Physical Layer Initial Review and Compilation: Infrared Media Conformance Specifications

Rev O
3/4/92
for IEEE802.11 PHY Working Group submission w/o 3/9/92.
Submitted by:

Richard Lee
Spectrix Corp.
P.O. Box 1301
Evanston, Illinois 60091-1301
Tel: (708) 251-5378 FAX: (708) 251-5318

Introduction: This submission is a summary of presentations and research into the available art on free space infrared data and networking systems. The table follows the PHY Working group's Doc. 802.11-92/4 PHY Layer Template Document and table of conformance specifications developed in the January, 1992 meeting. Other contextual information is added in order to properly dimension the system characteristics in a way that anticipates needs of the PHY and MAC groups in structuring appropriate standards. It also attempts to anticipate and address the important characteristics which customers of commercial networking products will seek standard features and performance.

Document Status: This is a "threshold" document in response to Doc. 802.11-92/4 PHY Layer Template Document to meet two goals: Implementation interoperability among different vendors of common devices, and protection or at least control over the network when operation is impaired by inhospitable co-resident networks or non-communication interference which occupies the same signalling channel. It is a first pass at a final set of specifications and dimensions for channel and system compliance standards. Its primary value is to identify the areas where both information exists and more detail is still required to complete the task of merging PHY (Channel Entity and Physical Layer Convergence Sub-layers) into a final specified multi-media MAC layer of systems presently contemplated for commercial use. Thus the art disclosed here related directly to foreseeable commercial devices and not to all possible (and many promising) theoretical areas of the infrared wireless technology. As a threshold document which sets forth the data for forming compliance standards we seek comment and where appropriate expansion of the detail given here. Future additions include including appropriate comments suitable for standards adoption, summarizing precise test standards in terms of performance thresholds and UUT diagrams which parallel (or exactly follow) standards for the other wireless media.

Table 1: Channel Modeling, Parameter and Characterization Data for Infrared (IR) Diffuse and Directed or Beamed Wireless LAN Applications

Propagation Mode and Application contexts:	**Diffuse (fixed or portable terminals)**	**Directed or Beamed (fixed terminals only)**
PLE Reference Detection and Modulation Formats-	Direct detection. OOK, Pulse Position Modulation.	Direct detection. OOK, Pulse Position Modulation.
Normal Channel Utilization (during session)	Continuous or Intermittent	Intermittent
Available Signalling Bandwidth	0.1 to 10 Mbits/second	to 50 Mbits/second.
BSA cell coverage/cell boundaries	Area or room-defined cells approximately up to the BSA link range in maximum dimension.	Cells resolve to a fixed workstation position, a few feet in diameter.
MDS/PLE Waveforms, Jitter Tolerances; Header and Packet Structures for Data rates identified above.	Open for comment	Open for comment
Conforming Network Topologies	Central control or peer to peer	Central control
Signal reception in relation to other co-channel users	Defined for exclusive PLAN Usage	Defined for exclusive PLAN usage
Available Channel Isolation (Re-Use) Options	Time, Code, Spatial (and later possibly wavelength)	Time, Code, Spatial, Path, Polarization

Central Control (Infrastructure) Network-Establishing communication and node interaction	Open for comment.	Open for comment
Peer to Peer Network-Establishing Communication and node interaction	Open for comment-this section should address switching to or from this mode to a central infrastructure networking mode to the extent this is likely to be an "overlay" mode of communication and operation.	Open for comment
Convergence Process from MAC to PHY Medium Layer	Mode I:Straight Binary to Binary or, Mode II (a and b): m-ary Pulse position (a-interval between reference and data-encoded pulses, or b- single unit pulse within the bit interval) modulation. Need specifications for interoperable symbol sets	Mode I: Binary to binary
Pre-amble, Framing Conventions	Open for comments	Open for comments
Symbol Encoding/decoding at MAC/PLE interface	Open for comments- Serial Manchester preferred.	TBD- Serial Manchester preferred.
PHY Control Features	These functions are required to optimize performance and minimize opportunity for cross BSA interference: Remote reception Signal or SNR level: 1 byte. Power control - 1 byte Directional emission control- 1 byte	These optional (?) functions are required to optimize performance: Remote reception Signal or SNR level: 1 byte. Power control - 1 byte Directional emission control- 1 byte
Station Management I/O and Set of Functions	Transmit defeat-Jabber inhibit/watchdog timer Local logic reset	Transmit defeat-Jabber inhibit/watchdog timer Local logic reset
PHY Quality of Service Indicators	External Indicator(s) for users' determination of the following active conditions: 1- Valid data reception 2- In-hospitable pernicious carrier or other interference present-channel blocked for communications	
Receiver Sensitivity and Susceptibility	Open for comment Should be specified in terms of minimum optical power in normal incidence on to the device aperture (power flux, e.g., uW/sq cm), according to each data signalling speed utilized required to meet or fall below one error in 4*10-5 MPDUs for a 512 octet MPDU. Minimum interference and jamming susceptibility are detailed in Table II below.	Open for comment.
Maximum Useable BSA, Peer to Peer Ranges	15-20 meters	100 meters (along a non-obstructed line of sight path)

Path/attenuation distance models:	Type I, Direct path dominated Reception: Free space loss model for point sources, n=-2 exponent accounts for on-axis propagation loss. Assuming the transmitter source is entirely within the field of view of the receiver: L_{db} = 10 log {(1/Range^2) x Effective receiver aperture area x cos (reception angle off normal) x cos (transmission angle off normal) x (1/pi) x Normalized source emmitance (on-axis watts/sr) }. Note: effective receiver aperture includes possible optical gain times the photodiode active area. Contribution Note: Need inputs on acceptable minimum angular tolerance especially for portable devices. Type II, Wide area, Multi-bounce Indirect Path Dominated Reception: In the reference (1) a simulation using a diffuse multi-path, multi-ray model in an in-room environment shows that additional bounce paths cumulatively add incident power at the rate of approximately -3 db for each successive, additional bounce. Conclusion: In-room IR diffuse reception is normally a combination of direct and indirect ray energy, and in such circumstances can be conservatively modeled to attenuate at a free space rate. A test boundary purely dependent upon indirect reception would in a "model room" additionally attenuate the propagating signal by an additional -3 to -6 db from the expected LOS reception level. "Model room" in this case means a rectangular cube (5 to 10 M in size, 3M high) with wall and ceiling surface reflectivity of 80%, floor reflectivity of 30%, transmitting from a central point on the ceiling, and receiving at floor level with a 85 degree FOV aperture. One reference (8) reports empirical results where reception that varied back and forth between a combination of direct and indirect and purely indirect shows signal variations that are consistent with the mathematical model and simulation in (1). To the extent real settings depart from the above model setting (and they most certainly do) will to a high degree influence the amount of both direct and indirect path reception. Alternative propagation strategies involving "directed-multi-point" bounce (Reference 7) or array (Reference 4) antennae are additional examples of how diffuse in-building infrared propagation is in some situations actually carried out.	Beam with uniform conically-shaped wavefront, receiver normal to axis of power flux-- Propagation loss, L_{db} = 10 log { pi x [aperture radius]^2/[tan (beamwidth/2) x Link Range]^2 }

Signal (energy) variation along a direct propagation path	< 1 db from predicted mean	< 1 db from predicted mean
Delay Spread--Peak	Relatively good agreement among the open research with regard to delay spread: 1. 15 nanoseconds, reference (2). 2. 20 nanoseconds peak in a 5M square room(reference (1)) with flood illumination and near perfect reflective surfaces. 3. General dispersion formula for dispersion in terms of maximum signalling bandwidth (without internal compensation for multi-path) using binary pulses of a 50% duty cycle transmitted in a rectangular cubic rooms to be: 260 Mbit-meter/second (eg, 26 Mbits/sec in a "model" room 10 M by 10 M) Note that direct detection systems used here do not incur multi-path degradation in the same fashion as coherent detection systems. Multi-path energy re-directed into the receiver aperture within the bit time interval is a constructive factor.	Virtually no dispersion
Delay Spread- RMS	Use peak values.	Virtually no dispersion
Coherence Time and Bandwidth	Free space techniques utilize a non-coherent carrier; some systems may chose to use a coherently modulated/demodulated sub-carrier. Due to the close physical proximity of indirect and direct reception paths and a small resulting spread in differential delay, coherence bandwidth should essentially equal the modulation bandwidth of the transmitter.	Same as diffuse.
Uptime/Availability under Normal Conditions	No generally established statistical model. Likelihood of outages are purely a function of amount of diffuse "flooding", design of apertures and the physical relationship of possible obstructions.	Same as diffuse.
Channel Temporal Variances	Stable, temporally invariant field with outages induced by opaque blockages across both direct and indirect optical paths.	Stable, temporally invariant field with outages only induced by line of sight obstruction.
Jamming Profile	Primary: Pernicious and alien Secondary: Non-conforming out of band sources. See Table 2 below.	Primary: Virtually no normal jammers due to fixed position and relatively small., discreet path(s) between stations and BSA access points.
Interference Profile	Primary: Unintentional radiators, optical sources within receiver field of view. Most notable and common sources of this type of interference are sun and tungsten lighting (see references (3), (6)). See Table 2 below.	Primary: Background optical sources with reflected/scattered energy within receiver field of view.

Multi-BSA cell overlap signal reception modeling.	These systems have inherent ability to control propagation leakage (or, interference range is virtually identical to the service range) from adjacent cells at BSA access points. Peripheral areas between unco-ordinated BSAs or stray emissions from portables (fixed location signals are easily separated) could generate zones of overlap. Such signal would have to have a difference less than the capture ratio of the receiver(s). Much of the overlap problem can be addressed by using power control, capture by companding pulse amplitudes, or if bandwidth permits and there are relatively few addresses to serve, code isolation techniques could be employed. Trial or temporary compliance test suggestion: conformance test with a "pernicious" jamming signal -10 db relative to desired signal at aperture and operating at threshold sensitivity of receiver. Observe no additional bit errors while receiver under test is challenged by the interference from the pernicious signal. Contribution note: Need contributions on establishing test standards and parameter for simulcast signal differentiation and data recovery under simulcast conditions.	Not applicable
Impulsive Noise/Interference Profile	1. EMI coupling/amplification within signal baseband processing stages. See reference (3). Compliance test suggestion: Use EIA radio test conventions for radiated and conducted susceptibility and emissions. 2. Fluorescent lights at time of turn-on impulse reported by one reference report (6) which lasts ~100 msec., thus this is too minor to be part of a conformance test .	Same as diffuse.

Bibliography of References	(1) Kahn, et al, *Simulation of Multipath Impulse Response for Indoor Diffuse Optical Channels*, Presentation at Worcester Polytechnic Ins titute Wireless LAN conference, May 10, 1991. (2) Chen et al, *Indoor high Speed Wireless Networks via Optical Transmission*, ITU Telecom '91 Technical forum, Geneva, (also Doc 802.11/91-126. (3) Samdahl, R. *Diffuse Infrared Conference Room Tests*. Doc 802.11-91/124. (4) Waskevich, D. *Financial Trading Application*, Doc. 802.11/91-123. (5) not used (6) Gfeller, F. and Bapst, U. *Wireless In-House Data Communication via Diffuse Infrared Radiation*. Proceedings of the IEEE 67, no. 11 (November), 1979: 1474-86. (7) Allen, D. *Infrared Wireless Networks*, Doc. 802.11/91-33 (8) Kotzin. M. *Short Range Communications using Diffusely Scattered Infrared Radiation*. Doctoral thesis, Northwestern Univ., June, 1981.	(1) Chu, T.S. and Gans, M.J. , *High Speed Infrared Local Wireless Communication*, IEEE Communications Mag. Aug., 1987 Vol. 25, No. 8.

Table 2: IR Channel Jammer and Interference Categories and Parameters

Propagation Mode:	Diffuse	Diffuse	Directed or Beamed
Intentional Categories/Conforming	**Example scenario and Possible Impact**	**Possible Remedies and Suggested Conformance standards and test conditions:**	**Impact/Remedies only noted if different treatment than diffus required.**
Alien	OPLAN Portable station enters physical coverage zone of PLAN and attempts access as if a PLAN station.	CSMA/LBT access protocols: System identification parameter does not match, suppresses communication and notifies OPLAN portable of prohibition until unit sets up and is granted "roaming" or guest access. Reservation access: Same as CSMA-access afforded only be negotiating roamer/quest access.	
Pernicious- (Intermittent, or Constant)	PHY "conformant" signals from non-PLAN device(s) but is not controlled by conformant MAC layer logic. Impact is only felt if unit enters PLAN BSA cell area, but potentially disrupts normal communications.	Provide simple channel status indicator to alert user to presence of incompatible contending jammer.	
Native	A-PLAN device under central control B- PLAN device not under central control, eg peer to peer. C- PLAN station goes into a pathological "jabbering mode" presumably due to defective transmitter.	A- Access governed by central control, no further remedy required. B- Access will follow intended design access rules, and impact communications accordingly. C- "Jabbering station" station has built in watchdog or similar time-out circuit to shut down errant stations.	
Intentional Categories/NonConforming			
Intermittent	Example: VCR remote control operating with in BSA coverage area./	Recommend simple susceptibility test to operate a consumer- grade device (at least 10 mW optical output) with continuous data pattern within 1 M of compliant station with less than 5% degradation in range or sensitivity.	
Constant	Example: Audio wireless products continuously operating within same BSA coverage area.	Same as intermittent test above.	
Unintentional (or Uncontrolled) Radiators which fall into common carrier channel (narrow or broadband)			
Fixed (or long dwell time) Sources	A-Sunlight B- Fluorescent lighting C-Tungsten, halogen lighting D- Hot oven or manufacturing floor steel melting furnaces	Except for D test as a composite of A,B, and C (refer to Figures 4,5 in Reference 6) generating 380 lux luminous intensity resulting in 100 uA photocurrent with a standard 1 cm^2 Si photodiode optical power flux meter. Resulting degradation in range or sensitivity is less than 5%. Contribution Note: Need to set relative weights among the different optical sources. D-Incidental, no standard recommended.	Less severe testing permissible.
Sweeping/Intermittent Sources	Treat same as fixed sources.	Treat same as fixed sources.	