IEEE 802.4L

Through-the-Air Physical Media, Radio

Running Objectives and Directions Document

Sixth issue

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.

Table of Contents

Subject	Base	Doc no

1. Scope

Subject	Base	Doc no
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.	PAR	4L/87-014

2. Purpose

Subject	Base	Doc no
To provide LAN access to moving automatic machines and other stations for which wireless attachment is appropriate.	PAR	4L/87-014
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

	Subject	Base	Doc no
- 1.	Meet FCC rules - spreading, scrambling, power, etc.	Jul 89	4L/89-11
- 2.	Meet 802.4 requirements implicit in ISO DIS 8802-4 1-10	Jul 89	4L/89-11
- 3.	Economy	Jul 89	4L/89-11
- 4.	Permit adjacent 802.4L-conformant radio LANs	Jul 89	4L/89-11
- 5.	Provide for both single-channel (direct peer-to-peer) and dual-channel (head-ended) operation	Jul 89	4L/89-11
- 6.	Single-channel system size: The objective is to permit a system diameter of 300 m. The minimum acceptable system diameter is 100 m.	Jul 89	4L/89-11
- 7.	Modulation technique must support office, retail and industrial environments.	Jul 89	4L/89-11
- 8.	Want high data rate at required BER and outage.	Nov 89	4L/89-17
- 9.	Robust with respect to multipath	Nov 89	4L/89-17
- 10.	Want to accommodate relative motion between Transmitter and Receiver	Nov 89	4L/89-17
- 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).	Nov 89	4L/89-17

3.2 System plan

Subject	Base	Doc no
The radio system plan for one community of users is proposed to be a single frequency bus mode with head end, but will accomodate 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.)	Jan 89 Jul 89	4L/89-02 4L/89-11
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)	May 89 Jul 89	
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.	Jul 88	
The 902-928 MHz band will be used in the first standard. ~~At least 2 channels will be accomodated in the band.~~	Jan 90	

Subject	Base	Doc no

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.	May 89 May 89	

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]	Jul 89	4L/89-11
2. Choose a modulation technique that does not include an amplitude modulation component, for [3] and to lower technical risk.	Jul 89	4L/89-11
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.	Jul 89	4L/89-11
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].	Jul 89	4L/89-11
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.	Jul 89	4L/89-11
~~6. Filtering should consider adjacent channel single frequency (single channel) and simultaneous dual frequency (dual channel) operation. [4,5]~~	~~Jul 89~~ Jan 90	~~4L/89-11~~ 4L/90-01
7. Initial focus should be on 902-928 MHz band. [3]	Jul 89	4L/89-11

3.4 Modulation

Differential Phase Modulation shall be used.	Nov 88/1	4L/88-02
Doc: IEEE p802.4L/89-16 is adopted as the basis for the description of the modulator.	Nov 89	4L/89-17
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	Nov 88/3	4L/88-02

3.5 Encoding

The goal is to encode the preamble and the frame delimiters without increassing the signal constellation.	Sep 89	4L/89-15
It is suggested to encode the MAC non-data symbol by a different chip sequence (e.g. Barker-11 backwards).	Sep 89	4L/89-15

Subject	Base	Doc no

Directions (cont..d)

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.	Jan 89	

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 less 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.	May 89	

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 10^8 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.	Sep 89 Jan 90	4L/89-15 4L/90-01

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 10E-2, a method is required to reduce outage rate to less than 10E-5.	Jul 88	

3.11 Velocity ranges

The following are the ranges for the velocity of the stations: (Base: Jan 89)

902-928 MHz	0 - 53.7 miles/h	Jan 89
2400-2483.5 MHz	0 - 20.0 miles/h	
5725-5875 MHz	0 - 8.3 miles/h	

3.12 Transmission Power

		Base	Doc no
XMTR power output:	1 W max	Jan 89	
Station antenna gain:	TBD	Jan 89	
Station antenna directivity:	TBD	Jan 89	
Receiver noise figure:	6 dB at 902-928 MHz	Jan 89	
	8 dB at 2400-2483.5 MHz	Jan 89	
	10 dB at 5725-5875 MHz	Jan 89	
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.		Nov 89	4L/89-15

Subject	Base	Doc no

Directions (cont..d)

3.13 Error correction codes

The goal is to avoid the use of Forward Error Correction code, if possible.		Sep 89	4L/89-15
Allowable overhead:	1.2x	Jan 89	
Type:	TBD	Jan 89	
Spectral efficiency:	TBD		

3.14 Propagation

Office/retail environment: 6 dB/octave under 10 meters — Jan 89

environment	slope dB/octave	standard deviation dB	exp	RMS Delay spread (within 20 dB from max peak) ns
open retail	10-13	4-7	3.3-4.2	80-140
factory	5.4-8.4	5-10	1.8-2.4	100-140
office	10-12	2-7	3.3-4.0	<50

Table 1. Channel characteristics

Table prepared	Nov 89	4L/89-17
Table updated	Jan 90	

Noise: — Jan 89

at 902-928 MHz	10 dB above thermal	
at 2400-2483.5 MHz	thermal	Jan 89

Contributions on noise are requested in the following format:

Device	Band	distance from source	Power *) level	Number of hits per second Threshold			
				-10 dB	-20 dB	-30 dB	-40 dB
		m	dBm				

Table 2. Characteristics of impulsive noise generators

Table prepared — Nov 89

Subject	Base	Doc no

Directions (cont..d)

Device	Freq	Power		Bandwidth	Duty cycle
		EIRP	Receive level		
	MHz	W	dBm	kHz	
(1)	(2)	(3)	(4)	(5)	(6)
Pager	931.6125	340		15	5 sec/call 1 call/5 min
Radio Channel	904			30	continuous
Pager	930.0		- 50 indoor	15	5 se/call 1 call/min
Field disturbance sensors	902-928	0.075		<1	continuous
Part 15 devices	902-928 2400-2483.5 5725-5875	.00075			
Digital oscillators					
Digital devices					

Table 3. Characteristics of Constant Wave Interferers

NOTES: * reference antenna : dipole for the appropriate band — Nov 89 — 4L/89-17
distance from source > 1 m — Jan 90 — 4L/90-01
vary measurements over a sphere with at least 10 measurements

* for impulsive noise measurements: make the measurements in the time domain
* for CW measurements: include a graph of frequency versus time behavior for sweeping devices, e.g. microwave ovens.

Subject	Base	Doc no

Directions (cont..d)

3.15 Antenna

NOTE: If the antenna is located 7 to 10 feet above ground it has 25 dB antenna gain over an antenna in a pocket.	Jan 89	

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.	Sep 89	4L/89-15

4. Meeting Plan

Type	Dates	Place	Objective
Plenary	Mar 12-16, 90 start: March 11, noon	Irvine, CA	802.4 draft
Interim	May 14-18, 90	Atlanta, GA	Prepare second 802.4 draft
Plenary	Jul 9-13, 90	Denver, CO	Second 802.4 draft
Interim	Sep ..-.., 90	?	Prepare 802.4 Voting draft
Plenary	Nov 12-16, 90	Kauai, HI	802.4 Ballot
Interim	Jan ..-.., 1990	?	prepare TCCC voting draft
Plenary	Mar 11-15, 1991	East coast	TCCC Ballot
Interim	May ..-.., 1991	?	Prepare Final draft
Plenary	Jul 8-12, 1991	West Coast	Final Draft
Plenary	Nov 11-15, 1991	Ft Lauderdale, FL	PM

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 detected 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 delimeter encoding, e.g. use a combination of an alternative constellation and correlation.~~
~~4a What is the characteristic of the impulse noise in the various media.~~
~~5 What are the implicatios on the LLC when the immediate response mode is required to communicate with stations in the outskirt?~~
~~6 How should a distributed antenna system be represented for ruling measurements.~~
7 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]
8 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]
9 What are the noise characteristics for various devices [refer to tables 2 and 3 above]
10 Is table 1 above accurate?

7. Referenced papers.

The following papers are of interest to the taskgroup members:

Environmental Monitoring for Human Safety Part 1: Compliance with ANSI Standards. By John Coppola and David Krautheimer, Narda Microwave Corporation. - RF Design--.

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

RF Radiation Hazards: Power Density Predeiction for Communications Systems. By Gary A. Breed, Editor. - RF Design, December 1987

Microprocessor Interference to VHF Radios. By Daryl Gerke, PE Kimmel Gerke & Associates, LTD. - RF Design, March 1988

Distributed Antennas for Indoor Radio Communications. By Adel A.M. Saleh, A.J. Rustako, Jr and R.S. Roman. - IEEE Transactions on Communications, Vol. Com-35, No12, December 1987

UHF Fading in Factories. By Theodore S. Rappaport and Clare D. McGillem. - IEEE Journal on selected Areas in Communications. Vol. 7. No 1. January 1989

Indoor Radio Communications for Factories of the Future. By Theodore S. Rappaport. - IEEE Commmunications Magazine. May 1989.

A differential offset OPSK modulation/demodulation technique for point-to-multipoint radio systems. By Tho Le-Ngoe. GLOBECOM 87.

8. Noise immunity vs spreading.

Constant Power, Varying Chip Rate, Constant Symbol Rate

Quantity	Formula or Nomenclature	$N_c = 1$ Base Case	$N_c = 11$ vs $N_c=1$	$N_c = 127$ vs $N_c=1$
# chips/symbol	N_c	1	11	127
Symbol period (s)	T_s	10^{-6}	1	1
Symbol rate (symbol/s)	$1/T_s$	10^6	1	1
Chip period (s)	$T_c = T_s/N_c$	10^{-6}	1/11	1/127
Chip rate (chip/s)	N_c/T_s	10^6	11	127
Symbol energy (J)	E_s	10^{-6}	1	1
Chip energy (J)	$E_c = E_s/N_c$	10^{-6}	1/11	1/127
Signal out of correlator (V)	$N_c \sqrt{E_s/T_s}$	$\sqrt{E_s/T_s}$	11	127
RMS noise into correlator (V)	$\sqrt{N_o N_c/T_s}$	$\sqrt{N_o/T_s}$	$\sqrt{11}$	$\sqrt{127}$
RMS noise out of correlator (V)	$\sqrt{N_c}\sqrt{N_o N_c/T_s}$	$\sqrt{N_o/T_s}$	11	127
Avg. signal to RMS Gaussian noise out of correlator		$\sqrt{E_s/N_o}$	1	1
E_s/N_o improvement from spreading (dB)		0	0	0

Incoherent Line Interferers Uniformly Distributed in Band (i.e., number increases with bandwidth)

$$L(t) = \sqrt{2} \sum^{\kappa N_c} L_i \cos(\omega_i t + \phi_i) \quad \text{where } \omega_i/2\pi < B_c$$

Quantity	Formula or Nomenclature	$N_c = 1$ Base Case	$N_c = 11$ vs $N_c=1$	$N_c = 127$ vs $N_c=1$
Interference power into correlator (W)	$\sum^{\kappa N_c} L_i^2$	$\sum^{\kappa} L_i^2$	11	127
RMS interference into correlator (V)	$\sqrt{\sum^{\kappa N_c} L_i^2}$	$\sqrt{\sum^{\kappa} L_i^2}$	$\sqrt{11}$	$\sqrt{127}$
RMS interference out of correlator (V)	$\sqrt{N_c}\sqrt{\sum^{\kappa N_c} L_i^2}$	$\sqrt{\sum^{\kappa} L_i^2}$	11	127
Avg. signal to RMS interference out of correlator	$\sqrt{E_s/(T_s \sum^{\kappa} L_i^2)}$	$\sqrt{E_s/(T_s \sum^{\kappa} L_i^2)}$	1	1
E_s/I_o improvement from spreading (dB)		0	0	0

8. Noise immunity vs spreading (cont..d).

M Incoherent Line Interferers in Band
(i.e., constant number independent of bandwidth)

$L(t) = \sqrt{2} \sum^{M} L_i \cos(\omega_i t + \phi_i)$ where $\omega_i/2\pi < B_c$

Quantity	Formula or Nomenclature	$N_c = 1$ Base Case	$N_c = 11$ vs $N_c=1$	$N_c = 127$ vs $N_c=1$
Interference power into correlator (W)	$\sum^{M} L_i^2$	$\sum^{M} L_i^2$	1	1
RMS interference into correlator (V)	$\sqrt{\sum^{M} L_i^2}$	$\sqrt{\sum^{M} L_i^2}$	1	1
RMS interference out of correlator (V)	$\sqrt{N_c}\sqrt{\sum^{M} L_i^2}$	$\sqrt{\sum^{M} L_i^2}$	$\sqrt{11}$	$\sqrt{127}$
Avg. signal to RMS interference out of correlator	$\sqrt{N_c E_s/(T_s \sum^{M} L_i^2)}$	$\sqrt{E_s/(T_s \sum^{M} L_i^2)}$	$\sqrt{11}$	$\sqrt{127}$
E_s/I_o improvement from spreading (dB)		0	10.4	21

Single Impulse Interferer

$v(t) = K\,\delta(t)$				
Energy from filter $2K^2 B_c = 2K^2 N_c / T_s$	$2K^2 N_c / T_s$	$2K^2 / T_s$	11	127
Peak voltage from filter $2 K B_c$	$2K N_c / T_s$	$2K / T_s$	11	127
Peak signal to peak impulse voltage ratio into correlator (V/V)	$\sqrt{E_s T_s} / (2K N_c)$	$\sqrt{E_s T_s} / 2K$	1/11	1/127
Total improvement in clipping potential due to spreading		0	10.4	21
Avg. signal to clipped impulse out of correlator (V/V)				

8. Noise immunity vs spreading (cont..d).

Constant Power, Constant Chip Rate, Varying Symbol Rate

Quantity	Formula or Nomenclature	$N_c = 1$ Base Case	$N_c = 11$ vs N_c=1	$N_c = 127$ vs N_c=1
# chips/symbol	N_c	1	11	127
Chip period (s)	T_c	10^{-7}	1	1
Chip rate (chip/s)	$1/T_c$	10^7	1	1
Symbol period (s)	$T_s = N_c T_c$	10^{-7}	11	127
Symbol rate (symbol/s)	$N_s = 1/T_s$	10^7	1/11	1/127
Chip energy (J)	E_c	10^{-7}	1	1
Symbol energy (J)	$E_s = N_c E_c$	10^{-7}	11	127
Signal out of correlator (V)	$N_c \sqrt{E_c/T_c}$	$\sqrt{E_c/T_c}$	11	127
RMS noise into correlator (V)	$\sqrt{N_o/T_c}$	$\sqrt{N_o/T_c}$	1	1
RMS noise out of correlator (V)	$\sqrt{N_c}\sqrt{N_o/T_c}$	$\sqrt{N_o/T_c}$	$\sqrt{11}$	$\sqrt{127}$
Avg. signal to RMS Gaussian noise out of correlator	$\sqrt{N_c}\sqrt{E_c/N_o}$	$\sqrt{E_c/N_o}$	$\sqrt{11}$	$\sqrt{127}$
E_s/N_o improvement from spreading (dB)		0	10.4	21

Incoherent Line Interferers in Band (i.e., constant number independent of bandwidth)

$L(t) = \sqrt{2} \sum L_i \cos(\omega_i t + \phi_i)$ where $\omega_i/2\pi < B_c$

Quantity	Formula or Nomenclature	$N_c = 1$ Base Case	$N_c = 11$ vs N_c=1	$N_c = 127$ vs N_c=1
Interference power into correlator (W)	$\sum L_i^2$	$\sum L_i^2$	1	1
RMS interference into correlator (V)	$\sqrt{\sum L_i^2}$	$\sqrt{\sum L_i^2}$	1	1
RMS interference out of correlator (V)	$\sqrt{N_c}\sqrt{\sum L_i^2}$	$\sqrt{\sum L_i^2}$	$\sqrt{11}$	$\sqrt{127}$
Avg. signal to RMS interference out of correlator	$\sqrt{N_c E_s/(T_s \sum L_i^2)}$	$\sqrt{E_s/(T_s \sum L_i^2)}$	$\sqrt{11}$	$\sqrt{127}$
E_s/I_o improvement from spreading (dB)		0	10.4	21

8. Noise immunity vs spreading (cont..d).

Single Impulse Interferer

Quantity	Formula or Nomenclature	$N_c = 1$ Base Case	$N_c = 11$ vs $N_c=1$	$N_c = 127$ vs $N_c=1$
$v(t) = K\,\delta(t)$				
Energy from filter $2K^2 B_c = 2K^2 / T_c$	$2K^2 / T_c$	$2K^2 / T_c$	1	1
Peak voltage from filter $2\,K\,B_c$	$2K / T_c$	$2K / T_c$	1	1
Peak signal to peak impulse voltage ratio into correlator (V/V)	$\sqrt{E_c T_c} / (2K)$	$\sqrt{E_c T_c} / 2K$	1	1
Total improvement in clipping potential due to spreading		0	0	0
Avg. signal to peak impulse out of correlator (V/V)	$\frac{N_c}{2K}\sqrt{E_c T_c}$	$\frac{1}{2K}\sqrt{E_c T_c}$	11	127
Improvement due to spreading (dB)		0	10.4	21