IEEE 802.4L

Through-the Air Physical Media, Radio

Minutes of the IEEE 802.4L Working Group

Phoenix, Arizona
November 9, 1988

Chairman. Vic Hayes

Secretary & Editor. Michael Masleid, Chuck Thurwachter.

Attendance.

D. Buchholz	Motorola, Inc.	(312) 632-5146
Rich Formeister	Fairchild Data Corp.	(602) 949-1155
Vic Hayes	NCR	31 3402 76528
Don Johnson	NCR	(513) 445-1452
Michael Masleid	Inland Steel Co.	(219) 399-2454
Tom Phinney	Honeywell, Inc.	(602) 863-5989
Orest Storoshchuk	G.M. of Canada	(416) 644-6994
Chuck Thurwachter	ITI	(313) 769-4292
Bruce Tuch	NCR	31 3402 76468

Contributions. If possible, send contributions to Vic Hayes early enough so that he has time to put the information into peoples hands before they come to the meeting.

Approval of minutes. Chuck Thurwachter moves that the minutes of the Danvers meeting be approved. Michael Masleid seconds. Vote: 9-0-0. PASSED.

Mailing list. People not present for two consecutive meetings are removed from the mailing list.

Editor. Michael Masleid and Chuck Thurwachter agree to edit the document. Michael will edit using MS Word, Chuck will do graphics.

Meeting Plan. The next interim meeting is scheduled to start January 16th at 1:00 PM, and end January 18th at noon. The meeting will be held at the O'Hare Hilton, located within O'Hare Airport, in Chicago. Contact Chuck Thurwachter (313) 769-4292.

Objective. Generate section 20, Radio Bus Physical Layer, and section 21, Radio Bus Medium for addition to the IEEE 802.4 Token-Passing Bus. The overall meeting schedule hopes to produce the final draft at the November 12-16th, 1990 plenary meeting in Phoenix. The radio bus sections will deal with microwave signalling. Infrared signalling will not be included as part of the radio bus sections. Infrared signalling is within the scope of the 802.4L working group and could be included in additional sections, however, the focus of the current working group is limited to microwave.

Working Document. A working document will be maintained that includes the objectives, directions and decisions, section drafts, and table of contents. This should include a record of the basis of the directions and decisions.

Contribution by Bruce Tuch of NCR. Bruce presented a paper titled Communication Over An Indoor Radio Channel, November 1988. The paper describes a modulation technique using a single receiver single transmitter model. NCR is doing prototype development focused on environments interesting to NCR, supermarkets and open offices, however, the technique may also be suitable for factory floor environments and multiple antenna head end topologies. Path attenuation is higher and path lengths are shorter in indoor environments. Their test indicate that the delay spread parameter (echo delay time) is smaller than indicated in the literature for outdoor environments. Small delay spread allows higher symbol rates. The measured value is 30 nS rms delay spread. The technique should achieve a net data signalling rate of 1 Mb/s.

Outage. Error rate as described for the token-passing bus is a single parameter that applies to all signals equally. In radio, two parameters are used. Bit error rate (BER) applies to signals that can be received. Outage describes the fraction of signals that can't be received due to shadows or signal cancellation. Bit error rate is controlled by using a forward error correcting (FEC) code. Outage is controlled (somewhat) by diversity.

Protocol tolerance to outage. The current version of the token-passing bus protocol does not tolerate asymmetrical outages. A station that passes the token, and hears nothing, will pass the token again. If the first token is transmitted successfully, and a second token is transmitted because the receive channel is blocked, then two tokens are put into circulation. Two tokens cannot be tolerated. The protocol requirement is that if a station can transmit to any other station, then it must be able to hear something (sense carrier at least, not necessarily data), when any station is transmitting.

Discussion:

What parameter of outage is needed for the token bus protocol? A protocol like Aloha net is needed. Transmit blind (no assumption that the message is received). Use a protocol with acknowledge, and a control passage mechanism that can recover from an outage. The 802 protocols were all devised assuming non fading media.

To achieve non fading, and control cost, a head end approach similar to what was proposed in broadband might be used. The reverse (switched) channels to the head end could be FSK with most of the cost of the receiver in the head end, the forward (continuous) channel out from the head end could be PSK. The long acquisition and lock time of PSK doesn't matter on a continuous channel.

The real problem with fading is in duplicating a token. I send it to you and I don't hear it, so I wait, and I send it to you again, but in the mean time you've passed it on, you think it has come back to you when you hear it the second time and in fact you've sent two tokens running around the ring. To prevent this from happening, you don't have to hear the message correctly, you only need a sense of channel busy. The protocol itself really has a ternary channel state: silent, busy (energy present), and busy with data. The head end could send silence (pseudo silence). If the station could not hear pseudo silence the station should know not to transmit. (The head end can also send clock, simplifying reverse channel design.)

The head end approach is (assumed to be) a dual frequency design, with a large cost associated with the head end. This may be typical for a factory application. A network of personal computers in an office may call for a low cost installation - a single frequency design, all stations the same, with costs divided equally among stations. The office may be small enough that the outage rate is acceptable without use of a head end. The standard should not require that a head end must be used.

More work needs to be done to see what can be achieved in reducing the asymmetrical channel outage. Specifically: reducing the probability that a station's transmitter can generate busy with data at other stations, while the station's receiver can only hear silence from other stations.

Modulation (Spreading Code). NCR proposes a direct sequence spread spectrum modulation technique that satisfies current FCC 15.126 rules without requiring wavers. The product (modulo arithmetic) of the MAC or FEC symbols and a short pseudo random sequence is transmitted. The sequence is 10 to 31 bits (chips) long per MAC or FEC symbol. This increases the bandwidth of the transmitted signal by an amount equal to the number of chips used. The received signal is multiplied by the same pseudo random sequence, restoring the original symbols.

Discussion:

If the pseudo random sequence (the spreading code) is correctly chosen, the receiver can take all of the energy received in one symbol time and concentrate it into one chip time. Interfering signals, on the other hand, are broken up by the receiver's multiplication process, and remain spread over the whole symbol time. The ratio of symbol time to chip time is the processing gain. High processing gain helps separate signal from interference. Unfortunately, increasing the processing gain (number of chips) requires a proportionate increase in receiver bandwidth. Increasing the bandwidth increases the number of potential interfering signals. If the FCC rules limit the total power that can be transmitted regardless of bandwidth used, there is little to be gained by increasing the spreading and bandwidth beyond the minimum allowed by the FCC.

If multiple widely separated antennas are used (with a headend) to increase diversity to the station, and the difference in path delay is greater than the path resolution (about one chip time), then the same frequency and code can be transmitted at all the antennas.

NCR proposes that minimal spreading should be used. This will allow the available spectrum to be divided into several bands. Co-located LAN's can then be assigned to the other bands (frequency multiplexing). In areas where other bands are used, frequency selective filters can be installed in front of the receivers as needed. A frequency selective filter can produce more interference rejection from co-located LAN's than can be achieved by using the same bands with different spreading codes. The minimum spread allowed by the FCC is 10 dB, equivalent to spreading codes of length 10 or more. NCR proposes using a value of 10 to 15 chips per symbol transmitted. For a 1 Mb/s data signalling rate, the transmission will be spread over perhaps 6 MHz, in an 83 MHz wide band there is room for many other channels.

Modulation (R-F channel). NCR proposes that the channel modulation should be quaternary differential phase shift keying (QDPSK). In this form of modulation, the channel symbol is conveyed by a signal that can be at one of four possible phase angles. The channel symbol is coded by the change in phase of the signal since the last channel symbol. The change, not the absolute phase angle, of the signal is important. A long preamble to determine absolute phase is not necessary. The way the phase changes (smoothing function) from one channel symbol to the next has not been determined. It will be picked to reduce spectrum usage, and to allow for subsequent non linear processing. (The transmit waveform can be chosen so that it will tolerate a non linear power amplifier.)

Path diversity. The differential phase shift keyed modulation technique allows use of multipath reflections to provide redundant communication paths. Imagine the spread spectrum signal put through a matched filter. (In this case the matched filter is a black box who's impulse response is the time inverse of the spreading code). The output of the matched filter will have correlation peaks (width equal to chip time, height above noise equal to processing gain) that correspond to the data that was being sent. The peaks will be separated by the channel symbol time (1.25 λs using 2 MAC or FEC bits per filtered channel symbol). Multipath reflection will cause the individual peaks to broaden or separate into a cluster by an amount equal to the delay spread. As long as the delay spread is larger than the chip time and smaller than the filtered channel symbol time, reflections improve the signal. The carrier phase of reflections within a group is random. This would not be good using coherent phase detection. But - the carrier phase of reflections between groups is not random. If the signal from one group is delayed one channel symbol time and multiplied by the signal in the next group, the phase shift between the groups is invariant and can be determined. (For instance: If there were only two channel symbols 180 degrees apart it would be enough to observe whether multiplier output polarity changed from one symbol to the next. In reality, there are four channel symbols 90 degrees apart, so 90 degree phase shifters must be used to recover the additional

symbols.) The paths are essentially time invariant over one symbol time even for moving vehicles (actually, the channel is time invariant over ~1300 symbol times), so the phase shift between symbols is the same for the line of sight signal, and for all of the reflections too. Since the phase shift changes are the same, the output of the demodulator is also the same for the line of sight signal and for the reflections. After demodulation the broadened correlation peaks can be integrated to provide a post detection integration (PDI) of the path diversity sample.

Timing. Normally, delay spread is small compared to channel symbol time. This results in distinct correlation peaks that can be used to recover channel symbol timing. The channel symbol timing can then be used to gate the correlation peaks in, and gate the inter peak noise out. The channel symbol time corresponds to a distance of 375 meters or 1230 feet. In open places this large, some care in antenna placement and aim is needed to control delay spread.

Antenna. There is no problem with antennas being too large. In fact, at 2.5 GHz, there is a problem with an omni directional dipole antenna being too small to capture much signal. It may be that a slightly longer antenna is needed, with some gain in the horizontal direction. It is expected that receiver thermal noise will be less than man made interference. Actually, the transmitted signal itself may be less than man made interference. Microwave ovens emit as much as one watt (though it should be below 100 mW). Through the air media transmit power is expected to be between 0.1 to 1.0 watts per antenna. It is a peculiarity of the FCC regulations that power to the antenna is regulated, but not antenna gain. A very high gain antenna can result in high power density. No bio-hazard is expected. Through the air media will usually use omni directional antennas with very low gain.

Contributions are needed in the following areas:

The token passing protocol is sensitive to signal outage. The failure mechanism has been covered here. The discussion indicates that if outages are symmetric (can't hear, can't talk), and if a robust carrier detect can be provided (always detects carrier when present, sometimes when it is not), then the token passing protocol will work with through the air media. How well can through the air media be made to accommodate the protocol?

Path diversity reduces the probability of outage. Large delay spreading limits possible data rate. What is the effect of remote antennas on echo contribution in a distributed antenna system?

High level R-F energy can cause biological damage. The FCC limits leakage R-F radiation from microwave ovens. What power level is hazardous? What power level will occur with through the air media?

Additions to directions:

Bruce Tuch moves that the use of differential phase modulation be added to the directions. Tom Phinney seconds. Vote 7-0-0. PASSED.

Bruce Tuch moves that the use of direct sequence spread spectrum be added to the directions. Tom Phinney seconds. Vote 7-0-0. PASSED.

Bruce Tuch moves that the spreading sequence to be chosen shall have at least 10 and not more than 15 chips (a processing gain of between 10 and 15 allowing frequency division multiplexing of co-located LANS). Tom Phinney seconds. Vote 7-0-0. PASSED.

Bruce Tuch moves that the directions should allow systems that receive what they transmit. Such a system does not require a head end and may be more cost effective for small networks. Tom Phinney seconds. Vote 7-0-0. PASSED.

In conclusion: The 802.4L working group wishes to convey thanks to co-chairmen Chandos Rypinski and David Greenstein for the progress we have achieved through their efforts.
