CELL PLANNING FOR WIRELESS LOCAL AREA NETWORK AND OPTIMAL ANTENNA LOCATION

Chang-Hoon Lee*, Eun-Soo Kim*, Seong-Cheol Kim*,
Mee-Suk Lee†, Sung-Man Kim† and Han-Uk Jung†

*Institute of New Media and Communications, Seoul National University,
†Convergence laboratory, Korea Telecom
E-mail : (lchjsa, dekim, sckim)@Maxwell.snu.ac.kr, kitlee@kt.co.kr
Tel : +82-2-880-8481, +82-2-885-4459

Keywords: WLAN, Cell planning, path loss model, indoor environment, optimal antenna position.

Abstract

This paper focuses on cell planning method and optimal Access Point (AP) location. Cell planning can reduce the adjacent channel interference and minimize the number of AP. We introduce some methods and compare one another and suggest an efficient method. Existing method considering objective functions is very complex. The new method considers a special condition - indoor environment. So this reduces a lot of calculation quantity. Next, topic is optimal antenna location. When AP is set up, generally AP is attached to the wall. At this time, constructive and destructive effects happen because service providers choose a omni-directional antenna to save cost. This paper will show optimal antenna location to avoid destructive effect.

1 Introduction

In deployment of WLAN, finding optimal location of Access Point is important issue. Using cell planning, we can reduce the adjacent channel interference and minimize the number of AP. A lot of research has been accomplished about cell planning methods. But, they are almost about outdoor environment. Unlike outdoor environment, there are different considerations in indoor cell planning caused by obstacles like walls, ceilings, desks and people. To find optimal AP position, we should use the path loss model of the environment and compensate cell location for the specific site. When radio wave goes through the obstacle like concrete wall, it experiences attenuation and service coverage has been reduced. If obstacle is a conduct wall, diffraction phenomenon has been occurred and signal strength has been rapidly dropped. And when it goes on aisle, it experiences canyon effect and cell coverage could be extended. In order to set up efficient WLAN network, we should consider these effects on indoor cell planning. In the section 1, we will introduce several cell planning methods and suggest a simple cell planning method including initial cell condition. In the section 2, we provide a proper antenna position. When we set up WLAN systems, we assume AP is located in the middle of classroom. But, because of cost and convenience, actually most of AP's are installed close to the wall. We suggest optimal antenna distance from the wall, especially concrete and conduct wall, which is minimizing the influence of first reflected wave.

2 Simple cell planning method

Full papers must be typed in English. This instruction page is an example of the format and font sizes to be used. MS Word users can download from the conference site these instructions in Word format. we intend to show the channel characteristics of indoor campus environment and provide a cell planning method to improve WLAN performance. Especially, we focus on wave propagation through concrete wall and conduct wall. Maximum dynamic range of measurement system we used is 95dB. In the campus environment, if there are no obstacles, the cell coverage is about 25m. Path loss model is given by

$$-PL_{dB} = 10\log\left(G_1 G_2 \left[\frac{\lambda}{4\pi r}\right]^n\right) \qquad (1)$$

λ : wave number
r : distance between AP and mobile
G_1, G_2 : transmitted and received antenna gain
$n=2$: propagation index through free space
$n=3.4$: propagation index through indoor environment

When radio wave goes through the concrete wall, about 10dB additional loss occurs. So we should reduce the cell size to about 20m. When wave propagates in the aisle, canyon effect occurs. The canyon effect is that when wave incident angle is large, it experiences a wave-guide effect and then wave can propagate longer. So cell coverage can be extended to 45m-ellipsoid. We certify this using ray tracing simulation tool and Continuous Wave (CW) measurement. Figure 1 shows Canyon effect by ray tracing tool in the aisle.

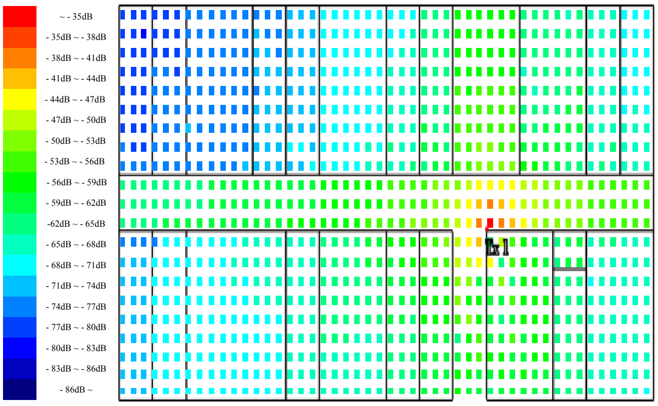


Figure 1. Canyon effect

There are many cell planning methods. First, The representative simple cell planning method is grid installation [2][3][4]. This is to divide the service area into K equally sized rectangles, where K is the number of available AP's and install an AP in the centre of each such rectangle. Using only map, we can install WLAN system without knowledge of the actual propagation characteristics and reduce the probability of coverage gaps. But this simple method has also some weak points. First, It is not easy to divide the service area into K rectangles because of obstacle like wall and stairs. Second, it is unlikely that access to a backbone infrastructure is readily available at the installation points. To install AP in the middle of room, we should pay more effort and cost at wiring and installation. Finally, it can waste frequency spectrum resources. Therefore it is hard to adapt grid installation method in real environment. Second method is automatic cell-planning method.[5] This utilizes objective functions (OF). When we set up a WLAN system, we should consider four global conditions that are area coverage rate, traffic coverage rate, spectral fitness and economics fitness. On the site where higher density data traffic is needed, we must consider above four global conditions. But, on the lower density traffic area, we have to only consider area coverage rate. So, in this case, we utilize the objective function below. [2]

$$g_i^{(k)} = f_a F_i(x,y,z) + n_e \log\left[\max\left\{1, D_i(x,y,z)\right\}\right] \quad (2)$$

$$f_1 = \sum_{i=1}^{M} w_i \left(g_i^{(k)} + \mu \max\left\{0, g_i^{(k)} - g_{i,max}\right\}\right) \quad (3)$$

$$f_2 = \max\left(g_i^{(k)} + \mu \max\left\{0, g_i^{(k)} - g_{i,max}\right\}\right) \quad (4)$$

$$g_{i,max} = \left(P_0\right)_{dBm} - \left(N_0 B\right) - \left(F\right)_{dB} - \left(SNR_{i,min}\right)_{dB} \quad (5)$$

$g_1^{(k)}$: path loss from the *i*th point to AP k
n_e : path loss exponent
fa : Wall-attenuation factor

f_1 : mini-sum objective function
f_2 : mini-max objective function
M : total number of measurement points in the service area.
P_0 : the transmit power
N_0 : the single-sided spectral noise density
F : the receiver noise figure
$SNR_{i,min}$: the minimum required SNR
$F_i(x,y,z)$: Number of wall separating the ith receiver and the transmitter
$D_1(x,y,z)$: Distance between the *i*th receiver and the transmitter

But, this method requires a lot of computation, which means the increase of cost and time. So, we suggest adapted grid installation method. Adapted grid installation process is a simple cell planning method using initial conditions. That's not just dividing service area into K sites equivalently but dividing variable size like each classroom size. The process is described as follows:

1. AP's are allocated at in the middle of classroom.
2. Overlapped cells are eliminated.
3. To easily install, the rest of cells are relocated close to the wall.

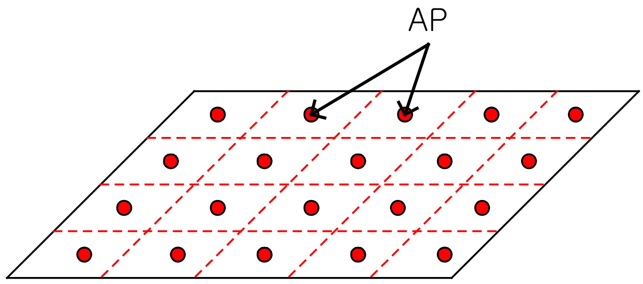


Figure 2. Grid installation

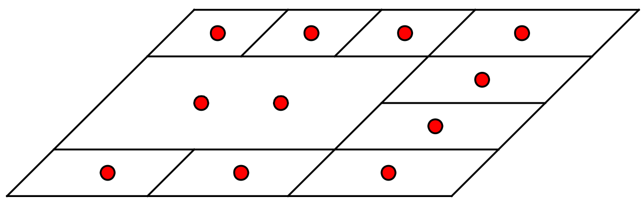
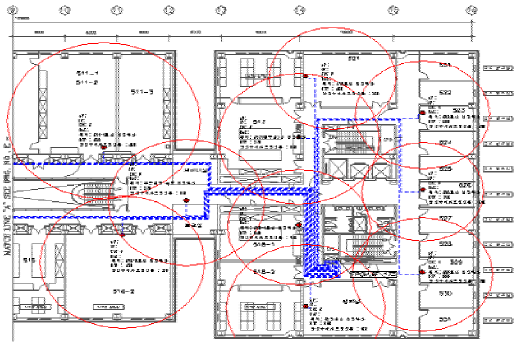
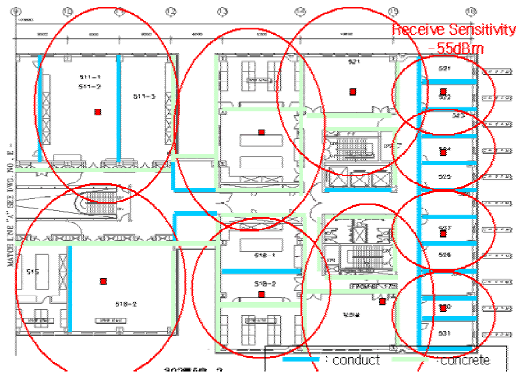


Figure 3. Adapted grid installation

In 2004, Korea Telecom set up WLAN system in Seoul National University. We adapt this new rule to the real environment and compare with the deployed WLAN system. We have much alike the cell planning result.



(a) Cell planning by using the measurment

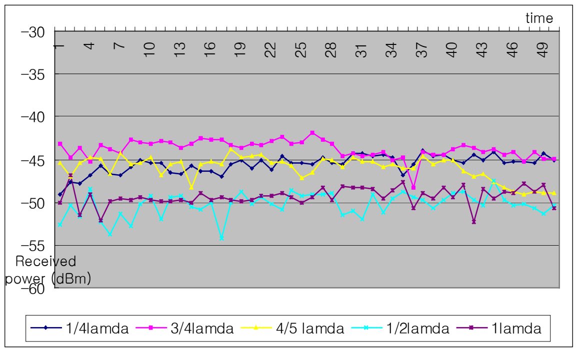


(b) Cell planning by using the new method

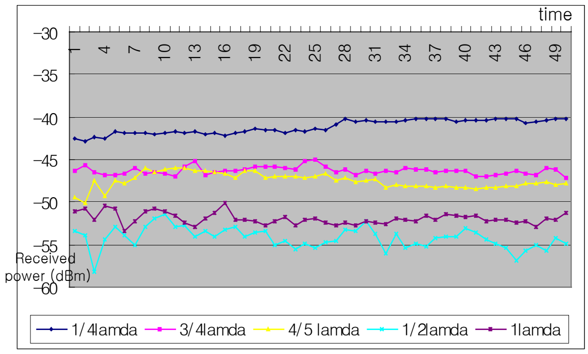
Figure 4. Cell planning on the campus environment

3 Optimal antenna location

In this section, we will provide a proper antenna position. When we set up WLAN systems, we assume AP is located in the middle of classroom. But, because of cost and convenience, actually most of AP's are installed close to the wall and the ceiling. We suggest optimal antenna distance from the wall, especially concrete and conduct wall, which minimizes the influence of first reflected wave. Optimal antenna distance from the wall is $(2n+1)\lambda/4$. And when AP antenna distance form the all was $n\lambda/2$, received signal strength drop about 5dB at concrete wall. When wall material is conduct, this phenomenon appears strongly.[6] Received signal strength drops about 10dB. It is because conduct wall reflect all incidence wave without attenuation. We carried out CW measurements and compare our suggestion with these results below Figure 5.



(a) Measurement on the concrete wall



(b) Measurement on the conduct wall

Figure 5. Measurement results

Next, we suggest optimal antenna height. On outdoor environment, transmitted antenna needs to be installed as highly as we could. Enough line-of-sight (LOS) means provide us with high performance link. But on indoor environment, we should consider the Fresnel zone. Though the AP antenna and received antenna have LOS, if there are obstacle like wall and ceiling in the Fresnel zone, the received power has been rapidly reduced. So we calculate maximal height so that the ceiling should not exist in first Fresnel zone. Fresnel zone definition is described as follows [7]:

$$R_1 - R_2 = \frac{n\lambda}{2} \quad (5)$$

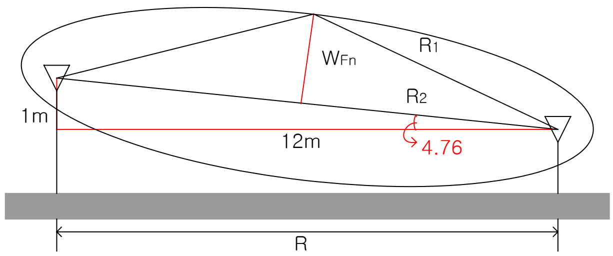


Figure 6. Fresnel zone

In general classroom, transmit antenna location from the ceiling has to be more than 1λ. So if transmit antenna exists within 1λ from the ceiling, the received signal strength drops about 7dB. We perform CW measurement as antenna elevation from the ceiling and compare our suggestion with CW measurements results.

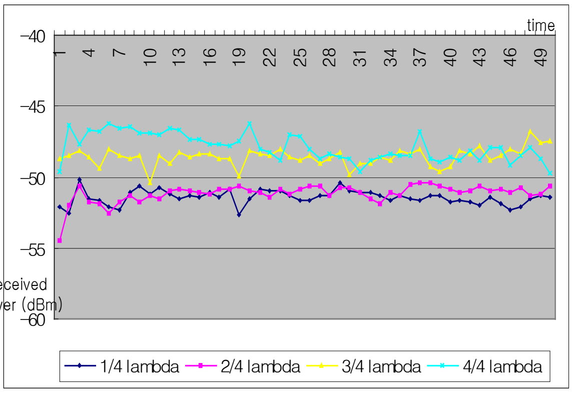


Figure 7. Measurement result

When we set up WLAN system, we should consider many factors. Among these considerations, especially we should give more attention the cell planning and the optimal antenna location that depend on environment.

4 Conclusion

In the deployment of WLAN, we should find optimal AP location and antennal position. In this paper, we suggest a more efficient cell planning method which is a adaptive grid installation. And we suggest the optimal antenna position from the wall and ceiling. By using above results, we can set up the WLAN system get the improvement of the WLAN performance.

5 Acknowledgements

This work was supported in part by KT, Brain Korea 21 Project in 2005 and in part by ITRC.

6 References

[1] IEEE Std 802.11b-1999 Supplement To IEEE Standard for Information Technology-Telecommunications And Information Exchange Between Systems Local And Metropolitan Area Networks Specific Requirements Part 11 : Wireless LAN Medium Access Control (MAC) And Physical Layer (PHY) Specifications : Higher speed Physical layer Extension in the 2.4 GHz

[2] M. Unbehaun and M. Kamenesky, "On the Deployment of Picocellular Wireless Infrastructure", *IEEE Wireless Communications* , **vol. 10**, pp.70-80(2003)

[3] A. Hills, "Large-Scale Wireless LAN design," IEEE Commun. Mag., **vol. 30**, pp. 98-104 (2001)

[4] Hakki CAVDAR, O.AKCAY "The Optimization of Cell Sizes and Base Stations Power Level in Cell Planning" *VTC, 2001 spring. IEEE VTS 53rd*, **vol. 4**, pp. 2344-2348 (2001)

[5] Huang X, Behr U, Wesbeck.W; "Automatic cell planning for a low-cost and spectrum efficient wireless network" *IEEE. GLOBECOM.*, **vol. 1**, pp. 276-282 (2000)

[6] Constantine A, Balanis , Advanced Engineering Electromagnetscs, JOHN WILEY & SONS

[7] Henry L. Bertoni, Radio Propagation for Modern Wireless systems, Prentice Hall PTR