IEEE P802.11
Wireless Access Method and Physical Layer Specification

DATE: June 25, 1991 **REVISED:** July 4, 1991

TITLE: **STRATEGIES FOR CHANNEL ASSIGNMENT**

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OVERVIEW

A code division spread spectrum channelized signal has the following special characteristics not usually present in a pure time or frequency division channelized plan:

1) a lesser signal-to-interference ratio is needed for separation of same-channel signals than for narrow spectrum bandwidth-efficient signals, and
2) the noise bandwidth of the recovered signal can be proportional to the information carried rather than the occupied spectrum.

Given that a channelized the physical medium is available, it is necessary to use this flexibility in a useful way for which the following are possibilities:

3) to provide parallel communication paths for each of many simultaneous users, or
4) to distinguish between overlapping coverage areas served by different radio Access-points.

The strategies to be described use the channelization property to permit simultaneous use of Access-points with overlapping radio coverage as in 4). Data transfer channels may be positioned on one of the following criteria:

5) according to a fixed geographic plan allowing all sites to be used simultaneously, or
6) dynamically assigned to achieve some form of optimization benefit.

RECOMMENDATION

It is recommended that none of the plans described be incorporated in the Standard, excepting possibly the Reference Plan in a model. They are offered as evidence that the air-interface and access protocol elsewhere offered, contains the necessary functions for an indefinitely large and a reasonable size smaller coverage system plans.

Table of Contents **Page**

TABLES

FIGURES

STRATEGIES FOR CHANNEL ASSIGNMENT

OVERVIEW

The starting point is no channelization. The entire systems uses a single rf channel resolving interference problems by sequential use. The main disadvantage is that the necessary signaling rate must be N (reuse factor) times higher than the signaling rate for one site in a channelized system. This results in N times higher peak power requirements in the Station.

The main advantage is that all of the capacity can be allocated to the sites on demand rather than in a fixed, uniform pattern.

A further advantage is that with only one transmitter at a time active, there is minimal need for power control.

The reuse factor, N, is dependent on modulation technique. Higher values are required with more spectrum efficient modulations undoing some of the benefit.

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2) the noise bandwidth of the recovered signal can be proportional to the information carried rather than the occupied spectrum.

Given that a channelized the physical medium is available, it is necessary to use this flexibility in a useful way for which the following are possibilities:

3) to provide parallel communication paths for each of many simultaneous users, or

4) to distinguish between overlapping coverage areas served by different radio Access-points.

While 3) is used and widely advocated for multi-channel mobile telephony, it is not a preferred function for LAN. It is philosophically inappropriate because **in LAN each user gets the whole system capacity for a fraction of the time rather than a fraction of the capacity for a considerable time period.** It is practically difficult because in the Station-to-access-point path, it is necessary to provide dynamic power control so that all Station transmitters are received at approximately equal signal levels. This is a particularly difficult function for transmitters that may be on for 100 µseconds or even less at high rates.

The strategies to be described use the channelization property to permit simultaneous use of Access-points with overlapping radio coverage as in 4). There are then further choices. Data transfer channels may be positioned on one of the following criteria:

5) according to a fixed geographic plan allowing all sites to be used simultaneously, or

6) dynamically assigned to achieve one of the following objectives:
   a) to enable a system design with fewer channels than are required for adequate isolation of reused frequencies/channels. (e.g. less than 9 channels)
   b) given sufficient channels for a reuse plan, to expand the number of cells within one channel access group so that available channels may be spread over only cells that are active.
   c) to avoid a need for coordination of usage times between independent systems with a common boundary.
   d) to minimize the accuracy and complexity of a coordination plan for continuous area coverage.

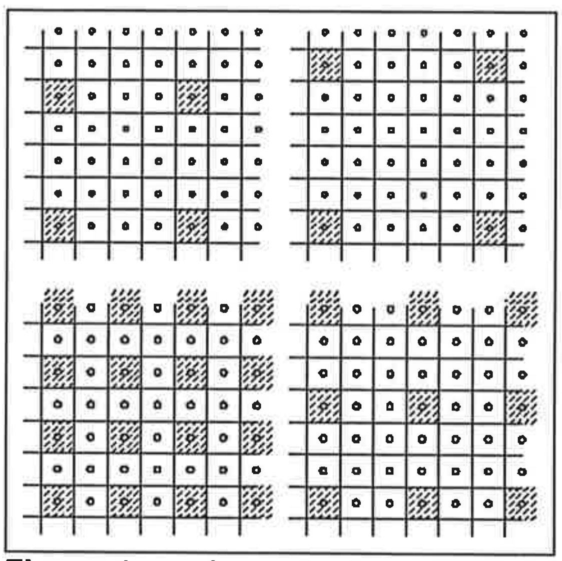

Figure 1 Layout for Channel Reuse with 4, 9, 16 and 25 Channels

Because of the assumed access protocol, the above applies to data transfer channels but not to a common setup channel which is used at all sites. For the setup channel, sequential use within one reuse pattern is assumed. One consequence is that this sequential use must be synchronized between contiguous reuse groups so that the separation of simultaneously used sites on the common channel is maintained.

The Reference Plan is based on 4) and 5) above, and it uses 9-channels in square 9-cell patterns which can be indefinitely repeated. When a common setup channel is used sequentially in each pattern, there is a timing requirement that setup occur in the same time interval for each cell position in the 9-cell pattern of all contiguous patterns.

For motivation 6c), there is no plan now proposed, but it is believed possible.

The Dynamic Channel Allocation Plan is motivated by 6b).

REUSE FACTOR:

The number of discrete channels used to provide complete coverage in a wide area. Since any regular plan is a loose fit on real systems, it is convenient and sufficiently accurate to use square cells for illustration. Figure 1 shows the reuse pattern for a single channel when 4, 9, 16 and 25 channels are available.

THE EFFECT OF RF MODULATION CHOICE

The minimum spacing of cochannel access-points is modulation dependent. The more signal-to-interference ratio that is required the greater the necessary spacing. Using 11 dB/octave, a 4/1 distance ratio is a 22 db signal level ratio (average) for one interferer and a desired signal.

If the probability of the desired signal being sufficiently above the interferer must be 10% or better, then the fading

TABLE I -- REUSE FACTOR N VS. MODULATION TYPE

Reuse Factor	Appropriate Modulation Type
4	Spread Spectrum with large chipping/bit ratio (e.g. >63)
9	Spread Spectrum with low chipping/bit ratio (e.g. 11-31)
16	Linear, spectrum efficient modulations

statistics are important. Since there is much less fading range relative to average level on wideband relative to narrowband signals, the degree of margin needed is modulation dependent. As an example only, and not a basis for decision, the following Table is the Author's unsupported estimate of the suitability of modulations (assuming DOQPSK for spread spectrum chipping).

The above table is more conservative than would be used with voice channels because of a high degree of transmission accuracy required for LAN.

CONTINUOUS COVERAGE CHANNEL PLANS

It is commonplace in continuous coverage systems to put down a regular pattern of channel group assignments of 7, 21 or other numbers of channels for hexagon based system plans; and 4, 9 or 16 channels for square based system plans. The assumption of square coverages is introduces no more inaccuracy than must be tolerated in real systems considering uncontrollable obstacle locations. A channel is used only at the geographical locations for which it has been planned. The larger the number, the greater the distance between reused channels under saturated usage. In telephone systems, where channels are trunks, nearly all channels can be used simultaneously and efficiently.

In packet data systems where each use of a channel is milliseconds at the longest, and **where each user is active less than 1% of the time; there can be serious loss of capacity from inflexible channel assignment algorithms**. With a fixed number of available channels, an assignment should only be consumed by actual usage and not by geographic constraints. This philosophy shows the greatest advantage when fewer than 50% of the available coverages areas are used simultaneously, and when the number of channels available for allocation is sufficient for distance isolation at the maximum possible usage density.

Two strategies for dynamic channel allocation are offered which are well suited to short holding time traffic found in packet LAN systems.

TIMING DESCRIPTION FOR SEQUENTIAL SETUP CHANNEL ASSIGNMENT

It is now assumed that one dedicated and separate channel is used to setup use of nine data transfer channels. The setup channel is used sequentially at each coverage area holding for a short time when there is no Request, and longer to process a request. It is desirable that less time be required for setup than for data transmission.

The most important parameters that go into the formulation of these plans are:

TABLE II -- ASSUMED TIME DURATION OF MESSAGE FUNCTIONS

<u>Approximate time required in µsec including propagation delay for--</u>

g)	Invitation-to-request and no response on setup chnl:	100
h)	Invitation-to-request and a Request on setup chnl:	200
i)	Grant plus 48 octet PDF on data xfr chnl:	600
j)	Grant plus 288 octet PDF on data xfr chnl:	2,800
k)	Scan time for 9 No-request coverages:	900
l)	Scan time for 9 Request coverages:	1,800
m)	Scan time for 16 No-request coverages:	1,600
n)	Scan time for 16 Request coverages:	3,200

a) number of channels in reuse pattern (e.g. 4, 9, 16...)
b) the peak and average duty cycle usage of each access-point
c) the setup time required as a fraction of the average message length
d) the setup time used when there is no request
e) timing restrictions from contiguous system operation

Assumed Parameters

For a particular <u>1 Mb/s medium</u> and message-based access protocol with a sequentially used setup channel serving nine coverage areas, the parameters for setup and data message transmission functions are shown in Table II above.

Access-point originated traffic is likely to use 40-50% of air-time. If the slot-width for Invitation-to-request and Request is defined by Station-originate, it is the same for Access-point-originate. One request opportunity may be lost for each Access-point originate message. Therefore, the total transportable traffic is similar regardless of its directional makeup.

Rounded numbers are used in the above assumptions which are sufficiently accurate for philosophical description.

Size and Scale Tradeoffs

The number of coverages scanned should not be too large, or the delay between access opportunities will be too great. If there are too few (less than 9) coverages in a scan, then more than one scanning group will be required for expanded small systems. In this case, the stepping rate for contiguous scanning groups must be synchronized to reduce interference setup channel interference.

A further object of the Dynamic Allocation Plan is to maximize the number of served coverages before synchronization is required. There is a size range for which a single scanning group is suitable--perhaps 16 to 25 coverages.

REFERENCE SYSTEM PLAN

A reference system plan, using synchronized setup channels could be conceived on a square plan of 3 x 3 coverages with a common setup channel and nine data channels as shown above in Figure 1 and also in Figure 2 below. Assuming that there are many like type plans laid out congruently, and that the timing of the setup channel is a uniform 200 µsec stepping period at 1 Mb/s signaling rate; it is then possible (considering only cochannel interference) for all channels to be used simultaneously for data transfer.

When message length and scan time are considered, it may not be possible to load all channels simultaneously.

If it takes 1.8 millisec to assign 9 coverages, and the messages each make use of the data channel only 0.6 millisec, then the first six assigned data channels will be vacant when the scan returns to the starting point. For short messages, only 33% of the available data channel time will be used. For 100% time utilization, the length of the data transfer use in one scan would have to match the setup time used on the setup channel in one scan.

With a mixture of message lengths occupying the data channels, there will be unused capacity when the average message length is less than the per channel scan time.

Layout of the Reference Plan

As shown in Figure 2, the italic numbers within the 25 cells represent the allocation of <u>regular 9-channel patterns</u> with one channel per coverage. Any given channel number is reused at spacings of two interposed coverages in four directions. This characteristic is independent of traffic, and it is optimum for 100% use of all channels in all coverages simultaneously. This representation is intended to provide a reference against which other possible plans may be compared.

It would be possible to have similar regular plans for 4 and 16 channels as well.

With more than nine access points, additional like patterns would be placed congruently as shown in Figure 1 above.

The possibility of fractional groups is present.

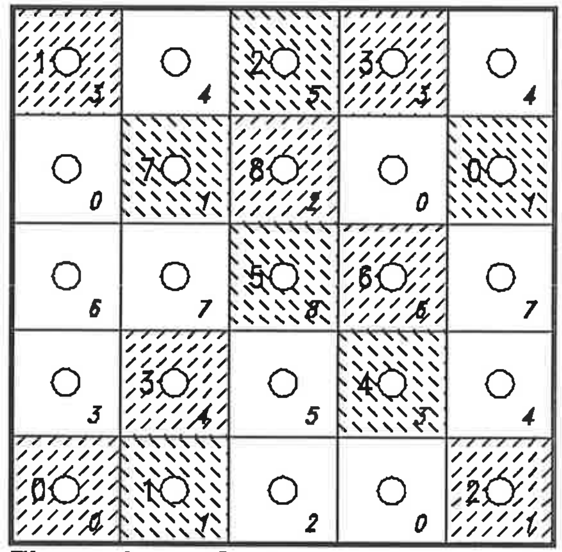

Figure 2 System Example: 25 Coverage, 9 Data Channel, 50% Simultaneously Active Coverages

DYNAMIC CHANNEL ALLOCATION PLAN

Rather than trying to increase utilization, the proposed plans assume that 100% use of all coverage sites simultaneously is not a requirement, and that 25 to 50% of the coverages simultaneously active is sufficient enabling advantages in other performance areas. Suppose now that the same number of channels is assigned consecutively as needed. The assignment process might proceed serially from left to right and ascending order of rows from the bottom left. A better sequence algorithm would recognize and follow successive squares of nine coverages so that pile-up of demand in more than 9 consecutive assignments would not cause the separation requirement to be violated.

A random distribution of 13 active channels (out-of-25) assigned in one scan sequence is shown for 9-channels available. The larger block numbers are the assigned channel.

The closest reuse distance in this illustration is three intervening coverages (compared with two previously) which would result in lesser cochannel interference. This increased separation occurs because the plan takes advantage of 50% simultaneous coverage utilization by not consuming a channel assignment except at active points.

Reducing the Number of Channels Required

Reducing the number of channels available makes a minimum channel spacing possibility below design criteria. It would be possible to increase the number of channels in the scanned group holding the percentage simultaneously in use constant.

Effect of Message Length on Simultaneously Used Coverages

There is an important difference in the scan algorithm for this plan that is not the case for the reference plan. Without a synchronization requirement, the holding time on one coverage is only 100 µsec when there is no request. The scan time for 13 requests and 12 no-requests is 3.8 millisec. An average message length of about 300 µseconds would sustain the 13/25 utilization. Longer messages would increase it.

If only one site had a request in one scan, the scan time would 2.6 millisec Also, Access-point-originate messages would use less than 100 µsec for setup.

CONCLUSIONS

Within the context of the message-based access protocol running at 1 Mb/s data rate with at least 10 independent channels, there are circumstances where dynamic channel assignment is advantageous.

Nine channels assigned in regular pattern is a good plan when synchronization of the stepping of the setup channel is available for systems of more than nine coverages. With a small number of additional coverages, in the range 10-25 cells, the need for synchronization can be avoided with dynamic channel assignment.

Application of Dynamic Channel Allocation

This method of operation spreads the capacity of a small number of channels over a larger number of radio coverages providing capacity on demand. The capacity has no tie to a location. There should be radio isolation at the edges from contiguous like-type systems, otherwise additional coordination considerations will exist.

Good proportions would be in the range of 20 to 50% of coverages simultaneously usable for 10 to 25 coverages in one group. The number of data channels can be less than the number of simultaneous coverages when there are at least 9 data channels at 50% and fewer at lesser usage factors.

Independence of Station Logic

Any or all of these algorithms are executed in the infrastructure logic. There is no dependence of the air-interface or the station logic on which of these plans is used. The only requirement is that the Station have sufficient channelization, and that the identity of the setup channel is standardized.

The implementation of these logics requires that control messages contain channel designation commands and that the default or initial channel be pre-agreed.

Complete Independent Operation of Coverage Areas

It is possible to have setup and data transfer an independent and parallel process on each channel. This possibility is not considered further because it may require the station to scan channels and make a decision on which channel to initiate operation. It is believed that this is unsuitable logic for moving stations, and that it raises the complexity of the station function unnecessarily. There is also the possibility that it will create a centrally managed handoff function which will create other delay factors.

RECOMMENDATION

It is recommended that none of these plans be incorporated in the Standard, excepting possibly the Reference Plan in a model. They are offered as evidence that the air-interface and access protocol elsewhere offered, contains the necessary functions for an indefinitely large and a reasonable size smaller coverage system plans.