WCDMA Downlink Capacity Analysis based on Deterministic Ray-Tracing Channel Model

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Abstract

In this paper the analysis for WCDMA downlink capacity is presented for a real service environment at Yeouido, Seoul, Korea which is considered as a typical high rise building environment. Ray-tracing technique is used to predict site-specific sector averaged pathlosses not only from the desired node B but also from undesired node Bs to scattered receiver locations in a given cell. Total required power of node B is estimated, which limits system capacity depending on the combination of service types, macro diversity and orthogonal factor.

Keywords

Downlink Capacity, WCDMA, Ray-tracing Technique.

Ⅰ.INTRODUCTION

Recently, rapid progress of wireless communication technology is observed as demands for QoS (Quality of Service) as well as data and multimedia services in addition to voice service are increasing in the wireless communication service industry. WCDMA is developed and selected as one of the third generation mobile communication standards to satisfy these demands. The most attractive feature of WCDMA is the multimedia service but usually occupies too much of limited wireless channel resources. WCDMA system capacity is assumed to be limited by downlink since emerging multimedia services such as wireless internet and VOD, etc. are known to be asymmetric services, which typically require much more traffics from node B to mobile terminals [1]. Therefore it is very important to estimate downlink capacity of WCDMA system for its optimal design and deployment.

The total power of each node B is properly allocated to mobile terminals in its own cell to meet the service requirement. If the estimated total power for a new call to be accepted exceeds the maximum allowed power at a given node B, the attempted new call in this cell will be blocked. It is necessary to know the total required power of a node B according to distribution of services for a given number of users. The crucial factors to determine total node B power are signal pathloss from the node B to a mobile terminal, macro diversity, orthogonal factor and combination of service types.

This paper is focused to analyze the system capacity for a real service environment at Yeouido, Seoul, Korea which has characteristics of a typical high rise building environment. The site specific sector averaged pathloss is obtained using ray-tracing tools called Wavepro^{TM}, which is explained in section Ⅱ. Section Ⅲ introduce the expression for the total node B power requirement in WCDMA system. In section Ⅳ, simulation procedure and results for the system capacity are described. Conclusions are followed in section Ⅴ.

Ⅱ. DETERMINISTIC RAY-TRACING CHANNEL MODEL

Well-known empirical channel models such as Okumura-Hata model or COST-231 model can not be used to predict the site specific pathloss. In order to overcome handicap of these empirical models, a radio propagation prediction tool based on ray-tracing technique can be used to obtain site-specific channel properties in high-rise environment. In this paper, the ray-tracing technique is used to predict the received signal power, which is used to calculate parameter f_i at an arbitrary position within the cell in high-rise urban environment. Parameter f_i is the ratio of the desired signal power to the undesired signal power as shown in the following equation

$$f_i = \frac{\sum_{j=1}^{M} P_{tot,j} L_{ji}}{P_{tot,h} L_{hi}} \qquad (1)$$

where $P_{tot,h}$ and $P_{tot,j}$ is the total transmitted power of the desired sector and the undesired sectors, respectively, L_i is the path loss and M is the number of undesired sectors. Accuracy of ray-tracing prediction tool, Wavepro^{TM}, can be proved by comparing predicted pathloss using Wavepro^{TM} and measured pathlosss in Rosslyn, USA as shown in Figure 1[2].

Pathloss prediction using Wavepro^{TM} at 2 GHz was made for the area of Yeouido, Seoul, Korea, whose ground plan and marked node Bs' locations are shown in Figure 2. Average height of buildings in this area is about 34 m from the ground, which is equivalent to the height of 10 stories building and standard deviation is 19.5 m. In addition, the terrain variation is almost flat and the street shape is like a nearly rectangular grid. Node B1 and node B3 have three sectors while node B2 has two sectors. The heights of node B1, node B2 and node B3 are 55.9 m, 31.5 m and 56.2 m from the ground, respectively. Mobile terminal is assumed to have an omni-directional receiving antenna with the height of 1.7 m from the ground. The parameter f averaged over entire receiver locations in Yeouido based on Wavepro^{TM} is 0.293 which is smaller than parameter f ranging from 0.55 to 0.75 based on empirical models such as Okumura-Hata model, COST-231 model and lognormal fading model.

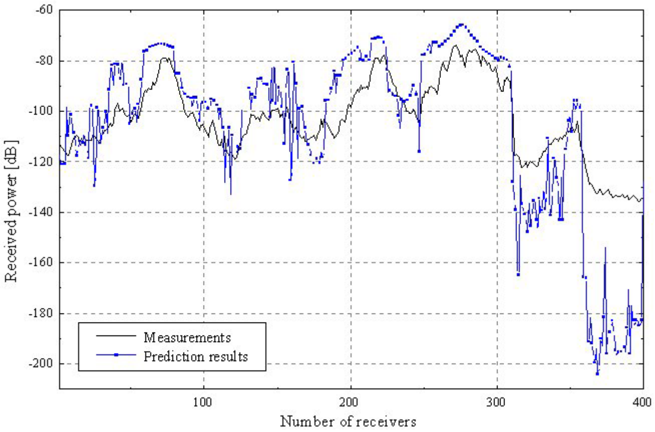

Figure 1. Comparison between simulation result and real measured data in Rosslyn, USA

Figure 2. Ground plan of Yeouido, Seoul, Korea

Ⅲ. CAPACITY ANALYSIS

The total node B power is determined with the following assumptions. First, all node Bs transmit at maximum power. Second, users are uniformly distributed over entire cells in consideration. Third, constant percentage of handover, constant macro diversity gain, constant voice activity are assumed. Fourth, variable orthogonal factor, three kinds of service rates and perfect downlink power control are assumed. We divide WCDMA downlink channels into traffic channels named dedicated physical channel(DPCH) and control channels that consist of both non-orthogonal group such as synchronization channel(SCH) and orthogonal group such as common pilot channel(CPICH) and common control physical channel(CCPCH). The traffic channels employ the downlink power control for maintaining the power level to ensure QoS, while the control channels do not employ the downlink power control but transmit constant power [3][4].

C/I, the ratio of received DPCH power to interference power, of a certain mobile terminal in a cell can be defined as

$$\left(\frac{C}{I}\right)_i = \frac{P_{hi}L_{hi}}{((1-\alpha)+f_i)P_{tot,h}L_{hi} + (1-\alpha)P_{oc}L_{hi} + \alpha P_{noc}L_{hi} + N_0 W} \tag{2}$$

where P_{hi} is the DPCH power received from node B h to mobile i, L_{hi} is the path loss, α is an orthogonal factor due to the mutipath (value 1 : fully orthogonal 1-path channel, value 0 : no orthogonality), $P_{tot,h}$ is the total transmitted power from its own node B, P_{oc} is orthogonal control channel power, P_{noc} is non-orthogonal control channel power, W is chip rate and N_0 is the noise spectral density of mobile receiver front-end that can be obtained from $N_0 = kT + noise\ figure$ (k :Boltzmann constant, T : temperature in Kelvin). C/I is maintained by the downlink power control at C/I_{target} that depends on bit rate, multipath as given in the following equation

$$\left(\frac{C}{I}\right)_{target} = \left(\frac{E_b/I_0}{W/R}\right) = \gamma \tag{3}$$

where E_b is bit energy, I_0 is interference spectral density, R is bit rate.

When a mobile terminal is in soft/softer handover region, it holds two active links and takes both signal for detection using maximum ratio combining(MRC) method. Therefore, target C/I is the sum of C/I at link 1 and C/I at link 2 [5].

$$\left(\frac{C}{I}\right)_{target} = \left(\frac{C}{I}\right)_1 + \left(\frac{C}{I}\right)_2 = \gamma_1 + \gamma_2 \tag{4}$$

Target C/I for mobiles in handover situation is defined as

$$\gamma_{ho} = \frac{G}{2}\gamma_{nho} \tag{5}$$

where index ho and nho indicates mobiles in handover and not in handover, G is a macro diversity gain [6][7].

Assuming the number of active users per sector as N, total transmitted node B power can be formulated as

$$P_{tot,h} = \sum_{i=1}^{(1-g)N} vP_{hi,nho} + \sum_{j=1}^{2gN} vP_{hj,ho} + P_{oc} + P_{noc} \tag{6}$$

where g is the fraction of mobiles in handover, v is activity factor depending on a service type, $P_{hi,nho}$ and $P_{hi,ho}$ are DPCH power not in handover and in handover, respectively. Rearranging equation (6) with equation (2) and (5), the total transmitted node B power is obtained as

$$P_{tot,h} = \frac{(1-g+gG)Nv\gamma\left((1-\alpha)P_{oc} + \alpha P_{noc} + \frac{N_0 W}{L_h}\right) + P_{oc} + P_{noc}}{1-(1-\alpha+f)Nv\gamma(1-g+gG)} \tag{7}$$

where f is an mean value of f_i and L_h is an average of L_{hi} and L_{hj}.

When the system supports three kinds of services such as speech, data1 and data2, required target C/I for each user changes depending on the type of service. The total transmitted node B power for multi-type of services is formulated as given in the following equation

$$\begin{aligned} P_{tot,h} = & \sum_{i=1}^{(1-g)S_S N} v_s P_{hi,nho} + \sum_{j=1}^{2gS_S N} v_s P_{hj,ho} + \sum_{k=1}^{(1-g)S_{D1} N} v_{D1} P_{hk,nho} + \sum_{l=1}^{2gS_{D1} N} v_{D1} P_{hl,ho} \\ & + \sum_{m=1}^{(1-g)S_{D2} N} v_{D2} P_{hm,nho} + \sum_{n=1}^{2gS_{S2} N} v_{D2} P_{hn,ho} + P_{oc} + P_{noc} \end{aligned} \tag{8}$$

where S_S, S_{D1} and S_{D2} are the fraction of speech, data1 and data2 service, respectively and v_s, v_{D1} and v_{D2} are the activity factor of speech, data1 and data2 service (v_{D1}=v_{D2}=1), respectively. Rearranging equation (8) with equation (2) and (5), the total transmitted node B power for multiple services is obtained as

$$P_{tot,h} = \frac{A+B+C+P_{oc}+P_{noc}}{1-(D+E+F)} \tag{9}$$

where

$$A = (1-g+gG)S_S N v_s \gamma_s \left((1-\alpha)P_{oc} + \alpha P_{noc} + \frac{N_0 W}{L_h}\right)$$

$$B = (1-g+gG)S_{D1} N v_{D1} \gamma_{D1} \left((1-\alpha)P_{oc} + \alpha P_{noc} + \frac{N_0 W}{L_h}\right)$$

$$C = (1-g+gG)S_{D2} N v_{D2} \gamma_{D2} \left((1-\alpha)P_{oc} + \alpha P_{noc} + \frac{N_0 W}{L_h}\right)$$

$$D = (1-\alpha+f)S_S N v_s \gamma_s (1-g+gG)$$

$$E = (1-\alpha+f)S_{D1} N v_{D1} \gamma_{D1} (1-g+gG)$$

$$F = (1-\alpha+f)S_{D2} N v_{D2} \gamma_{D2} (1-g+gG)$$

γ_s, γ_{D1} and γ_{D2} are the C/I target of speech, data1 and data2 services.

Ⅳ. SIMULATION RESULTS AND DISCUSSION

To estimate the downlink capacity, we consider three kinds of service such as 12.2kbps speech, 64kbps data and 144kbps data. Service environments in consideration are described in section Ⅱ. Estimation was made considering the change of the following parameters: the combination of service types, macro diversity and orthogonal factor. Parameters used in this estimation is summarized in Table Ⅰ while Table Ⅱ specifies the combination of service types.

Table Ⅰ. Simulation parameters

Parameter	Value
Propagation model	Ray-tracing model
Chip rate (W)	3.84Mcps
Activity factor (v)	Voice: 0.67, Data: 1
Noise spectral density(N_0)	-167dBm (noise figure: 7dBm)
Fraction of mobiles in handover(g)	0.2
Macro diversity gain(G)	0.79
E_b/I_0 target	12.2kbps Voice: 6dB 64kbps Data: 2dB 144kbps Data: 1.5dB
P_{noc}(assuming $P_{\max}$=20W)	0.2W
P_{oc} (assuming $P_{\max}$=20W)	3.8W

Table Ⅱ. Combination of service types

Case / R	Case1	Case2	Case3	Case4	Case5
12.2kbps	70%	60%	50%	40%	30%
64kbps	20%	20%	30%	35%	40%
144kbps	10%	20%	20%	25%	30%

Figure 3 shows the total node B power required to support the given number of users depending on the combination of service types. From this figure, the system capacity can be easily determined once the maximum total node B power is given. The estimation of the system capacity is performed with macro diversity gain of 0.79 and orthogonal factor of 0.5. The results show that downlink capacity decreases as the fraction of high data rate services increases. Figure 4 illustrates the effect of macro diversity. It is assumed that combination of service types is case 2 and orthogonal factor is 0.5. As explained in section Ⅲ, mobile in handover can have a power gain since it takes signals from two node Bs using MRC. As a result, the downlink capacity of the system increases with macro diversity. Figure 5 shows the effect of orthogonal factor. The simulation conditions are identical as Figure 4 except that orthogonal factor changes with the number of multipath. It is revealed that system performance is better with higher orthogonality.

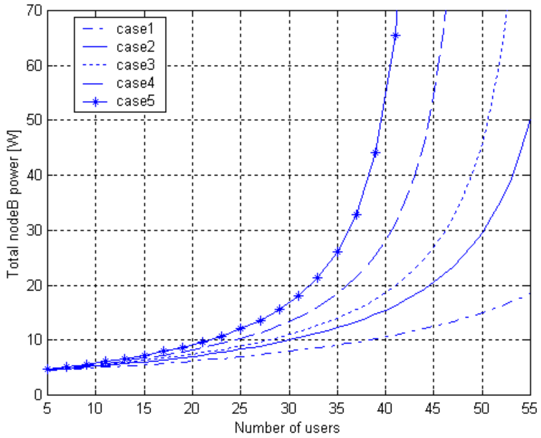

Figure 3. Total node B power in various service combination

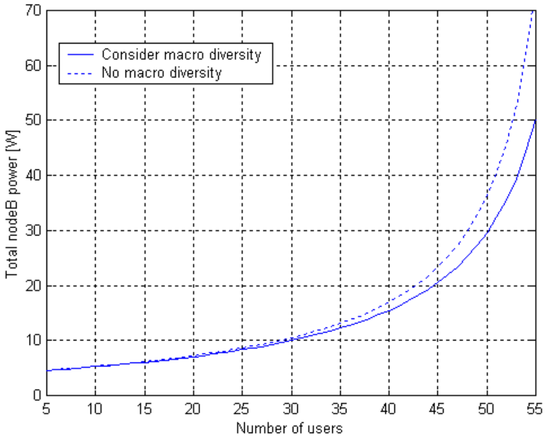

Figure 4. Total node B power with macro diversity

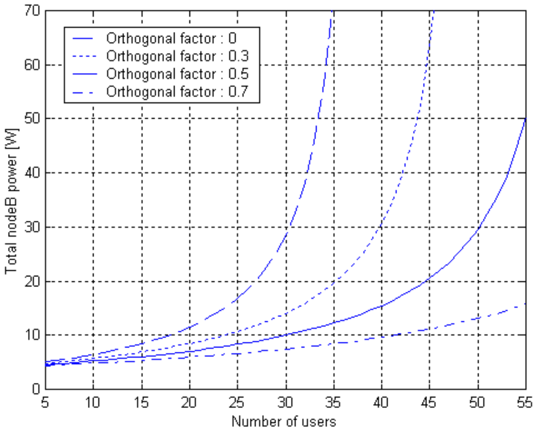

Figure 5. Total node B power in various orthogonal factor

Ⅴ. CONCLUSIONS

The WCDMA downlink capacity analysis has been presented. We illustrated WCDMA capacity in terms of total required power of a node B according to distribution of services for a given number of users in various situations. Unlike previous works, we calculated system capacity for a real environments and estimated pathloss using ray-tracing method. Because ray-tracing channel model includes various elements that affect pathloss such as characters of buildings, landform, diffraction, reflection and multipath, etc., we could estimate pathloss more accurately using this model than using empirical channel model. However, the applicable area of this approach is restricted because we calculated system capacity in specific region, Yeouido, Seoul, Korea that is high-rise urban environments.

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