This document provides a base for the discussions of the IEEE 802.4L Working Group. Each decision will be marked in this document along with the reference to the motion on which the decision has been based (column Base) and with the reference of the document on which the present decision is based (Doc no).

After each meeting a new document will be prepared to reflect the decisions made at the meeting.

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1. Scope

To define an alternative Physical Layer for Through-the-air communication, which is part of a local area network using 802.4 media access techniques and which is primarily for mobile environments.

2. Purpose

To provide LAN access to moving automatic machines and other stations for which wireless attachment is appropriate.

To add description of standards criteria for through-the-air transmission parameters to support Physical Layer Service.

To prepare, if necessary, a petition to the FCC for rule making which authorizes use of radio spectrum for wireless LAN.

3. Directions

3.1 Design Principles

- 1. Meet FCC rules - spreading, scrambling, power, etc.  
  - 2. Meet 802.4 requirements implicit in ISO DIS 8802-4 1-10  
  - 3. Economy  
  - 4. Permit adjacent 802.4L-conformant radio LANs  
  - 5. Provide for both single-channel (direct peer-to-peer) and dual-channel (head-ended) operation  
  - 6. Single-channel system size: The objective is to permit a system diameter of 300 m. The minimum acceptable system diameter is 100 m.  
  - 7. Modulation technique must support office, retail and industrial environments.  
  - 8. Want high data rate at required BER and outage.  
  - 9. Robust with respect to multipath  
  - 10. Want to accommodate relative motion between Transmitter and Receiver  
  - 11. For a given operating band (902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHz), want the interoperability relationship of differing modems to form a direct inclusion relationship (full and not partial ordering).

Points of interoperability:
finish definition of the primary air interface before considering any other interfaces.

3.2 System plan

The radio system plan for one community of users is proposed to be a single frequency bus mode with head end, but will accommodate single frequency station-to-station operation for small systems. The physical layer including the head end and radio system shall support the existing 802.4 MAC. (Among other things, this implies that when any station is transmitting, all stations must hear something.)

In the single frequency bus mode with head end normal token rotation shall be used, only for stations in the outskirt, immediate response mode will be considered, (see issue 5)

Whatever plan is evolved, it shall be suitable for use under current FCC part 15 regulations, in particular the three bands, 902-928 MHz, 2400-2483.5 MHz, and 5725-5875 MHz.

The 902-928 MHz band will be used in the first standard. At least 2 channels will be accommodated in the band.

V. Hayes, NCR Corporation...

V. Hayes, NCR Corporation...

Nieuwegein, The Netherlands
3.2 Directions (cont'd)

3.2 System plan (cont'd)

To separate transmissions of stations of nearby networks, the preamble will contain a Network Identification.

3.3 System Design Parameters

Relation to the Objective List in [3.1]

1. Use a 7-bit (length-127) scrambler if the adopted chip rate is < 127. [1] The preferred polynomial is $1 + X^4 + X^7$. [1+3]

2. Choose a modulation technique that does not include an amplitude modulation component, for [3] and to lower technical risk.

3. Permit differential demodulation for fast acquisition, to provide robustness for the time-varying (fading) radio channel, and to simplify the receiver [3]. The primary disadvantage of this approach is a 2.3 dB (theoretical) loss in S/N.

4. Use some form of quaternary PSK as a reasonable means of decreasing signaling rate (for multipath) without excessively compromising S/N or [3,7].

5. Spread the minimum amount practical [1,3]. The preferred spreading code is $+ + + + + + + +$. This is a known Barker code, with bounded auto-correlation, bounded periodic auto-correlation, and bounded odd periodic auto-correlation, and good spectral properties.

6. Filtering should consider adjacent channel single frequency (single channel) and simultaneous dual frequency (dual channel) operation. [4,5]

7. Initial focus should be on 902-928 MHz band. [3]

8. The design goal for the overhead of each Ph-PDU be 25 octets or less. This includes synchronization pattern, network id, CRC on the Ph-PDU content, and FEC flush. Note that the overhead can be different for the forward and reverse channel.

3.4 Modulation

Differential Phase Modulation shall be used.

Doc: IEEE 802.4L/89-16 is adopted as the basis for the description of the modulator.

For the spreading sequence at least 10 and not more than 15 chips shall be used. This provides a processing gain of between 10 and 15 allowing frequency division multiplexing of co-located LANs.

3.5 Encoding

The goal is to encode the preamble and the frame delimiters without increasing the signal constellation.

It is suggested to encode the MAC non-data symbol by a different chip sequence (e.g. Barker-11 backwards).

V. Hayes, NCR Corporation

Nieuwegein, The Netherlands
3.6 Data Rate

The data rate for comparison purposes shall be 1 Mbit/s. We can only consider the IEEE
data rates of 1 to 20 Mbit/s.

3.7 Distribution System

The design model shall assume a 16 antenna array in a square grid. For purpose of
analysis, it will be assumed that the antenna array is driven by one power splitter with equal
length loss cable from the splitter to each antenna.

3.8 Performance definition

The performance of the Token Bus standard will be expressed in the number of MAC
Service Data Units with undetected errors per time unit, at 0 frame overhead.

The performance requirement is: less then one MSDU with undetected errors per year at
200 bit data units.

The frame loss rate shall be less then 1 per $10^{-5}$ frames transmitted.

3.9 Bit Error Ratio

The Bit Error Ratio (BER) at the MAC/PHY interface shall be $10^{-8}$ or less achievable in
all but $10^{-3}$ or less of the area of spatial coverage of the system in a minimally-conformant
system, and where additional antenna and receiver diversity can be used to reduce the area of
outage as required.

3.10 Outage

MAC protocol assumes the communication channel is always available. Since the radio
medium is known to have an outage rate on the order of $10^{-2}$, a method is required to reduce
outage rate to less than $10^{-5}$.

3.11 Velocity ranges

The following are the ranges for the velocity of the stations:

- 902-928 MHz: 0 - 53.7 miles/h
- 2400-2483.5 MHz: 0 - 20.0 miles/h
- 5725-5875 MHz: 0 - 8.3 miles/h

3.12 Transmission Power

- XMTR power output: 1 W max
- Station antenna gain: TBD
- Station antenna directivity: TBD
- Receiver noise figure: 6 dB at 902-928 MHz
- 8 dB at 2400-2483.5 MHz
- 10 dB at 5725-5875 MHz

For a distributed antenna system, we assume that each transmitter should be measured
separately (for complying with the regulation). The transmit carriers should not be phase
locked but should be approximately the same frequency.

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Nieuwegein, The Netherlands
3.13 Error correction codes

The goal is to avoid the use of Forward Error Correction code, if possible.
- Allowable overhead: 1.2x
- Type: TBD
- Spectral efficiency: TBD

3.14 Propagation

Office/retail environment: 6 dB/decade under 10 meters

<table>
<thead>
<tr>
<th>Environment</th>
<th>Slope</th>
<th>Standard Deviation</th>
<th>Exp</th>
<th>RMS Delay Spread (within 20 dB from max peak)</th>
<th>Coherence Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>open retail</td>
<td>10-13</td>
<td>4-7</td>
<td>3.3-4.2</td>
<td>80-140</td>
<td></td>
</tr>
<tr>
<td>factory</td>
<td>5.4-8.4</td>
<td>5-10</td>
<td>1.8-2.4</td>
<td>100-140</td>
<td></td>
</tr>
<tr>
<td>office</td>
<td>10-12</td>
<td>2-7</td>
<td>3.3-4.0</td>
<td>&lt;50</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Channel characteristics

Coherence time is defined as follows:
Given a time-variant (wide-sense stationary) channel impulse response of

\[ c(T_0) = \alpha(T_0) e^{-j2\pi f T} \]

where \( T \) is the delay and \( \alpha(T_0) \) is the attenuation of the signal
components at delay \( T \) at time instant \( t \).

Let \( C(f) = \int_{-\infty}^{\infty} c(T_0) e^{-j2\pi f T} \, dt \)

be the Fourier transform of this impulse response.

\[ 2\phi(\Delta f, \Delta t) = \frac{1}{2B} |C(\Delta f, \Delta t)|^2 \phi(\Delta f) \]

where \( B \) is the expectation, is called the spaced-frequency spaced-time correlation function.

If you hold \( \Delta t \) to 0 you have the spaced-time correlation function. The period of time over
which the magnitude of this function is essentially non-zero is the coherence time of the
channel.

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1 the environment is not static and thus Doppler effects may occur even when the sending and receiving stations are not themselves moving (with respect to the earth, each other, the surrounding "building", etc.).

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Nieuwegein, The Netherlands
Directions (cont.d)

Table prepared
Nov 89 4L/89-17

Table updated
Jan 90

Noise:
- at 902-928 MHz 10 dB above thermal
- at 2400-2483.5 MHz thermal

Contributions on noise are requested in the following format:

<table>
<thead>
<tr>
<th>Device</th>
<th>Band</th>
<th>distance from source</th>
<th>Power *) level</th>
<th>Number of hits per second Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-10 dB  -20 dB  -30 dB  -40 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>dBm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Characteristics of impulsive noise generators

Table prepared
Nov 89
<table>
<thead>
<tr>
<th>Device</th>
<th>Freq</th>
<th>Power</th>
<th>Bandwidth</th>
<th>Duty cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pager</td>
<td>931.625</td>
<td>340</td>
<td>15</td>
<td>5 sec/call</td>
</tr>
<tr>
<td>-</td>
<td></td>
<td></td>
<td></td>
<td>1 call/5 min</td>
</tr>
<tr>
<td>Radio Channel</td>
<td>904</td>
<td></td>
<td>30</td>
<td>continuous</td>
</tr>
<tr>
<td>Pager</td>
<td>930.0</td>
<td>-50</td>
<td>15</td>
<td>5 sec/call</td>
</tr>
<tr>
<td>Field disturbance</td>
<td>902-928</td>
<td>0.075</td>
<td>&lt;1</td>
<td>continuous</td>
</tr>
<tr>
<td>sensors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part 15 devices</td>
<td>902-928</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>2400-2483.5</td>
<td></td>
<td>.00075</td>
<td></td>
</tr>
<tr>
<td>-</td>
<td>5725-5875</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital oscillators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digital devices</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. Characteristics of Constant Wave Interferers
Directions (cont..d)

NOTES: * reference antenna: dipole for the appropriate band
distance from source > 1 m
vary measurements over a sphere with
at least 10 measurements

* for impulsive noise measurements:
made the measurements in the
 time domain

* for CW measurements:
  include a graph of frequency versus
  time behavior for sweeping
  devices, e.g. microwave ovens.

It appears that the magnetron has a negative resistance on turn-on and turn-off, and this causes relaxation oscillations at the beginning and end of each power cycle, which cause an apparent broadband emission. In reality, during the beginning and end of each power cycle, the magnetron produces a series of very short bursts of carrier (<< 300 ns each) with decaying power and a frequency which changes slightly during the burst, and with more substantial changes in frequency from one burst to the next.

In the middle of each power cycle the magnetron just stays on, with occasional instantaneous frequency changes due to shifts in mode-locking caused by the changing magnetron plate voltage and the motion of the stirrer in the oven cavity. (See addendum L1, and IEEE 802.4L-89/19 for time domain pictures of this phenomenon.) These instantaneous changes may be accompanied by additional bursts. (See IEEE 802.4L90-8a figure 4-46.)

3.15 Antenna

3.16 Higher Layer concerns

When considering the use of the immediate response mode for stations in the outskirts of the coverage area, thus avoiding the higher probability of losing the Token, the implication is that a station can use only the responder services of LLC type 3.

Use of LLC types 1 or 2, or the initiator services of LLC type 3, will cause the station to try to get and later pass the token.
### 4. Meeting Plan

<table>
<thead>
<tr>
<th>Type</th>
<th>Dates</th>
<th>Place</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interim</td>
<td>May 14-18, 90</td>
<td>Atlanta, GA</td>
<td>Prepare second 802.4 draft</td>
</tr>
<tr>
<td>Plenary</td>
<td>Jul 9-13, 90</td>
<td>Denver, CO</td>
<td>Second 802.4 draft</td>
</tr>
<tr>
<td>Interim</td>
<td>Sep ...., 90</td>
<td>?</td>
<td>Prepare 802.4 Voting draft</td>
</tr>
<tr>
<td>Plenary</td>
<td>Nov 12-16, 90</td>
<td>Kauai, HI</td>
<td>802.4 Ballot</td>
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<tr>
<td>Interim</td>
<td>Jan ...., 1990</td>
<td>?</td>
<td>prepare TCCC voting draft</td>
</tr>
<tr>
<td>Plenary</td>
<td>Mar 11-15, 1991</td>
<td>East coast</td>
<td>TCCC Ballot</td>
</tr>
<tr>
<td>Interim</td>
<td>May ...., 1991</td>
<td>?</td>
<td>Prepare Final draft</td>
</tr>
<tr>
<td>Plenary</td>
<td>Jul 8-12, 1991</td>
<td>West Coast</td>
<td>Final Draft</td>
</tr>
<tr>
<td>Plenary</td>
<td>Nov 11-15, 1991</td>
<td>Ft Lauderdale, FL</td>
<td>PM</td>
</tr>
</tbody>
</table>
5. Possible Document Outline

20. Radio Bus Physical Layer
   20.1 Nomenclature
   20.2 Object
   20.3 Compatibility Considerations
   20.4 Operational Overview
   20.5 General Overview
   20.6 Application of Network Management
   20.7 Functional, Electrical and Mechanical Specifications
   20.8 Environmental Specifications

21. Radio Bus Medium
   21.1 Nomenclature
   21.2 Object
   21.3 Compatibility Considerations
   21.4 General Overview
   21.5 Functional, Electrical and Mechanical Specifications
   21.6 Environmental Specifications
   21.7 Transmission Path Delay Considerations
   21.8 Documentation
   21.9 Network Sizing
   21.10 Guidelines
6. Issues

1. Is a Bit Error Ratio (BER) of 10**-8 detectable and 10**-9 achievable with operation with a dual frequency head-end distribution system.

2. Is the BER described in issue 1 achievable for direct station-to-station operation and what is the condition to achieve this BER.

3. What Forward Error Correcting Code (FEC) is suited for channels with burst errors characteristics.

4. Considering the agreement that non-data will not be encoded as a PHY symbol. Find a method of start and end delimiter encoding, e.g., use a combination of an alternative constellation and correlation.

5. What is the characteristic of impulse noise in the various media?

6. What are the implications on the LLC when the immediate response mode is required to communicate with stations in the outskirt?

7. How should a distributed antenna system be represented for billing measurements?

8. What are the trade-offs in data rate vs noise immunity (long vs short codes) [refer to doc: IEEE p802.4L/89-17, pages 6-8]

9. What are the trade-offs of long codes vs short codes at higher frequencies (wider bands) and multiple channels (FDM vs CDM) [refer to doc: IEEE p802.4L/89-17, pages 6-8]

10. What are the noise characteristics for various devices [refer to tables 2 and 3 above]

11. Is table 1 above accurate?

Data on coherence time is needed. Part of the data could be recovered from Oshawa measurements and from Rappaport’s report. More measurements are to be made when the results prove some parameters have been missed.

7. Referenced papers.

The following papers are of interest to the taskgroup members:

- RF Radiation Hazards: An update on Standards and Regulations. By Mark Gomez, Assistant Editor, and Gary A. Breed, Editor. - RF Design, October 1987

V. Hayes, NCR Corporation

Nieuwegein, The Netherlands