Improving Capacity of soft Handoff Performance in Wireless Mobile Communication using Macro Diversity

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Abstract :

The soft handoff is a process on transferring the on going call from one radio resource to another radio resource without any interruption. Rather, mobile unit looks next base station for possible new connection without breaking the old connection. This transfer of call takes place, when the mobile unit moves far away from old base station and approach toward new base station. At the far away distance from old base station, the signal to noise power at the mobile unit becomes poorer and the service quality get degrade. At this far away distance mobile unit may see the another new base station, which may provide the better signal to noise ratio of the same signal via mobile switching center (MSC). Thus the mobile unit may get the same signal from the two different base stations simultaneously. The capacity of the CDMA communication network depends on the diversity technique used. The capacity gain of CDMA communication network can be defined by the comparison of network capacity with macro diversity and without macro diversity. In This paper we represented the capacity as number of users increases with Micro diversity as compared to capacity without Micro diversity.

Keywords :-
VAF (Voice Activity Factor), Interference Distribution Factor, BS (Base Station).

1. Introduction :

The soft handoff in cellular code-division multiple-access (CDMA) systems is a technique whereby mobiles near cell boundaries communicate the same transmitted signals to more than one base station (BS) within their vicinity [7,4, 8]. Soft handoff is important because it provides enhanced communication quality and a smoother transition compared to the conventional hard handoff. On the reverse-link, signals transmitted by mobiles in the handoff area may reach all the nearby BS's, even though the signals are not intended for them and the mobile signals appear as interference in these nearby cells. By putting more matched filters in the receiver, BS's can receive signals from mobiles in the nearby soft- handoff areas. Notice that no extra channels are required to accomplish soft handoffs on the reverse links. Soft handoff provides macro diversity, which is due to more than one BS being involved in the communications. The signal-to-interference ratio (SIR) is improved by combining the signals from the different BS's, and this, in turn, increases reverse-link quality and extends cell coverage [1,2]. As there are at least two BS's involved in the soft-handoff process, where each BS supports a forward-link channel to the mobile, the number of available channels on the forward link decreases as the number of mobiles in soft handoff increases. This factor has a effect effect on the system capacity.

2. Macro Diversity :

The macro Diversity provides soft Handoff by combining the signals transmitted by the involved base station's . When the signal from the two base stations are combined , the probability that the signals from the base station's are simultaneously subjected to deep shadowing is much smaller than that from a single base station.

During soft Handoff process more than one base station take part in the communication process and the signals are combined at the mobile unit. This form of diversity is known as base station diversity or Macro Diversity. This is the power full technique to combat the shadowing effect in cellular mobile radio system and improve the transmission performance at the cell boundaries.

3. Factor influencing the Capacity of CDMA

The following factors affect the capacity of CDMA network.

3.1 Path loss

The path loss varies with the distance between the fixed base station and the moving mobile station. In free space it follows the inverse square power-law which means that the received power will decrease according to the square of the communication link distance d. For other cases, then simplest empirical model of the path loss, μ, is

$$\mu(d) = k.d^{\beta} \quad (1)$$

where β is the path loss exponent ranging from 2 in free space to 4 in a dense urban area. If in our model we use β = 4 and the constant k = 1, we can rewrite our path loss model equation (1) in dB as

$$\mu(d) = 40 \log d \text{ dB} \quad (2)$$

The term excess path loss for equation (1) is used, since the attenuation the free space attenuation.

3.2 Voice Activity Factor (VAF)

Voice activity factor denotes activity of speech in terms of time of the speaker. The speaker is silent (no voice) most of the time. The fraction of time for which the speech of the speaker is active (voice) is called voice activity factor. One advantage of CDMA is that it can readily exploit the nature of human conversation to increase system capacity. It can suppress the transmission from a user when there is no voice present or in other words transmission is activated only when the voice is present. Most existing digital voice coders can monitor user voice activity and studies show that typical speech is active only 35% to 40% of the time [5]. Exploitation of this situation introduces less interference to the system since it reduces the average transmit power during silence periods and hence increases the system capacity. Typical values for the voice activity factor (ν) range from 0.35 to 0.4.

3.3 The Interference Distribution Factor

The capacity of CDMA network is affected by the interference of other users [5]. The interference in CDMA is high due to similar frequency spectrum of all the mobile units. The interference at a base station is highly dependent on the mobile station location and the position of the base station. There are two scenarios for interference distribution namely multicell and single cell network. The inter cell interference factor f can be evaluated by the serving cell and power received from mobiles in other cells. The interference factor is low in the following conditions: (i) Serving cell radius is small (ii) path loss slope has a higher value (iii) The standard deviation of path loss is small. The interference factor [10] for two way handoff and three way handoff is given in Table 1.

Table 1 Intercell interference factor (f)

$\sigma(dB)$	**Interference**	**Factor (f)**
	Two way soft handoff	Three way soft handoff
0	0.44	0.44
2	0.43	0.43
4	0.47	0.45
6	0.56	0.49
8	0.77	0.57
10	1.28	0.75
12	2.62	1.17

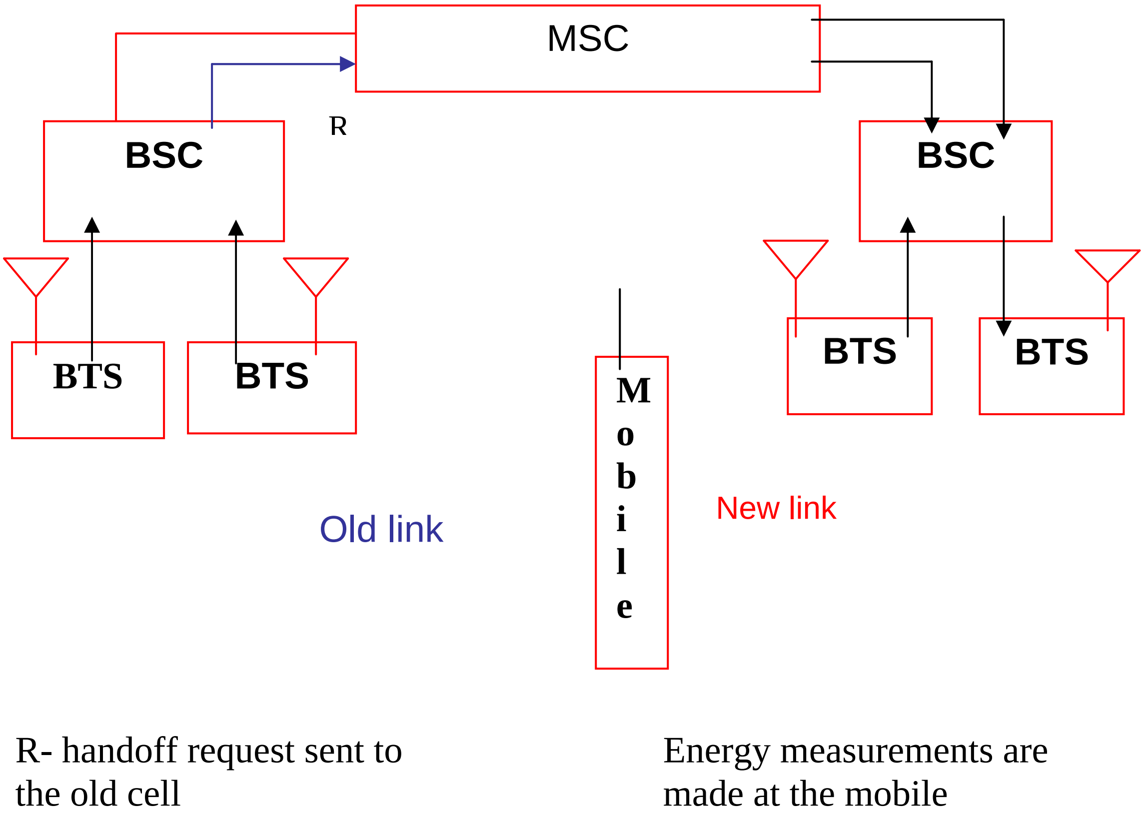

Figure 1 Soft Handoff Architecture

4.1 Capacity Without Macro diversity*:*

Consider a CDMA forward link system with coherent demodulation, which is achieved by sending a CDMA pilot with all the traffic channels [5,3]. Suppose no diversity technique is applied, i.e., signals are not combined at the mobile unit. The mobiles near the BS's have a higher SIR than those mobiles near the boundary, the SIR on the forward link is dependent on the mobile's location. Consequently, the forward-link capacity is limited by the SIR, when mobiles are located at the boundary.

Consider the twelve-cell scenario in the figure 2, which has the hexagonal cell in the architecture. Let us consider M channels in each cell. The radio capacity is calculated from the carrier to interference ratio(C/I). The C/I received by the mobile at a distance r from the base station of a CDMA cell shown in figure 2 is based on nine interfering cells, given as follows [7]:

$$(C/I)_s = \frac{\alpha r^{-4}}{\alpha (M-1) R^{-4} \mu + \alpha 2 M R^{-4} \mu + \alpha 3 M (2R)^{-4} \mu + \alpha 6 M (2.633R)^{-4} \mu + \eta} \qquad (3)$$

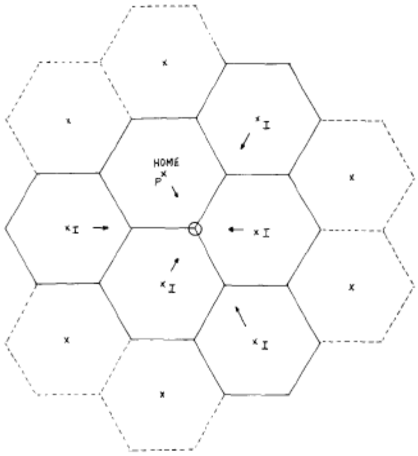

Figure 2 CDMA system and its interference

Where r =Distance of MS from BS M= Number of channels R =Cell radius, η = noise power
The bit energy to noise ratio can be calculated from (C/I) by the following relation

$$\frac{C}{I} = \left(\frac{E_b}{I_0}\right)\left(\frac{R_b}{B}\right) \quad (4)$$

Where R_b = data rate
B = bandwidth

The capacity of CDMA system in terms of the numbers of users are given by

(3)

$$M_{\max} = G_p \cdot \left[\frac{\eta_c}{\left(E_b / I_0\right) \cdot v_f \cdot (1+f)}\right] \quad (5)$$

Where G_p = Processing gain
η_c= power control factor
E_b/I_0= bit energy to interference ratio
ν_f= voice activity factor
f= interference factor

4.2 Capacity With Macro diversity:

The SIR of the mobiles within the soft-handoff zone can be improved by combining the received signals from the BS's. $\left(\frac{E_b}{I_0}\right)_0 = \left(\frac{E_b}{I_0}\right)_1 + \left(\frac{E_b}{I_0}\right)_2$ (6)

Therefore, the capacity can be increased in proportion to the increase in SIR. The mobile receiver block diagram is shown in figure 3, in which matched filter are used to detect the signals coming from the neighboring BS's. After demodulating with the carrier, which is provided by the pilot from its own BS, the received signals are matched with their corresponding spreading codes. The outputs of the matched filters are co phased and combined. It is also called maximum ratio combiner.

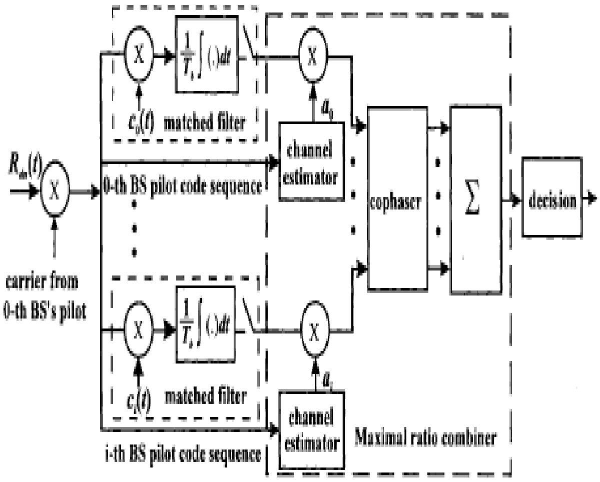

Figure 3 Mobile Receiver Block Diagram [6]

The channel attenuation is estimated from the CDMA pilot signal, and maximal ratio combining is performed by weighting the amplitudes of the signals according to their channel attenuation [6,9]. The weighted signal amplitudes are co phased and summed together to give maximal amplitude, where polarity determines the logical value of the regenerated bit.

5. Results & Discussion :

For the analysis of capacity of CDMA system, we have assume a processing gain of 21 dB (127 chips per information bit) and a signal to noise ratio of 20 dB, the capacity in terms of the maximum number of users per cell for different values of normalized distance in the soft handoff zone has been calculated. We have considered the nine co channel interfering cells shown in fig. 2, the curves of the capacity of the forward-link system for a VAF of 3/8 and 1/2 are shown in fig.4 and fig.5. The figure 4 shows the capacity without macro diversity for different values of voice activity factor. The capacity is a function of the voice activity factor. The capacity is higher for the lower value of the voice activity factor. For example, the voice activity factor 3/8, the capacity is higher as compared to the voice activity factor 1/2.
Similarly, figure 5 shows the capacity with macro diversity for different values of voice activity factor. Again, the capacity is higher for lower value of the voice activity factor. The voice activity factor 3/8, the capacity is higher as compared to the voice activity factor 1/2. It is noted that the capacity for mobiles in the soft-handoff zone is much higher than that for mobiles in no handoff zone, hence, the capacity becomes limited by mobiles at the boundaries. The capacity gain on the forward link is the capacity difference between the capacity for mobiles at r =R and R_h=0.84R. The capacity for mobiles at r = R is 43 and 32 users per cell for a VAF of 3/8 and 1/2, respectively, while the capacity for mobiles at R_h= 0.80 R is 46 and 34 users per cell for VAF's of 3/8 and 1/2, respectively.
Figure 6 shows the effect of the interference on the capacity of CDMA system without diversity. It is seen from this graph that the capacity of the CDMA system decrease with increase interference. Also, figure 7 shows the capacity of CDMA system with diversity using interference factor of value of 1.5. This graph shows that the capacity decreases with increase in interference in the CDMA system.

Consequently, the capacity gain due to macro diversity is three and two users per cell, which corresponds to a gain of 7.0% and 6.1% for VAF's of 3/8 and 1/2, respectively. As the system capacity is limited by R_h = 0.84 R, the excess capacity due to macro diversity becomes an increase in SIR for mobiles in soft handoff.

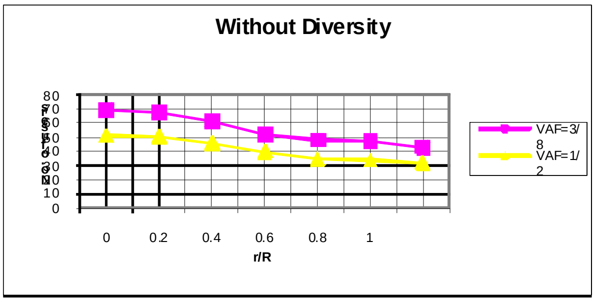

Figure 4 Capacity versus r/R , No diversity

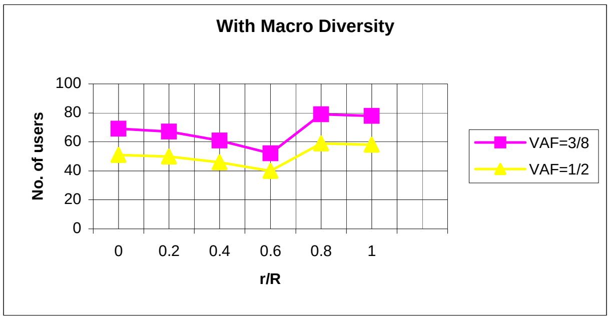

Figure 5 Capacity versus r/R ,Macro diversity

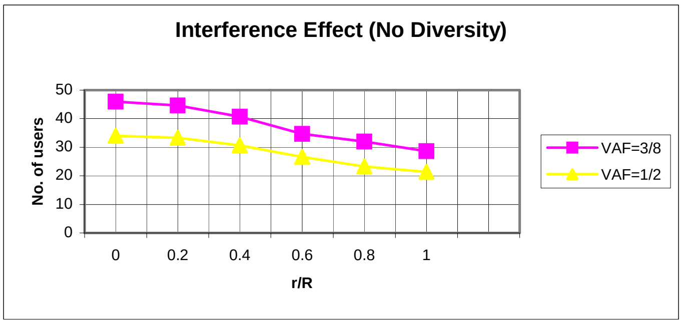

Figure 6 Capacity versus r/R with f=1.5, No diversity

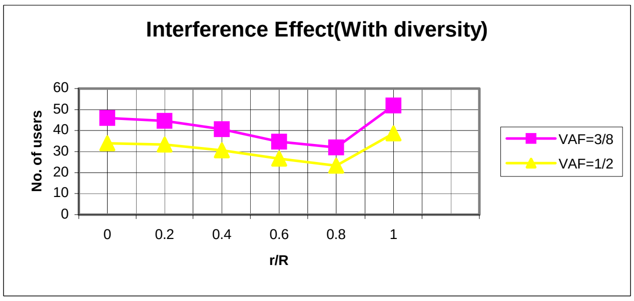

Figure 7 Capacity versus r/R with f=1.5, with diversity

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