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Title: **Multipath Fading Channel Modeling for High Speed PHY**

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Introduction

The intent of this report is to provide insight as well as prompt discussion of the various concerns in modeling multipath fading for a DS-SS WLAN environment. Multipath fading is an especially important concern in high data rate indoor wireless communcations. The numerous environments encountered in typical WLAN applications requires careful consideration in accurately and realistically modeling the indoor radio channel to assess its performance impact in computer simulations of the system. Use of computer simulation models provides a powerful means to assess system performance in the presence of channel impairments such as fading. It is especially advantageous when performance predictions cannot be obtained analytically. Validation of a computer model naturally requires accurate modeling of all components involved in the link. This submission addresses various issues which need to be addressed to arrive at a suitable fading channel model or models. The typically encountered multipath environments will be discussed briefly, followed by a description of the fading characteristics and related parameters..

Multipath environment

Due to the large variety of environments, it is usually impossible to evaluate system performance based on a single, well-defined channel model. The channel impulse response varies significantly with the environment as well as within the environment; the path delays in an office building differ from those in a factory, for example. The layout of the office environment, the type of material used in wall partitions, the number of people in the WLAN area all serve as considerations in the determination of a suitable channel model. Whereas an open environment with few walls and one or more stable paths suggests Rician fading, an area with numerous partitions (e.g. cubicles) shows a better fit for Rayleigh fading path characteristics.

Another consideration is the typical distances involved in signal transmission. The maximum delay spread T_m, generally defined as the time difference between the latest and earliest arriving paths, and more importantly, the rms delay spread, τ_{rms}, is related to the channel propagation characteristics. When used for LAN extension, the distance between transmitter and receiver is usually < 50 m and consequently would have τ_{rms} much less than that for, say, warehouse applications. A recent paper reports typical median τ_{rms} of 100 ns for factories and 25 ns for office buildings. Such delay spreads on the order of the chip rates (referred to as frequency-selective fading) cause performance degradations due to ISI (more accurately, ICI – interchip interference).

Multipath fading characteristics

The indoor radio environment for WLANs is considered to be extremely slowly time-varying in relation to the data rates involved. Channel dynamics are related to motion of people and equipment in the vicinity of the network (no movement indicates a fairly static channel and can be easily modeled with fixed path gains, delays and phases). Since the resulting Doppler frequencies are very low with respect to the data rates, the above parameters can be considered nearly time-invariant.

However, the packetized nature of the received data requires reconsideration of the above assumptions. Packets are received randomly in single quantities or in bursts from a single user or several users from different locations. Thus, each of the received packets may have arrived affected by different channel characteristics. Packets originating from a single user may be separated by multiple chip durations.

Clearly, it is impossible to completely determine channel statistics for all possible situations. It is nevertheless important to arrive at some conclusion as to a model or models which can be representative of a realistic and typical environment.

Modeling specifics

The complex, lowpass channel impulse response is commonly represented by the expression

$$h(t) = \sum_{l} \beta_l \delta(t-\tau_l)\exp(j\varphi_l)$$

where l denotes the path index, β the Rayleigh-distributed path gain, τ the path delay and φ the uniformly distributed path phase. The desired goal, of course, is to determine the above parameters as accurately as possible for specific environments. The three techniques to determining these parameters are[6] (i) field test data, (ii) statistical modeling (iii) ray tracing (a site-specific computer simulation technique). Numerous papers, e.g. [1]-[6] provide empirical and analytical results of these approaches.

Realistically, the number of paths in the channel would be unresolvably infinite. Obviously, discrete channel modeling is more suited for computer simulations. One method for determining the number of paths, L, to be used in the model can be computed using[3]

$$L = \text{int}\,(T_m/T_c + 1)$$

L is the number of paths used in implicit diversity techniques such as RAKE receiver demodulation in capturing multipath energy.

Another widely-used model[1], based on time-domain measurements taken in an office building, assumes that paths arrive in clusters and that both clusters and rays within clusters form Poisson processes with different, but fixed, rates. This model has been widely used for performance predictions in various papers and also serves as a reference indoor radio channel model for SPW (a system-level simulation CAE tool).

Selected Journal papers (all IEEE Transactions Papers):

1. A Statistical Model for Indoor Multipath Propagation – Saleh/Valenzuela, SAC5 2/87
2. Channel Modeling and Adaptive Equalization of Indoor Radio Channels – Sexton/Pahlavan, SAC7, 1/89
3. SSMA Performance of Orthogonal Codes for Indoor Radio Comm – Pahlavan/Chase, COM38, 5/90
4. Autoregressive Modeling of Wideband Indoor Radio Propagation, Howard/Pahlavan, COM40, 9/92
5. DS-CDMA with Predetection Diversity for Indoor Radio Comm – Wang, etc., COM42, 2/94
6. Transmission Techniques for Radio LAN's – A Comparative Performance Evaluation Using Ray Tracing – Falsafi, Pahlavan, Yang, SAC14, 4/96