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802 LAN Access Method for Wireless Physical Medium

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TITLE: **WIRELESS SYSTEM ARCHITECTURE— MAJOR CHOICES AND CONSIDERATIONS**

AUTHOR: Chandos A. Rypinski,
Chief Technical Officer
LACE, Inc.
921 Transport Way
Petaluma, California 94954 USA

Telephone: 707 765 9627
Facsimile: 707 762 5328

BACKGROUND

A functional goal, an application suitability, a type of environment and some special circuit capability have been assumed in developing the major architectural features of a wireless access system.

CONCLUSIONS

The value of minimizing the distance between access-points and the air path-length is very high, because it also minimizes size, cost, complexity and power drain. Because parallel use is possible, the capacity of an array of access-points can be quite high.

Above all: Unless reach is minimized, the potential for interference to existing 1.7 - 2.3 GHz services may prevent FCC authorization of use of these frequencies for many years.

To realize these technical and economic advantages, it is necessary to have central control of access best implemented with in-band data messages. Central select and enable of useful transmission is incompatible with the philosophy of other 802 access methods (possibly excepting 802.9), but it is essential to avoidance of a large proportion of transmissions where no useful information is transferred, and to meet FCC philosophical objectives.

Attachment A offers rules for the trade-off between reach requirements in the radio LAN and the level of interference to existing microwave point-to-point spectrum users.

WIRELESS SYSTEM ARCHITECTURE— MAJOR CHOICES AND CONSIDERATIONS

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WIRELESS SYSTEM ARCHITECTURE— MAJOR CHOICES AND CONSIDERATIONS

BACKGROUND

A functional goal, an application suitability, a type of environment and some special circuit capability have been assumed in developing the major architectural features of a wireless access system. Some of these premises are arguable, and they are presented below.

Functions

a) LAN capacity and speed capability approaching or equaling that of existing wired LANs.
b) Inclusion of some of the subsets of digital connection-oriented services.
c) Scalable medium signaling rate so that reach-rate tradeoffs may be made within the Standard.
d) The system topology will assume multiple wireless coverages working cooperatively but economically rational with as few as two coverages.
e) User equipments may be fixed, movable or moving without discontinuity from passage between different wireless coverage areas.

Suitability

f) On-premises, ubiquitous commodity (low cost) function with extendability to campus, warehouse and yard exterior situations.
g) Variant range must include high-value (premium cost) communication in industrial and financial contexts.

Environment

h) Dependence upon and compatibility with the telephone twisted pair wiring defined in EIA/TIA 568 for operation within user-controlled premises.
i) Non-exclusive co-use of radio frequencies now occupied by point-to-point microwave radio links.

Circuit Functions

j) modems for digital line signal suited to UTTP medium and transmittable by either radio or wireless medium.
k) fast clock and framing acquisition so that channel set-up time is not over three octets.
l) the user station must be minimized in size and power drain, if necessary, moving functions to shared equipment on the fixed side of the wireless interface.

It is probable that many knowlegable engineers might consider it impossible to satisfy all of these conditions at the same time, but it is believed possible and will be assumed, and the detail points will be taken up and justified in future contributions.

MODEL AND TOPOLOGY

It is necessary to assume a model to show the effect of some of the options even though real systems may be substantially different. Figure 1 is a drawing of the model showing 16 equal coverage areas which could be a part of a much larger plan

Equal, horizontally omni-directional, transmitting and receiving fixed site equipments are located on a square grid with pitch = D between intersections. The required minimum overlap reach is half diagonal distance to an adjacent equipment. For greater overlapping coverage, this distance must be increased 1.4 times for considerable overlap. The radius circle for these two degrees of overlap are also shown in Figure 1.

Access-point is the term used for the fixed radiation point in a wired system. Each access-point has a designed or observed coverage area that probably overlaps adjacent points.

Station is used for the user equipment whether fixed or mobile, and the reach of the station is designed to be equal to the reach of the access-points.

Non-interference is assumed (default) if the ratio of the distance for the interfering path is 4 times (12 dB minimum) that of the desired path. The circular range for this interference level for worst case covered stations is also shown in Figure 1.

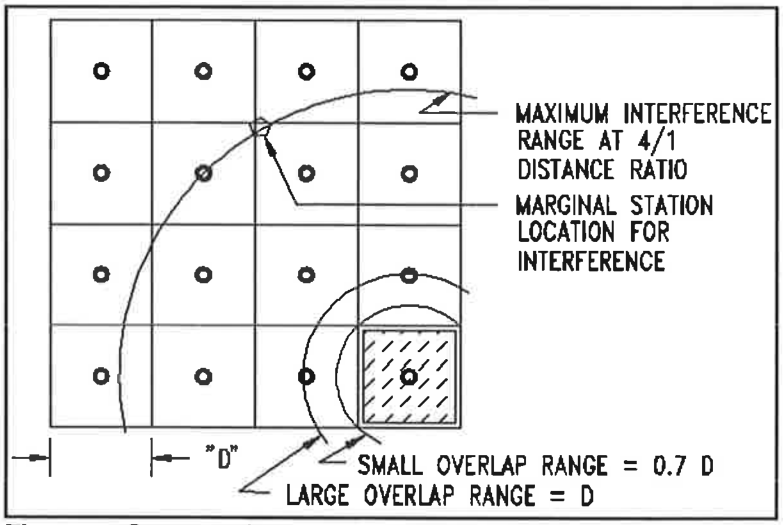

Figure 1 Coverage Model for 16 Equal and Symmetrical Access-points Including Overlap and Interference Range Circles.

Overlap Design

As shown, a circular coverage provides overlap over most of the assigned square coverage area when the range is great enough to reach diagonal corners. This point is shown in greater detail in Figure 2, below.

It is evident that an increase in the size of the range circles by 10 or 20% would extend redundant coverages to the small area cusps on the diagonals.

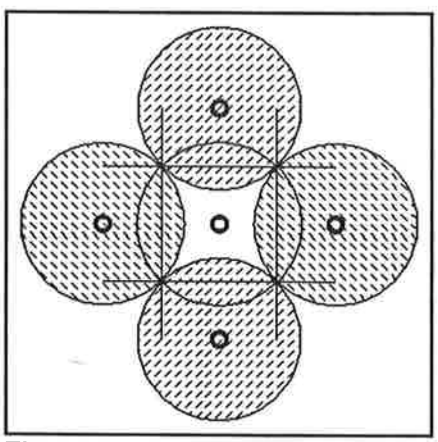

Figure 2 Detail of Circular Coverage Overlaps from Four Adjacent Coverages Using a Range Sufficient to Reach a Diagonal Corner.

Interference Range

If a distance ratio of 4:1 is assumed, the translation to power can assume optical propagation for the desired signal which is 6 dB/octave. The interfering signal is much less likely to have an optical path, and the last octave may be set at 12 dB/octave. This range ratio will result in an 18 dB signal-to-interference ratio.

If 1 is the diagonal distance to the corner of the coverage square, then the interference range is 4 times further as shown in Figure 1, but this is only the case for stations situated at maximum distance from their related access point as indicated by the "pentagon" symbol in the Figure. If the station is closer to the desired access-point, then the interference range is decreased. The circle shown is a worst case. Within this circle, the satisfactory range of the enclosed access-point is diminished not destroyed.

The reusability of a frequency is every 4th row for very conservative design. Slight statistical degradation might be expected from every 3rd row. Every 2nd row is conditionally usable depending upon an algorithm that takes into account the station signal level.

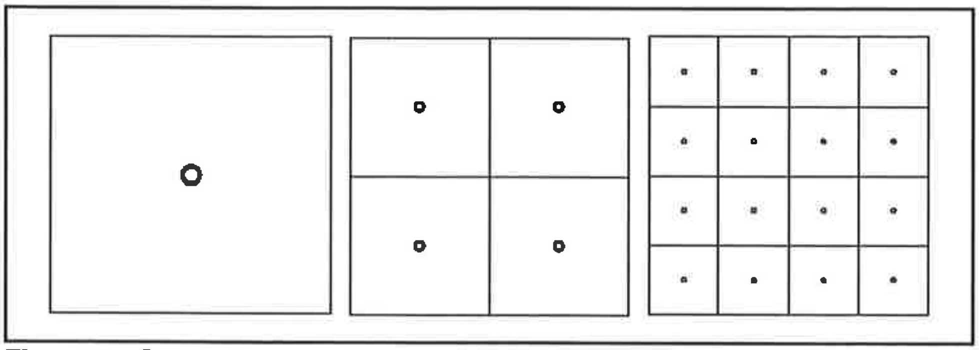

Figure 3 Coverage Layouts for Access-points with Reach Ratios 1 : 0.5 : 0.25.

TABLE I — SCALING FACTORS FOR TIME DISPERSION LIMITED WIRELESS ACCESS-POINT GRID

GRID PITCH DIM "D"	RANGE x D of 1	AREA PER ACCESS-PT	RELATIVE DATA RATE	REL. POWER REQUIRED	CAPACITY PER MHZ
1	0.7	1	1.0	0 dB	1.0
2	1.4	4	0.5	+6 dB	0.125
4	2.8	16	0.25	+12 dB	0.0156

REACH OF ONE ACCESS-POINT

There are a number of inducements to minimize the reach of each individual access-point.

Above all: Unless reach is minimized, the potential for interference to existing 1.7 - 2.3 GHz services may prevent FCC authorization of use of these frequencies for many years.

In addition, there are a number of technical and functional reasons for minimizing reach two of which are listed as follows:

A Considering time dispersion in the medium, the maximum data rate is doubled each time the maximum reach is halved.

B Considering only spacing of non-interfering frequency reuse, each time the maximum reach is halved, the capacity of the system is quadrupled.

As shown in Figure 3, a given area may be covered by 1, 4 or 16 access-points with a relative reach distance of 1, .5 or .25. The functional capacity of these three configurations are shown in Table I.

When total system coverage is obtained from a "carpet" of a large number of access-points and when reach is limited by time dispersion, the system capacity per unit coverage varies as $1/(\text{reach})^3$. The power required doubles each time the rate doubles (3 dB), however the path loss is reduced 6 dB when the reach is halved. Net, 3 dB less power is required each time the reach is halved.

Assuming that the time dispersion limit on data rate is a linear function of path length, is not clearly indicated by many interpretations of available experimental data. This assertion must eventually be justified.

For a constant capacity system, the data rate would quadruple each time D is ~~doubled~~ halved. Then the transmitter power would go as $(\text{reach})^4$, and there would be 1/4th as many transmitters, and interfering effect would vary as $(\text{reach})^2$.

FURTHER BENEFITS OF SHORT REACH

There are a number of additional benefits for short reach which are noted below, but not further discussed in this contribution.

C Required transmitter power and battery drain are minimized

There is great importance to protecting the possibility of battery powered stations and line-powered access-points. Too much complexity in the receiver or too much speed in the logic can make sufficiently low current drain unattainable.

D The shorter the reach, the greater the probability of an optical (unobstructed) propagation path between station and access-point.

A short path to the station increases the signal-to-interference ratio. The longer path from the interferer is much more likely to be obstructed and further attenuated. Ultimately, the capacity of the system is determined by the ratio of the service range to interference range as it controls the separation between independently usable access-points.

E Downward directed antennas at access-points are increasingly attainable at shorter distances.

It is important that access-point antennas have reduced radiation levels upward and at flat horizontal. This further increases the signal cut-off rate (amplitude/distance slope) at the edges of the desired coverage area.

F Smaller service coverage area for each access-point decreases the likelihood of propagation shadows.

While shadows are often lighted by bounce signals, these are the signals that are contaminated by multipath time dispersion. It is commonplace to over-power radio systems to provide the margins for indirect coverage. A substantial power gain (20-30 dB) is available from avoidance of dependence on coverage by reflection or scatter.

Inducement for Longer Reach

Longer reach is often sought on the assumption that access-point equipment is expensive both for purchase and installation. The hope is that system cost will be lower when fewer access-points are used.

Superficially, the question depends on the relative cost of a simple radio and a complex radio with a better reach-rate product. The better radio will not only cost more, but it will be larger, take more power and take much longer to develop and secure agreement on the correct air-interface. Even more subtle, the more complex radio will take more time to acquire clock and recover from path outage.

It is believed that multiple access-point plans will evolve with low cost electronics.

> The lower cost and higher performance system will result from selection of a short reach system plan using many simpler transducers at the access-points.

Growth in Reach-rate Capabilities

Assume that a starting technology is based on a simple receiver with one monopole antenna at the station. A number of enhancements may evolve which would increase the reach-rate product without changing the air interface or higher level protocol.

Assume that the second generation receiver has a multi-port receiver with selection diversity between three antennas oriented XYZ. There would be a great improvement.

Suppose that there are multi-port selection diversity receivers at each access-point driven from directive antennas with a horizontal beamwidth of 30°. These narrow beam antennas are much less affected by large-delay off-course multi-path signals, and would produce a significant improvement in the maximum rate at a given reach.

> The selection of a simple modulation and receiver design does not preclude evolutionary growth in the available reach-rate product. There are several ways to increase performance with more complexity and insight into the exact nature of the impairments.

SINGLE CHANNEL SIMPLEX OPERATION

LAN traffic is directionally unsymmetrical in packet size and volume; and this is quite different than telephone circuits. Potentially, full duplex is inefficient for LAN, and this is also the case for voice if there is no transmission of silence.

For wireless LAN there is a possibility of direct peer-to-peer communication which cannot be accomplished except with single channel operation.

A fundamental reason for two-frequency operation in land mobile radio is avoidance of receiver overload by other mobile transmitters that are nearby and might be on channels only one or more slots distant from the operating channel. The receiver dynamic range required is far less with two-frequency operation.

The present wireless LAN does not have this problem because the nearby transmitter is the only transmitter that is ON and the station does not have to receive through it. This is inherent in time division multiplexing. Nearby transmitters for another service (such as a PCS subscriber unit) might be a problem where nearby = 1 meter.

ENHANCEMENT OF INDEPENDENT USE OF A COMMON CHANNEL

Interference limited system design is well recognized as one of the essential elements of a cellular system. It is easy to set a geographic definition of a separation between two fixed stations for which they are non-interfering. It is much less clear for a mobile station that wanders around.

If Access-point N is within interference range of Access-point X, and the distance between them is continuously decreased from far; a point is reached where the coverage of N starts to decrease on the near side. With much less spacing, N still has coverage; but it is a circle of diminished size and the center is offset away from the interference.

If access-points are artfully located, the probability of stations being close rather than far can be considerable biased. In this case, closer access-points can have a low interference probability.

It is necessary for a smart controller to the received level of a communication station at Access-point N to decide whether Access-point X is actually capable of interfering. It would help to know the azimuth of the station to 1 part in 8 (maybe 4).

> It is **mandatory for access-point receivers to report the signal level to a central controller** to enable implemention of smarter algorithms for independent use of other nearby access-points without harmful interference. This will increase the number of parallel reuses possible within a fixed number of access-points.

CENTRAL CONTROL OF ACCESS

A form of system operation using the above described topology and dependent on a central controller is defined and assumed. The explanation for this definition follows.

System Definition (Partial)

1) Each access-point in one cluster or system is connected to a port on a common-equipment by two unshielded telephone twisted pairs.
2) A transmission from a station may pass through any one or more access-points to reach the central controller. Two consecutive transmissions may use different access-points.
3) Stations are expected to receive transmissions only from the nearest access-point and directly from some nearby stations.
4) Stations transmit only after a "permission" message from the central controller. Stations know nothing about the overall status of the system.

Required Centrally-controlled Functions

The grant of access for stations must be centrally controlled contrary to the philosophy of other 802 LANs. The alternative is to broadcast all transmissions to all stations and to provide in each the logic to determine that its transmission is permitted.

With many access-points, broadcast by simultaneous transmission causes much air-time to be used for implementation of a principle, but which in most cases is to provide idle stations with information about which they are not concerned unless they have something to transmit.

In the 802.4 and 802.5 MACs, a large proportion of the station logic is concerned with access control and provision for recovery from lost transmissions.

> Minimum logic and cost in stations is obtained by locating access control centrally.

Message-based Access Control

The central controller must perform at least the following functions:

5) to solicit and record registration messages from stations newly activated on the system.
6) maintain a directory of active stations and the preferred access-point port through which they can be reached currently.
7) operate a background poll to detect deactivated stations which have not informed the controller of that change by message.
8) to forward datagrams to each station as received from other stations or from an interface to external networks.
9) to solicit requests for access from stations and to grant permission for stations to send datagrams at times selected to be non-interfering with other users in the system.

At a later date, a contribution will be offered with a full in-band message-based access protocol designed to perform these functions.

CONCLUSIONS

The value of minimizing the distance between access-points and the air path-length is very high, because it also minimizes size, cost, complexity and power drain. Because parallel use is possible, the capacity of an array of access-points can be quite high.

Above all: Unless reach is minimized, the potential for interference to existing 1.7 - 2.3 GHz services may prevent FCC authorization of use of these frequencies for many years.

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ATTACHMENT A
RULES FOR OTHER USER REACH--INTERFERENCE TRADEOFF

GENERAL

The interference from a radio LAN system to a fixed point-to-point microwave system can be calculated (estimated), a subject to be taken up in a later contribution. The proportionality of this interference depends, in part, upon parameters of the radio LAN, particularly transmitter radiated power and the intensity of usage of the aggregate of all transmitters. It is possible to estimate the significance of the reach requirement against this interference potential.

The estimate assumes a small area over which the distance and antenna factor of the microwave system are constant. The aggregate power of all interferers is summed with each weighted by its ON-time duty cycle.

Shown below are the tradeoff rules which are believed to apply.

Given:

1) Uniform grid of RLAN transmitters and receivers with spacing pitch = D and transmitter EIRP = P on a level surface.

2) All radio LAN antenna heights are equal with omni-directional patterns.

3) All transmission paths are optical.

4) The total data capacity is held constant for comparisons.

5) The interfering effect is proportional to the power sum of all transmitters which are operated simultaneously within an estimating area.

6) The transmission bandwidth for both LAN and existing user radio systems is equal and cochannel.

RULES

A) For a given D and P, the interfering effect is proportional to the total data traffic carried within the estimating area, and independent of the rate at which it is carried and the distribution between transmitters.

e.g.: If the rate is doubled, then the required transmitter power is doubled, but it transmits only half the time contributing the same average power as before.

B) The interfering effect of a given system design for a fixed capacity is proportional to the square of the maximum reach of each access-point.

e.g.: If D is doubled, then the required reach is doubled and the transmitter power must be increased by 6 dB on this account. To maintain the same transmission capacity, the rate must be increased proportionally to the increase in coverage area for each access point (a factor of 4), because one access-point replaces four, and because the reuse distance is doubled; and this requires a further 6 db increase in power at each access-point. Since the number of access-points is decreased by a factor of 4, the power sum is decreased 6 dB.

C) If an increase in reach requirements results in non-optical paths, then 12 dB per octave increase in transmitter power is required minimim plus fade and shadow margins.