COVERAGE AND CAPACITY STUDIES FOR A CDMA CELL IN DIFFERENT RADIO PROPAGATION ENVIRONMENTS

T. Rama Rao[(1)] and M.V.S.N. Prasad[(2)]

(1) Universidad Carlos III de Madrid, Leganes, Madrid, Spain. Email: ramarao@ieee.org
(2) Radio & Atmospheric Sciences Division, National Physical Laboratory, New Delhi, India

ABSTRACT:

Coverage and capacity are significant issues in the planning process for cellular mobile networks. In this paper we focus on calculations for capacity, coverage for a Code Division Multiple Access (CDMA) cell for Universal Mobile Telecommunication System (UMTS) networks in different propagation environments.

INTRODUCTION:

Present day wireless communications is all pervasive, influencing every area of modern life, reaching any where, any time, and in any form. The escalation of wireless communications in recent years has been exponential and the telecommunications landscape is changing daily. Next generation wireless communications are being designed to facilitate high-speed data communications in addition to voice calls. The evolution of cost-effective, high-quality mobile networks requires flexible utilization of available resources. With the need for high speed wireless data and increased frequency congestion, there is considerable interest on proper understanding of the radio channel. Knowledge of radio wave propagation characteristics is vital for designing any mobile/wireless communication system in a given region. Radio wave propagation models are necessary to determine propagation characteristics for any arbitrary installation. The predictions are required for a proper coverage planning, the determination of multipath effects as well as for interference and cell calculations, which are the basis for the any network planning process.

Radio link is interference limited, when the interference levels are well above the receiver sensitivity level. An interference limited network is usually considered to be capacity limited, ie., the interference level is setting the limits of the network spectral efficiency. On the other hand, noise limited networks are considered to be coverage limited, ie., the network has cell range rather than spectrum efficiency limitations. In this scenario, the interference containment aspect of CDMA facilitates increase in capacity in the network [1, 2]. UMTS radio networks are based on CDMA technology and are currently offering in several countries. The aim of the technology is to realize the user requirement for new services such as enhanced and multimedia messaging through high-speed data channels. The performance of the radio interface in cellular CDMA systems is difficult to analyze, due to the trade-off between coverage and capacity, caused by the interference limited nature of these systems.

This paper focuses on main factors that affect the coverage and capacity in a CDMA cell based on propagation prediction models; COST-231 Hata model, COST 231 Walfisch-Ikegami model [3] and Hata model [4] and using a simple expression signal- interference ratio and energy-per-bit to noise power density level, which involves received power, number of users and coverage area [2, 5, 6, 7]. The aim is to explore the capacity/coverage of the uplink/downlink of a CDMA system in different realistic radio signal propagation environments: free space, rural, suburban and urban areas [8].

CAPACITY AND COVERAGE CALCULATIONS:

The capacity of a CDMA cell depends on many different factors, such as power control accuracy, interference power. In this present study we are considering perfect power control. We begin by calculating the signal-to-noise (interference) power [2, 5]. If there are N users in a cell and the signal is denoted by S then the interference can be calculated as $I = (N - 1) S + \eta$, where η is the back ground thermal noise. Hence the SNR is given by

$$SNR = \frac{S}{(N-1)S+\eta} = \frac{1}{(N-1)+\eta / S} \qquad (1)$$

Suppose the digital demodulator for each users can operate against the noise at an energy per bit-to noise power density level is given by E_b/N_0, whose numerator is obtained by dividing the desired signal power by the information bit rate, R, and dividing the noise (or interference) by the total bandwidth, W. This result in

$$E_b / N_0 = \frac{W/R}{(N-1)+\eta/S} \qquad (2)$$

where W/R is generally referred to as the "Processing gain" and the back ground noise determines the cell radius for a given transmitter power. The above equation can be written as the capacity in terms of number of users,

$$N = 1 + \frac{W/R}{E_b/N_0} - \frac{\eta}{S} \qquad (3)$$

That means, the number of users is reduced by the inverse of the per user signal-to-noise ratio (SNR) in the total system spread bandwidth, W. However, if the user is not speaking during part of the conversation, the output of the coder is lowered to prevent the power from being transmitted unnecessarily. This reduces the average signal power of all users and consequently the interference received by each user. The capacity is then increased proportional to this overall rate reduction, provide. In order to attain an increase in capacity, the interference due to other users should be reduced. This can be done using antenna sectorization and monitoring of voice activity [5]. Thus with sectorization and voice activity monitoring factor α, the average E_b/N_0

$$E_b / N_0 = \frac{W/R}{(N_s-1)\alpha+\eta/S} \qquad (4)$$

Where N_s, the number of users per sector and the interference to be that received by one sector's antenna. Now, consider interference from the jth user in neighboring cell k, then the ratio of other cell interference to the received signal strength at home base station is I/S [5]. Then equation (4) becomes

$$E_b / N_0 = \frac{W/R}{(N_s-1)\alpha+(I/S)\alpha+\eta/S} \qquad (5)$$

Where $(I/S) = (r_m/r_o)^m \cdot (\xi_o - \xi_m)$, r_m is the random distance to the corresponding home cell base station, r_o is the distance to the neighbouring cell, $\xi_o - \xi_m$ represent the shadowing parameter and m is the path loss exponent [5]. We can also write the above equation as

$$S = \frac{\eta}{\dfrac{W/R}{E_b/N_0} - (N_s-1)\alpha - (I/S)\alpha} \qquad (6)$$

Finally, the received power at the base station from the user1, is given by

$$S = S_1 - L_p - U \qquad (7)$$

Where S_1 is the transmission power of the user, L_p is propagation pathloss at distance d from the mobile station to base station and U is the shadow fading losses. From equations (6) and (7) we can build relation among the received power, number of users and the coverage area.

RESULTS & DISCUSSIONS:

The propagation loss is usually calculated by using propagation models. The model that is most commonly used is the Okumura-Hata. The model is developed by combining propagation theory and extensive measurement campaigns. In the present study we utilized COST 231-Hata model [3] for urban and dense urban environment and Hata model [4] for suburban and rural environments. The radio wave propagation within urban environments is characterized by the multipath situations [9]. Dominant phenomena are diffraction on building corners, reflection at building walls and wave guiding in street canyons. Therefore in addition to Hata model, we have also utilized Walfish-Ikegami model [3].

Figure 1 shows a comparative depiction of pathloss for various radio propagation environments. At various distances pathloss due to free space has been plotted to get an idea of threshold. As expected the free space path losses will be lower than other propagation environments. In the dense urban area, it can seen that the loss is very high due to tall, closely packed buildings and other obstacles. At distances 4 km onwards path loss in suburban category exhibits much higher values than rural environment. At 10 km distance the difference in path loss comes to around 20 dB. At various distances the difference in losses between Walfish-Ikegami & COST 231 Hata models is marginal.

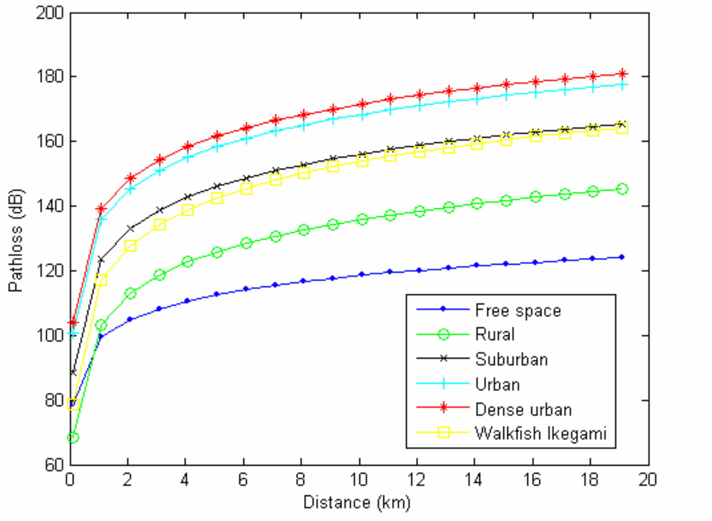

Fig. 1. Pathloss vs. distance in different propagation environments

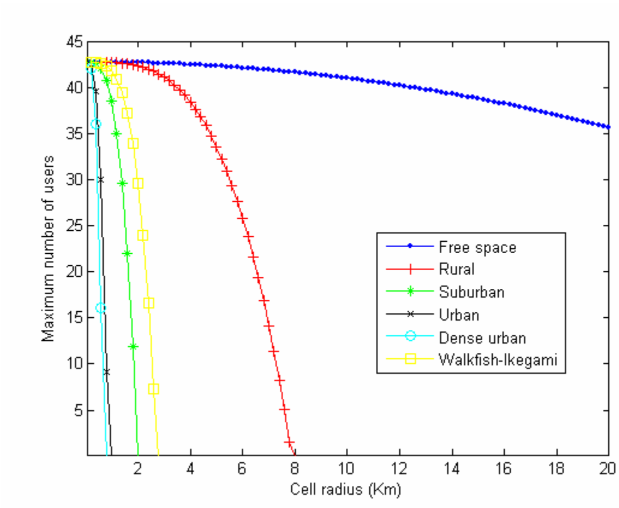

Fig. 2. Uplink capacity in different propagation environments.

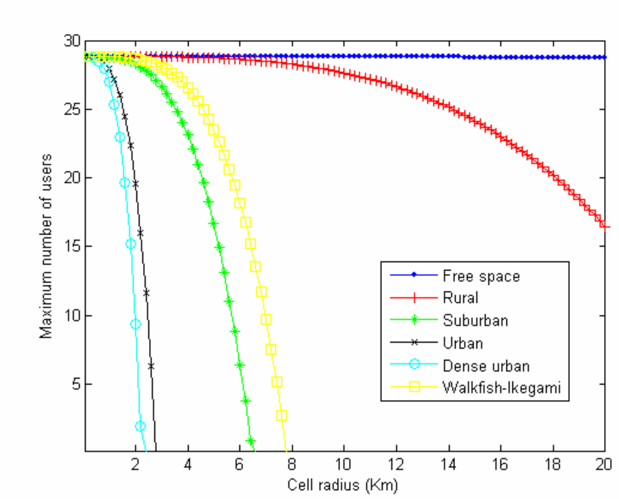

Fig. 3. Downlink capacity in different propagation environments.

Figures 2 and 3 shows uplink and downlink capacity in terms of number of users and cell radius in different radio propagation environments using equations (6) and (7). Since propagation loss is proportional to link distance and this value implies a maximal distance for the link that is the effective radius of the cell or sector in a particular direction [8, 11]. As it can be seen, the capacity of the downlink is higher than the uplink. The main reason is that the power received in downlink is much higher, and the need of a higher E_b/N_0 does not compensate the effect. On the other hand, as uplink E_b/N_0 is lower than downlink one, the number of near possible users is higher. The results showing that the coverage area is around few meters in urban areas, close distance to the base station and depends on data rate of the service. Where as coverage area is much higher in suburban and rural areas [8, 11]. With lower values of path loss Walfish-Ikegami model predicted higher coverage area than Hata model.

Figure.4 shows pathloss of users in uplink and down link in an urban radio environment. It can be seen that coverage is uplink limited, while capacity is downlink limited. The coverage is limited by the uplink because of the maximum available transmitting power of the mobile, the downlink sets limitations on the capacity due to the increasing interference [10, 11]. Table.1 shows the parameters [10, 11] used in our present study.

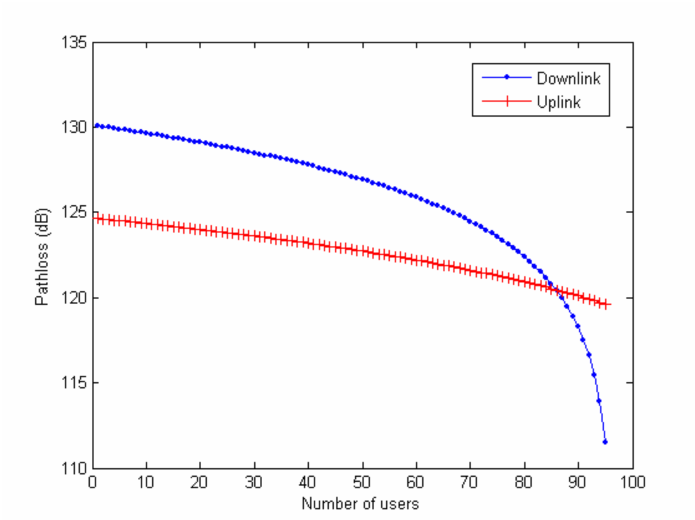

Fig. 4. Pathloss vs. number of users

Table 1: Parameters used in our simulations

Parameter	Value
Frequency	2 GHz
Chip rate	3.84 Mcps
Downlink Eb/No	2.5 dB
Uplink Eb/No	1 dB
Downlink transmitted power	10 W
Uplink transmitted power	125 mW
Service rates	12.2kbps (voice)– 64kbps (data)– 144kbps (data)
Service activity factors	0.67(voice) – 1(data)
Mobile Station (MS) height	1.5 m
Base Station (BS) height	50 m
Building roof top height	30 m
Streets width	20 m
Diffraction angle	30º
Building separation distance	40 m
Shadow fading loss	8 dB

CONCLUSIONS:

CDMA based mobile networks need efficient network planning. The network planning process will allow the maximum number of users with adequate signal strength in a CDMA cell. With proper analysis of capacity and coverage related issues, the key differences arise between 2G (GSM) and 3G (UMTS) networks due to the different levels of service offered will be minimized. The simple expression derived in this present work using equations (6) and (7), describing the relationship between coverage, capacity, data rates and number of users can be used in CDMA cellular system planning to set limits on the maximum number of users that can be admitted into the cell in order to meet coverage and capacity requirements. An attempt is made in the present study to characterize a CDMA system in different propagation environments using propagation models and systems parameters for downlink and uplink configurations. However, there are limitations in our simulations, as we assumed perfect power control. In our future work, we will consider imperfect power control and other factors in deriving relationship between coverage and capacity.

REFERENCES:

[1] Andrew J Viterbi; CDMA: Principles of Spread Spectrum Communication, Addison-Wesley, 1995.
[2] Rappaport T.S; Wireless Communications: Principles and Practice, Prentice Hall, 2002.
[3] COST 231 report, Digital Mobile Radio towards Future Generation Systems, 1999.
[4] Hata M; Empirical formula for prop. loss in land mobile radio services, IEEE Trans. VT, Vol.29, No.3, pp.317-325, Aug, 1980.
[5] Gilhousen K.S,et al; On the Capacity of a Cellular CDMA System, IEEE Trans. on VT, Vol. 40, No. 2 , pp.303-312, May 1991.
[6] Veeravalli..V, Sendonaris; The Coverage–Capacity Tradeoff in Cellular CDMA Systems, IEEE Trans.VT, Vol.48, No.5, pp.1443-1450, Sep.1999.
[7] Lee W C Y; Overview of Cellular CDMA, IEEE Trans.VT, Vol.40, No.2, pp 291-302, May 1991.
[8] Zreikat A.I, et al; A Comparative Capacity/Coverage Analysis for CDMA Cell in Different Propagation Environments, Wireless Personal Communications, Vol. 28, pp.205–231, 2004.
[9] Parsons J D; Mobile radio propagation channel, Wiley & Sons, 2000.
[10] Holma H and Toskala A; WCDMA for UMTS, Wiley & Sons, 2000.
[11]. Lee J.S and Miller L.E, CDMA system Engineering Handbook, Artech House, 1998.