IEEE P802.11

Wireless Access Method and Physical Layer Specification

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TITLE: **INDEPENDENT CONTIGUOUS RADIO LANs**

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SUMMARY

It is concluded that the overlapping and inter-penetration radio coverage that might occur in topology models named "twin towers" and "shopping mall" is controllable to a point where no material system degradation results. The conditional assumptions are:

1) There are one access and N (e.g. 9) data transfer channels.
2) Interference-limited system design.
3) Message-based access control.
4) Predominant communication via Access-points which use directive antennas and rule defined installation location.
5) Non-directional antennas on Stations.
6) Inter-system synchronization is not required, but is desirable. If employed, a further reduction in interaction may be obtained.
7) Channelization is a secondary means of system isolation best used where the traffic per autonomous group is small compared with system capacity.

The final conclusion is the combination of two major subsidiary conclusions:

a) Material overlapping coverage from Access-points may be avoided by using inwardly directed illumination from quadrantal pattern directive antennas.
b) Interference experienced by any one Station from another Station in another system, where there is little or no distance or obstacle path attenuation, has sufficiently low probability that automatic repetition of failed messages is an adequate remedy.

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GENERAL ANALYSIS

While it is obvious that contiguous LANs will have inter-penetration of signal presence, the quantitative considerations are not obvious and may be model-specific.

In the limit, two independent systems might attempt to exist in the same Basic Service Area (BSA) now defined as 100% overlap. It is also possible that two independent and contiguous systems on opposite sides of an administrative boundary might have a little or a lot of inter-penetrating radio coverage. It is now necessary to define the loss of capacity or coverage in a first system from interference from a second system.

<u>Case CSMA:</u> If the interfering signal is merely strong enough to make the channel look "busy" to an Access-point or mobile in the first system (using carrier sensing access control), then a small signal is an interference factor which could affect an entire BSA. Effectively, the overlap might be more than 50%. Without an infrastructure Access-point relay, no use can be made of antenna directivity to reduce the effect.

<u>Case Interference Limited:</u> If instead, the desired signals in the first system are sufficiently stronger than the interfering signal to be usable, the affected area in the first system may be limited to its fringes in one direction. The overlap might affect only 10% of the coverage area of the first system.

This case presupposes that access has no connection with background signal levels. Instead, access is based on an exchange of messages where the desired signal is sufficiently strong to be usable.

The choice of access method is significant for common-boundary systems. The benefits of interference-limited coverage definition are basic and well known in prior art. The definition of interference is now arbitrarily selected to be 22 dB S/I ratio (an average cluttered-path loss-difference for two octaves of distance).

Now considered, are radio antenna beam shape and location rules sufficient to produce this operating difference in signal levels in topologies that would otherwise have unacceptable interference. This technique is considered assuming suitable choice of channelization, access method and co-channel discrimination methods.

This problem could be completely solved by capacity division between the interfering BSAs. Rather than compromise capacity and spectrum utilization goals, methods of limiting overlapping coverage and its effects are considered.

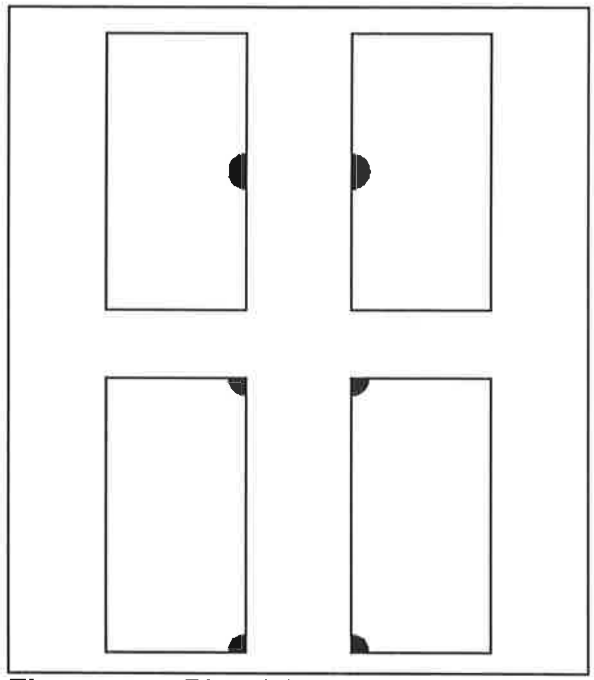

Figure 1 Plan View of Facing Office Towers Corner and Wall Placement of Sectoral Pattern Access-Points

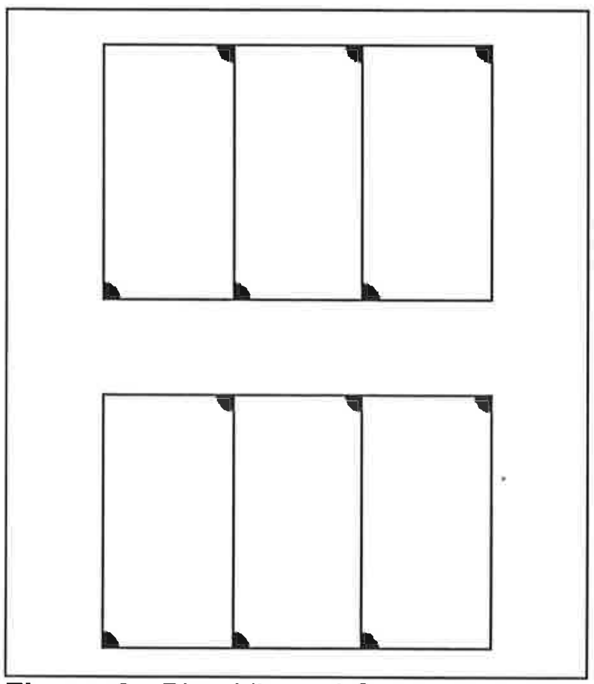

Figure 2 Plan View of One Level of the "Shopping Mall" Model With Six Shops

MODELS

Two difficult models have been described in 802.11 discussion which will now be called 1) shopping mall, and 2) twin towers.

Shown in Figure 1 is a plan view of two sets of **"twin towers."** The interference mechanism results in part from low path loss across the space between the buildings. Stations located near windows could produce a strong signal across that space in the other tower. The problem is further complicated because the model is actually three dimensional, and there may also be cross-floor interference across the space.

The dark spots represent quarter and half circle coverage Access-points which will be discussed further below.

Shown in Figure 2 is a plan view of one level of a **"shopping mall"** layout. The same problem exists across the central space to shops on the same and other levels as in the twin towers but also there is a problem of cross-coverage between adjacent shops.

Problem Statement for Twin Towers (TT) Model

The general assumption is that one floor of a first system will have common coverage of the opposite offices for at least one floor below and above the opposite floor. The isolation between floors in the same building might be adequate for cochannel operation with message-based access, even though inadequate with CSMA.

Because the systems on each side might be very large, channelization cannot be used for inter-system isolation. An attempt to use channelization for this purpose, beyond the level practiced in a regular coverage plan, would be a form of capacity division.

Problem Statement for Shopping Mall (SM) Model

The problem is different in that the opposite sides are many small systems rather than a few larger systems. It is also probable that the amount of traffic in each small system would be a small fraction of the total capacity. The problem is similar in that there is low attenuation across an intervening open space. More than two levels is infrequent but possible.

Antenna Design for Access-points

Antennas with a wide range of azimuth and elevation directivity patterns are designable. At higher frequencies in the microwave region there is a greater range of possibilities because of smaller physical size. It can be assumed that necessary quadrantal and semi-circle beams can be developed.

Vertical directivity also has great value in reducing inter-floor overcoverage. Requirements for coverage in the knee holes of steel desks should be avoided.

Unfortunately, the perfect pattern will not give perfect results because of re-radiation or diffraction from illuminated objects. Nonetheless, with a few exceptions, secondary paths result in losses substantially greater than optical paths.

CHANNELIZATION AND SYNCHRONIZATION FOR THE TWO MODELS

The primary use of channelization is to provide simultaneous availability in overlapping coverages and to minimize harmful interference from reuse of channels at minimum spacing. This is part of maximizing the traffic capacity of a given bandwidth and per Access-point coverage area.

The default channelization assumption for 1 Mb/s signaling rate is 12-vector, 31-chip direct sequence spread spectrum (as proposed by J. Cheah in another context). One code is reserved as an access/setup channel. A typical plan would use 10 of the 12 channels for 9 coverages. The remaining two would be reserved for irregular problems or for autonomous groups.

Since the setup channel is used sequentially in a defined pattern, it is necessary or highly desirable that setup messages be transmitted at the same position and time in contiguous patterns implying timing synchronization. Synchronization is not needed for separate data transfer channels.

Synchronization

Let it now be assumed that nine equal 200 μsec slots are defined as a setup scan frame with a duration of 1.8 milliseconds. This interval could be distributed as the zero crossings of a 1111.1 Hz sine wave distributed by wireless or twisted pair.

Assuming a timing accuracy requirement of 20 µseconds and a reference clock accuracy of 0.001%, a free running time of 2 seconds would be available.

Plan for Twin Towers (TT)

All systems would use the same data transfer channels and the same plan except that it is assumed that only 3-of-9 data channels are assigned next to the outer wall on one floor of one system. On the opposite side a different set of three channels would be used chosen as the extension of a regular plan continuing a general two-dimensional plan.

The floor above and below would be a rotation of the same plan so that three consecutive floors would use all nine channels. On the opposite side, the same thing would be done except horizontally and vertically offset.

Looking at a vertical cross section three coverages wide and five floors high for the data transfer channel assignments on opposite sides of the open space, this the way it might be a plan for a coordinated arrangement:

1			5		
4			8		
7			2		
1			5		
4			8		
	2			6	
	5			9	
	8			3	
	2			6	
	5			9	
		3			4
		6			7
		9			1
		3			4
		6			7

The difference in channel assignments does not result in a complete separation, but there is more separation than would be the case without a plan. Used as a backup for separation by Access-point antenna directivity, a good result can be obtained.

The channel separation is important to Stations without directive antennas receiving some other Stations across the open space. The possibility of interfering use of a data transfer channel is diminished by at least 1/9th.

All Access-points use the common setup channel 1/9th of the time--sequentially. Sequential operation within one system is inherent. The functional requirement is that the setup channel in all coverages areas assigned data channel-N transmit at the same time, and this requires inter-system synchronization as described above. If they are not synchronized, there is an increased probability of overlap interference which is less quantifiable.

Because of the nature of the Access-protocol, it is not necessary to reduce the interference to zero or to zero missed messages. It is necessary to reduce the probability of interference to a level where the capacity lost from repetition is negligible--e.g. 2%.

When a Station hears a message from an adjoining system, it is not likely to be interference. It will be ignored if it has a non-matching system identifier. It is necessary for a transmission from the interfering system to cause a desired transmission to be missed. The most frequent case might be interference with an Invitation-to-request--but then there will another opportunity in milliseconds. Interference with messages is improbable because Station transmitters are so infrequently on.

The probability of Station-to-Station interference will be considered below.

Plan for Shopping Mall (SM)

If TT is 5 high by 3 wide, then SM is 2 or 3 high by 20 wide where most shops will have one Access-point and a few will have more than one. What is much easier is that the amount of traffic for one Access-point in the shopping mall may be much less than for one in an office. File downloads and bulk data transfers will be rare. Transaction data for several cash registers does not in the aggregate tax a 9600 baud telephone circuit. There is no interference from Station transmitters except when they are on.

The SM plan for two levels might look like this:

	1	2	3	1	2	3	1	2	level 2 west
	2	3	1	2	3	1	2	3	level 1 west
level 2 east	4	5	6	4	5	6	4	5	
level 1 east	5	6	4	5	6	4	5	6	

Opposite sides of the open space would not use the same channels. Reuse of the same channels on different levels could be offset. With a repeating pattern of four, the offset separation would be one shop greater.

What doesn't meet the eye is that capacity sharing is in effect, and rf isolation is not actually required. Assume two 1's that are close enough for interaction and each sending 1,000 messages per hour with average duration of 2 milliseconds. Each is using two seconds per hour, and the chance of them both needing the channel simultaneously is very small independently of rf isolation. It is also possible that one Station receiving could be affected by a few other Stations.

Overlap of Access-point coverage is more harmful but also much more controllable with correct positioning and directivity. It is here that rf isolation matters.

The system will operate without synchronization of the setup channel, but if it is added the capacity will be greater.

The peak capacity of the system would be greater than 50% utilization of each numbered group of access points simultaneously operated.

The open front and a requirement for coverage into the pedestrian area might create need for modified Access-point antenna designs.

Interference Potential Between Non-isolated Stations in Different Systems

It is useful and interesting to estimate the interference potential between Stations when there is no rf isolation, and the only factor is usage time.

All of the following is based on a medium signaling rate of 1 Mb/s, and a message-based access protocol which is similar but not identical to one offered in IEEE 802.11/91-19 in January 1991. It is intended that the revised Access-protocol be presented at the November or earlier meeting.

Traffic Assumption: The average up and down usage per station in a small group of high usage Stations is 16 megabits or 2 megaoctets per hour. Because of a segmentation size limit, the average message length is 250 octets including overhead and 200 octets without inclusion of overhead. There are then 5,000 messages per hour of average duration 2 milliseconds. The load of the average Station is 10 seconds per hour or 0.28%. It is assumed that this load is evenly divided between transmitting and receiving.

The above assumption is considered a level that could easily be reached by a few, highly used individual Stations. It is believed much too heavy for the average of a group. Therefore, the estimates below are significantly pessimistic on this basis.

Transmission on a Data Channel--no rf isolation: The average Station is receiving 5 seconds per hour, and one interfering Station is transmitting 5 seconds per hour. The probability of overlap interference to one Station is 0.28% per message received.

Transmission on the Setup Channel--no rf isolation: A Station receives on the setup channel for 100 μsec before each received or transmitted message. The total receiving time for 5,000 messages is 0.5 seconds (0.014%) The transmitting time to setup one message is 67 μsec. 5,000 setup messages total 0.335 seconds (0.0093%). The probability of overlap might be 0.0233% for each message transfer.

Significance of rf isolation: rf isolation keeps the number of possible interfering Stations small.

CONCLUSION

Not withstanding the arguability of the detail of the above assumptions and calculation methods, there is only a very small fraction of the channel time when a Station is receiving and susceptible to interference from another station spending a like small fraction of its time transmitting.

Considering the TT model only a small fraction of the total Stations in each system will be at a location where direct interference is likely. A major factor ignored in the above estimate is that the signal from the Access-point will often be much greater than that of the interference, and then the message will be correctly received regardless of the interference then present. An opinion is that this will be the case more than half the time.

Considering the SM model, most Stations may be in a position to create inter-system interference. Fewer Stations will be pushed back in depth, but there will also be a smaller aggregate number of Stations. The traffic per Station will be much smaller, and the consequences of possible interference are then also smaller.