in the same system.

d) The presumption that overpowering transmitters will assure adequate performance on obstructed radio paths thereby assuring large interference range and low reuse factor.

An example of the effort required to make digital communication work in the 2.4 GHz band in a recent, excellent and credible contribution[5] by E. Geiger of Apple. The technique combines the use of frequency hopping in a way that minimizes the effect of many spectrally narrow interferers, segmented transmissions and XY forward error correction of segments to greatly reduce the incidence of unusable transfers. The need for this type of function in narrowband systems has been overlooked in all other 2.4 GHz PHY proposals.

This work is a warning that a simple narrow band channel cannot produce reliable communication without the artful use of a considerable fraction of the transfer capacity for redundancy and error correction.

802.11 Proposed LBT Direct Sequence Spread Spectrum

The proposed DS SS[2] plan is reasonable, but divides the capacity and spectrum used into three parts to support parallel independent systems. The peak transfer rate is then limited to one-third of what it might be with time rather than frequency division sharing.

The presumption of a listen-before-talk access control makes inevitable a poorer use of channel time than is possible with a central manager. The reuse factor for the assumed autonomous groups requires a much high reuse factor (16-25) than would be needed with privileged antennas at access points and an organized infrastructure.

802.11 Proposed Time and Code Division Spread Spectrum

The code division SS plan of Dr. J. Y. C. Cheah[6] has been offered but is not currently advocated. He proposes that with a 31 chip symbol, there are at least 12 codes available that are sufficiently orthogonal to enable overlapping coverage to be resolved by code discrimination. In the 2.4 GHz band, this modulation would allow at least a 2 Mbps rate (without use of quadrature phase) and possibly double that. There would be far less loss from self interference with code discrimination than with protocol recovery from detected collisions used in the LBT uncoded DS SS.

This plan was originally intended for 2.4 GHz, but in this discussion has been normalized to the bandwidth and other assumptions for use of the 5.85 GHz ISM band.

802.11 Proposed Short Symbol Direct Sequence Spread Spectrum

A direct sequence plan proposed by this contributor uses a short symbol length to attain a high megabit data transfer rate. The spreading is used solely to mitigate multipath propagation and Rayleigh fading further extending the advantage inherent in wider bandwidth.

As compared with the three plans above, this is the only PHY which has set out with high transfer rate and capacity per hectare as a primary goal. Others have focused on minimizing infrastructure cost, or on using existing technology; and then arguing that the capacity provided is adequate.

While the offered technology is arguable (though there has been little discussion of the technical detail), the service and functional goal is both fundamentally different from that of any present 802.11 2.45 GHz PHY proposal. Arguments against use of 5.85 Ghz by reason of cost or power drain are simply not valid in the context of short reach. This is less of a cost obstacle than dealing with narrowband and microwave oven interference at 2.5. While the final choice might be considerably different than this proposal, it may also be the best available starting point. The high capacity/function capability is both needed and feasible.

Optimization for a Fixed Narrow Bandwidth-- e.g.; 10 MHz

Regardless of technical desirability, maximized use of a 10 MHz bandwidth is and will be a reality. This constraint may be the one that lead the development of common technology for licensed and unlicensed operation. It is imaginable, that on private premises infrastructure would be provided (financially and administratively) by the operator of the premise; and in public places (airports, convention centers, hotels, hospitals), by a service provider. Rights to use of air spectrum space would be defined in the same patterns as property lines.

The channel switching feature is not necessarily part of the access method, but rather a system service access selector.

It would be desirable to have the technique upwardly and downward scalable 5 and 20 MHz with proportional changes in capacity. The same protocol might be used independently of rate.

A further need is a common air interface within the common bandwidth. This contributor believes that the commonality between voice and data channels is best achieved with a common cell relay definition (as in ATM). However, it is also possible to have a common chipping rate and different symbol definitions for data and voice. Long symbols would maximize range at low bandwidths, and short symbols would maximize transfer rate for sequential multiplexing.

Much of the work and many of the contributions on modulation types done in support of frequency hopping is equally applicable to this problem.

> The computer data communication community must accept that service provider compatibility is desirable to users. This achievement will widen market and usage.

Users off-premises may be willing to pay for service. Given that opportunistic pricing will exist as it does for hotel telephone calls, the data service may still be cheap if the charge is based on data transferred rather than open connection time. The dogma that they won't must be abandoned, and replaced by an effort to make the cost reasonable.

CONCLUSIONS

The present PHYs under development by the PHY group address the needs of and optimizes for spontaneous, autonomous groups. The result is unlikely to be useful for any public network compatible connection type service or for LAN comparable interactive communication.

It is necessary and desirable to have parallel effort on two additional sets of premises:

ETSI HIPERLAN and 5.85 GHz ISM bands

Premise: To provide high transfer rate and capacity/hectare services supporting bandwidth-on-demand connection-type and connectionless services consistent with business in-building needs. Capacity objective: 100 Mbps/ha minimum Transfer rate objective: 16 Mbps minimum.

ET band 1.85-1.99 GHz

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2. "Wireless Access Methods and Physical Layer Specifications," N. Silberman and J. Boer -- Editors, Draft 802.11 PHY Group working document 802.11-93/83r1, 7/12/93

3. "Radio Equipment and systems (RES)- HIPERLAN - Services and Facilities," European Telecommunication Standards Institute (DTR/RES-10-03)

4. "FQPSK: A modulation-power efficient RF amplification proposal for increased spectral efficiency and capacity GMSK and $\pi/4$-QPSK compatible PHY standard," Kamilio Feher, University of California at Davis, IEEE 802.11-93/97, 7/13/93

5. "An RF Data Transport Protocol--The RF Adaptation sublayer and RF Physical Layer Specifications for Slow Hopping Spread Spectrum Radio LAN," Ed Geiger, Apple compute, Cupertino CA, IEEE 802.11-93/104

6. "A Proposed IEEE 802.11 Radio LAN Architecture," Jonathon Y. C. Cheah, Hughes Network Systems, San Diego, IEEE 802.11/91-7 (Pages 13-18 show 31-bit 12-vector correlation diagrams)