The Performance of W-CDMA Highways Infostations

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Abstract. *The expected value of the signal to noise ratio of W-CDMA infostations is derived. A model of 5 cells is used to analyze the system performance. The infostations are assumed to exist in rural zones. The performance of the infostations is studied for different breakpoint distances, different infostations separation, a different number of users for each infostation and for different bit rate.*

Keywords

W-CDMA, infostations, shadowing.

1. Introduction

In the primer years of the cellular revolution, voice service have become a common place and ubiquitous, and the attention of researcher has shifted to wireless information. It is clear that the information services have an almost unlimited potential in the wireless environment [1]. Recently, an array of isolated wireless ports called infostation has been proposed [2]. This system is characterized by isolated pockets of high bandwidth connectivity.

Frenkiel *et al* [1] studied the infostation performance in one and two dimensions coverage. The effect of shadowing was neglected. Borrás *et al* [2] studied the cellular excess capacity for the infostations where the infostations are assumed to be overlaid on the GSM system. Irvine *et al* [3] gave an efficient UMTS data service provision using infostations.

In this work, we introduce a model for cigar-shaped infostations in rural highways zones with general propagation exponent using a two-slope model and then investigate the expected value of the signal to noise ratio of the data users.

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 converts to s_2. In this way the path loss is given by:

$$L_p\,[dB] \approx L_b + 10 + 10 s_1 \log(d/R_b) + \xi_1 \quad \text{if } d \le R_b\,, \tag{1}$$

$$L_p\,[dB] \approx L_b + 10 + 10 s_2 \log(d/R_b) + \xi_2 \quad \text{if } d > R_b\,, \tag{2}$$

where d is the distance between the infostation of the cell d and the mobile, L_b and R_b are given by [4]:

$$L_b\,[dB] = \left| 10 \log\left[\left(\frac{\lambda^2}{8\pi\, h_b\, h_m}\right)^2\right]\right|\,, \tag{3}$$

$$R_b \approx 4\, h_b\, h_m / \lambda\,. \tag{4}$$

Here, h_b is the base station antenna height, h_m is the mobile antenna height, λ is the wavelength and ξ_1 and ξ_2 are Gaussian random variables of zero-mean and a standard deviation of σ_1 and σ_2, respectively.

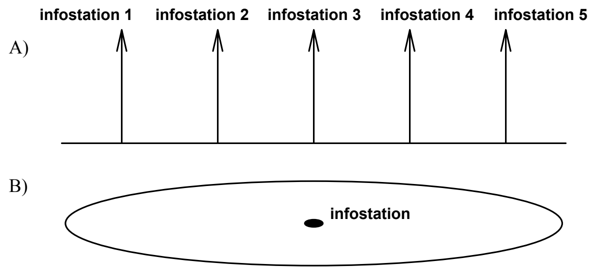

Fig. 1. The five infostations model: A) the five infostations model, B) the infostation coverage.

Typical values of the above mentioned parameters are R_b = = 300 m, s_1 = 1.75 ÷ 2.25, s_2 = 3.5 ÷ 4.5, σ_1 = 2 ÷ 3 dB, and σ_2 = 4 ÷ 6 dB.

3. Interference Analysis

Fig. 1 shows the configuration of the 5 infostations model and the coverage of each infostation. Infostations are regularly spaced every 2R. If the user i is at a distance r_{i0} from its infostation base station and at a distance r_{id} from the interfering infostation base station d as shown in

Fig. 2, then the interference signal ratio $L(r_{id}, r_{i0})$ due to the distance only is given as

- If $r_{id} \le R_b$ and $r_{i0} \le R_b$ then $L(r_{id}, r_{i0})$ is

$$L(r_{id}, r_{i0}) = (r_{id}/r_{i0})^{s1} . \qquad (5)$$

- If $r_{id} > R_b$ and $r_{i0} \le R_b$ then $L(r_{id}, r_{i0})$ is

$$L(r_{id}, r_{i0}) = \frac{r_{i0}^{s1}}{R_b^{s1}(r_{id}/R_b)^{s2}} . \qquad (6)$$

- If $r_{id} > R_b$ and $r_{i0} > R_b$ then $L(r_{id}, r_{i0})$ is

$$L(r_{id}, r_{i0}) = (r_{i0}/r_{id})^{s2} . \qquad (7)$$

Now the ratio of the interference signal $I(r_{id}, r_{i0})$ due to the distance and shadowing is given by

$$I(r_{id}, r_{i0}) = 10^{(\xi_{id}-\xi_{i0})/10} \, L(r_{id}, r_{i0}) , \qquad (8)$$

ξ_{id} and ξ_{im} are given as:

- If $r_{id} \le R_b$ and $r_{i0} \le R_b$ then $\xi_{id} = \xi_1$ and $\xi_{i0} = \xi_1$.
- If $r_{id} > R_b$ and $r_{i0} \le R_b$ then $\xi_{id} = \xi_2$ and $\xi_{i0} = \xi_1$.
- If $r_{id} > R_b$ and $r_{i0} > R_b$ then $\xi_{id} = \xi_2$ and $\xi_{i0} = \xi_2$.

The total intercellular interference to carrier ratio is given

$$(I/C)_{inter} = N_u \sum_{d=1}^{4} I(r_{id}, r_{i0}) , \qquad (9)$$

where N_u is the number of users per each infostation.

The expected value of I/C is given by

$$E\{I/C\}_{inter} = N_u \sum_{d=1}^{4} \exp(\beta^2\sigma^2/2) L(r_{id}/r_{i0}) \qquad (10)$$

with $\beta = \ln(10) / 10$.

The general value of σ^2 is given as:

- If $r_{id} \le R_b$ and $r_{i0} \le R_b$ then $\sigma_{id} = \sigma_1$, $\sigma_{i0} = \sigma_1$, and

$$\sigma^2 = 2(1 + C_{d0})\sigma_1^2 , \qquad (11)$$

where C_{d0} is the correlation coefficient between the random variable ξ_{id} and ξ_{i0}.

- If $r_{id} > R_b$ and $r_{i0} \le R_b$ then the value of σ^2 is given by

$$\sigma^2 = (\sigma_1 - \sigma_2) + 2(1 - C_{d0})\sigma_1 \sigma_2 . \qquad (12)$$

- If $r_{id} > R_b$ and $r_{i0} > R_b$ then $\sigma_{id} = \sigma_2$, $\sigma_{i0} = \sigma_2$ and

$$\sigma^2 = 2(1 - C_{d0})\sigma_2^2 . \qquad (13)$$

The intra-cellular interference to carrier ratio is given by:

$$(I/C)_{intra} = (N_u - 1)(1 - \phi) , \qquad (14)$$

where ϕ is the orthogonality factor of the downlink.

The expected value of the total interference to carrier ratio is given by:

$$E\{I/C\}_t = \{I/C\}_{inter} + (I/C)_{intra} , \qquad (15)$$

and the expected value of E_b/N_0 is given as

$$E\{E_b/N_0\} = G_p / E\{I/C\}_t , \qquad (16)$$

where G_p is the processing gain. For a user with a high bit rate and using QPSK modulation, the relation E_b/N_0 has to be 10 dB or more [1].

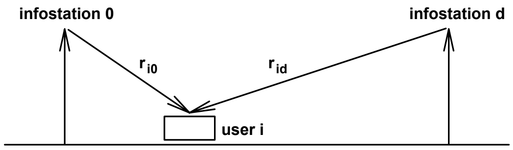

Fig. 2. Schematic diagram of infostation base stations and mobiles for highway microcells.

4. Numerical Results

In our estimation, we have assumed that W-CDMA chip rate is 3.84 Mchips/sec and data rate is 3.84 Mbit/sec, i.e., $G_p = 1$. For our calculations, some reasonable figures are applied. The correlation coefficients $C_{d0} = 0.0$ (worst case), $s_1 = 2$, $s_2 = 4$, $\sigma_1 = 2$ dB, $\sigma_2 = 4$ dB, $R = 1000$ m, and $N_u = 1$ unless other values are mentioned. The orthogonality factor ϕ is assumed to be 0.95. The effective range is the maximum range at which E_b/N_0 is the required E_b/N_0.

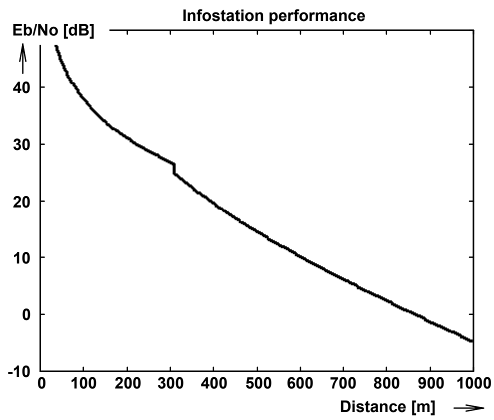

Fig. 3. The E_b/N_0 ratio as a function of user distance from the reference station, $s_1 = 2$, $s_2 = 4$, $\sigma_1 = 2$ dB, $\sigma_2 = 4$ dB and $R = 1000$ m.

Fig. 3 shows the E_b/N_0 as a function of the distance from the infostation base station. It can be seen that the ratio is monotonically decreased with increasing the distance of the user. Here we can notice that the user can receive the full data rate up to 613 m.

The effect of the infostations separation on the infostation performance is shown in Fig. 4. We can notice here that reducing the separation between the infostations reduces the effective range of the infostation.

The effect of the break-point distance on the infostation performance is shown in Fig. 5. Here we can notice that, in general, the performance is better when the break-point distance is 300 m compared to the case when the break-point distance is 400 m.

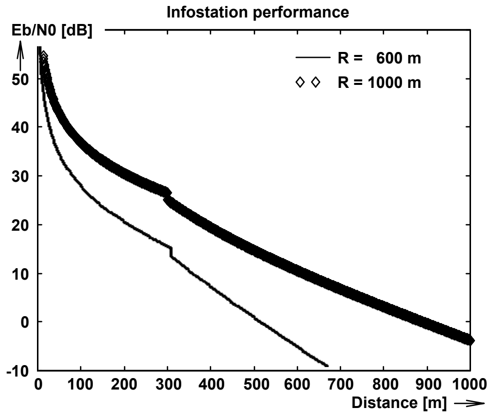

Fig. 4. The effect of the infostations separation distance on the infostation performance.

The effect of reducing the bit rate is shown in Fig. 6. We assume that the bit rate is 0.96 Mbit/sec, i.e., $G_p = 4$. The effective range is 680 m, 562 m for $N_u = 2$ and 4 respectively. Thus, the maximum info-station capacity is G_p with a range of 562 m. Thus reducing the bit rate will give a rise of the effective range or increment in the number of users.

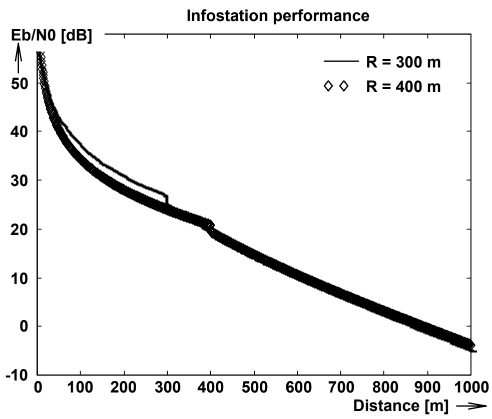

Fig. 5. The effect of the break point distance on the infostation performance

5. Conclusions

We have presented a model that determines the expected value of signal to noise ratio interference of W-CDMA rural highway cigar-shaped infostations. The performance of the infostation is analyzed using a general two-slope propagation model with lognormal shadowing. The effect of the break-point distance, the infostations separation, the number of users in infostation coverage and the bit rate is studied. We noticed that reducing the bit rate gives a rise of the effective range or increment in the number of users.

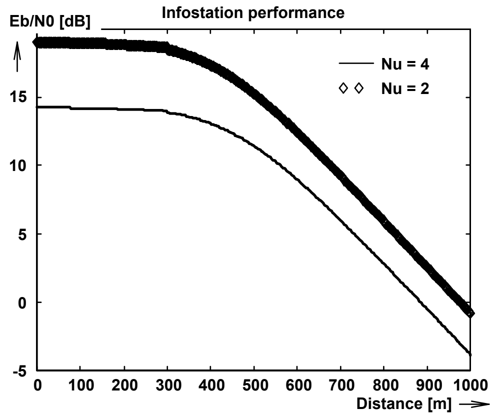

Fig. 6. The performance of the infostation for users with $G_p = 4$.

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