Wireless Personal Communications 71.3 (2013): 1649-1662

**DOI:** http://dx.doi.org/10.1007/s11277-012-0900-3

# Multipath Effect on the WCDMA Uplink Capacity of Highways Cigar-shaped Microcells with Users within Cars and Buses

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**Abstract:** In this work, the effect of the multipath on the capacity and the interference statistics of the sectors of the highways cigar-shaped W-CDMA microcells is studied. A model of five microcells is used to analyze the uplink. The capacity and the interference statistics of the microcell are studied for different antenna sidelobe levels and different sector ranges. In the study, imperfect power control and limited transmitted power are assumed. Users are assumed to be within equally spaced buses and cars. The uplink capacity of the sector is studied assuming three types of services, namely, voice, 3G data and 3.75G data (representing the High Speed Uplink Packet Access). It is shown that, the sector uplink capacity depends on the buses and cars density within the sector. The capacity is also given as a function of the number of buses and cars within the sector.

**Keywords:** W-CDMA, Uplink capacity, Shadowing.

## 1- Introduction

It is very well known that CDMA capacity is characterized as being interference-limited, so reducing the interference increases the capacity. Also, it is well known that urban microcell shapes may approximately follow the street pattern and that it is possible to have cigar-shaped microcells [1]. **The optimum way to have communication coverage in highways is to deploy cigar-shaped microcells each one with two sectors.**

Min et al. [2] studied the performance of the CDMA highway microcell where users are uniformly distributed within the highway road. The variance of the interference was not given. Hashem et al. [3] studied the capacity and the interference statistics of the hexagonal macrocells for a propagation exponent of 4.0. Ahmed et al. [4] studied the capacity and the statistics of the interference of shaped W-CDMA microcells in highways with uniform distribution of users assuming that the intracellular interference variance was null. In [5], the uplink capacity and the interference statistics of cigar-shaped road microcells in over-ground train service were studied assuming perfect power control and unlimited transmitted power. In [6], the W-CDMA uplink capacity and interference statistics of cigar-shaped microcells in over-ground train service with imperfect power control was studied assuming unlimited transmitted power and ignoring the power assigned to the W-CDMA uplink pilot. In [7], the W-CDMA uplink capacity and interference statistics of rural highways cigar-shaped microcells with imperfect power control and uniform distribution of users were obtained. In [8] which represent one of the newest works in this area, the WCDMA multiservice uplink capacity of highways cigar-shaped microcells has been given assuming simultaneous voice and data services. The WCDMA uplink capacity and interference statistics of highways shaped microcells with imperfect power control and finite transmitted power have been presented in [9].

The entire up mentioned works except [5] and [6] have assumed uniform distribution of users within the microcells (up to 100 simulation points in each sector). No one of the above mentioned works except [3] has taken into account the effect of the multipath components that can exist due to the nearer scatterers. **The effect of the multipath is to reduce the capacity of the communications systems since it is practically impossible to collect the power of all of the multipath components reducing the received power of the desired signal.**

In this work we will assume that users exist within a given number of buses and cars in each sector and that the buses and the cars are equally spaced. For the users within the bus or the car, we can assume a uniform distribution of these users within the limited space of the buses or cars. Out of the bus or the car, the distribution of users is null.

In this work, we will use a model of five cigar-shaped microcells to calculate the uplink capacity and interference statistics of a WCDMA system utilizing the two-slope propagation model with Normal shadowing and for the first time including the multipath components, assuming an imperfect power control and limited transmitted power.

The main contribution of this work is to study the effect of the multipath on the uplink capacity of the sectors of a cigar- shaped microcells considering three types of service namely, voice service, traditional data service (3G) y High Speed Uplink Packet Access (HSUPA) presenting 3.75G data service, assuming that the users exist within limited number of cars and buses.

## 2- Propagation Model

A two-slope propagation model with lognormal shadowing is used in the calculations. The exponent of the propagation is assumed to be $s_1$ till the break point $R_b$ and then it changes to $s_2$. In this way the path loss is given by:

$$L_p(dB) = L_b + L_g + 10 s_1 \log_{10}\left(\frac{r}{R_b}\right) + \xi_1 + \delta \qquad \text{If } r \le R_b \qquad (1)$$

$$L_p(dB) = L_b + L_g + 10 s_2 \log_{10}\left(\frac{r}{R_b}\right) + \xi_2 + \delta \qquad \text{If } r > R_b \qquad (2)$$

where

- $L_b$ is the path loss at $r = R_b$,
- $L_g$ is the car or bus window's insertion loss assumed to be 3 dB,
- $\xi_1$ and $\xi_2$ are Gaussian random variables of zero-mean and a standard deviation of $\sigma_1$ and $\sigma_2$ respectively representing the deviation from the mean value,
- $\delta$ is the multipath loss term. The multipath fading is assumed to be composed of M equal-strength Rayleigh fading paths [3].
- $r$ is the distance between the base station of the microcell C and the mobile.

, $L_b$ and $R_b$ are given by:

$$L_b(dB) = 20\log_{10}\left(\frac{4\pi}{\lambda}\right) + 10\, s_1 \log_{10}(R_b) \qquad (3)$$

$$R_b \approx \frac{4 h_b h_m}{\lambda} \qquad (4)$$

where

- $h_b$ is the base station antenna height,
- $h_m$ is the mobile antenna height and
- $\lambda$ is the used wavelength.

We have to mention that the user within the cars has an effective height of 0.8 to 1.2 m meanwhile it is 1.5 to 2.5 m for the bus user. For that reason their $R_b$ will be lower than the $R_b$ of the users within the buses. Thus, the range limit is due to the users within the cars. Normal possible number of users within a car is 4 to 5 users while, for the bus the normal possible number of users is 40 to 50.

**3- Uplink Analysis**

Fig. 1 shows the configuration of the five microcells model. The sector range is assumed to be R. If the interfering user *i* is at a distance $r_{im}$ from the nearest base station and at a distance $r_{id}$ from the base station of the microcell under study d, as shown in Fig. 2, then the interference loss term $L(r_{id}, r_{im})$ due to the distance only is given as:

- If $r_{id} > R_b$ and $r_{im} \le R_b$ then $L(r_{id}, r_{im})$ is given as

$$L(r_{id}, r_{im}) = R_b^{(s_2 - s_1)} \left( \frac{r_{im}^{s_1}}{r_{id}^{s_2}} \right) \tag{5}$$

- If $r_{id} \le R_b$ and $r_{im} > R_b$ then $L(r_{id}, r_{im})$ is given as

$$L(r_{id}, r_{im}) = R_b^{(s_1 - s_2)} \left( \frac{r_{im}^{s_2}}{r_{id}^{s_1}} \right) \tag{6}$$

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

$$L(r_{id}, r_{im}) = \left( \frac{r_{im}^{s_2}}{r_{id}^{s_2}} \right) \tag{7}$$

The case when ($r_{id}$ and $r_{im} \le R_b$) has not taken into account since it is impractical one.

Now the total interference loss term $L_t(r_{id}, r_{im})$ due to the shadowing, multipath and distance is given by:

$$L_t(r_{id}, r_{im}) = L_{shad}\ L_M\ L(r_{id}, r_{im}) = 10^{(\xi_{id} - \xi_{im})/10} \left( \frac{\delta_{im}}{\delta_{id}} \right) L(r_{id}, r_{im}) \tag{8}$$

Where $L_{shad}$ is the shadowing loss term, $L_M$ is the multipath loss term.

$\xi_{id}$ and $\xi_{im}$ are given by:

- If $r_{id} > R_b$ and $r_{im} \le R_b$ then $\xi_{id} = \xi_2$ and $\xi_{im} = \xi_1$.
- When $r_{id} \le R_b$ and $r_{im} > R_b$ then $\xi_{id} = \xi_1$ and $\xi_{im} = \xi_2$.
- 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 Fig. 1. We will find the capacity and the interference statistics of the right sector (drawn in black in Fig. 2) that provides half of the coverage to microcell d. We will assume that users in the region S0 and S1 will connect with the best (with lower propagation loss) of the two nearest microcells. Thus, users in S1 can not communicate with the central base station C1. In the S1 region, we will use the upper limit approximation (users in S1 never communicate with C1) to calculate the interference statistics. Also 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 power level of the desired signal (of any one of the supported services s) received by the base station be $P_{rx,s}$. The interference from an active user communicating with the home microcell will be also $P_{rx,s}$. A user $i$ in the S0 region will not communicate with the home base station $d$ but rather with base station $m$, if $\phi(\xi_{id} - \xi_{im}, r_{id}/r_{im}) = 1$, where

$$\phi(\xi_{id} - \xi_{im}, r_{id}/r_{im}) = \begin{cases} 1, & if \;\; L(r_{id}, r_{im})10^{(\xi_{id}-\xi_{im})/10} \le 1 \\ 0, & otherwise. \end{cases} \quad (9)$$

Assuming a uniform density of users within the bus or the car and that the activity factor of the user is $\alpha$, then for the right part of S0 the expected value of $I_{S0}$ is given as:

$$E[I_{S0}]_r = \alpha \int_{S0r} \rho_{B,C} \; A \; L(r_{id}, r_{im}) \; f\left(\frac{r_{id}}{r_{im}}\right) U(r) \quad dr \quad (10)$$

Where $\rho_{B,C}$ is the users density within the bus or the car respectively, A is given by [10]:

$$A = \frac{M}{L-1} \quad (11)$$

Where L is the number of the fingers of the RAKE receiver.

$$f\left(\frac{r_{id}}{r_{im}}\right) = E\left[10^{(\xi_{id}-\xi_{im})/10}\phi(\xi_{id} - \xi_{im}, r_{id}/r_{im})\right] \quad (12)$$

$$= e^{(\beta\sigma)^2/2} \quad Q\left[\beta\sqrt{\sigma^2} - \frac{10}{\sqrt{\sigma^2}}\log_{10}\{1/L(r_{id}, r_{im})\}\right] \quad (13)$$

Being $\beta = \frac{\ln(10)}{10}$ and $U(r)$ is an indicator function given as:

$$U(r) = \begin{cases} 1, & if \;\; the \; bus \; or \; the \; car \; exists \\ 0, & otherwise \end{cases} \quad (14)$$

**We have to mention that in all of the integrations, *dr* is used to indicate *$dr_{id}$*.**

Now the general value of $\sigma^2$ is given as:

- 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 $\sigma^2$ is given by

$$\sigma^2 = (\sigma_1 - \sigma_2)^2 + 2(1 - C_{dm})\sigma_1\sigma_2 \quad (15)$$

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

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

$$\sigma^2 = 2(1 - C_{dm})\sigma_2^2 \quad (16)$$

*The $Q(x)$* function used in (13) is defined as

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{-v^2/2} dv \tag{17}$$

The expected value of $I_{S1}$ due to right part of the S1 region is given as:

$$E[I_{S1}]_r \approx \alpha \int_{S1r} \rho_{B,C} \ A\, L(r_{id}, r_{im}) \ E\left[10^{(\xi_{id}-\xi_{im})/10}\right] \ U(r) \ dr \tag{18}$$

For the left part of S0 and S1, the interference signal is injected through the sidelobe of the sector antenna. The expected value of $I_{S0}$ due to the left part of S0 is given by:

$$E[I_{S0}]_l = \alpha \ \ Sll \int_{S0l} \rho_{B,C} \ A\, L(r_{id}, r_{im}) \ f\left(\frac{r_{id}}{r_{im}}\right) U(r) \quad dr \tag{18}$$

Where *Sll* is the sidelobe level of the directive antenna used in each sector.

The expected value of $I_{S1}$ due to the left part of S1 is calculated as:

$$E[I_{S1}]_l \approx \alpha \ \ Sll \int_{S1l} \rho_{B,C} \ A\, L(r_{id}, r_{im}) \ E\left[10^{(\xi_{id}-\xi_{im})/10}\right] U(r) \ dr \tag{19}$$

Thus the expected value of the intercellular interference from the left and right sides is

$$E[I]_{inter} = E[I_{SO}]_r + E[I_{S1}]_r + E[I_{SO}]_l + E[I_{S1}]_l \tag{20}$$

For a given service s, the expected value of the total intercellular interference power is given as

$$E[P]_{inter} = P_{rx,s} \ E[I]_{inter} \tag{21}$$

And the expected value of the intracellular interference power is given by

$$E[P]_{intra} = \alpha P_{rx,s} \ (N_u - 1 + N_u \ Sll) \tag{22}$$

Taking into account the imperfect power control with a standard deviation error of $\sigma_c$ (dB), the expected value of total interference power $P_{intf,s}$ due to the service s will be:

$$P_{int\,f,s} = e^{\beta^2 \sigma_c^2 / 2} (E[P]_{intra} + E[P]_{inter}) \tag{23}$$

The expected (mean) number of users $E(N_u)$ is calculated using (25).

The variance of $I_{S0}$ due to right part of S0 is given as

$$\mathrm{var}[I_{S0}]_r = \int_{S0r} \rho_{B,C} \ [L(r_{id}, r_{im})]^2 \left\{ B \ p\alpha\, g\left(\frac{r_d}{r_m}\right) - C \ q\alpha^2 f^2\left(\frac{r_d}{r_m}\right) \right\} \quad U(r) \, dr \tag{24}$$

Where B and C are given by [10] :

$$B = \frac{M(M+1)}{(L-1)(L-2)} \tag{25}$$

$$C = \frac{M^2}{(L-1)^2} \tag{26}$$

$g$ , p and $q$ are given by:

$$g\left(\frac{r_{id}}{r_{im}}\right) = E\left[10^{(\xi_{id}-\xi_{im})/10}\phi(\xi_{id}-\xi_{im}, r_{id}/r_{im})\right]^2$$

$$= e^{2(\beta\sigma)^2}\ Q\left[2\beta\sqrt{\sigma^2} - \frac{10}{\sqrt{\sigma^2}}\log_{10}\{1/L(r_{id}, r_{im})\}\right] \tag{27}$$

$$p = e^{2\beta^2\sigma_c^2},\ q = e^{\beta^2\sigma_c^2} \tag{28}$$

To calculate the variance of the total interference, we have to take into account the effect of the imperfect power control with a standard deviation error of $\sigma_c$ (dB). The variance of $I_{S1}$ due to right part of S1 is given as:

$$\mathrm{var}[I_{S1}]_r \approx \int_{S1r}\rho_{B,C}\,[L(r_{id}, r_{im})]^2\left\{B\ p\alpha E\left[(10^{(\xi_{id}-\xi_{im})/10})^2\right] - C\ q\alpha^2 E^2\left[10^{(\xi_{id}-\xi_{im})/10}\right]\right\}U(r)\,dr \tag{29}$$

The variance of $I_{S0}$ due to left part of S0 is given as:

$$\mathrm{var}[I_{S0}]_l = Sll^2\int_{S0l}\rho_{B,C}\,[L(r_{id}, r_{im})]^2\left\{B\ p\alpha\, g(\frac{r_d}{r_m}) - C\ q\alpha^2 f^2(\frac{r_d}{r_m})\right\}U(r)\ dr \tag{30}$$

The variance of $I_{S1}$ due to left part of $S_1$ is obtained as:

$$\mathrm{var}[I_{S1}]_l \approx Sll^2\int_{S1l}\rho_{B,C}\,[L(r_{id}, r_{im})]^2\left\{B\ p\alpha E\left[(10^{(\xi_{id}-\xi_{im})/10})^2\right] - C\ q\alpha^2 E^2\left[10^{(\xi_{id}-\xi_{im})/10}\right]\right\}U(r)\ dr \tag{31}$$

Thus the total intercellular interference variance due to the total region S0 and S1 is given by:

$$\mathrm{var}[I]_{\mathrm{int}\,er} = \{\mathrm{var}[I_{S0}]_r + \mathrm{var}[I_{S1}]_r\} + \{\mathrm{var}[I_{S0}]_l + \mathrm{var}[I_{S1}]_l\} \tag{32}$$

The intracellular interference variance is given by:

$$\mathrm{var}[I]_{\mathrm{int}\,ra} = (N_u - 1 + N_u\, Sll^2)\,(p\alpha - q\alpha^2) \tag{33}$$

The total variance of the interference is calculated as

$$\mathrm{var}[I]_t = \mathrm{var}[I]_{\mathrm{int}\,er} + \mathrm{var}[I]_{\mathrm{int}\,ra} \tag{34}$$

For a given service s, the total variance of the interference power is given by:

$$\mathrm{var}[P_{\mathrm{int}\,f}]_s = P_{rx,s}^2\ \mathrm{var}[I]_t \tag{35}$$

The expected value of total interference due to S simultaneous services is given by:

$$E[P_{\mathrm{int}\,f,t}] = \sum_{s=1}^{S} P_{\mathrm{int}\,f,s} \tag{36}$$

The variance of total interference due to S simultaneous services is given by:

$$\mathrm{var}[P_{\mathrm{int}\,f,t}] = \sum_{s=1}^{S}\mathrm{var}[P_{\mathrm{int}\,f}]_s \tag{37}$$

In the uplink, a fraction ε $P_{rx,s}$ of the received power $P_{rx,s}$ is used in the detection. Thus, the uplink carrier-to-interference ratio $(C/I)_{up}$ for a given outage probability γ is given as:

$$\left(\frac{C}{I}\right)_{up} = \frac{P_{rx}}{E\left[P_{\text{int}\, f,t}\right] + P_N + Q^{-1}(\gamma)\,\text{var}\left[P_{\text{int}\, f,t}\right]} \tag{38}$$

The $(E_b / N_o)_{up}$ ratio is given as:

$$\left(\frac{E_b}{N_o}\right)_{up} = \left(\frac{C}{I}\right)_{up} G_p \tag{39}$$

Where $G_p$ is the processing gain (spreading factor) of the service under study.

## 4- Numerical Results

**Our WCDMA system under study is assumed to be asynchronous one.** For our calculations some reasonable figures are applied. The azimuth side lobe level is assumed to be –15 dB, the correlation coefficients $C_{dm}$ = 0.5, $s_1$ = 2, $s_2$ = 4, $\sigma_1$ = 3 dB, $\sigma_2$ = 6 dB, a bus $R_b$ of 400m, a car $R_b$ of 200m, R = 1000m, M =4 and ε = 0.9375 unless other values are mentioned. The bus length $L_B$ is assumed to be 8 m and that the car seats are within 1.5 m. Also it is assumed that the number of the users within the bus is 40 users while it is 4 for the car. We assume that the accepted outage probability is 1% and that the uplink capacity of the sectors is calculated at this probability. Also we assume that:

- The maximum transmitted power for the traditional data service is 26 dBm,
- The maximum transmitted power for the voice service is 22 dBm,
- The maximum transmitted power for the HSUPA service is 30 dBm,
- The microcell effective antenna gain is 12 dB and
- The Thermal noise of the base station receiver is -100 dBm.

We assume that the highway has two directions with two lanes in each one of them. Uplink capacity is calculated assuming that the distance between the cars and the buses in each lane is 100m. The starting distance of calculation of the first lane is 0 m. It is 25m, 50m and 75m for the second, third and forth lanes respectively.

Firstly we study the case of voice service where the processing gain (spreading factor) is $G_p$ = 256, the activity factor α is assumed to be 0.66 and $(E_b/N_o)_{up}$ = 7 dB [11]. **Convolutional coding (rate 1/2) with block interleaving is assumed to be used as a FEC. Here we assume that the RLC is working at the transparent mode with SDU size of 40 bytes and PDU size of 40 bytes.**

Fig. 3 shows the outage probability of the sector when 10 equally spaced buses and cars exist within each lane of the sector (40 cars and buses within the sector). The sector capacity is 54.9, 53.1 and 50.3 voice users for $\sigma_c$ of 0.5 dB, 1 dB and 1.5 dB respectively. It can be noticed that the increment of $\sigma_c$ causes a decrement of the uplink capacity. This is due to the fact that the increment of $\sigma_c$ provokes an increment of both intracellular and intercellular interference and in consequence a lower capacity. **For $\sigma_c$ = 1 dB, the uplink total bit rate is 795 kbps.**

Let us study the case when the number of the fingers L within the RAKE receiver is 3. Fig. 4 shows the outage probability of the sector when 10 equally spaced buses and cars exist within each lane of the sector. The sector capacity is 48.6, 46.9 and 44.2 voice users for $\sigma_c$ of 0.5 dB, 1 dB and 1.5 dB respectively. Here it can be noticed that the capacity shown here is lower than the capacity shown in Fig. 3. The reduction of capacity is due to the increment of the values of A, B and C that represent the effect of the multipath.

Let us study the case when the multipath dose not exists. This can be done assuming that L=M =∞. Fig. 5 shows the outage probability of the sector. The sector capacity is 57.8, 55.9 and 53 voice users for $\sigma_c$ of 0.5 dB, 1 dB and 1.5 dB respectively. Comparing this result with the result shown in Fig. 3, it can be deduced that the multipath has a negative effect on the uplink capacity.

The effect of changing the number of the buses and cars within the sector on the sector uplink capacity is depicted in Fig. 6 assuming $\sigma_c$ is 1 dB. It can be noticed that, the sector uplink capacity will increase with the increment of the number of buses and cars from 3 to 40 within the sector and then it remains constant for higher cars and buses density. The possible number of users within 40 full buses and cars (representing a high traffic case after the end of a sport event for example) is of the order of 880 users. With the upper limit of the uplink capacity of 53.1 voice users, only 6 % of the voice users can communicate in this scenario. For higher number of cars and buses within the sector, the percentage of the users that communicate is lower.

Let us study the case **of 120 Kbps** data service where the processing gain (spreading factor) $G_p = 32$, $\alpha = 1$ and $(E_b/N_o)_{up} = 3$ dB [11]. **Convolutional coding (rate 1/2) with block interleaving is assumed to be used as a FEC. Here we assume that the RLC is working at the acknowledged mode with SDU size of 1280 bytes and PDU size of 80 bytes. Window size is assumed to be 256 PDUs.**

Fig. 7 shows the outage probability of the sector when 40 equally spaced buses exist within each sector. The sector capacity is 10.8, 10.1 and 9.1 data users for $\sigma_c$ of 0.5 dB, 1 dB and 1.5 dB respectively. **For $\sigma_c$ = 1 dB, the uplink total bit rate is 1200 kbps.**

Fig. 8 shows the sector uplink mixed capacity of voice and 3G data services assuming that $\sigma_c$ =1 dB.

Let us now study the sector uplink capacity for the HSUPA service assuming that users exist only in the sector under consideration. Two different processing gains (spreading factors), namely, 16 and 8 will be considered. Here we assume $\sigma_c$ = 1 dB, $\alpha$ = 1 and $(E_b/N_o)_{up}$ = 4.8 dB. **The forward error correction uses a TTI of 2 msec or 10 msec employing hybrid ARQ (HARQ) to reduce the required SNR at the nodeB.**

Fig. 9 shows the uplink capacity of the HSUPA service. It can be noticed that, the uplink capacity is 5.1, 2.8 HSUPA users for $G_p$ of 16 and 8 respectively.

Finally let us study the case when only one HSUPA users is incorporated. Fig. 10 shows the voice sector uplink capacity as a function of the HSUPA user's distance from the base station under study. It can be noticed that, the maximum capacity is got when the HSUPA user is at 2000m from the base station under study and that the minimum capacity is got at a HSUPA user distance of 1000 m from the base station under study. This is due to the fact that the intercellular interference is the maximum at a distance of 1000m from the base station under study.

We have to mention that, increasing the number of multipath taps M and the number of the RAKE receiver fingers (increasing the RAKE receiver complexity) will reduce the intercellular interference and thus increase the uplink capacity.

If the standard ITU Vehicular Channel A is used to calculate the uplink interference and capacity, uplink capacity will be little bit higher than those given previously. This is due to the lower contribution of the third to sixth taps in comparison with our channel (that we used in this work) with equal power in all taps.

Simulation results that not have been shown here show that the uplink capacity will be almost the same as the analytical results given above if we consider that the distance between the cars and the buses is Normally distributed with a mean of 90 to 110 m and $\sigma$ of 5 to 6 m.

**The above given capacities can be used to get the probability of blocking and delay considering a given traffic pattern (Poisson for example).**

## 5- Conclusion

The uplink capacity of the sector has been studied using a general two-slope propagation model with normal shadowing. We have presented a model that gives the capacity and interference statistics of a W-CDMA cigar-shaped microcells. The effect of the multipath on the sector capacity has been studied. The uplink capacity of the sector has been given assuming three types of services, namely, voice, 3G data and 3.75G data. It has been noticed that the capacity will be the maximum when 40 or more buses and cars exist within the sector.

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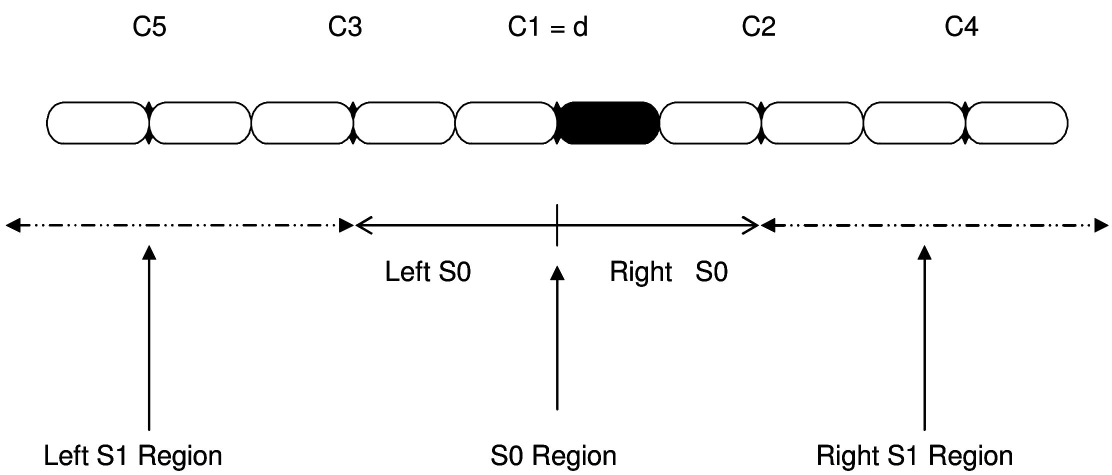


**Fig. 1:** The 5 microcells model.

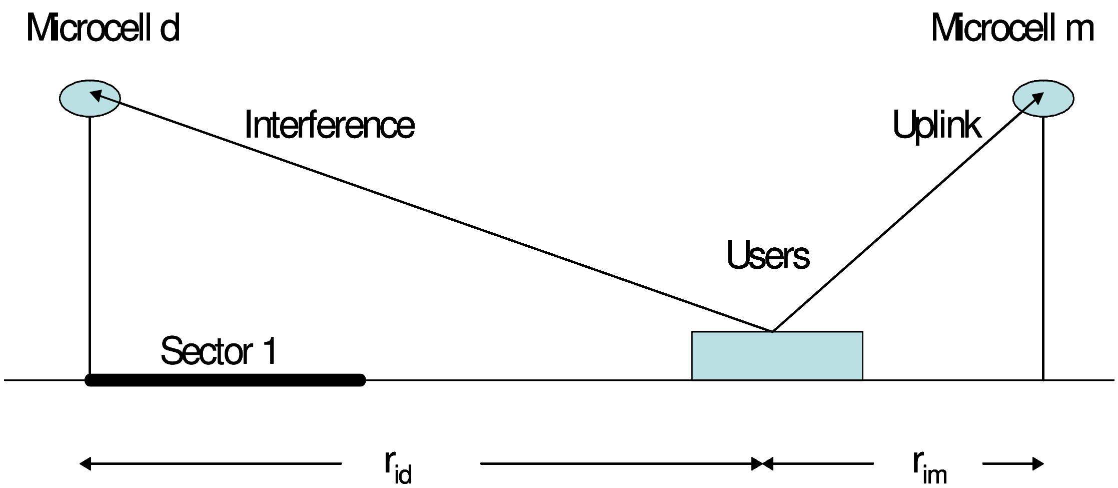


**Fig. 2:** Schematic diagram of base stations and mobiles.

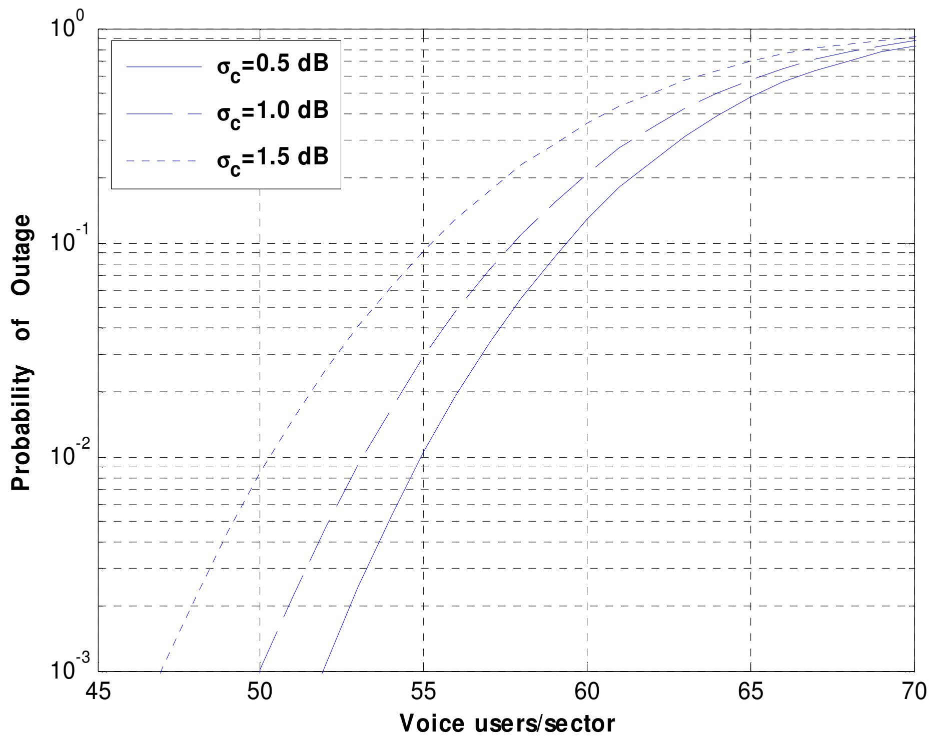


**Fig. 3:** The outage probability of the sector with 10 equally spaced buses and cars within each lane of the sector where M = L = 4.

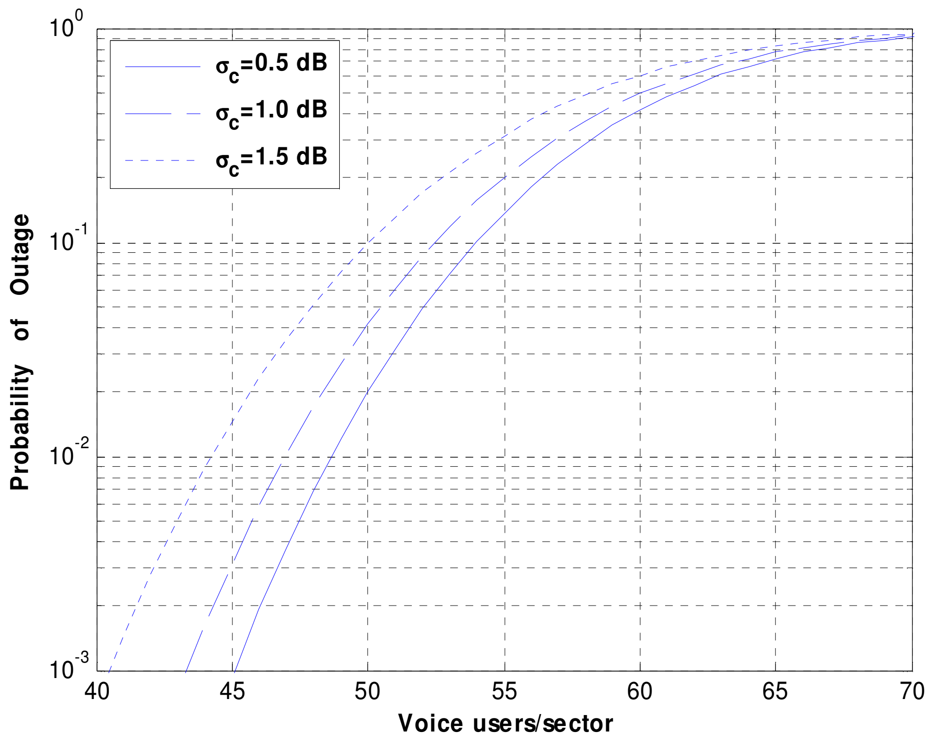


**Fig. 4:** The outage probability of the sector with 10 equally spaced buses and cars within each lane of the sector where M= 4 and L = 3.

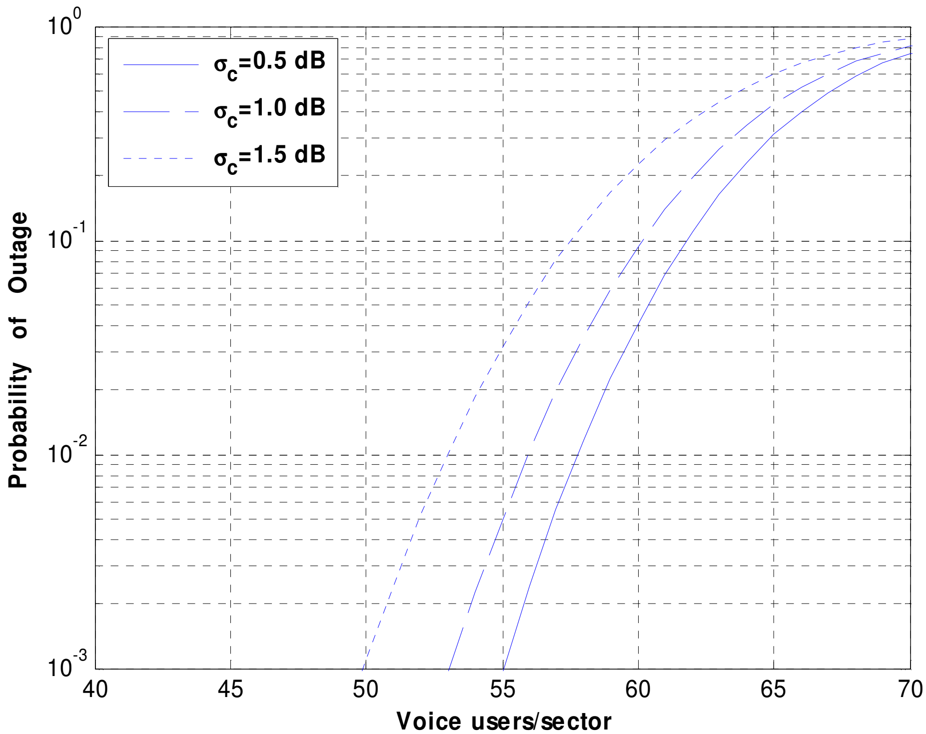


**Fig. 5:** The outage probability of the sector with 10 equally spaced buses and cars within each lane of the sector without any multipath.

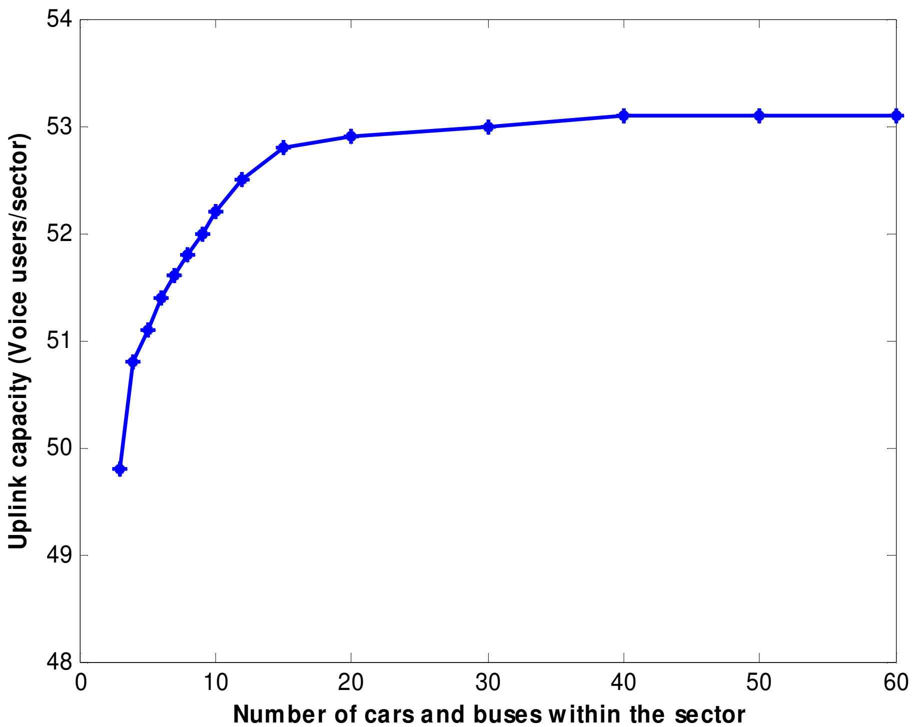


**Fig. 6:** Sector capacity as a function of the number of buses and cars within each sector.

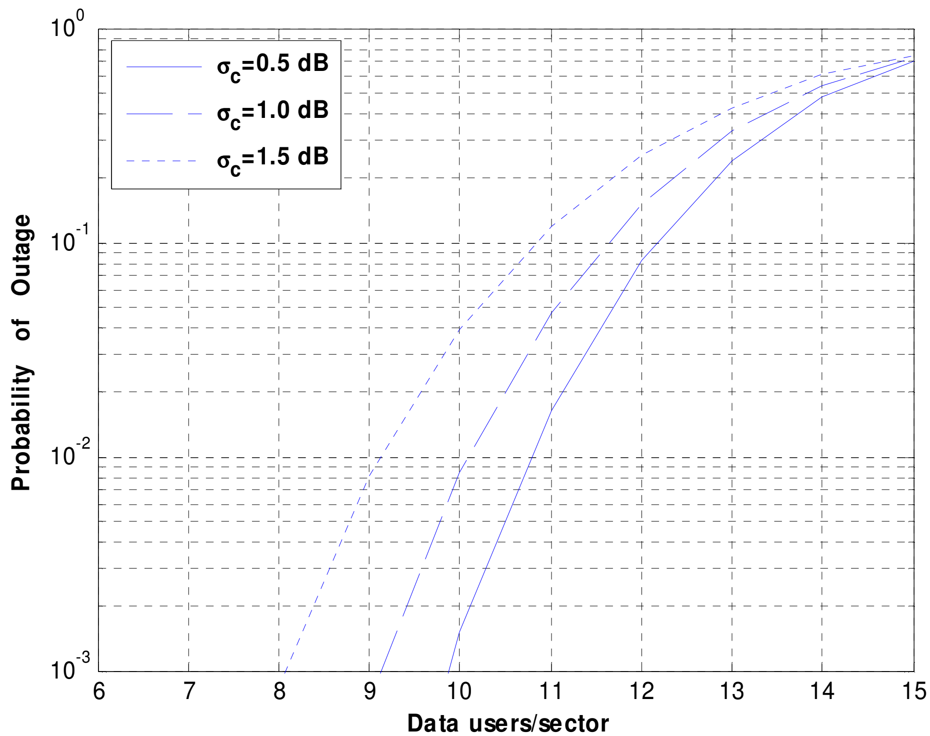


**Fig. 7:** Outage probability of the sector (data service).

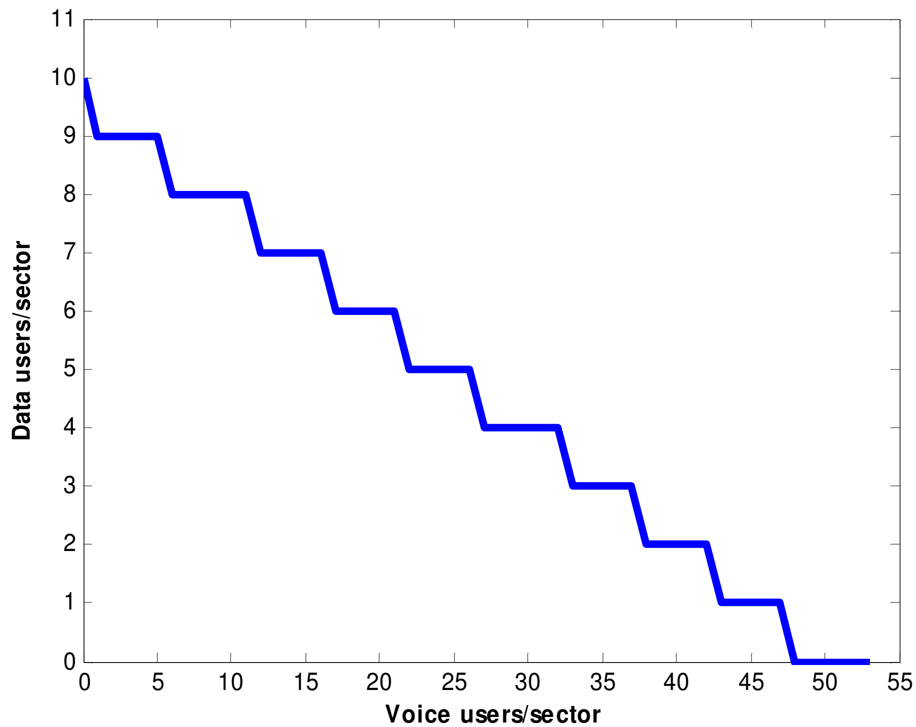


**Fig. 8:** Mixed capacity of voice and 3G data.

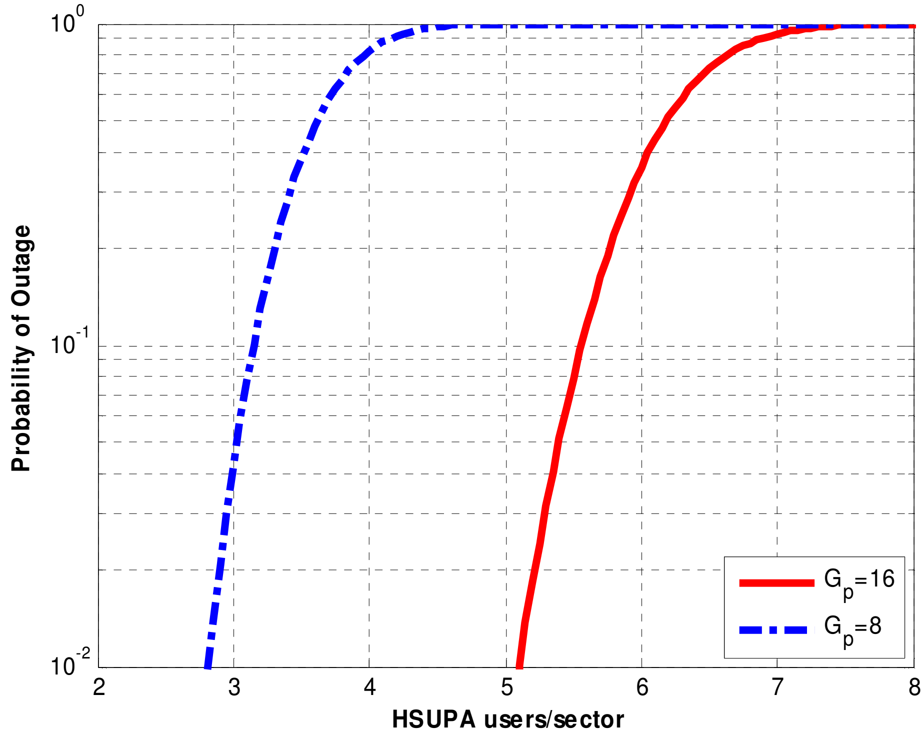


**Fig. 9:** Uplink capacity for the HSUPA service.

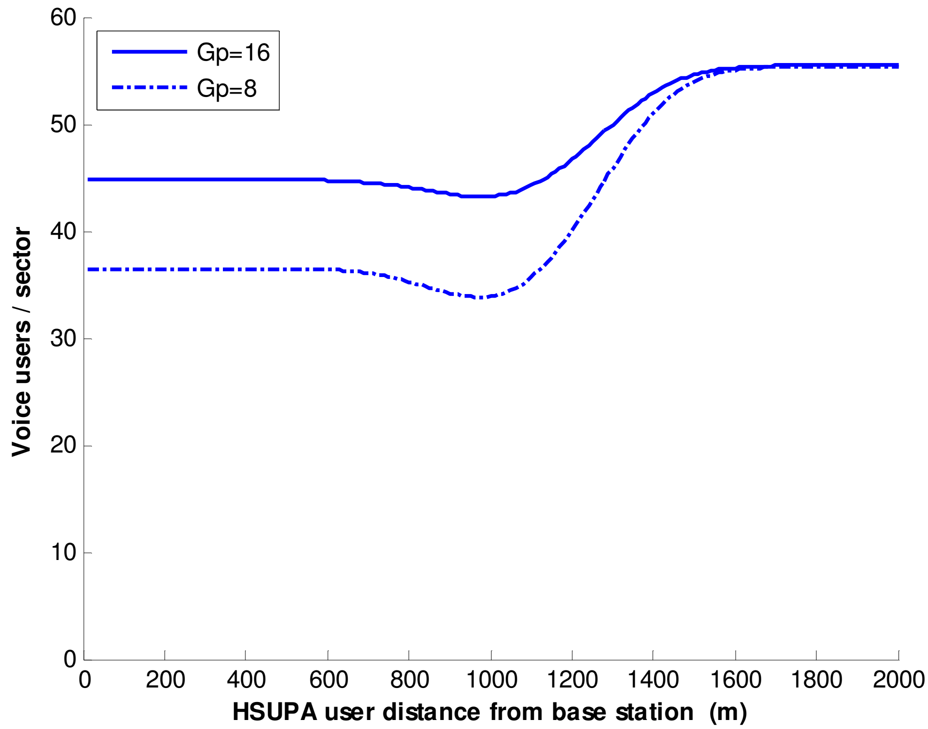


**Fig. 10:** Sector capacity as a function of the HSUPA user distance from the base station under study.

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