

INDOOR CHANNEL MODEL FOR LINK BER ESTIMATION

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Abstract— with their low cost and high-speed data rate capabilities, installations of IEEE 802.11-based wireless local area networks (WLANs) are growing exponentially. Although many organizations have started using WLANs, there are still very few tools available that can help the design of WLAN networks. As a result, the current deployment of WLAN networks remains ad-hoc in nature. The objective of this research is to investigate performance optimization of WLAN networks by optimizing the position of access points. To do so, propagation models are available that can predict the signal strength and interference in a WLAN system by taking into account environment specific parameters such as the structure of the building, presence or absence of *stationary* obstacles etc [1]. This paper investigates the influence of *moving* obstacles, such as people, on radio wave propagation inside a building and the effect on received signal quality in a WLAN. Our findings suggest that the presence of *moving* obstacles, such as people, seriously affects the performance of the system by introducing heavy variations in the received signal strength.

INTRODUCTION

WLAN networks have become very popular means for providing wireless networking facility for home users, educational institutions, companies etc. due to their ease of installation and their high data rates provision, apart from providing, albeit limited, mobility to users. Most people deploy WLAN access points in the immediate vicinity of where wireless coverage is desired and the system typically seems to work. However, such an ad-hoc deployment will work only if there are very few access points. The performance of such an ad-hoc deployed network is much less than what could be achieved by proper network design. Indeed, many organizations are already noticing the actual data rate limitations of large scale, highly loaded WLANs that have been installed in an ad-hoc fashion. The optimal deployment of a WLAN system, however, should consider various factors that influence the performance of the system and the overall network performance and Quality of Service (QoS) that can be achieved. An important performance measure is the achievable throughput. Throughput however depends upon the Bit Error Rate (BER), which in turn depends on the signal quality and signal to interference ratio (SIR).

As the received signal quality has a crucial impact on the network performance, accurate prediction of the received SIR is important for automatic optimal network deployment. Moving obstacles in the propagation path introduce large variation in the received signal strength due to fast fading and changing small area shadowing. Most common RF propagation prediction techniques alone are only capable of predicting the mean received signal strength.

This paper investigates the prediction of complete received signal statistics rather than just its mean value and investigates the influence of variable shadowing due to the movement of people in the propagation area and its effect on optimal network deployment and performance.

The full paper is organized as follows. Section I will give the rationale and motivation behind the current research. Section II will describe the measurement campaign conducted for the purpose of collecting data for statistical investigation into the influence of people on the received signal strength. The proposed novel method of site-specific prediction of signal statistics and SIR will be described in Section III. Section III will conclude the paper.

I. INDOOR CHANNEL MODEL

A) Rationale

The WLAN systems deployed in indoor environments provide wireless access through access points (APs) placed in convenient places such as on ceilings, walls or some times even placed on desks near which wireless access is desired. From the radio wave propagation point of view, the signal between the AP and the user terminal propagates rather horizontally over the coverage area, crossing obstacles of various types such as desks, chairs and people etc. The net effect is an attenuation caused by static obstacles and a more varying signal due to moving obstacles such as moving people. As a consequence, there are rapid and frequent transitions between line-of-site and non-line-of-site situations, causing a variation in the statistics of fast fading, which is closely associated with the shadowing process. The characteristic of shadowing caused due to moving people resembles fast fading in propagation environments. From the modeling point of view, it is therefore most convenient to treat people shadowing and narrowband fast fading as a single entity – a closely coupled process, in which the parameters of the fading and shadowing are time-varying.

B) Distribution of the fading

The model described here represents the channel statistics in terms of parametric distributions, which can be approximated by a combination of Rice, Rayleigh and Log-Normal components (1). The rationale behind using a combination of different distributions is that the total narrowband fading signal in indoor environments can be decomposed into two distinct parts, a coherent part, which is usually associated with the direct line-of-site path between the AP and the user terminal, and a diffuse part arising from a large number of multipath Non-Line-of-Site components of differing phases. A similar pattern is observed for a land mobile satellite communication system when buildings and trees block a line of sight between the satellite and the mobile station [3].

$$P(r, k, \sigma_S, \mu_S) = AP_{Rice}(r, k) + (1 - A)P_{RG}(r, \sigma_S, \mu_S) \quad (1)$$

Where:

$$P_{Rice}(r, k) = \frac{r}{\sigma_R^2} e^{-\frac{r^2}{2\sigma_R^2}} e^{-k} I_0\left(\frac{r\sqrt{2k}}{\sigma_R}\right) \quad (2)$$

$$P_{LN}(S_0, \sigma_S, \mu_S) = \frac{1}{\sqrt{2\pi}\sigma_S} e^{-\frac{(20\log(S_0) - \mu_S)^2}{2\sigma_S^2}} \quad (3)$$

$$P_{Rayl}(r, S_0) = \frac{r}{S_0^2} e^{-\frac{r^2}{2S_0^2}} \quad (4)$$

$$P_{RG}(r, \sigma_S, \mu_S) = \int_0^{\infty} P_{Rayl}(r/S_0)P_{LN}(S_0, \sigma_S, \mu_S)dS_0 \quad (5)$$

$$\sigma_R = \sqrt{\frac{1}{1+k}} \text{ for receiving power of } 1W$$

k..... Rician k-factor (-)

σ_s Standard deviation of slow fading due to moving people (dB)

μ_s Mean attenuation due to moving people (dB)

A..... Time sharing between both states (s)

P_R Local mean signal level with absence of moving people predicted by ray tracing model (dBm)

The signal variation of the coherent part is characterized by Rice distribution with appropriate k factor (2). The signal variation of the diffuse part is characterized by the combination of Lognormal and Rayleigh distribution (3, 4, 5). The transition between these states is governed by two states Markov model [3]. The time share of shadowing (A) controls the switching between the two states.

Figures 1 - 3 show a sample of the measured signal level fluctuation in time and its probability density function in an environment where one person, five people and fourteen people respectively are moving in the propagation path between a fixed AP and a user terminal. Below is a description of the measurement campaign.

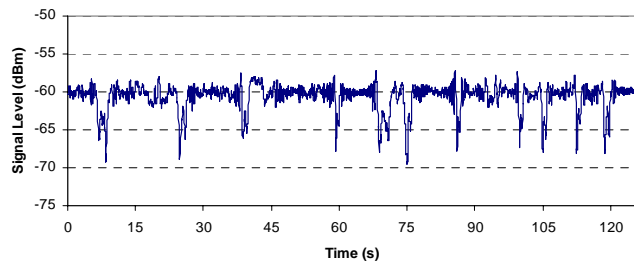
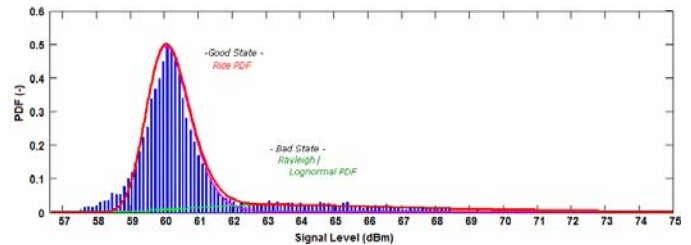


Figure 1a. Sample of signal level fluctuation in time for one person



b). Example of theoretic probability density functions for one person

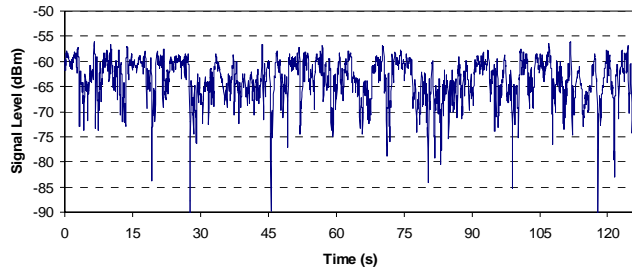
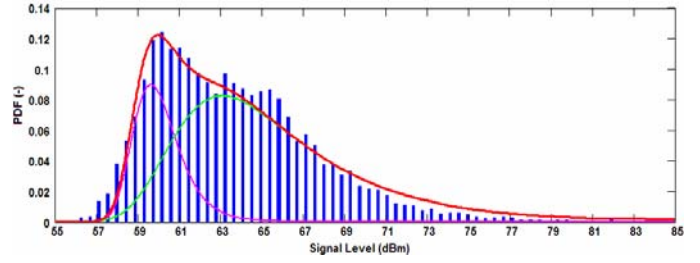


Figure 2a - Sample of signal level fluctuation in time for five people



b). Example of theoretic probability density functions for five people

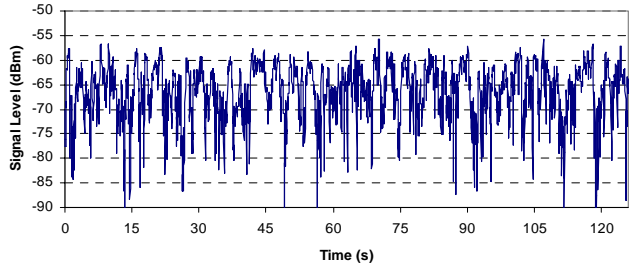
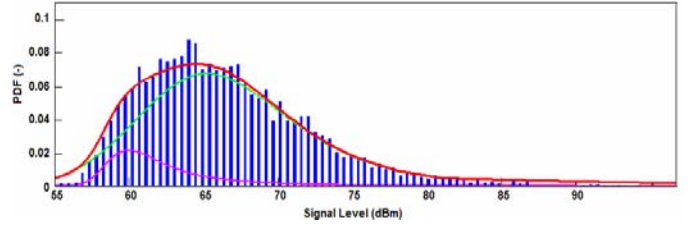


Figure 3a - Sample of signal level fluctuation in time for fourteen people



b). Example of theoretic probability density functions for 14 people

The proposed indoor channel model (Fig.4) is similar to the Lutz's land mobile satellite channel model [3]. Where the fading process $\alpha(t)$ is switched between Rician fading representing LOS (good) state of channel and Rayleigh / Lognormal fading representing NLOS (bad) state of the channel.

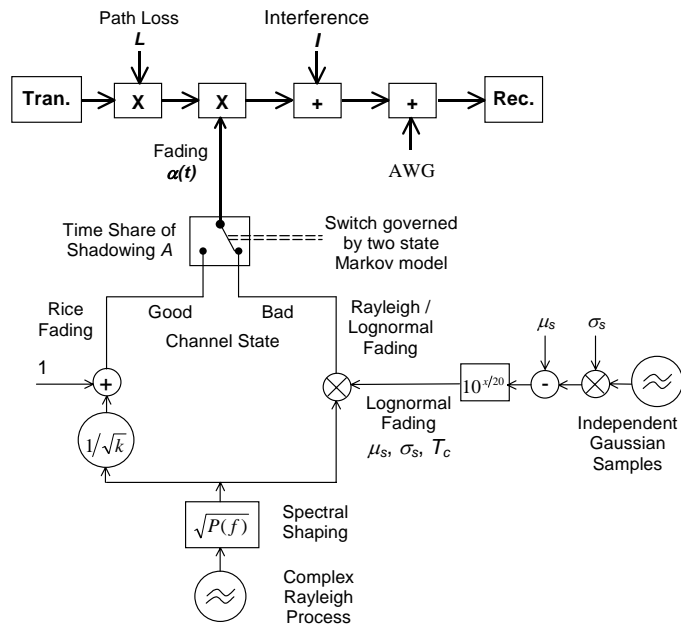


Figure 4. Indoor Channel Model considering people movement for link BER estimation

I. INDOOR CHANNEL PARAMETERS

A. Measurement Campaign

In order to utilize the model in a link level simulator for a site-specific prediction of BER and channel throughput, the dependence of channel parameters on configuration of environment with moving people is needed. Detailed measurement of WLAN signals fluctuation in various situations i.e. a varying number of people moving randomly between a transmitter and receiver, is required in order to be able to derive empirical relations for estimation of the channel parameters.

The measurement configuration presented here is shown in Fig.7. The object of this measurement was to find dependencies between signal level variation of single dominant cluster of rays, people density ρ_p and average length l of ray in the cluster, which propagates over the area with moving people. Therefore, the measurement was carried out on a large open football pitch, where a dominated part of energy was carried by single cluster of rays between transmitter and receiver. Because of such an open space we were able to avoid reflected rays from walls and ceilings. Around the football pitch was a wire mesh fence. A signal generator (Fig. 6) acting as a transmitter and a network analyzer (Fig. 5) as receiver were placed on the pitch at a distance of 10 metres apart. Attached to these devices were vertical monopole antennas. Both antennas were placed at a height of 1.5 metres.



Figure 5 – Network analyzer with vertical monopole



Figure 6 – Signal generator with vertical monopole

In the area of 49 m^2 , between both terminals a specified numbers of people were randomly moving while signal level fluctuation was recorded.

After the measurement was complete the empirical relations (6, 7, 8) then were extracted from the signal level distributions obtained. The time-sharing A is equal to the probability of line-of-site between the transmitter and receiver.

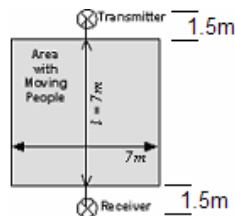


Figure 7a. Measurement Layout



b). Picture of measurement configuration

Derived Empirical relations for estimation of the channel parameters of single cluster of rays

Standard Deviation

$$\sigma_s(l, \rho_p) = \log_7(55l\rho_p + 1) + 0.5 \quad (6)$$

Mean Attenuation

$$\mu_s(l, \rho_p) = (3l\rho_p)^{0.7} \quad (7)$$

Time Sharing

$$A(l, \rho_p) = (1 - \rho_p)^{0.2l} \quad (8)$$

Where:

lLength of the ray over area with moving people (m)

ρ_pDensity of people

(Number of people over an occupied area) (m^2)

These relations derived for single cluster of rays are especially useful for application in a ray-tracing model. Where a power level fluctuation could be determine for each ray depending on environment and the ray trajectory.

The comparison of extracted channel parameters from the measurement and the empirical model approximation (6, 7, 8) is in the following Figures 8, 9, and 10.

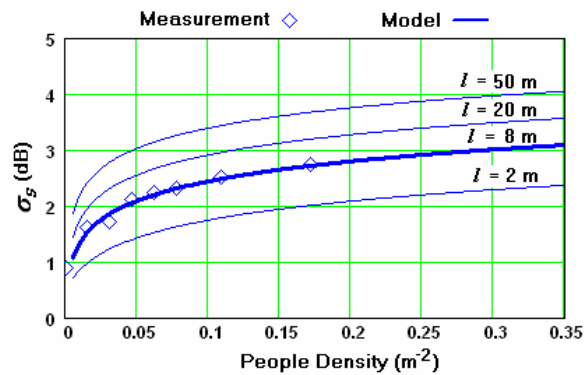


Figure 8. Comparison of empirical approximation standard deviation and measurement

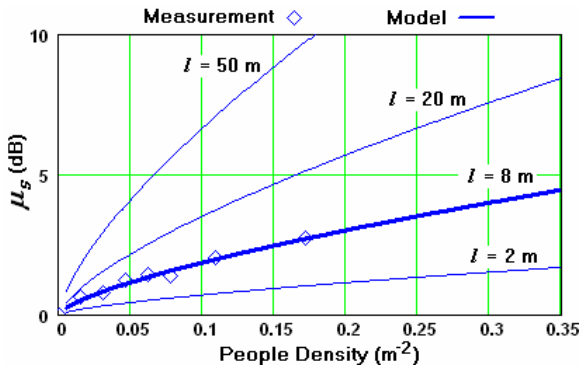


Figure 9. Comparison of empirical approximation mean attenuation and measurement

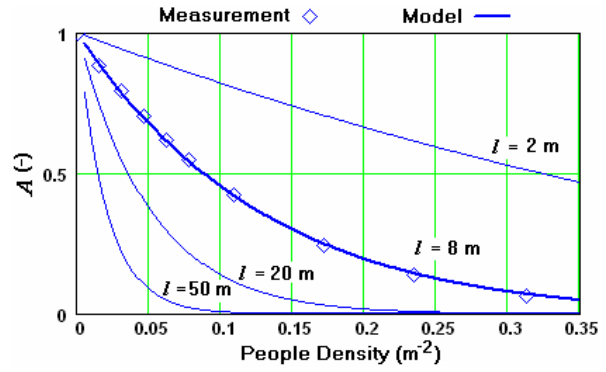


Figure 10. Comparison of empirical approximation of time sharing and measurement

II. RAY-TRACING PREDICTION

In order to accurately predict the signal quality in the channel (Fig.4), at every point of the investigated scenario, all parameters, except the AWG (Additive White Gaussian Noise), must be site-specifically predicted. Path loss prediction and channel parameters (Fig.4) are performed by a deterministic ray-tracing model known as Motif Model [2]. The level of interference is changing in nature, however its variation has been mainly neglected and its local mean level, the sum of contribution from surrounding interferers, is based on the appropriately filtered mean signal level predicted from surrounding interfering Access Points and other appliances such as microwave ovens, e.g. However, the temporal influence of other appliances on an optimal network deployment need to be addressed in further research.

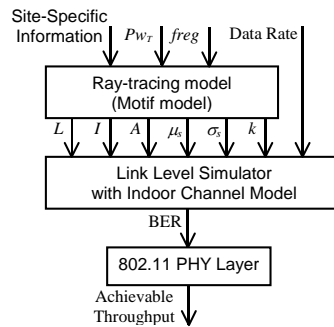


Figure 11. Structure of the Simulator

Once the empirical parameters are outputted from the propagation model they are used as inputs to the Link Level Simulator, using the channel model described above, and an estimation of BER can be obtained and used as an input to the physical layer for a wi-fi system. Figure 12 shows a sample output from the Link Level Simulator, illustrating the dependency of BER on Path Loss and standard deviation, modulation of 11 Mbps.

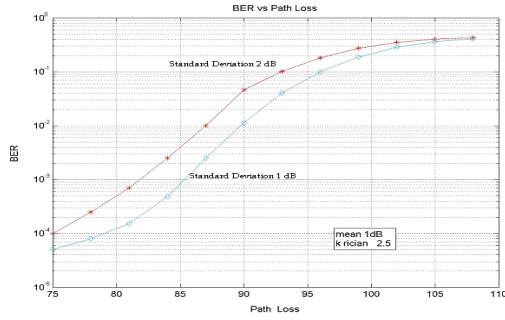
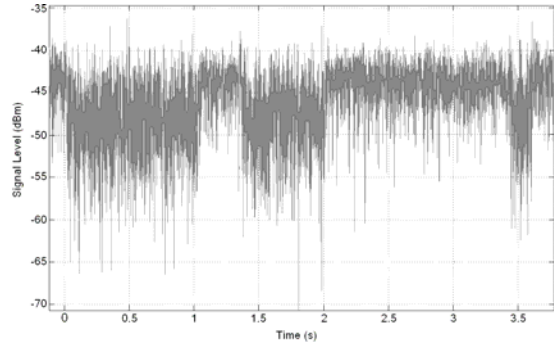


Figure 12a. BER dependency on Path Loss and standard deviation.



b). Example of simulated signal level fluctuation in time for channel parameters shown in Figure 12c

A. Site-Specific prediction of channel parameters

The Rician k channel parameter in (x, y, z) location is given as a rate between power of the dominant cluster of the rays and the rest (9).

$$k(x, y, z) = \frac{P_{W_{DR}}(x, y, z)}{P_W(x, y, z) - P_{W_{DR}}(x, y, z)} \quad (9)$$

The other channel parameters (10, 11, and 12) are simply expressed as a mean value of channel parameter of single clusters from relations (6, 7, and 8) weighted by signal level of cluster.

Mean signal attenuation due to moving people

$$\mu_S(x, y, z) = \frac{1}{P_W(x, y, z)} \sum_{r=1}^{R(x,y,z)} \mu_{S,r} P_{W_r}(x, y, z) \quad (10)$$

Standard Deviation of NLOS due to moving people

$$\sigma_S(x, y, z) = \frac{1}{P_W(x, y, z)} \sum_{r=1}^{R(x,y,z)} \sigma_{S,r} P_{W_r}(x, y, z) \quad (11)$$

Time sharing due to moving people

$$A(x, y, z) = \frac{1}{P_W(x, y, z)} \sum_{r=1}^{R(x,y,z)} A_r P_{W_r}(x, y, z) \quad (12)$$

Where:

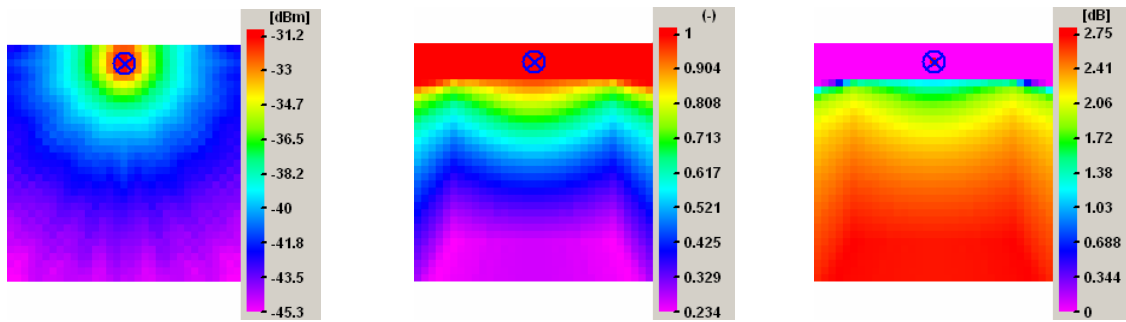
$P_{W_{DR}}(x,y,z)$..Power of the dominant cluster (W)

$R(x,y,z)$Number of clusters (-)

$\mu_{sr}(x,y,z)$ Mean signal attenuation due to people of single cluster of rays (dB)

$\sigma_{sr}(x,y,z)$ Standard deviation of signal level fluctuation in single cluster of rays due to moving people (dB)

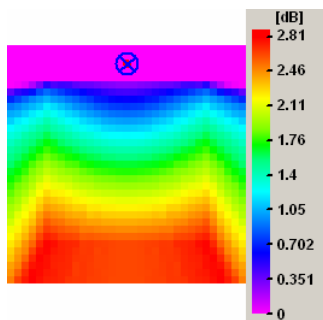
Example of channel parameters prediction by the ray-tracing model in measurement configuration and with people density $P_p = 0.172$



a) Signal Level P_{wR}

b) Time Sharing A

c) Standard Deviation σ_s



d) Mean Attenuation μ_s

B. Example of channel parameters prediction in real environment

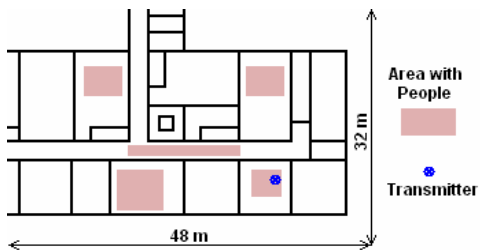


Figure 13. Floor layout with areas of major people appearance

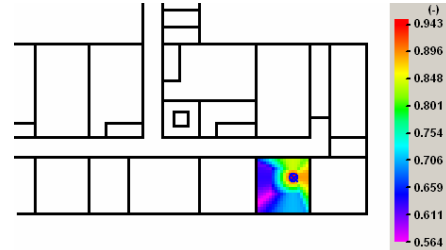


Figure 14. Probability of Non-Shadowing of LOS cluster of rays (A)

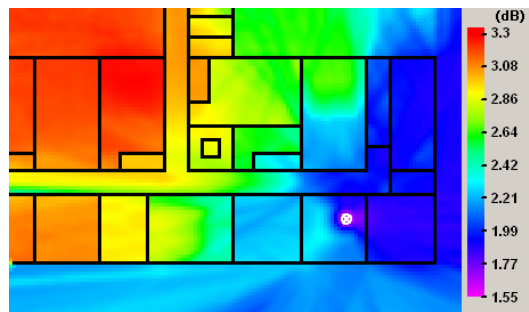
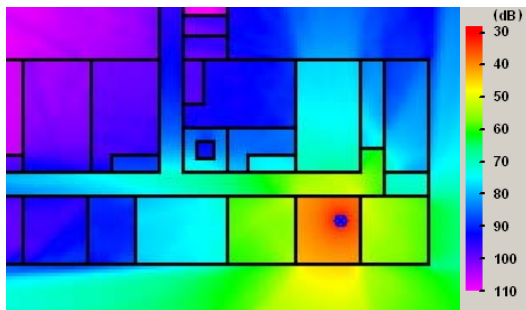


Figure 15. Mean path loss prediction

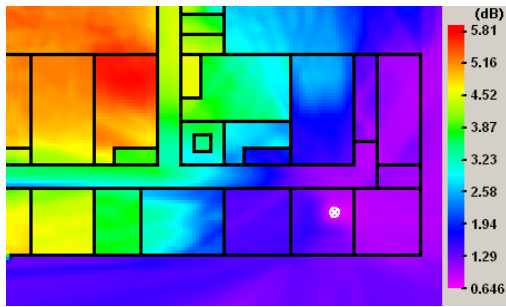


Figure 17. Mean signal attenuation due to shadowing by moving people

Figure 16. Standard deviation of signal fluctuation due to shadowing by moving people

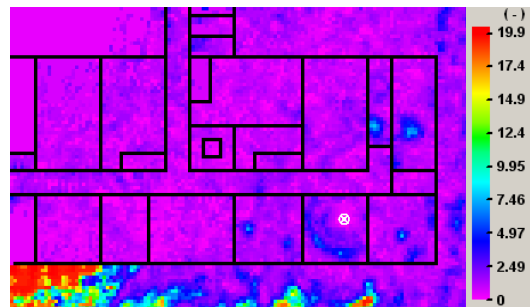


Figure 18. Rician k -factor prediction

Conclusions

This paper presents an accurate prediction of the effects of moving people shadowing in an indoor radio propagation environment and analyses its effect on the performance of a WLAN system. The paper shows that with measurement the empirical parameters can be derived and used to evaluate BER using the Link Level simulator with proposed channel model. The overall project is expected to develop into a system capable of planning WLAN systems.

Acknowledgment

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