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Research Article

WCDMA Multiservice Uplink Capacity of Highways Cigar-Shaped Microcells

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The multiservice uplink capacity and the interference (intracellular and intercellular) statistics (mean and variance) of the sectors of cigar-shaped wideband code-division multiple access (WCDMA) microcell are studied using a model of 5 highway microcells in rural zone. The two-slope propagation loss model with lognormal shadowing is used in the analysis. The capacity and the interference statistics of the microcell are studied for different sector ranges, antenna side lobe levels, standard deviation of the power control error, breakpoint distance, and different intersites correlation coefficient. It is shown that reducing the antenna side lobe level increases the sector capacity. Also, it is shown that the sector range that gives the quasi the maximum sector capacity is in the order of 800 to 1200 m.

1. INTRODUCTION

It is well known that WCDMA is characterized as being interference limited, so reducing the interference results in increasing the capacity. Three techniques are used to reduce the interference: power control (PC) which is essential in the uplink and that can double the downlink capacity, voice activity monitoring that can increase the capacity by 50% (assuming an activity factor of 0.66, thus the new capacity will be $1/0.66 = 1.5$ times the old one without using voice activity monitoring) and sectorization. It is well known that the microcells shape may approximately follow the street pattern and that it is possible to have cigar-shaped microcells [1]. The conditions that describe the rural highway cigar-shaped microcells under this study are:

(1) the number of directional sectors of the cigar-shaped microcell is two and a directional antenna is used in each sector;
(2) the sector has typically a range of 1 km.

Figure 1 shows the azimuth radiation pattern of the directional antenna used in each sector and the cigar-shaped microcell azimuth coverage.

Min and Bertoni studied the performance of the CDMA highway microcell using both the one-slope propagation model and the two-slope propagation model but without taking into account the interference variance [2]. They have concluded that the two-slope propagation model is most adequate to be used in the study of the microcells capacity. In [3], the impact of the cell size and the propagation model parameters on the performance of microcellular networks have been studied. The two-slope model of propagation has been used in the analysis. In [4], the Erlang capacity was calculated for a tessellated hexagonal code-division multiple-access (CDMA) cellular system, where transmissions are subject to an inverse fourth-power path-loss law and lognormal fading. Hashem and Sousa [5] studied the capacity and the interference statistics for hexagonal macrocells using a propagation exponent of 4.0. In [6], an analytical computation of the interference statistics with application to mobile radio systems has been given assuming hexagonal macrocells. In [7], the effect of the imperfect power control on the uplink of CDMA cellular networks has been given for hexagonal macrocells calculating the interference statistics assuming a Rayleigh fading channel.

In [8], the capacity and the mean and variance statistics of interference of cigar-shaped microcells for highways in rural zones using wideband code-division multiple access (WCDMA) have been studied. A general propagation exponent using a two-slope propagation model and log-normal shadowing was used. It has been assumed that users are uniformly distributed within the microcells, the intracellular

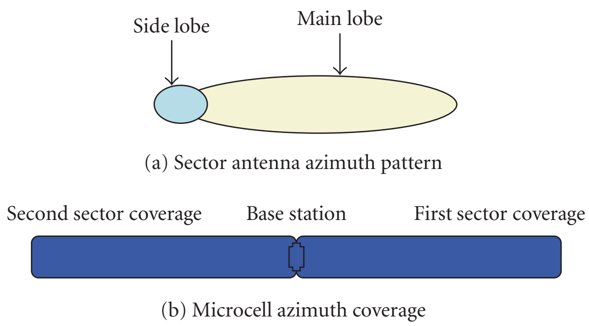

Figure 1: The sector and microcell coverage.

interference variance is null, and that the power control is perfect. In [9], the uplink capacity and interference statistics of WCDMA cigar-shaped microcells for highways in rural zones with nonuniform spatial traffic distribution and imperfect power control were given.

In [10], the capacity of cross-shaped microcells has been given assuming imperfect power control and constant interference to noise ratio. In [11], WCDMA uplink capacity and interference statistics of a long tunnel cigar-shaped microcells have been studied using the hybrid model of propagation and assuming imperfect power control, an infinite transmitted power and an activity factor of 0.5 for voice users (over head was not taken into account). In [11], it was shown that the sector capacity increases when the sector radius increases where nothing shows that at a given sector range (1.5 km approximately), the sector capacity should begin to reduce. All this is due to the fact that the transmitted power was assumed to be infinite. Also in [11], it was not taken into account that a percentage of the mobile transmitted power is assigned to the pilot signal. In [12], the WCDMA uplink capacity and interference statistics of cigar-shaped microcells in rural zones highways have been studied assuming imperfect power control and finite equal transmitted power for the voice and data services. It has been assumed that the WCDMA can support only one service at a given time. Thus, the mixed capacity was not given. Also, it was assumed that the maximum transmitted power of the voice and data users is equal but this is not the case in the multi-service situation. Multi-service means that the system can support more than one service in a given time.

In this work, for cigar-shaped microcells in rural highways zones, we use a two-slope propagation model with general exponent and then investigate the multi-service sector capacity and interference statistics (mean and variance values) of the uplink assuming imperfect power control and finite unequal transmitted power by the mobile for the voice and data services. Those assumptions and the multi-service analysis have not been shown in the previous authors works in [8, 9, 11, 12].

The paper has been organized as follows. In Section 2, the propagation model is given. Section 3 explains the method to calculate the capacity and the interference statistics of the uplink. Numerical results are presented in Section 4. Finally, in Section 5 conclusions are drawn.

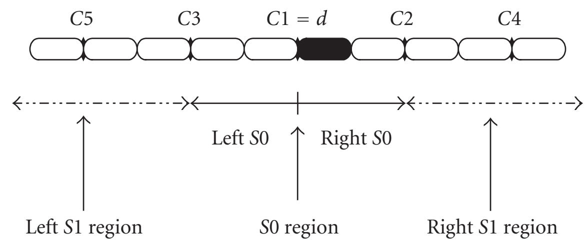

Figure 2: The 5 microcells model.

2. PROPAGATION MODEL

In [2], it has been shown that the two-slope model of propagation is the best propagation model that can be used to study the capacity of the sector of cigar-shaped microcells in highways. Thus, we will use the two-slope propagation model with lognormal shadowing in the calculations of the capacity and the interference statistics. The exponent of the propagation is assumed to be γ_1 until the break point (R_b) and then it converts into a larger value γ_2. In this way the path loss at a distance r from the base station is given by

$$L_p(\text{dB}) = L_b + L_g + 10\gamma_1 \log_{10}\left(\frac{r}{R_b}\right) + \xi_1 \quad \text{If } r \le R_b,$$
$$L_p(\text{dB}) = L_b + L_g + 10\gamma_2 \log_{10}\left(\frac{r}{R_b}\right) + \xi_2 \quad \text{If } r > R_b, \tag{1}$$

where

(1) L_b (the loss at a distance R_b) and R_b are given by

$$L_b(\text{dB}) = 20\log_{10}\left(\frac{4\pi}{\lambda}\right) + 10\gamma_1 \log_{10}(R_b),$$
$$R_b \approx \frac{4h_b h_m}{\lambda}, \tag{2}$$

(2) L_g is the car window penetration loss assumed to be 3 dB,
(3) h_b is the base station antenna height,
(4) h_m is the mobile antenna height,
(5) λ is the wavelength,
(6) ξ_1 and ξ_2 are Gaussian random variables of zero mean and a standard deviation of σ_1 and σ_2, respectively. ξ_1 and ξ_2 represent the effect of shadowing (loss deviation from the mean value).

Practical values of s_1, s_2, σ_1, σ_2, and R_b are (see [8])

(1) $\gamma_1 = 2.0$ to 2.25,
(2) $\gamma_2 = 4.0$ to 6.0,
(3) $\sigma_1 = 2$ to 3 dB,
(4) $\sigma_2 = 4$ to 6 dB, and
(5) $R_b = 300$ m.

3. UPLINK ANALYSIS

Figure 2 depicts the configuration of the 5-microcell model used in analysis where the sector range is assumed to be R.

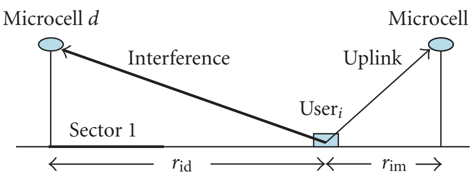

FIGURE 3: Schematic diagram of base stations and mobiles for highway microcells.

In WCDMA systems, each microcell controls the transmitted power of its users. If the interfering user i is at a distance r_{im} from its base station and at a distance r_{id} from the reference microcell base station, as shown in Figure 3, then the ratio of the interference signals $L(r_{id}, r_{im})$ due to the distance only is given as follows.

(1) If $r_{id} > R_b$ and $r_{im} < R_b$ then $L(r_{id}, r_{im})$ is givenas

$$L(r_{id}, r_{im}) = R_b^{(\gamma_2-\gamma_1)} \frac{r_{im}^{\gamma_1}}{r_{id}^{\gamma_2}}. \quad (3)$$

(2) If $r_{id} < R_b$ and $r_{im} > R_b$ then $L(r_{id}, r_{im})$ is given as

$$L(r_{id}, r_{im}) = R_b^{(\gamma_1-\gamma_2)} \frac{r_{im}^{\gamma_2}}{r_{id}^{\gamma_1}}. \quad (4)$$

(3) If (r_{id} and $r_{im} > R_b$) then $L(r_{id}, r_{im})$ is given by

$$L(r_{id}, r_{im}) = \left(\frac{r_{im}}{r_{id}}\right)^{\gamma_2}. \quad (5)$$

Now, the ratio of the interference signals $L_{shd}(r_{id}, r_{im})$ due to the distance and shadowing is given by

$$L_{shd}(r_{id}, r_{im}) = 10^{(\xi_{id}-\xi_{im})/10} L(r_{id}, r_{im}), \quad (6)$$

where ξ_{id} and ξ_{im} are given as follows.

(1) If $r_{id} > R_b$ and $r_{im} < R_b$ then $\xi_{id} = \xi_2$ and $\xi_{im} = \xi_1$.
(2) If $r_{id} < R_b$ and $r_{im} > R_b$ then $\xi_{id} = \xi_1$ and $\xi_{im} = \xi_2$.
(3) In case of (r_{id} and $r_{im} > R_b$) then $\xi_{id} = \xi_2$ and $\xi_{im} = \xi_2$.

We will divide the total intercellular interference (I_{inter}) into interference from users in the $S0$ region (I_{S0}) and interference from users in the $S1$ region (I_{S1}), where these regions are shown in Figure 2. We will find the capacity and the interference statistics of the right sector (drawn in black in Figure 2) that provides half of the coverage to microcell d. We assume that users in the region $S0$ and $S1$ connect to the best (with lower propagation loss) of the two nearest microcells. In the $S1$ region, we will use the upper limit approximation (users in $S1$ never communicate with $C1$) to calculate the interference statistics. This will compensate the use of only 6 sectors to calculate the intercellular interference statistics instead of using unlimited number of sectors (microcells).

Let the mean value of the desired signal power received by the base station for a given service s be $P_{r,s}$. The mean value of the interference from an active user communicating with the reference microcell, assuming the same service, will be also $P_{r,s}$. A user i in the $S0$ region will not communicate with the reference base station d ($C1$) but rather with base station m ($C2$ or $C3$) whenever the propagation loss between the user i and base station m is lower than the propagation loss between the user i and the base station $C1$, that is, if $\phi(\xi_{id} - \xi_{im}, r_{id}/r_{im}) = 1$, where

$$\phi\left(\xi_{id} - \xi_{im}, \frac{r_{id}}{r_{im}}\right) = \begin{cases} 1, & \text{if } L(r_{id}, r_{im}) 10^{(\xi_{id}-\xi_{im})/10} \le 1, \\ 0, & \text{otherwise.} \end{cases} \quad (7)$$

Assuming a uniform density ρ_s of users for each service, the density of users in each sector is $\rho_s = N_{u,s}/R$ users per unit length. For the right part of $S0$ the expected value of I_{S0} for a given service s is given as

$$E[I_{S0}]_{r,s} = \alpha_s \rho_s \int_{S0r} L(r_{id}, r_{im}) f\left(\frac{r_{id}}{r_{im}}\right) dr. \quad (8)$$

Being

$$f\left(\frac{r_{id}}{r_{im}}\right) = E\left[10^{(\xi_{id}-\xi_{im})/10} \phi\left(\xi_{id} - \xi_{im}, \frac{r_{id}}{r_{im}}\right)\right] = e^{(\beta\sigma)^2/2} Q\left[\beta\sqrt{\sigma^2} + \frac{10}{\sqrt{\sigma^2}} \log_{10}\left\{\frac{1}{L(r_{id}, r_{im})}\right\}\right], \quad (9)$$

where

(1) $\beta = \ln 10/10$,
(2) α_s is the activity factor of the user for the service s assumed to be 0.66 for voice users and 1.0 for data users.

Now the general value of σ^2 is given as follows.

(1) If $r_{id} \le R_b$ and $r_{im} > R_b$ or $r_{id} > R_b$ and $r_{im} \le R_b$ then the value of σ^2 is given by

$$\sigma^2 = (\sigma_1 - \sigma_2)^2 + 2(1 - C_{dm})\sigma_1\sigma_2, \quad (10)$$

where C_{dm} is the inter-sites correlation coefficient.

(2) When (r_{id} and $r_{im} > R_b$) then $\sigma_{id} = \sigma_2$, also $\sigma_{im} = \sigma_2$ and then

$$\sigma^2 = 2(1 - C_{dm})\sigma_2^2. \quad (11)$$

The function $Q(x)$ is the complementary distribution function of the standard Gaussian distribution defined as

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-v^2/2} dv. \quad (12)$$

The upper limit of the expected value of I_{S1} due to right part of the $S1$ region for the service s is given as

$$E[I_{S1}]_{r,s} \approx \alpha_s \rho_s \int_{S1\,r} L(r_{id}, r_{im}) E\left[10^{(\xi_{id}-\xi_{im})/10}\right] dr. \quad (13)$$

The expected value of the intercellular interference from the right side of the regions $S0$ and $S1$ for the service s is

$$E[I]_{r,s} = E[I_{S0}]_{r,s} + E[I_{S1}]_{r,s}. \quad (14)$$

Thus the expected value of the total interference from the left and right sides for the service s is given by

$$E[I]_{inter,s} = E[I]_{r,s}(1 + \text{Sll}), \quad (15)$$

where Sll is the side lobe level of the directional antenna used in each sector.

The expected value of the total intercellular interference power for the service s is given as

$$E[P]_{\text{inter},s} = P_{r,s}E[I]_{\text{inter},s}. \tag{16}$$

The expected value of the intracellular interference power due to the service s is given by

$$E[P]_{\text{intra},s} = P_{r,s}E[I]_{\text{intra},s} \approx P_{r,s}\alpha_s N_{u,s}(1+\text{Sll}). \tag{17}$$

Taking into account an imperfect power control with standard deviation error of σ_c(dB), the total expected interference power for the service s will be

$$E[P_{\text{intf}}]_{t,s} = e^{\beta^2\sigma_c^2/2}\left(E[P]_{\text{intra},s} + E[P]_{\text{inter},s}\right). \tag{18}$$

Using soft handoff, a fraction ψ of the sector users will be in connection with more than one base station (practically with two base stations). In this case, the expected value of the interference power for a given service s will be

$$E[P_{\text{intf}}]_{t,s} = K_{\text{SHO}}e^{\beta^2\sigma_c^2/2}\left(E[P]_{\text{intra},s} + E[P]_{\text{inter},s}\right), \tag{19}$$

where K_{SHO} is an interference reduction factor that can be derived from [13],

$$K_{\text{SHO}} = (1-\psi) + \frac{\psi}{G_{\text{SHO}}}, \tag{20}$$

where G_{SHO} is the soft handoff gain. Practical value of K_{SHO} in quasi 1D case (our case when the width of the highways is neglected since it is very narrow in comparison with the sector radius) is 0.95 to 0.98.

The expected value of the total interference power due to all services will be

$$E[P_{\text{intf}}]_t = \sum_{s=1}^{M} E[P_{\text{intf}}]_{t,s}, \tag{21}$$

where M is the number of the services that the system supports.

The variance of the interference power P_{S0} due to right part of $S0$ for the service s is given as [7]

$$\begin{aligned}\text{var}\,[P_{S0}]_{r,s} \\ &= \rho_s P_{r,s}^2 \int_{S0\ r} [L(r_{\text{id}}, r_{\text{im}})]^2 \left\{ p\alpha_s g\left(\frac{r_{\text{id}}}{r_{\text{im}}}\right) - q\alpha_s^2 f^2\left(\frac{r_{\text{id}}}{r_{\text{im}}}\right)\right\} dr,\end{aligned} \tag{22}$$

where

$$\begin{aligned} g\left(\frac{r_{\text{id}}}{r_{\text{im}}}\right) &= E\left[10^{(\xi_{\text{id}}-\xi_{\text{im}})/10}\phi(\xi_{\text{id}}-\xi_{\text{im}}, r_{\text{id}}/r_{\text{im}})\right]^2, \\ &= e^{2(\beta\sigma)^2} Q\left[2\beta\sqrt{\sigma^2} + \frac{10}{\sqrt{\sigma^2}}\log_{10}\left\{\frac{1}{L(r_{\text{id}}, r_{\text{im}})}\right\}\right], \\ p &= e^{2\beta^2\sigma_c^2} \qquad q = e^{\beta^2\sigma_c^2}. \end{aligned} \tag{23}$$

The upper limit of the variance of P_{S1} due to right part of $S1$ for the service s is given as

$$\begin{aligned}\text{var}\,[P_{S1}]_{r,s} \\ &\approx \rho_s P_{r,s}^2 \int_{S1\ r} [L(r_{\text{id}}, r_{\text{im}})]^2 \Big\{ p\alpha_s E\left[\left(10^{(\xi_{\text{id}}-\xi_{\text{im}})/10}\right)^2\right] \\ &\qquad - q\alpha_s^2 E^2\left[10^{(\xi_{\text{id}}-\xi_{\text{im}})/10}\right]\Big\} dr.\end{aligned} \tag{24}$$

Thus the variance of total intercellular interference power due to the total region $S0$ and $S1$ for the service s is given by

$$\text{var}[P]_{\text{inter},s} = \left\{\text{var}\,[P_{S0}]_{r,s} + \text{var}\,[P_{S1}]_{r,s}\right\}(1+\text{Sll}). \tag{25}$$

The variance of the intracellular interference power due to the service s is calculated as

$$\text{var}[P]_{\text{intra},s} = N_{u,s}P_{r,s}^2(1+\text{Sll})\left(p\alpha_s - q\alpha_s^2\right). \tag{26}$$

The variance of the total interference power due to the service s is given by

$$\text{var}[P]_{t,s} = \text{var}[P]_{\text{inter},s} + \text{var}[P]_{\text{intra},s}. \tag{27}$$

The variance of the total interference power due to all services s is given by

$$\text{var}\,[P_{\text{intf}}]_t \sum_{s=1}^{M} \text{var}[P]_{t,s}. \tag{28}$$

In the uplink only $\varepsilon P_{r,s}$ of $P_{r,s}$ is used in the demodulation ($\varepsilon = 15/16 = 0.9375$). Thus, for a given outage probability, the uplink carrier-to-interference ratio $[C/I]_s$ for a given service s is given as

$$\left[\frac{C}{I}\right]_s = \frac{\varepsilon P_{r,s}}{E[P_{\text{intf}}]_t + P_N + \kappa\sqrt{\text{var}\,[P_{\text{intf}}]_t}}, \tag{29}$$

where P_N is the receiver noise power and κ is a factor that depends on the outage probability (2.13 for outage probability of 2% and it is 2.33 for an outage probability of 1%).

For a given service, the $(E_b/N_o)_s$ ratio is given as [14]

$$\left[\frac{E_b}{N_o}\right]_s = \left[\frac{C}{I}\right]_s G_{p,s}, \tag{30}$$

where $G_{p,s}$ is the processing gain of the service s.

Assuming a given number of users for each service, the outage probability versus number of users can be obtained using (30).

For mixed services of voice and data, the ratio between the maximum transmitted power by data users and the maximum transmitted power of the voice users given in dB should be

$$\left(\frac{P_{\text{td}}}{P_{\text{tv}}}\right)_{\text{dB}} = (1+\delta)\left[10\log_{10}\left(\frac{G_{pv}/(E_b/N_o)_v}{G_{pd}/(E_b/N_o)_d}\right)\right], \tag{31}$$

where

(1) P_{td} is the transmitted power of the data users located at the sector border,
(2) P_{tv} is the transmitted power of the voice users located at the sector border,
(3) δ is a constant with a value of 0.0 if only the mean value of the interference is considered. When the interference variance is also considered, it has a value of −0.1 to 0.1 depending on the parameters of the services under study,
(4) G_{pv} is the voice service processing gain,
(5) G_{pd} is the data service processing gain,
(6) $(E_b/N_o)_v$ is the required (E_b/N_o) for voice service given in natural numbers, and
(7) $(E_b/N_o)_d$ is the required (E_b/N_o) for data service given in natural numbers.

4. NUMERICAL RESULTS

In our estimation we assumed that the WCDMA chip rate is 3.84 Mchips/sec. For our calculations some reasonable figures are applied. Receiver noise power of −100 dBm assuming that the receiver noise figure is 7 dB, an azimuth side lobe level of −15 dB, inter-sites correlation coefficients C_{dm} of 0.5, $\gamma_1 = 2$, $\gamma_2 = 4$, $\sigma_1 = 3$ dB, $\sigma_2 = 6$ dB, $R_b = 300$ m and $R = 1$ km unless other values are mentioned. Also we assume the following.

(1) A maximum transmitted power $P_{tv\text{-}max}$ of 20.4 dBm for the voice service.
(2) A maximum transmitted power $P_{td\text{-}max}$ of 25 dBm for the data service.
(3) Base station antenna gain of 12 dB.
(4) SHO gain of 1 dB [13].
(5) SHO users fraction ψ of 0.1.

We assume that the accepted outage probability is 1% and that the capacity of the sectors is calculated at this probability.

Firstly, we study the case of voice-only users (15 kbits/sec) assuming that the activity factor α is 0.66 and the required (E_b/N_o) is 6.7 dB [15]. Figure 4 shows the outage probability of the sector for three different values of σ_c, that is, 1.0, 1.5 and 2.0 dB. For an outage probability of 1%, the capacity of the sector is 54.7, 51.8, and 48.1 voice users, respectively.

Next we study the case of data-only users assuming a bit rate of 120 kbps ($G_p = 32$), required $(E_b/N_o) = 2.5$ dB, and $\alpha = 1$ [14]. Figure 5 shows the outage probability for three values of σ_c, that is, 1.0, 1.5, and 2.0 dB. For an outage probability of 1%, the capacity of the sector is 12.9, 11.8, and 10.6 data users, respectively.

Let us now study the case of mixed services. Figure 6 shows the outage probability as a function of the number of voice users/sector for three values of σ_c, that is, 1.0, 1.5, and 2.0 dB assuming that 5 data users exist within each sector. For an outage probability of 1%, the capacity of the sector is 33.8, 30.2, and 25.5 voice users respectively. Figure 7 shows the mixed capacity of the sector when $\sigma_c = 1.5$ dB.

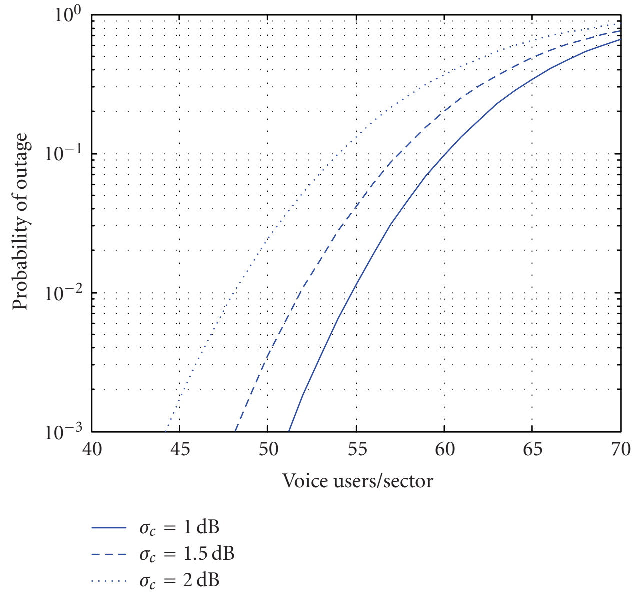

Figure 4: Outage probability of the sector for voice users only.

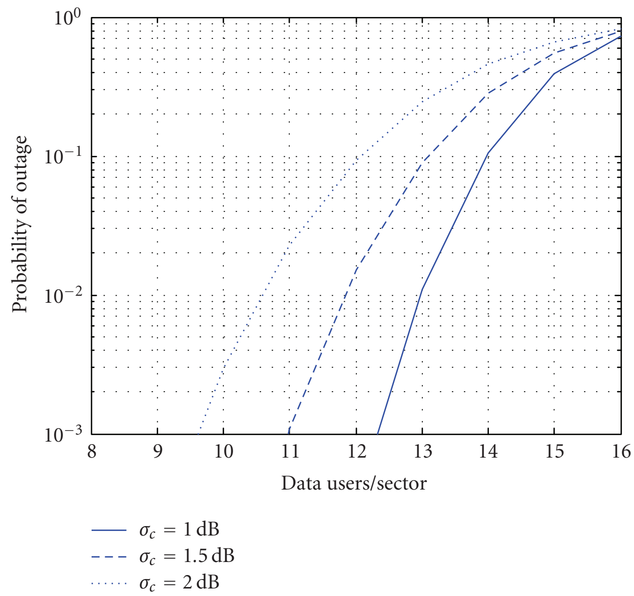

Figure 5: Outage probability of the sector for data users only.

Figure 8 shows the effect of the sector range R on the sector uplink capacity when $\sigma_c = 1.5$ dB. It can be noticed that for $300 \le R \le 900$ m the capacity increases when R increases and then it remains constant for $900 \le R \le 1000$ m. At higher sector range, sector capacity reduces monotonically. In practice, R could have a value of 1000 to 2000 m. To start with, one base station could be deployed each 4.0 km of the highway. With the time, another base station could be deployed in between, reducing the distance between the base stations to 2.0 km.

Figure 9 shows the effect of the side lobe level Sll on the sector uplink capacity. It can be seen that reducing the side

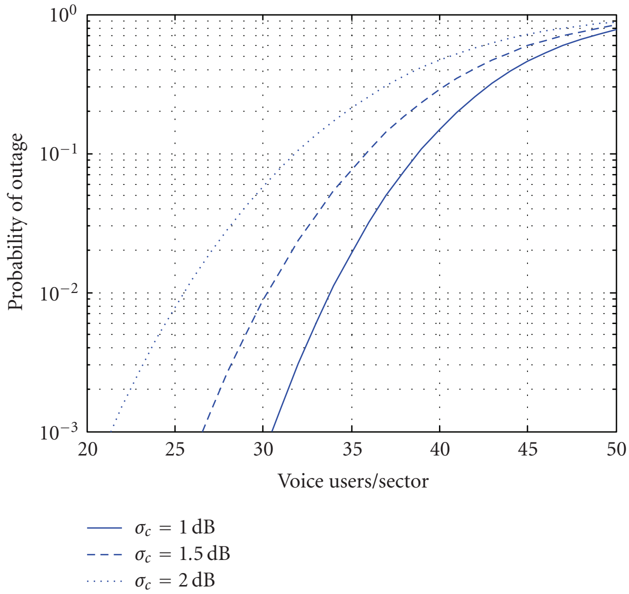

FIGURE 6: Outage probability of the sector for mixed voice and data users.

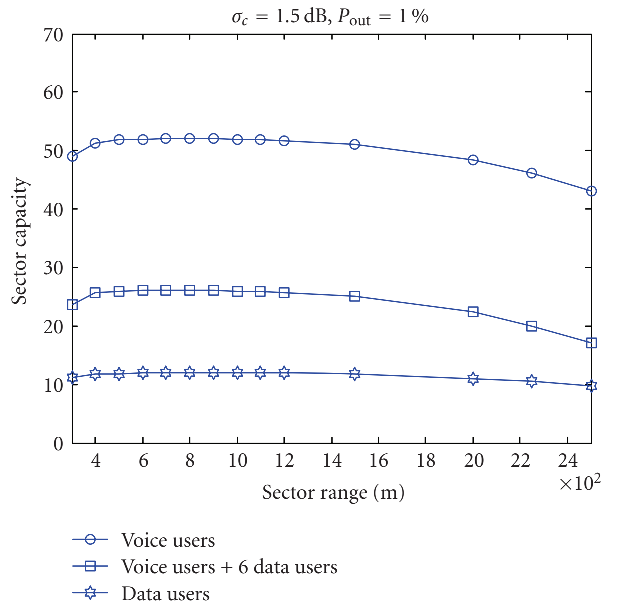

FIGURE 8: Sector capacity for different R for (voice users only, mixed services (voice users +5 data users), and data users only).

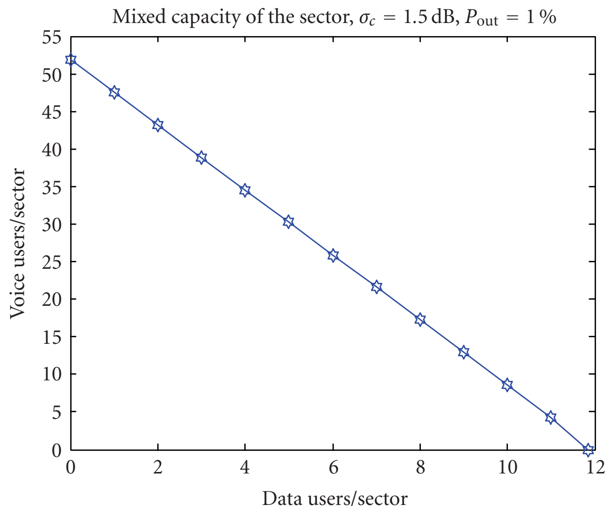

FIGURE 7: Mixed capacity of the sector.

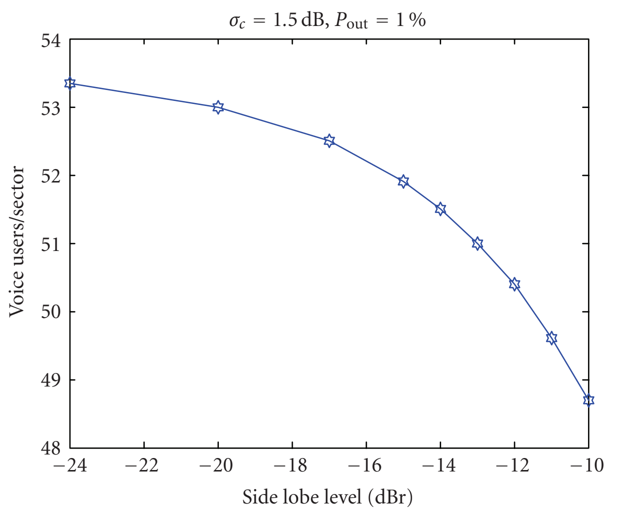

FIGURE 9: Effect of the antenna sidelobe level on the sector uplink capacity.

lobe level will increase the capacity of the sector. An antenna with azimuth side lobe level of −15 dB or better is a good choice.

Figure 10 points out the effect of the break point distance R_b on the sector uplink capacity. It can be noticed that the effect of the break point distance on the uplink capacity of the sector is very small (0.2 users) and that the maximum capacity is obtained at R_b of 450 m.

Figure 11 depicts the effect of the inter-sites correlation coefficient C_{dm} on the sector uplink capacity. It can be noticed that the effect of the inter-sites correlation coefficient C_{dm} on the uplink capacity of the sector is very small (0.1 users). This is due to the fact that the intercellular interference affected by the inter-sites correlation coefficient is small compared with the intracellular interference not affected by the inter-sites correlation coefficient.

Figure 12 shows the effect of the propagation exponent γ_1 on the sector uplink capacity. It can be noticed that increasing the value of γ_1 will reduce the sector uplink capacity. This is due to the fact that increasing γ_1 will increase the propagation loss which reduces the power level of the received signal reducing the capacity (as shown by (29)).

Figure 13 represents the effect of the propagation exponent γ_2 on the sector uplink capacity. It can be noticed that increasing the value of γ_2 from 4 to 4.75 will increase the sector uplink capacity. Also, it can be noticed that increasing γ_2 from 4.75 to 6 will reduce the sector uplink capacity. This is due to the fact that increasing γ_2 will increase the isolation

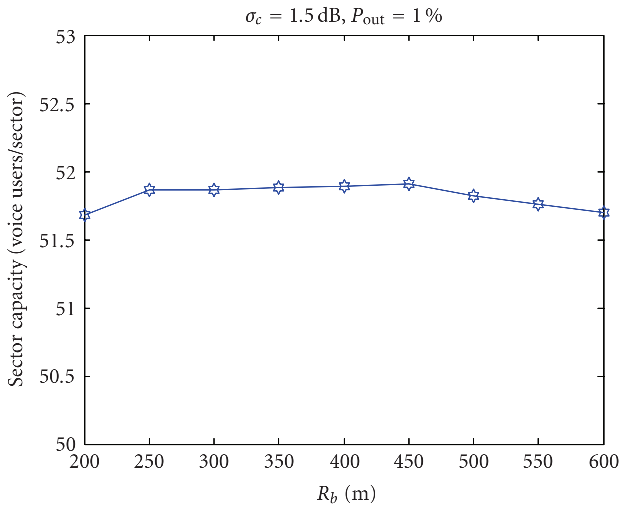

Figure 10: Effect of the break point distance R_b on the sector uplink capacity.

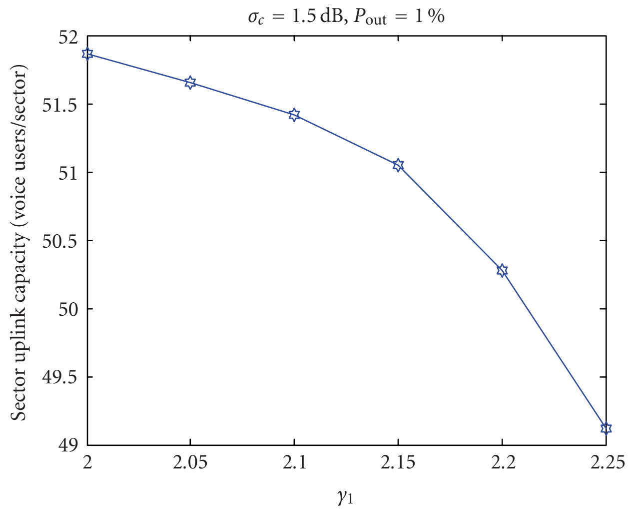

Figure 12: Effect of the propagation exponent γ_1 on the sector uplink capacity.

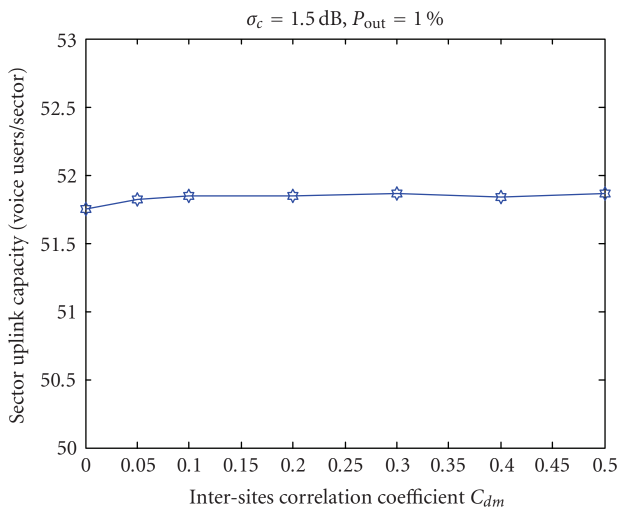

Figure 11: Effect of the inter-sites correlation coefficient on the sector uplink capacity.

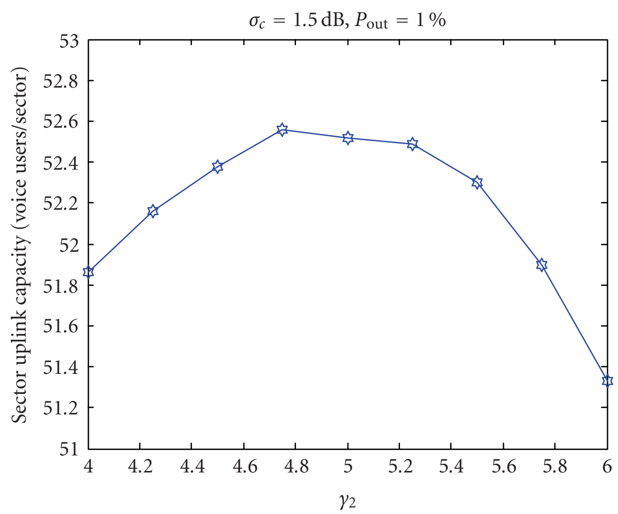

Figure 13: Effect of the propagation exponent γ_2 on the sector uplink capacity.

(lower intercellular interference and thus higher capacity) between the microcells. Nevertheless, increasing γ_2 increases the propagation loss lowering the sector uplink capacity. For γ_2 between 4 and 4.75, the effect of the isolation is dominant. Thus, the capacity increases. For γ_2 higher than 4.75, the effect of the propagation loss is dominant.

Finally, we will study the effect of reducing the base station receiver noise figure using new technologies such as high temperature filters and super low noise amplifiers (amplifiers with noise figure lower than 0.5 dB). Figure 14 shows that the effect of reducing the receiver noise figure is quasi null when the sector radius is 1000 m. Nevertheless, at higher sector range, the effect will be notable. Reducing the noise figure of the receiver from 7 to 5 dB will increase the sector uplink capacity by 0.5 voice users for a sector range of 1500 m. For a sector range of 2000 m, reducing the noise figure from 7 to 5 dB will increase the sector uplink capacity by 1.4 voice users. Thus, for a sector range of 1500 m or lower, it is unnecessary to use high-cost components in the receiver since its effect is marginal.

It has been noticed that 98.4% of the interference is due to $S0$ region (4 sectors). Thus, the 5 microcells (10 sectors) model is sufficient for calculating the interference statistics with a high accuracy.

5. CONCLUSION

We have presented a model to calculate the capacity and interference statistics of a multi-service WCDMA in rural highway cigar-shaped microcells. The capacity of the sector has been studied using a general two-slope propagation model with lognormal shadowing and imperfect power control and

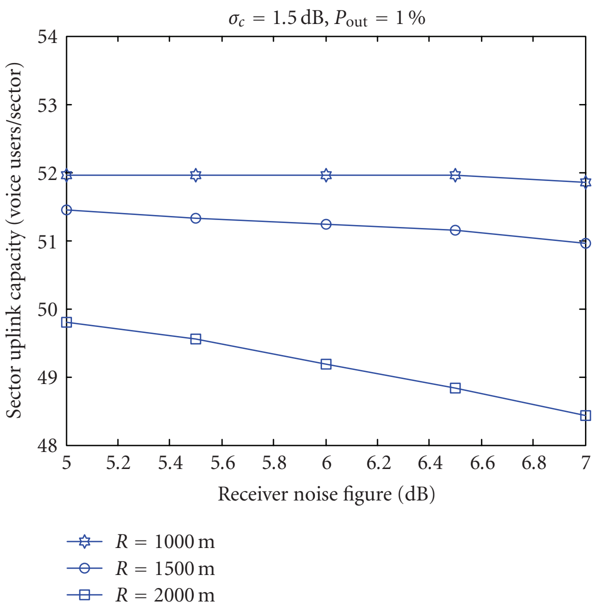

Figure 14: Effect of the base station receiver noise figure on the sector uplink capacity.

finite transmitted power. The effects of the sector range and the sidelobe level of the directional antenna have been studied. It has been concluded that reducing the antenna side lobe level increases the sector capacity. Also it has been concluded that the optimum sector range to get the maximum sector capacity is in the order of 900 to 1000 m when the break point distance is 300 m. It has been noticed that the effect of the breakpoint distance on the uplink sector capacity is quasi null. Also, it has been noticed that the effect of the inter-sites correlation coefficient on the sector uplink capacity is negligible.

To get the quasi-maximum possible sector capacity, the following conditions should be fulfilled.

(1) The sector range should be higher than 800 m and lower than 1200 m.
(2) The sidelobe level of the directional antenna should be −15 dB or better.

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