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Comparative Analysis of Power Control Algorithms for WCDMA Systems

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Abstract: *Efficient radio resource management in WCDMA systems is essential while considering the limitation in channel capacity imposed by Interference. An Effective Power control scheme salvages this major draw by controlling the transmit power level of mobiles within a coverage area. Currently, several power control schemes have been developed and some implemented with the aim of providing the required quality of service using the lowest possible transmission power. This paper presents a comparative analysis of common power control algorithms developed to be employed by WCDMA systems.*
Keywords: *Power Control, WCDMA, ASPC, EAPC, FSPC, MASPC.*

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I. Introduction

In Universal Mobile Telecommunication System (UMTS), coverage and capacity are interdependent. UMTS is based on Wideband Code Division Multiple Access (WCDMA) technologies which are capable of delivering high data rate services. However, when the number of users increases, the capacity will be decreased because the capacity of WCDMA systems is interference limited. Therefore, it is important to minimise the interference in the systems. One of the critical sources of interference is transmission power from other users in the uplink (mobiles to base stations) [1]. If the transmission power in the uplink is not properly controlled, a mobile close to the base station may transmit excessive power causing large interference to other users connecting to the same cell. This scenario results to the near–far effect resulting from one user's transmission power becoming a source of interference to others which significantly reduces system capacity. Consequently, it is vital that a mechanism to control the transmit power be developed, which led to the development of various power control schemes aimed at mitigating the near-far problem. Currently, several power control schemes have been developed and some implemented with the aim of providing the required quality of service using the lowest possible transmission power. While some of these algorithms have effectively mitigated the near-far problem, it is important to note that this is usually not without loop holes which could either be detrimental to the system or may not be feasible for implementation. There are many centralized and distributed power control algorithms, but the scope of this paper is to evaluate only some of the commonly used distributed power control algorithms.

II. Power Control Algorithms

Power control is basically classified into open-loop and closed-loop power control. Open-loop power control is employed at the beginning of a connection, it sets the initial transmit power levels for the UE and in downlink direction it determines the transmit power levels for the downlink channels. The open loop power control uses the measurement reports of the UE about the received power from the BS, and it then decides how to set the transmit downlink power levels [2]. Power control for UMTS is closed loop which involve a combination of inner-loop and outer-loop power control algorithms. The inner loop power control is also known as the fast closed loop power control. The fast closed loop controls the transmission power levels for UE and BS based on the received signal-to-interference ratio (SIR) level at BS and UE, to combat fading characteristics of the radio channel [2]. The Transmit Power Control (TPC) commands are sent by UE and BS providing the information either to increase or decrease the transmission power levels. The outer loop power control provides the target SIR level for the inner loop power control. The outer loop power control adjusts the target SIR to achieve the desirable Block Error Rate (BLER) for the particular service (voice or data) carried out by the UE. The change in the mobile speed or the multipath propagation environment also results in the adjustment of the targeted SIR [2].

System availability is the main performance metric considered in this work. This is a very important parameter that is fundamental in system analysis. The outage probability which is described as the probability that the signal to noise ratio (SNR) at the output is below a given threshold value (Γth)-outage threshold value is adopted as a means to evaluate system performance employing any of the algorithms. The outage threshold is a limit value for the SNR that measures the quality of service, QoS. This paper focuses on only five power control schemes employed in WCDMA systems, namely: Distance based power control algorithm, Adaptive Step power control algorithm, Fixed step power control algorithm, Modified Adaptive Step Power Control Algorithm and Enhanced Adaptive Step Power Control Algorithm.

i. **Distance Based Power Control algorithm (DBPC)**

The distance-based power control (DBPC) algorithm developed by [3] uses the distance between base station and each mobile station to allocate transmitted power to each each of its served mobile. No correction or feedback is provided, and this is therefore an open loop power control mechanism. Thus, more transmitted power should be allocated to mobiles which are far from their corresponding base station. In order to avoid having very small transmitted powers for mobiles close to the base, mobiles whose distance is less than a certain threshold value dmin, the same transmitted power is allowed.

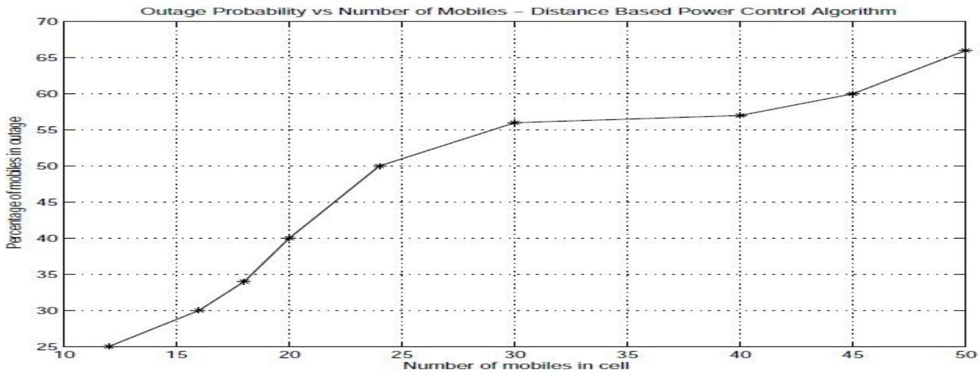

Figure 1: Outage probability of Distance Based Power Control Algorithm

ii. **Fixed Step Power Control (FSPC) Algorithm**

The fixed step size power control algorithm or command is embedded in 1 bit, meaning either a single step increment or decrement of the output power, which is easier to implement and leads to less control bits overhead. However, the fixed step leads to oscillations with high variance around the SIR_{target} and thus restrains the capability of the power control algorithm to follow radio interface variations [4]. The fixed step size power control procedures can be described with the following steps:

- The base station estimates the received SIR from a particular mobile.
- The estimated SIR is compared with the corresponding SIR target.
- If the estimated SIR is lower than the target, then the base station sends an “up” TPC command. Otherwise, a TPC “down” command will be sent.
- The mobile station obeys the command by increasing or decreasing the transmit power on a fixed step size typically 1Db
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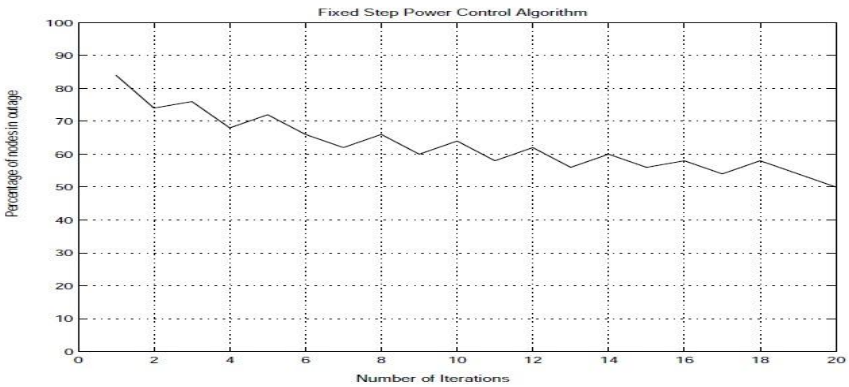

Figure 2: Outage probability of Fixed Step Power Control Algorithm

iii. **Adaptive Step Power Control (ASPC)**

The Adaptive Step Power Control (ASPC) is a closed– loop power control mechanism that was originally proposed for uplink transmission using adaptive step sizes as opposed to fixed step sizes, in order to achieve faster convergence towards the target SIR. Adaptive-Step size Power Control (ASPC) algorithm was proposed by [5] such that if the mobile station detects the same TPC from a base station in a set of consecutive slots, the step dedicated to this mobile is increased. On the contrary, if an alternative sequence of up and down TPCs of a mobile is received by a mobile station, the step dedicated to this mobile is reduced.

The steps of operation are as follows [5]:

1. The mobile stations measure the observed value of the SIR at each iteration and compare it with a preset threshold value.
2. If the observed SIR is larger than the threshold, then the mobile sends a power down command to the base station. Otherwise, it sends a power up command.
3. The first power update command is interpreted as a fixed step modification. However, the step size is adapted dynamically if successive feedback commands request additional change in the power level in the same direction (for instance, two or more consecutive power up commands result in a larger step size).
4. The base station interprets the power control command from each of its mobile stations and updates the transmitted power accordingly.
5. The power control updates take place in multiple steps of different sizes

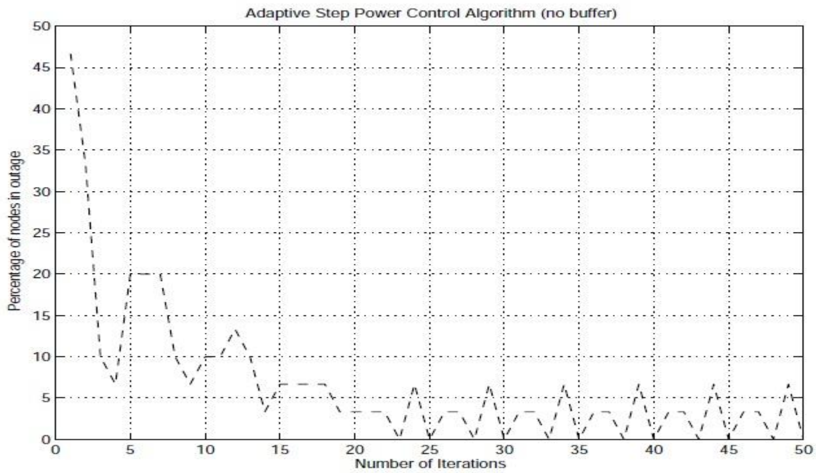

Figure 3: Outage probability of Adaptive Step Power Control Algorithm

iv. **Modified Adaptive Step SIR{based Power Control (MASPC)**

MASPC is a variation of the ASPC algorithm that uses two thresholds, a higher and a lower end critical threshold for the SIR. This prevents the oscillations observed at lower values of outage in the ASPC algorithm. When the mobiles are in the buffer region, they do not send any feedback and the system converges rapidly without oscillating at lower outage percentages. This algorithm also uses the information from the previous iteration in order to adapt the step size accordingly like ASPC [6]. If a mobile is found in outage then it looks that what the previous state (outage or non outage) was of the mobile, if it was in outage then the power is adjusted (increased) by factor $\mu\delta$, (δ-Step Size), if it was in non-outage then power is adjusted by factor δ, and if the initial power allocation caused by this mobile in outage then power is adjusted by factor $\mu\delta$. In other case when a mobile is found in non-outage then it looks that what the previous state (outage or non outage) was of the mobile, if it was in non-outage then the power is adjusted (decreased) by factor $\nu\delta$, if it was in outage then power is adjusted by factor δ and if the initial power allocation caused by this mobile in non-outage then power is adjusted by factor δ [6].

The mode of operation of the MASPC algorithm is as follows [6]:

1. The mobile stations measure the observed value of the SIR at each iteration and compare it with the preset lower and higher critical threshold values.
2. If the observed SIR is smaller than the lower critical threshold, then the mobile sends a power up command to the base station. The first power update command is interpreted as a fixed step modification; however, the step size is adapted dynamically if successive feedback commands request additional change in the power level in the same direction.
3. If the observed threshold is between the lower and the higher critical threshold values, then the mobile does not send any control signal to the base station.

4. The increment step size is chosen larger than the decrement step size. This ensures that mobiles in outage can quickly come out of outage.
5. Once the mobiles are out of outage and not in the buffer region, the smaller decrement step size brings the mobile into the buffer region. As pointed out in step (3), when the mobile is in the buffer region, it does not send power change commands. This eliminates the oscillations observed at low outage percentages in MSPC.

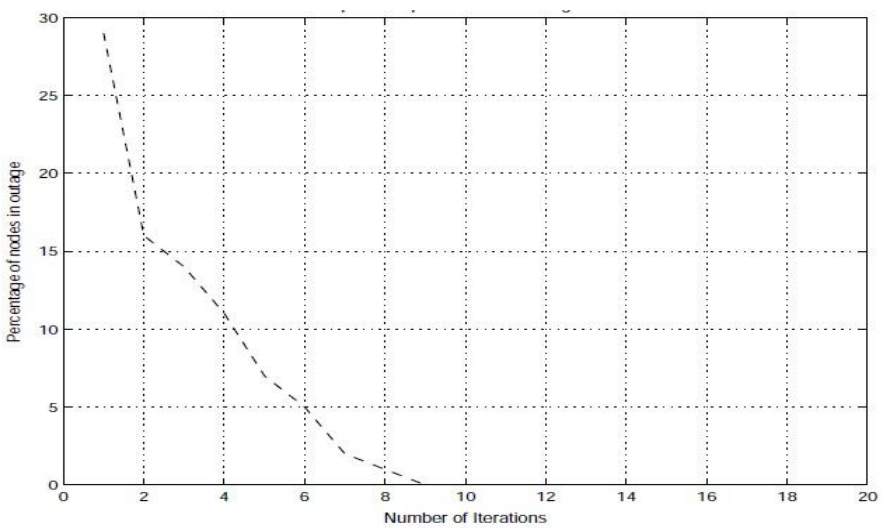

Figure 4: Outage probability of Modified Adaptive Step Power Control Algorithm

V. Enhanced Adaptive Power Control (EAPC) algorithm

The EAPC algorithm is simply the combination of the FSPC algorithm, the AS method, and the DCPC algorithm [1]. Just like the FSPC algorithm, the commands are transmitted to the MS, which applies Adaptive Step to generate a reconstruction $\bar{e}_G(t)$ of the Power Control (PC) misadjustment, and then updates its power as in the DCPC algorithm, but using the reconstructed value instead of the true e(t) [1]. The pseudo code for the Enhanced Adaptive Power Control algorithm follows these steps:
1) The mobile stations measure the observed value of the SIR at each iteration and compare them with the preset lower and upper critical threshold values.
2) If the observed SIR is smaller than the lower critical threshold, then the mobile sends a power–up command to the base station. The first power update command is interpreted as a fixed step modification; however, the EAPC algorithm dynamically adjusts the step size if successive feedback commands request additional change in the power level in the same direction.
3) If the observed threshold is between the lower and the upper critical threshold values, then the mobile does not send any control signal to the base station, thereby eliminating oscillations observed at low outage percentage of Multiple Step Power Control (MSPC) algorithm.
4) The increment in size is chosen larger than the decrement in size. This ensures that MS's in outage can quickly come out of outage.
5) Once the MS's are active and not in the buffer region, the smaller decrement size brings the MS back into the buffer region.

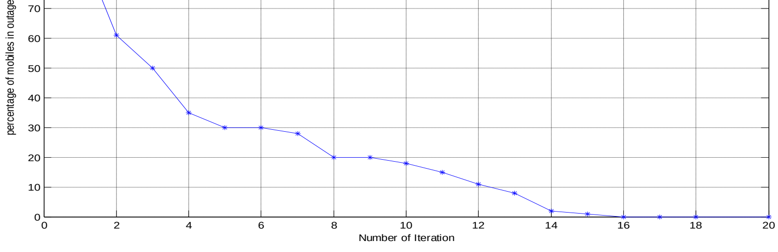

Figure 5: Outage probability of Enhanced Adaptive Step Power Control Algorithm

III. Result Analysis

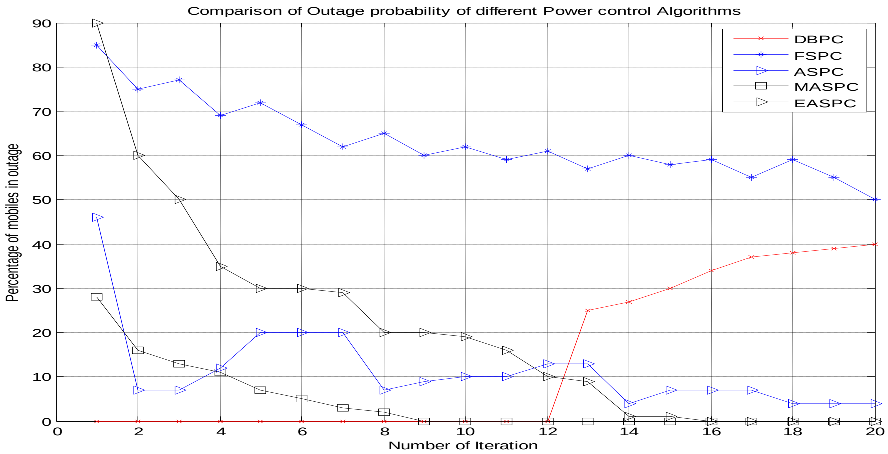

Figure 6: Comparison of Outage probability of the various power control techniques considered in this work

Fig. 6 shows the outage probability of the various power control techniques considered in this work, it shows the extent that the various techniques have succeeded in reducing the outage probability in a WCDMA network. From Fig. 6, for the DBPC algorithm, it could be seen that when the number of mobiles increased, the outage probability increased also. For FSPC algorithm, even at the 20th iteration, the outage percentage is still about 50% which is equivalent to operation at half the available capacity. While for ASPC algorithm, irregular oscillations are noticed due to the single threshold value employed in the algorithm. The MASPC showed a better improvement when compared to all the analyzed algorithms, with no mobile in outage after the 8th iteration though this would come at the expense of system complexity. The EAPC algorithm also provides an improved performance with no mobile in outage after the 16th iteration.

IV. Conclusion

In this paper we compared various existing downlink power control algorithms for WCDMA systems based on outage percentage. From results obtained from the comparison of the following algorithms (DBPC, FSPC, ASPC, MASPC and EAPC), the Enhanced Adaptive Step power control algorithm was shown to give better results compared to other algorithms because the complexity is less when compare to other power control algorithms. The Enhanced Adaptive-Step Power Control Algorithm, which could be easily implemented, is an interesting variant of the one-bit command PC of WCDMA System. The reduced outage percentage with time results to an increased channel capacity. The important parameters of the EAPC algorithm are the additional upper and lower critical threshold regions and improved step size adaptation.

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