Transmission Characteristic and Propagation Evaluation of Wireless LAN in Premises

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Abstract

The transmission performances of 2.4GHz wireless LAN system have been measured to establish the radio link design in the Sophia University. The packet loss rate, the signal level, and the noise level were measured. For typical outdoor areas, courtyard and piloti were used. Based on the measurement results, the propagation parameters for link design were estimated. By comparing the estimated values and the measured values, applicability of the wireless LAN system is clarified.

1 Introduction

Recently, the demand of wireless LAN has increased at the university. The coverage of wireless LAN base station is not large, rather consists of a pico-cell, which its shapes are not uniform rather complex due to diffraction or reflection of obstacles. The coverage area estimation is one of the most important tasks to optimally deploy wireless LAN systems.

The objective of this paper is to establish the link design method, which is a method of where and how many to place a wireless base station, in the university premises. First, to clarify propagation characteristics, the packet loss factor, the signal level, and the noise level are measured. 2.4GHz direct spread spectrum system was applied as a wireless LAN system. For outdoor measurements, courtyard and piloti were used. The distance attenuation constants etc. were estimated from the measured values classified by the environments, and estimated the distance characteristic of the signal to noise ratio.

2 Main Parameter of Wireless LAN System and Measurement Equipment

The DS (Direct Spreading) method and the FH (Frequency Hopping) method are standardized as wireless LAN system of 4GHz. Wave LAN and the antenna made by the NCR Company based on DS method are used in the measurement. Various wireless LAN equipment based on DS method are used today, but the basic performances are almost the same. Main parameters of the wireless system used in the measurement are shown in Table Ⅰ. Main characteristics of outdoor antenna used in the measurement are shown in Table Ⅱ.

■Table Ⅰ. Wireless system parameter

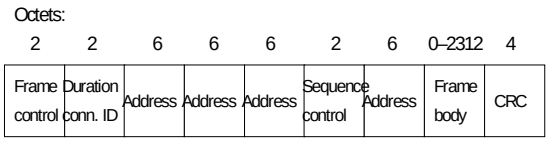
Frequency	2.4GHz (2471-2497MHz)	Official output	10mW/Mh or less
Modulation method	DSSS method	Receiver sensitivity	-90dBm
MAC	CSMA/CA with ACK	Delay speed (FER: Less than 1%)	400ns
Transmission speed	2Mbps	Bit error rate	More excellent than 10^{-8}
Spreading	11-chip Barker Sequence		

■**Table Ⅱ.** Main characteristics of the antenna (※used with inner card antenna)

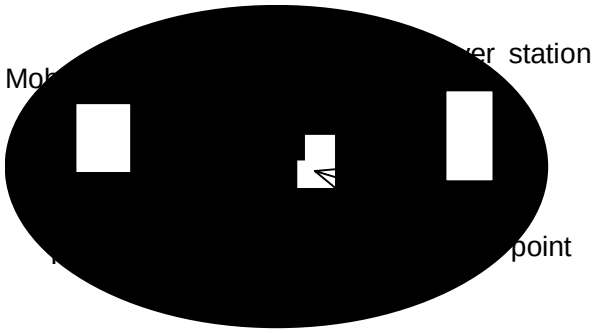
	Antenna gain	Size
Outdoor antenna	7dBi	460×8×8mm

3 Transmitted Information

Fig.1 shows the composition of the transmitted frame. The frame size is changeable from 1 to 2014 bytes. The frame size during the measurement was 1024 bytes. 1 frame length is 4 ms.. The frame was continuously transmitted while measuring the reception rate, the signal level, and the noise level. Both downlink (from the access point to the mobile station) and uplink (from the mobile station to the access point) were measured.



■**Fig.1** Standard IEEE 802.11 frame format



■**Fig.2** Equipment for measurement

4 Measurement and Method

Fig.2 shows the measurement equipment. 10 Mbps Ethernet connected the server and the access point. For outdoor access point, two kinds of antennas were used. One was card antenna (PC card), and the other was outdoor antenna.

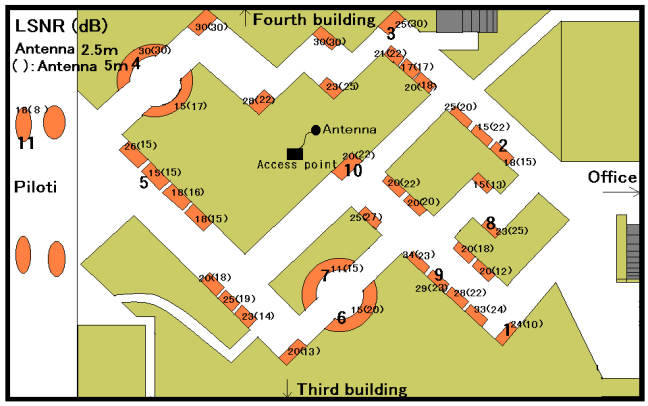
Fig.3 shows the rough sketch of the courtyard and the piloti. There are buildings at three sides of the courtyard and a piloti at another. Trees of various heights are planted and there are benches at the passage. The outdoor antenna of the access point was placed at the position assumed to be the center of the courtyard. The signal to noise ratio of the mobile station with PC card was measured sitting at all benches (37 places) including piloti and standing at the same places. It was measured for two cases, which the outdoor antenna was at a height of 2.5m and 5m.

The signal level, the noise level, the packet loss factor were measured at 11 places (1-11 of Fig.3). Measuring time is 180 seconds.

5 Measurement Results and Consideration

Fig.3 shows also LSNR when the antenna was at a height of 2.5m. Values in parentheses are the LSNR when the antenna was at a height of 5m. There were only few places, which had line of sight because of the trees and the leaves. In courtyard, SNR were almost the same when antenna height was 2.5m and 5m. At the piloti, there were big differences. SNR when the antenna was at a height 2.5m were larger than that of 5m. This is because the roof over the piloti hides the antenna when it is at a higher position. SNR of places that were out of sight were low and were about 15dB. SNR measured sitting and standing were almost the same. There were places when SNR were higher standing, and higher sitting. SNR was not necessarily high when it is near the antenna because of the trees and the leaves. SNR dropped nearly 10 dB when mobile station's antenna (PC card) faced the opposite way form the access point's antenna (outdoor antenna) compared to that, which faced the access point. SNR fell when people stood in the line of sight and rose when stood at the place, which reflects and helps

the signal reach the mobile station.



■**Fig.3** Layout of courtyard and piloti

The measurement result of the packet loss, the signal level of access point and mobile station, and the noise level at 11 places are described next. In courtyard, all packets reached regardless of the antenna height, but in piloti, there were 3.4% packet loss when it was at 5m. This is because of the roof. 720 packet were transmitted every 180 seconds. The noises were almost constant. Uplink and downlink were not balanced. If the antenna is placed at a height of 2.5m, it is able to cover not only courtyard and piloti, but also a part of main street next to the piloti as a service area.

6 Propagation Estimation

$$E = A - 10\alpha \log d \cdots(1)$$

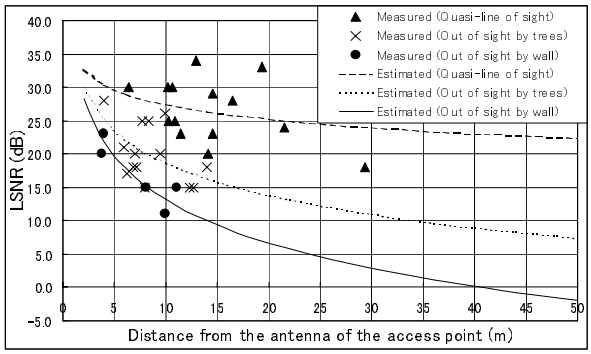
(1) is the propagation equation. E : Electric field (dB). d : Distance (m). A: Constant value depending on frequency, and the antenna height of access point and mobile station. α :Constant value depending on obstacles which exists on the line of sight, and the antenna height of the access point.

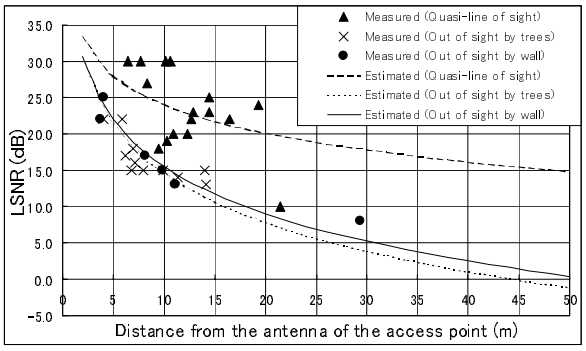
The propagation was estimated using equation (1). E is assumed to be signal to noise ratio (LSNR) of the access point because the noise is almost constant. The phase difference by the reflection is not considered. The measured value was classified into 3 groups, "quasi-line of sight", "out of sight by trees", and "out of sight by walls". A and α were estimated by least squares method of all measured values and equation (1).

TableⅢ is a value of A and α used to estimate propagation. α is smaller than that of empty space because the reception level rises by reflection of the buildings surrounding the courtyard. Also it is smaller than that of the laboratory. (※The α of the laboratory was 1.91-2.26, though it was not described in this paper.) This is because the percentage of the signal penetrating the window is lower in courtyard than in laboratories.

■**Table Ⅲ.** Estimated A and α in courtyard and piloti

Antenna height		2.5m	5.0m
A		34.79	37.17
α	Quasi-line of sight	0.734	1.310
	Out of sight by trees	1.614	2.255
	Out of sight by walls	2.162	2.164





■**Fig.4 (Left)** Estimated LSNR and measured values in courtyard and piloti. (Antenna height 2.5m)

■**Fig.5 (Right)** Estimated LSNR and measured values in courtyard and piloti. (Antenna height 5m)

Fig.4 shows the estimated LSNR and the measured values when the antenna height is 2.5m. For quasi-line of sight measurement, values are excluded which were taken when the mobile station's antenna was facing the opposite way from the access point. This is because reception level falls 10dB in this case, so the estimated LSNR for this case will be 10dB lower than that of Fig.4. Attenuation by the distance is low when there is quasi-line of sight, but rises when it is out of sight. The values differs most in quasi-line of sight measurement. This is because the measured values weren't classified into smaller groups such as "quasi-line of sight by branches" and "quasi-line of sight by leaves" due to the small amount of measurement values.

Fig.5 shows the estimated LSNR and the measured values when the antenna height is 5m. Why measured values of quasi-line of sight differ is as described before. There aren't any big differences between two kinds of out of sight measurement values.

7 Summary

In this paper, the propagation characteristics in premises were described. Though there were small characteristic differences of propagation by the direction of antenna of the mobile station, and the environment, it is able to cover the entire courtyard and piloti for outdoor as a service area if the access point's antenna was set up under the same situation as the measurement. For courtyard, the signal level rose by the reflection. The estimation was accurate enough, but can improve more if the reflection is considered, and will be able to apply to the main street and classrooms.

To establish the link design and the area estimation method, defining the movement characteristic and percentage of the mobile station to be at the place is also important. To establish these methods is the target of now on.

References

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