# Soft Handoff Gain in SCDMA Cellular Systems

Bassam Hashem[1]
Saudi Telecom Company
Riyadh, Saudi Arabia
bahashem@stc.com.sa

**Abstract – Synchronous CDMA (SCDMA) employed in the reverse link of a cellular system is known to increases the system capacity. However, it is only possible to synchronize the user transmission at one base station. When the mobile is in soft handoff, it communicates with more than one base station simultaneously and hence its transmission will not be synchronized at some of the base stations. In this paper we investigate the gain from SCDMA in the reverse link of a system employing soft handoff. We show that SCDMA provides capacity gains ranging from 28% to 63% depending on the communication channel.**

## I Introduction

In CDMA systems, each user uses a spreading code to distinguish its transmission from other users. Typically, these codes are orthogonal in the forward link (from base station to mobile) but not in the reverse link (uplink). An uplink synchronous transmission scheme (USTS) was proposed for the 3GPP standard to enhance the uplink system capacity where orthogonal spreading codes are used. In this paper, simulations are performed to investigate the gain from SCDMA in a multi-cell scenario employing both power control and soft handoff. When in soft handoff, the mobile (UE) communicates with more than one base station and it is only possible to synchronize its transmission at one base station (Node-B).

We assume the UE signal to be time aligned at the base with an accuracy of 1/8th of a chip. Reference [1] shows that this is an achievable time alignment accuracy even at high speeds. To achieve such time accuracy, the home Node-B (the Node-B where the UE is synchronized) sends time alignment commands to the UE asking it to delay/advance its transmission. This is similar to the way power control is achieved. In the 3GPP standard contributions, it was proposed to steal some of the power control commands and use them for time alignment.

## II. Simulation Assumptions

The simulated system consists of a central Node-B where statistics are collected and two outer rings of cells. The UEs are distributed uniformly across the cells. No sectorization is assumed. The UE measures the average pilot signal strength [i.e. including distance and shadowing (lognormal with 8 dB standard deviation) but not multi-path fading] to decide which Node-B to communicate with. The Node-B with the strongest average pilot is chosen as the home Node-B. The UE calculates the difference between the strongest average and the second strongest average pilot signal. If the difference is less than the SHO_Threshold, the UE is assumed to be in soft handoff (SHO) with the second Node-B. When in SHO, the UE is synchronized at the home Node-B, but not the second Node-B. The gain from the synchronization is thus only appreciated at the home Node-B. The SHO_Threshold in the simulations is set at 3 dB which gives a probability of 20% that a UE is in SHO. When in SHO, selective combining is assumed which means that the larger SIR at the two Node-Bs is assumed to be the achieved SIR. The required Eb/No to achieve a block error rate (BLER) of 1% is assumed to be 3dB and the SF to be 256. The used BLER curve is shown in Figure 1.

In an urban mobile environment, the signal transmitted by the UE will arrive at each Node-B via more than one path. The uplink transmissions can only be synchronized for one of these paths. This is called the main path. In these simulations, we assume that the Node-B receiver has three Rake fingers assigned for each UE. The home Node-B averages the received power from each finger over an interval of four frames and selects the finger with the highest average as the main finger. This finger is time aligned. The main finger is assumed to be time aligned (or “synchronized”) with an accuracy of 1/8th of a chip even when the UE is mobile.

The inner loop power control is implemented with a step size of 0.5 dB at a rate of 1500 commands per second. That is to say that the Node-B sends 1500 power control commands per second to each UE asking it to increase or decrease its power depending on the received Eb/No. The outer loop step-up size is 1 dB. The target BLER is 1% and hence the step-down for the outer loop is 1/99 dB [2]. The dynamic range to compensate for multi-path fading is limited to 20 dB.

## III. Simulations Results

The desired BLER for these simulations has been set at 1% meaning that when the radio system is operating below its maximum capacity, this BLER target should be achieved. Since power control is employed, fewer UEs will not result in a lower BLER as the UEs will reduce their transmitted powers such that the BLER will be maintained at 1%. Two types of channels are simulated. These are the ITU Vehicular Channel B and the ITU Outdoor-Indoor Channel A [Table 1]. In the CH A model, most of the received power comes from

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[1] This work was conducted while the author was working for Nortel Networks Company

**Table 1: Used ITU Channel Models**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| CH A | Relative Delay (ns) | 0 | 110 | 190 | | 410 | |
| | Avg Power (dB) | 0 | −9.7 | −19.2 | | −22.8 | |
| CH B | Relative Delay (ns) | 0 | 200 | 800 | 1200 | 2300 | 3700 |
| | Avg Power (dB) | 0 | -0.9 | -4.9 | -8.0 | -7.8 | -23.9 |

the main path as the second component is about 10 dB below the main one. The CH A model is close to a single path channel. Hence, synchronizing the main path removes most of the intra-cell interference. However, in the CH B model, the second multi-path component is of comparable strength with the main component. Hence, synchronizing the main path removes only part of the intra-cell interference. The CH B model, however, does benefit from diversity among the different multi-path components.

Figure 2 shows the CH B simulation results for the multi-cell environment with a velocity of 10 Km/h for conditions both with and without SHO. The baseline is the asynchronous CDMA (ACDMA) without SHO where the capacity is 92 users/cell. In this case we define the “capacity” as the point where the addition of users causes the BLER to rise above the target (in this case 1%). This figure also illustrates that for this particular combination of parameters, the system capacity increases to 108 users/cell if either SCDMA or SHO is introduced[2]. A system using both SCDMA and SHO with a SHO_Threshold of 3 dB has a higher system capacity of 138 users/cell. The application of SCDMA over ACDMA with SHO in a multi-cell environment provides about a 28% increase in system capacity (i.e. 28% more users). Note that in this scenario with a 3 dB SHO_Threshold, approximately 20% of the UE are in SHO mode (and are thus synchronized to only their home Node-B).

Figure 3 shows the capacity simulated with the CH A propagation model. The simulated capacity is 42 for CDMA without SHO. The capacity is increased to 54 users/cell with SHO. By introducing SCDMA, the capacity is increased to 88 users/cell (an increase of 63% in capacity). The capacity is lower for CH A with ACDMA because of the loss of the multi-path diversity. This loss, however, is compensated for in SCDMA by removing most of the intra-cell interference.

Finally, Figure 4 shows simulations for CH B for a UE with a velocity of 50 Km/h. Assuming the main finger is still synchronized maintaining an accuracy of 1/8 of the chip, the system capacity is 52 and 66 users/cell for ACDMA and SCDMA, respectively. This is a 27% increase in system capacity through the use of SCDMA in a mobile, multi-cell environment.

## IV. Conclusion

In this contribution, we reported the reverse link capacity gain (users per cell) in a CDMA system that employs soft handoff. Assuming that the main multi-path finger is synchronized at the home cell, SCDMA resulted in 28% increase in system capacity for ITU CH B and 63% increase for ITU CH A. It should be noted that the absolute capacity numbers reported here depend on the BLER curve used in the simulations. A different curve was tried where an Eb/No of 5 dB was required to achieve the 1% target BLER. The capacity numbers were lower but the gain from SCDMA was still the same. Hence, we conclude that the application of synchronous CDMA to the reverse link does provide significant capacity gains even in a multi-cell environment employing both power control and soft handoff.

## References

[1] B. Hashem, “Reverse Link Capacity of Synchronous CDMA Systems,” *IEEE Vehicular Technology Conference, Vancouver-Canada 2002*

[2] Sampath, A.; Sarath Kumar, P.; Holtzman, “On setting reverse link target SIR in a CDMA system,” *IEEE Vehicular Technology Conference, Vancouver-Canada 20021. 1997, IEEE 47th , Volume: 2 , 1997 Page(s): 929 -933 vol.2*

[3]Piechoclri, R.J.; Tsoulos, G.V., “A macrocellular radio channel model for smart antenna tracking algorithms,” *Vehicular Technology Conference, Volume: 3, 1999 Page(s): 1754 -1758.*

[4] C50-20010611-018R, “1xEV-DV Evaluation Methodology Addendum.doc,” *3GPP2-WG5, Vancouver, Canada, June 2001*

[5] Shihe Li, “The Key technologies in SCDMA wireless access,” . *Microwave Conference Proceedings, 1997. APMC '97, Page(s): 169 -172 vol.1*

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[2] That the same capacity is achieved with either technique is considered a coincidence.

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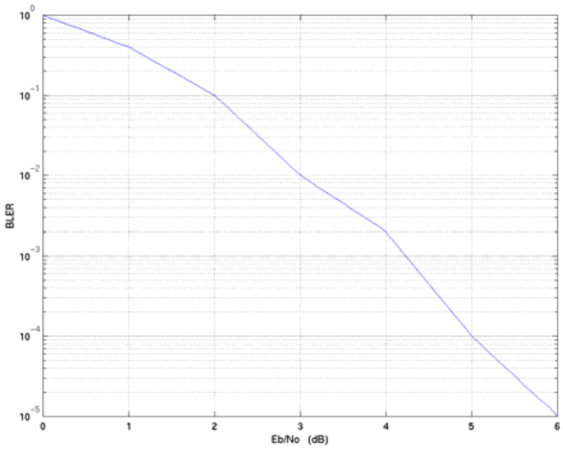

Figure 1: BLER curve used in the simulations

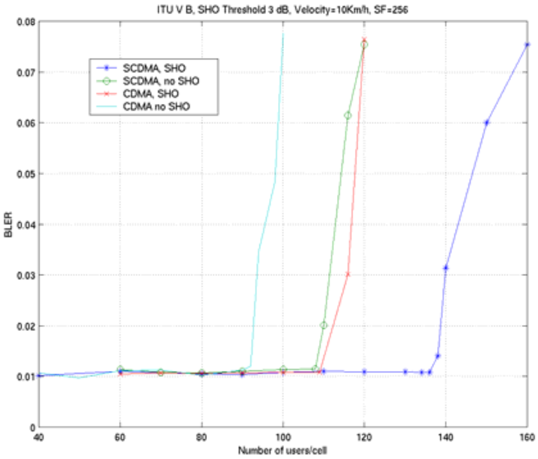

Fig 2: Channel model: ITU Vehicular CH B, Velocity 10 Km/h

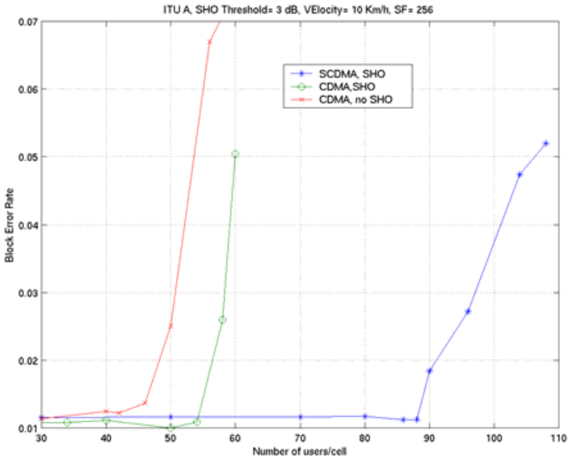

Fig 3: Channel model: ITU Outdoor-Indoor CH A, Velocity 10 Km/h

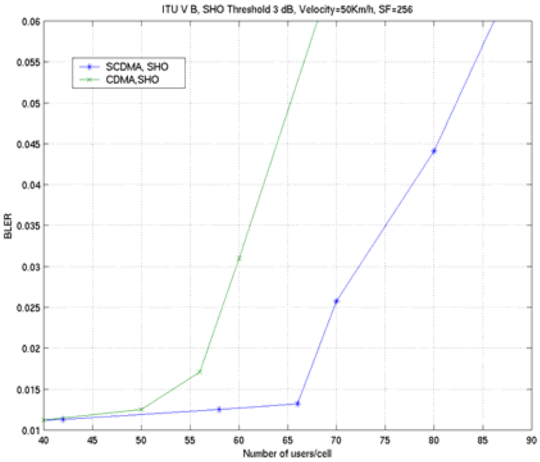

Fig 4: Channel model: ITU Vehicular CH B, Velocity 50 Km/h

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