IEEE 802.11
802 LAN Access Method for Wireless Physical Medium

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TITLE: **LIMITATIONS OF CSMA IN 802.11 RADIOLAN APPLICATIONS**

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OVERVIEW

In 802.11, there have been several contributions recommending that the Committee adopt CSMA (Carrier Sensing Multiple Access) as the keystone of the 802.11 Access Protocol. The primary motivation is seen to be the desire to truncate argument about alternatives in the interest of getting on with the Standard drafting.

There is no issue concerning the importance of early completion to meet the market needs of portable computers, but there is an issue on the competence of a system using Carrier Sensing as a primary part of the access method. The reasons why the use of this method will not produce the desired result are now presented.

CONCLUSION: "ACCENTUATE THE POSITIVE"

What is the alternative to CSMA? The rules for a radio system are:

1) do not depend on absence of signal as a logic state.

2) do depend on presence of signal with coded information that identifies the transmitting station and system, defines the purpose of the current transmission and offers a basis to estimate how long the channel will be in use for the current and related transmissions.

The information in 2) above has meaning to each receiving station that is involved or wants to use the channel subsequently. The necessary information for the transmit decision is not deducible from inconclusive carrier absent information.

The history of practice of both the negative and positive views of these principles goes back to 1960 and before. There are many lessons that do not need learning yet again.

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Definition of Radio CSMA

Each station desiring to transmit, listens on the Channel first. If no signal is heard, it is assumed that the Station is clear to transmit. The system may be enhanced by requiring immediate ACKnowledgment from the addressed Station. This would be a way of detecting unsuccessful transmission, but not the cause of failure where collision is one of several explanations.

ACK is not part of the 802.3 MAC. If left to the higher layer functions, there is the possibility that an unplanned high frequency of message repeats will overload or disturb normal processing capacity.

Basic Differences

The main reason for a different MAC is that one of the basic assumptions of the wired system does not apply to radio systems, namely: broadcast mode rules are invalid on radio. Broadcast mode means: when one station transmits all others in the LAN can receive well enough to accurately decode the message.

In a radio system: when one station transmits, an unpredictable number of other stations can hear the transmission directly well enough to decode. An unpredictable number will experience interference when two stations transmit simultaneously some of which will receive the stronger signal without knowing the weaker is there and some of which will receive neither.

The baseband cable system in which CSMA is successful has less than 6 dB end-to-end loss, but the radio system will have at least a 50 dB dynamic range between strongest and weakest usable signals.

RADIO SYSTEM PROPERTIES

Provided that distance attenuation of the cluttered path is about 37-39 dB per decade the following practical rules apply:

1) If the design maximum service range is 1, Stations at distances up to 4 will create destructive interference to Stations receiving service at maximum range.

2) If the service range is 1, Stations at distances up to 16 may be received within the service area at levels above receiver sensitivity and which are not necessarily decodable in any way. Under anomalous conditions, the range for detectable signals can be much greater.

3) If a Station is receiving service at range 0.5, Stations at distances greater than 2 will not normally cause interference.

4) Systems which maximize frequency reuse are range limited by cochannel interference, not by path attenuation. Background signals are commonly present or detectable while useful communication is taking place.

5) If a system is designed on the basis of an interference range of 3 rather than 4 (more intensive frequency reuse), it will still work but the interference probability is increased.

Low frequency reuse numbers in the range of 7 to 12 have been used. Such increased reuse is more likely to be successful when the geographical distribution of traffic load is peaked in specific localities and where the access-points are placed in the middle of these density peaks.

Conservative reuse numbers are in the range 16-25 with 21 being very common. Clearly there is a tradeoff between service reliability and spectrum efficiency for frequency division channelized systems.

It is possible to influence the necessary reuse distance by choice of modulation. Pure binary modulations are more tolerant to cochannel interference from like signals, than are modulations with more than two phases or amplitudes in a data symbol.

> Spectrum efficiency is more rapidly improved by interference tolerance in modulation technique than by bandwidth compression from use of multi-level modulations.

Co-channel Protection Ratio

This ratio is the necessary level of the desired signal relative to interference at which degradation of the desired signal is negligible. At 11 dB/octave of distance attenuation, a distance ratio of 4:1 implies 22 dB difference between desired and interfering signal. This is about what some experimental results have shown for one particular digital modulation neglecting Rayleigh fading probabilities. Fade allowance would add at least 7 dB more to the required margin.

Math and Topology

The resulting ratios for systems of hexagons have been worked out before 1977. In a "carpet" plan it is questionable as to how many interferers should be considered. The first circle of closest access-points is 6 for hexagons and 4 for squares. It is improbable that all of the worst case conditions will exist simultaneously. A brief summary of results is shown without detailed demonstration.

For a square coverage model: The nearest reuses are vertically, horizontally and diagonally. The worst case distance for desired coverage is a diagonal corner now assigned distance = 1 from a central access-point.

Reuse level:	4	9	16
Diagonal distance:	4	6	8
Cartesian distance:	~2.9	~4.3	~5.7

The worst case for the desired signal is in the corner of the square. The interference considered is that of multiple access-points transmitting toward the mobile. Location distribution probability makes estimation of the Station to access-point interference much more complex to estimate.

It may be concluded that safe system design requires many more separate derived channels than does what is necessary to work on a probability basis.

CONSEQUENCES OF A CSMA ACCESS PROTOCOL–PEER-TO-PEER

The ideal circumstance for CSMA is operation in a rural or light density suburban area where other like systems are at a great distance.

If used in the inwardly oriented shopping Mall, a small system on a given channel would be inhibited from transmitting by signals originating from an illogically great distance (e.g. another Mall). Assuming that frequency division channelization is used, the intermodulation products from the mixing of two transmitters on other channels would create detectable carriers sufficient to inhibit transmission without need.

Inhibiting transmission from other nearby systems may seem alright. It could work as a form of self-regulated time-sharing. This is true if the aggregate load is light--under 5% use of air time.

There is a non-obvious difficulty with CSMA. When a Station about to transmit hears no signal, it is not a conclusive indication that no interference will be created. The case exists for a distant communication where the distant transmitter is inaudible, but if transmission is initiated, the distant receiver will be interfered with.

CONSEQUENCES OF A CSMA ACCESS PROTOCOL--CENTRAL REPEATER

Even though a two-frequency central repeater (headend) architecture precludes direct peer-to-peer communication, it has other advantages to justify consideration.

By definition a central repeater can hear all transmitters served by that repeater. This is accomplished with a favored location and antenna design. Using separate frequencies for up and down links, the repeater can rebroadcast whatever it hears. A Station knows whether its transmission is successful because it can hear the rebroadcast in real time. A similar situation exists in broadband cable systems with headend.

For use in broadband cable systems, some 802.3 protocol components (ASICs) match bits for the first several octets of transmitted and received messages to detect collisions.

Inter-action Between Separated LANs

If there are two or more like type cable LAN systems in the same building (co-located LANs), there is no interference between them. Like type co-located radio LANs do interfere with each other, and may have extensive overlapping coverage.

If a Station monitoring downlink frequency on System 1 hears no signal, it is inconclusive whether there is also no signal being originated on Systems 2, 3 or 4 because there is no guarantee that a Station can hear any other than his own repeater.

On the other hand, if a Station does hear a signal, it could be from Systems 2, 3 or 4 just as well because there is no guarantee that he cannot hear the other systems. In this case the Station is incorrectly blocked from transmitting.

Duplex Efficiency Limitations

A two-frequency system inherently provides a full duplex medium whether or not it is needed. With CSMA, the sole function of the downlink transmission is to inform all Stations that a busy condition exists whether or not they need to know--when the system is being used to route traffic out of that LAN via headend bridging.

Two-frequency duplex is highly inefficient when the traffic is one-way bursts as is much of 802 type packets. This traffic is directionally asymmetric in detail. If the access protocol depends on the duplex property, it is probable that the two directions cannot be loaded with independent traffic simultaneously. The generality is that on the average it can only be efficient when the traffic is directionally symmetrical and the two directions of flow are independently loaded.

SIMULTANEOUS SEIZURE WINDOW

If two stations start to transmit consecutively, there is a certain time interval over which they will like two consecutive events. As that time difference approaches zero, the possibility exists that they will transmit simultaneously defeating mechanisms intended to prevent that occurrence.

One mechanism occurs by chance. A first station transmits, but due to propagation time and delay inherent between input and output of a radio receiver, a second station starts to transmit at a later time which is less than this delay. The second station was unable to detect carrier in time to inhibit transmission. The total delay interval from propagation and circuit reaction is a "simultaneous seizure window" the magnitude of which must be minimized.

Simultaneous seizure can be made to occur by CSMA logic. Carrier is detected on the channel by two stations intending to transmit. When the carrier goes off, both transmit simultaneously without hearing the other.

Remedies for this have been used. A random delay is introduced between the end of carrier present and the beginning of transmission. There is some art in using this method and maintaining fairness. This logic is also defeated by circuits called "channel grabbers," an opportunity for hackers.

A subtle reason why frequency division multiplex and narrow channels are adverse in LAN is that they have inherently longer response delay than wider channels. This delay matters.

HISTORY OF CARRIER SENSING IN MOBILE TELEPHONY

Before 1960, carrier sensing was used to indicate a busy condition to a lamp indicator on telephone switchboards serving mobile telephone systems. It was well known that Operators repeatedly responded to carrier indications when no one was there.

After IMTS was developed (1960-64), an idle channel was marked with tone to indicate where the next use should take place. It was soon discovered that mobiles could not distinguish between idle tones from contiguous systems using the same channel groups. This problem was never resolved except by greater system separations.

After 1974 (Rydax ACS) and 1977 (Nordic), data messages were used to setup connections.

In cellular HCMTS (1978), there are 21 color-coded set-up/signaling channels broadcasting a data stream that is common to 312 talking channels (USA/Canada). Everything is done with ping-ponged data messages. Is there not a lesson here?

IEEE 802.4L

Many of the Committeemen, who did not take part in 802.4L, should be reminded that there have been repeated attempts to convince that wireless LAN Committee to figure out a wireless extension to 802.3 CSMA/CD. 802.11 was formed on the conclusion that wireless required it's own MAC, and would not be satisfactory with an adaptation of an existing 802 MAC.

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