

SOFT HANDOFF IN CDMA SYSTEMS

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Abstract

This report analyzes the performance of a soft handoff algorithm of the type that has been proposed in the IS-95 CDMA standard. In the soft handoff scheme, multiple base stations are involved in the communication to and from one mobile station to improve the handoff performance on the boundaries between two base stations by providing channel diversity. On the other hand, there are additional resources used during soft handoff. There is, thus, a tradeoff between diversity advantage and resource utilization. We present a simulation that provides quantification for this tradeoff. The results can be used to gain insight and help select the appropriate handoff thresholds.

Introduction

The act of transferring support of a mobile from one base station to another is termed handoff. Handoff occurs when a call has to be handed off from one cell to another as the user moves between cells. In a traditional "hard" handoff, the connection to the current cell is broken, and then the connection to the new cell is made. This is known as a "break-before-make" handoff. Since all cells in CDMA use the same frequency, it is possible to make the connection to the new cell before leaving the current cell. This is known as a "make-before-break" or "soft" handoff. Soft handoff requires less power, which reduces interference and increases capacity. The implementation of handoff is different between the narrow band and the CDMA standards.

This is an effort to analyze a soft handoff strategy, taking into consideration the trade-offs between selecting system parameters and the performance benefits. We consider a scenario involving two base stations and a single mobile, where the changes in the pilot signal strength are tracked and a conditional decision is made allowing communication with only one base station. This results as an outcome of simple measurements, which determine the strongest signal and results in handover to the corresponding base station.

In a CDMA system the same frequency band is shared between all the cells. Thus there is well-defined efficient bandwidth utilization. Though there is frequency reuse the orthogonal nature of the waveforms

serves to distinguish between the signals that occupy the same frequency band. A typical handoff scenario is taken into account wherein the need for a mobile to alter its frequency or rather to switch its carrier frequency is negated. The main idea of a soft handoff scheme is to ensure that there is connectivity with the old base station while the new base station has been assigned to take control over the communication link. This way at a given instant of time we have the mobile maintaining a constant communication link with at least one base station simultaneously ensuring a non disrupted call activity. The algorithm may be designed in such a way as to ensure that as soon as the mobile is within the range of the new cell, the old base station releases the connection of the call.

We have analyzed the performance of an existing soft handoff algorithm with the help of an analytical model. The outcome of such an experiment utilized certain parameters such as the number of Active Set updates, the assignment probabilities and the outage probabilities and the number of base stations with respect to a single mobile. The algorithm and the results obtained from the simulation are discussed in the next few sections.

The Importance Of Soft Handoff

In power controlled CDMA systems soft handoff is preferred over hard handoff strategies. This is more pronounced when the IS-95 standard is considered wherein the transmitter [the base station] power is adjusted dynamically during the operation. Here the power control and

soft handoff are used as means of interference-reduction, which is the primary concern of such an advanced communication system. The previous and the new wideband channels occupy the same frequency band in order to make an efficient use of bandwidth, which makes the use of soft handoff very important. The primary aim is to maintain a continuous link with the strongest signal base station otherwise a positive power control feedback would result in system problems. Soft handoff ensures a continuous link to the base station from which the strongest signal is issued.

Problem Definition

The main function of the soft handoff algorithm is to maintain an Active Set based on the measured pilot strength. We have the forward traffic channel and the reverse traffic channel. A reference signal is considered as the pilot signal referring to the forward CDMA traffic channel. There are several such pilot signals in the channel. The main function of the mobile station is to measure and report the pilot signal strengths to the base station. This is a repetitive process. As soon as the measured signal crosses a certain predefined threshold value it becomes a member of the Active Set. The main problem lies in identifying this threshold level. A reference pilot is picked from the Active Set and then a handoff decision is made after comparing the received pilot strength with that of the reference. Originally the Active Set consists of a single base

station but after repeated experiments and measurements other base stations are added when the signal strength between them and the user exceeds the predefined add threshold. There are three parameters that are considered in the analysis - T_{add} or the Add Threshold, T_{drop} or the Drop Threshold and the drop timer. Both T_{add} and T_{drop} are negative values. If any non-member pilot signal strength exceeds the T_{add} then the pilot is added to the set or is made a member of the set. The pilot is still continuously measured and at any instant if it drops below the drop threshold, T_{drop} , the mobile starts a drop timer. This timer is designed such that it is reset and disabled as soon as the pilot strength goes above T_{drop} before the drop timer expires. Upon expiry of the timer the pilot also is removed from the Active Set. The experiment was conducted for several values and it was found that high thresholds and long drop timer settings tend to maintain more stations in the Active Set. Similarly low thresholds and short drop timer settings increased the rate of Active Set updates. Here the base station utilization factor and the number of Active Set updates serve as a good yardstick to measure the system performance as is evident from the results obtained.

Software Implementation

The simulation of the algorithm described above in MATLAB using a single program. We considered an environment in which we had two base stations A & B and single mobile user moving from base station A in

the direction of base station B with no interference. A pilot signal is assumed to be transmitted by each base station that is measured at the mobile and used for all decisions. The pilot signal from each base station is modeled by the formula: $S_a(d) = K1 - K2x\log(d) + u(d)$ where d is the distance, K1 and K2 are constants that can be used to model any given environment and u and v are gaussian random noise sequences.

The main parameter of interest, namely, the Active Set is basically a registry that lists base stations that are capable of providing reliable communication with the mobile. Reliable communication refers to the threshold levels that the received pilot signal must satisfy and these thresholds are programmable by the user. The Active Set also holds the base station that the mobile is currently communicating with and in case a handoff is required, a base station from the Active Set is chosen as the next base station. The user can also choose drop timer values and the number of sampling points as well as the number of simulation cycles.

The program provides the user the option to choose from any of two simulations. The first simulation plots the assignment probabilities to base stations A & B and the probability that both base stations A & B are in the Active Set as well as the Outage Probability (no base station in the Active Set and hence call dropping) with respect to the distance. The second simulation plots the number of Active Set updates against the size of the Active Set for varying values of the drop timer.

Results

We provide results of the above-mentioned simulations with the optimum values of all parameters obtained by running this simulation over many sets and combinations of values.

As expected the assignment probability of base station A decreases with increasing distance. This is because we have assumed the user to be moving from base station A in the direction of base station B. Similarly the assignment probability of base station B increases with distance. The probability of both the base stations being in the Active Set is maximum at the boundary region of the two cells. This is expected because the pilot signals have almost the same strength in this region. It is interesting to note that the outage probability is also maximum in the boundary region. The inference we can draw from this scenario is that an effort to reduce the outage probability by manipulating the threshold values (mostly decreasing the thresholds) will result in more base stations existing in the Active Set. Also the width of the graph in figure 2 is increased (along with the height of the peak). This implies that overall there will be more base stations for a longer period of time in the Active Set thus requiring more system resources to implement the algorithm. Therefore a tradeoff has to be struck between the outage probability and the system resources required.

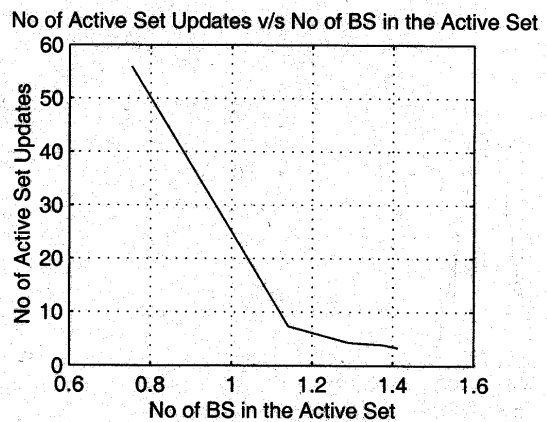
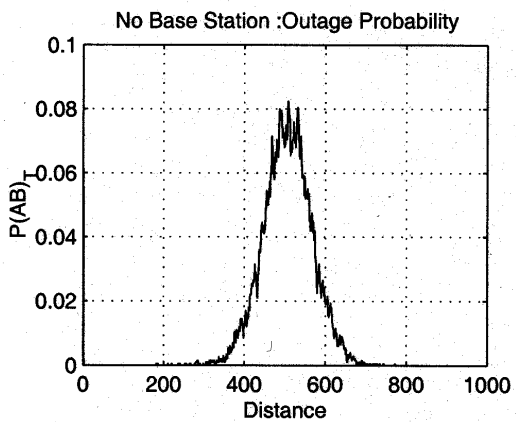
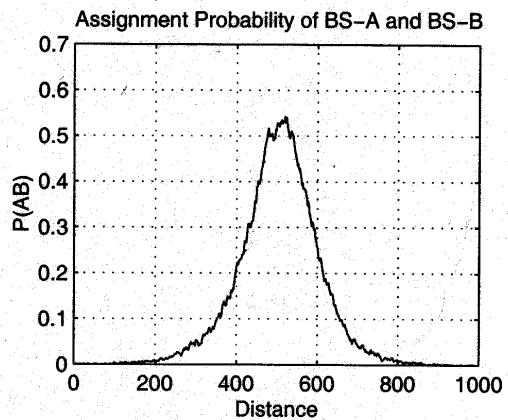
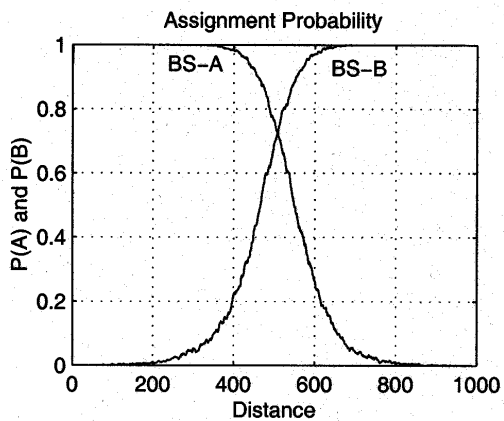


Figure 4 shows the variation in number of Active Set updates with the number of base stations in the Active Set with increasing drop timer values. It can be seen that there is a sharp decrease in number of updates from a timer value of 1 to 5. Also increasing the timer value any further does not produce any significant improvement in the performance. The number of updates represents the system overhead incurred in this algorithm. Hence it can be inferred that a drop timer value of 5 is ideal for this algorithm.

Conclusions

We have presented a very simple and efficient Soft Handoff algorithm. The performance of the soft handoff algorithm can be analyzed using the simulation we have presented. Our conclusion is that the introduction of the drop timer greatly reduces the system overhead with only a slight increase in the resource usage. As a next step the same algorithm could be extended to accommodate more base stations and interference factor could also be considered. It could be an interesting feature to observe the behavior of this model in the event of non-availability of the channel.

References

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