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Research Paper

Spectrum Implementation of Radio Resource Management in Mobile Networks Using Power Control Algorithm

[1]Onuigbo, Chika M.,[2]Ogili SolomonNnaedozie,[3]Dimeze Amadi I.
[123] Department of Electrical and Electronic Engineering
Enugu State University of Science and Technology (ESUT), Enugu State, Nigeria.

Abstract
The conventional focus of research and education in the field of telecommunications often centers on channel coding and source coding for a single user. Radio resource management (RRM) plays a crucial role in systems where efficient utilization of limited radio resources and the provision of quality of service (QoS) are important considerations. Spectrum implementation of radio resource management in mobile networks using power control algorithm was implemented in this research. The area of the simulation was taken to be 2000m x 2000m while the number of nodes varies from 0 to 160. Numerical results were used to represent a normal geographical environment with all the parameters. The path loss exponent, α, was taken as $2 < \alpha < 6$, with four different values of α taken as α_1, α_2, α_3 and α_4 and values as 2.5, 3, 2 and 5, respectively. Simulation results showed that the outage probability of the distance based power allocation control algorithm has a decrease of 23% while distributed balancing power allocation control algorithm presented a decrease of 20%. Throughput results also showed that distance based power allocation control algorithm has an increase of 25% whereas distributed balancing power allocation control algorithm: increase of 30%. Thus, distributed balancing power allocation control algorithm showed a better radio resource management technique among the two.

Keywords: *Radio Resource Management, Distance based Power Allocation Control Algorithm, Distributed Balancing Power Allocation Control Algorithm, Outage Probability, Throughput.*

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I. INTRODUCTION

Efficient utilization of the scarce spectrum allocation for cellular communications is certainly one of the major challenges in cellular system design. An efficient allocation of resources is the key to high system capacity (Rao and Sinha, 2002). In radio and transmission subsystems, techniques such as deployment of time and space diversity systems, use of low noise filter and efficient equalizers, and deployment of efficient modulation schemes can be used to suppress interference and extract the desired signal. The rapid growth in demand for mobile communication has led to intense research and development efforts towards a new generation of cellular systems. Traditional telecommunications research and education frequently dwell on channel coding and source coding with a single user in mind, but when several users and adjacent base stations share the same frequency channel it may not be possible to attain the maximum channel capacity (Tripathi et al, 2001). Anpalagan et al (2006), opined that the 3G+ wireless systems can be characterized by aggregate bit rates in the range of Mbps, quality-of-service (QoS) support for interactive multimedia services, global mobility, service portability, enhanced ubiquity, and larger user capacity and coverage. In such systems, a major role is played by radio resource management (RRM) in the provision of QoS and efficient utilization of scarce radio resources. As Tarapiah et al (2015) put it, several radio access technologies (RATs) reflect the heterogeneity concept, composed of different Radio Access Networks (RAN) with each RAN interfacing with a Common Core Network (CCN). RANs can exist in different cellular networks, such as Universal Terrestrial Radio Access Network (UTRAN) either Frequency Division Duplexing (FDD) or Time Division Duplexing (TDD), GSM EDGE Radio Access Network (GERAN), as well as other public non-cellular broadband wireless hotspots.

Considering device-to-device (D2D) communication as a technology in mobile communication network, power consumption reduction is a major advantage of power control and channel allocation algorithm on the side of users' equipment. It also reduces end-to-end transmission delay by making it possible for two users in close proximity to directly communicate without traversing other networks or base stations (Su and Zhu, 2019). By reusing cellular network spectrum, D2D communication allows increased user inter-network connection activity thereby improving spectrum utilization rate and system capacity (Jameel et al, 2018). The capacity of the system in Code Division Multiple Access (CDMA) is sufficiently maximized when each mobile transmitter power level is controlled in such a way that its accompanying signal arrives at the site of the cell with the required minimum signal-to-interference ratio (SIR) (He et al, 1997). Should a mobile signal arrive at the cell site with such a signal considered to be too weak, the weak user is often dropped. Conversely, should the received power from the mobile unit be too strong, even though the performance of the mobile unit will be acceptable, it will nevertheless add undesirable interference to other users in that cell (Hossain et al, 2013). A block diagram of power control in CDMA and cellular networks is shown in Figure 1.

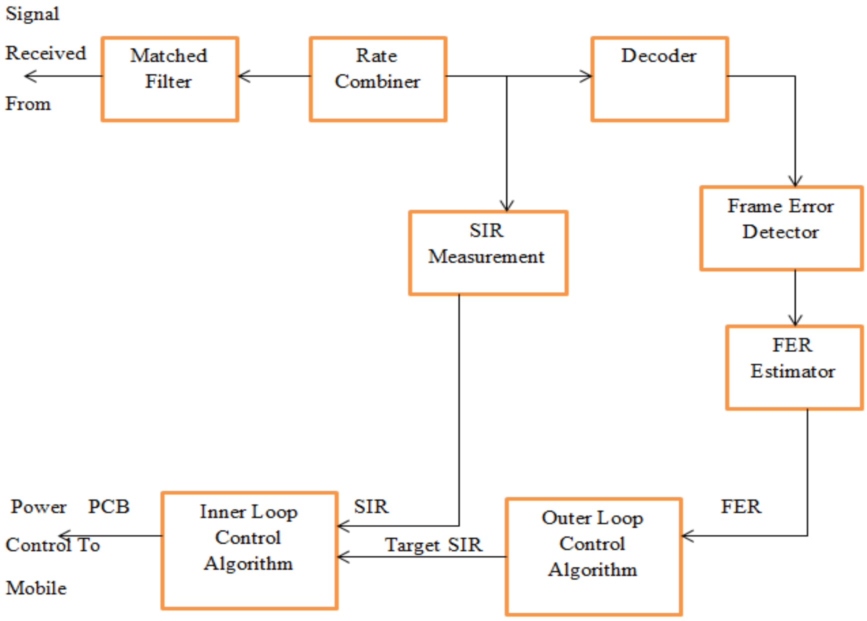

Figure 1: Power Control Block Diagram in CDMA and Cellular Networks

The purpose of power control is to regulate the signal strengthto reduce overall interference (Berggren, 2001). All these are geared towards achieving high speed quality; high capacity and lower power consumption which are major goals needed to be achieved in cellular radio communication systems. Specifically, power control algorithm is aimed at keeping the transmitted power (for the mobile station in the uplink power control and base-station in downlink power control) at the minimum power required to achieve the target Quality of Service (QoS) in the system to guarantee a seamless communication (Koivo and Elmusrati, 2009).

II. LITERATURE REVIEW

Some related works are hereby reviewed for a deeper insight into the subject being studied.

In Hassan and Abdulsalam (2014), it was demonstrated that power control is essential in cellular networks due to its capability to mitigate the near-far problem, improve the quality of service, increase the capacity of the system, extend battery life of the mobile terminal and significantly reduce biological effects arising from electromagnetic radiation. Three different power control algorithm types were studied. These were Distributed Balanced Algorithm (DBA), Distributed Power Control (DPC) Algorithm and Foschini’s and Miljanic’s Algorithm (FMA). Using MATLAB codes for each of the three algorithms, results were presented and compared. The DPC was found to be the fastest to reach the optimum power value.

Xintong et al, (2018) did a work titled, “A Power Control Algorithm Based on Outage Probability Awareness in Vehicular Ad Hoc Networks.” In the paper, the problem of adaptive power control based on outage probability minimization in Vehicular Ad Hoc Networks (VANETs), called a Power Control Algorithm Based on Outage Probability Awareness (PC-OPA) was presented. To fulfill power control, cumulative interference was assumed to be available at the transmitter of each terminal. The transmitters sent data by maximum power and then got the cumulative interference-aware outage probability. It was shown that the PC-OPA can achieve a significant performance gain in terms of the outage probability and throughputs. Comparing MPC (Maximum Power Control algorithm) and WFPC (Water-Filled Power Control algorithm), the proposed PC-OPA decreased by 23% in terms of the outage probability and increased by 25% in terms of throughputs. However, the application was limited to ad-hoc networks rather than conventional networks.

Na Su, and Qi Zhu (2019) in Power Control and Channel Allocation Algorithm for Energy Harvesting D2D Communications focused on D2D users. This algorithm first used a heuristic dynamic clustering method to cluster D2D users and those in the same cluster shared the same channel. Then, D2D users in the same cluster were modeled as a non-cooperative game, the expressions of D2Dusers' transmission power and energy harvesting time were derived by using the Karush–Kuhn–Tucker (KKT) condition, and the optimal transmission power and energy harvesting time were allocated to D2D users by the joint iteration optimization method. Simulation results showed that the proposed algorithm could effectively improve the system performance. The work does not apply to device to everything (D2X) communication.

Namyoon et al, (2019) worked on Power Control for D2D Under laid Cellular Networks: Modeling, Algorithms and Analysis. For the distributed power control method, the optimal on-off power control strategy was proposed, which maximized the sum rate of D2D links. Analytical expressions were derived for the coverage probabilities of cellular, D2D links, and the sum rate of the D2D links in terms of the density of D2D links and the path-loss exponent. The analysis revealed the impact of key system parameters on the network performance. Simulation results verify the exactness of the derived coverage probabilities and the sum rate of D2D links. The work was only for under-laid cellular networks and this is a major shortcoming.

The foregoing reviews are meant to show areas where the spectrum implementation of radio resource management in mobile networks using power control algorithm is applied. The methodology of this work is hereby presented to address the limitations seen in the presented reviews.

III. METHODOLOGY

Characterization of the environment for the experimental setup is carried out and results are shown in tables 3.1 and 3.2. Specifically, the environmental parameter setting is given in table 3.1.

Table 3.1: Parameter Setting for Simulation

Description	Value
Area of Simulation	2000m x 2000m
Number of Vehicles	0 – 180
Distance of Transmission	100m – 300m
Channel Bandwidth	5 – 20 MHz
Signal-to-Noise Ratio, SNR	15 – 30 dB
Doppler Frequency Shift	100 – 300 Hz

The path loss exponents for different environments are shown in table 3.2.

Table 3.2: Path Loss Exponents for Different Environments

Environment	Path Loss Exponent, α
Free Space	2
Urban Area Cellular Radio	2.7 – 3.5
Shadowed Urban Cellular Radio	3 – 5
In building Line-of-Sight	1.6 – 1.8
Obstructed Building	4 – 6
Obstructed Factories	2 – 3

A model of the urban road system in a VANET environment as an experimental setup is shown in Figure 2.

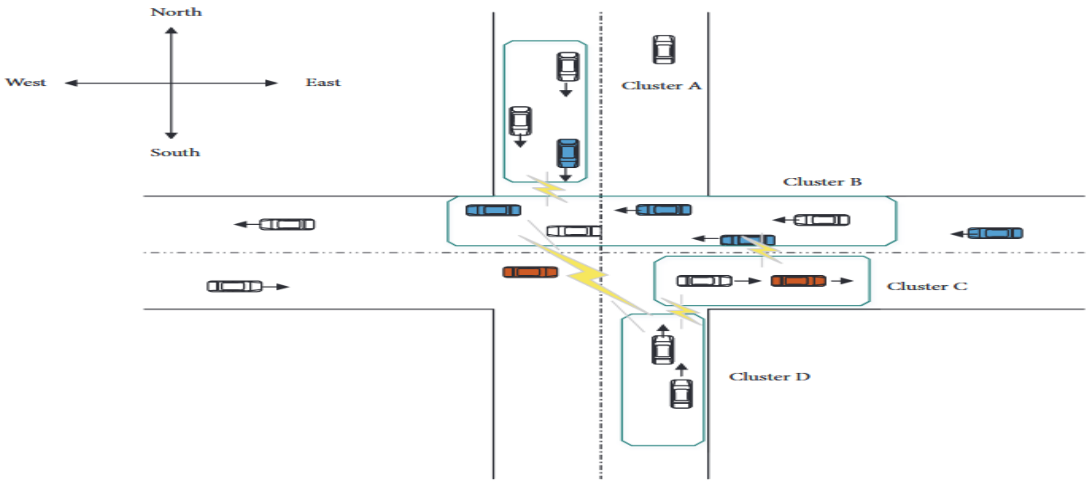

Figure 2: Urban road system model

Tables 3.1 and 3.2 are parametric values of an open loop cellular communication network which is the experimental environment represented by the urban road system model.

A power control algorithm capable of maximizing resource management and allocation in a cellular communication network is now proposed. The first proposed algorithm meant for an open loop, distance based power control allocation algorithm is shown in Module 3A.

Module 3A: Distance Based Power Allocation Algorithm

```
1. Initialize the number of iterations
2. Initialize the number of mobiles
3. Initialize $d_{min}$, R, k, n
4. for i = 1 to iterations
    Generate uniformly distributed vector of mobile-to-base station distance
    Initialize power
    for j = 1 to mobiles
    if $d_{am} \leq d_{min}$
    $p_m(j) = k (d_{min}/ R)^n$
    else
    $p_m(j) = k(d_{am}(j)/R)^n$
    end
    Calculate $SIR_{observed(j)}$ and compute outage
    end
5. Calculate the outage percentage using the outage counter and the number of mobiles.
6. Plot outage percentage versus mobiles
```

The second proposed algorithmalso meant for an open loop power control, is a Distributed Balancing Algorithm (DB), presented in Module 3B.

Module 3B: Distributed Balancing Algorithm (DB)

```
1. Initialize the number of iterations
2. Initialize the  number of mobiles
3. for i = 1 to iterations
    Generate uniformly distributed vector of mobile-to-base station distance.
    Generate a vector of link gains of mobiles from their base station gain.
    Generate a vector of link gains of mobiles from other base station gains.
    Initialize power
    Initialize DB correction coefficient $C_{ik}$
    for j = 1 to mobiles
    total received power = ∑power * gain + 6 *∑power *gain
    Cik = total received power/gain
    Power (j) = $\sum power * C_{ik}(j)/\sum C_{ik}$
    end
    Calculate $SIR_{observed(j)}$ and compute outage
    end
end
4. Plot outage percentage versus mobiles
```

The two algorithms in Modules 3A and 3B are proposed for simulation in the model developed in a Simulink environment in MATLAB.

The pseudo codes of the algorithms were then applied to the model of Figure 2 by simulating them in turn so that the results of one could be compared to the other. The model used for the simulation is shown in Figure 3.

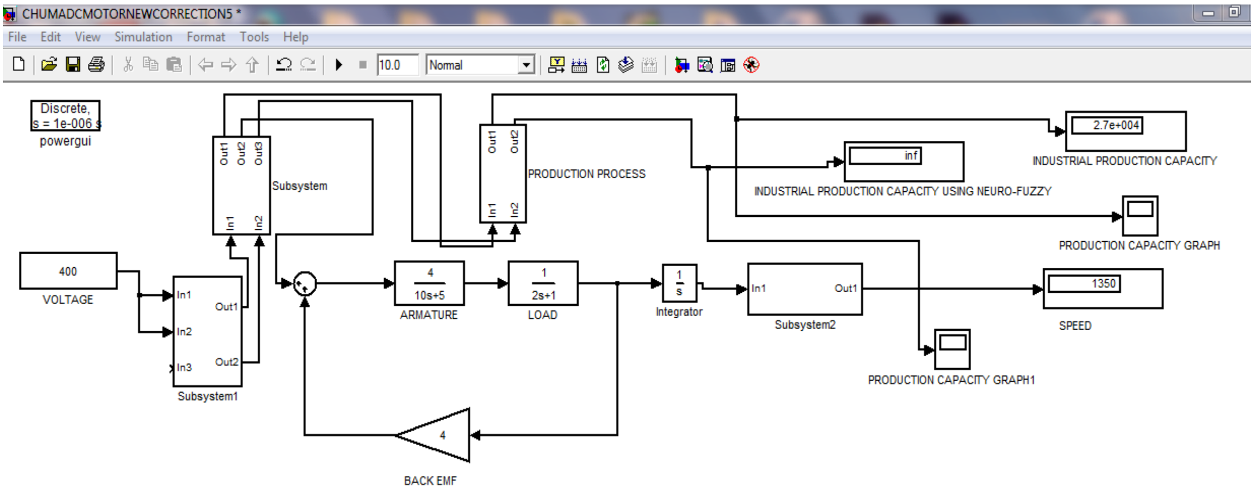

Figure 3: Simulink Model of Simulation Environment

The required model used for the simulation of the pseudo codes of Modules 3A and 3B is shown in Figure 3.

The results from the simulations of the modules of the algorithms earlier proposed to be computed and plotted to show the preferred algorithm by their different percentages.Considering the distance based algorithm, the data shown in tables 3.3(a) and (b) were obtained as results.

Table 3.3(a): Distance Based Power Control Algorithm

Percentage of Mobiles in Outage (%)	0	10	20	30	40	50	60	70	80

Table 3.3(b): Distance Based Power Control Algorithm

No. of Mobiles in Cell	10	15	20	25	30	35	40	45	50	55

For the distributed balancing algorithm, the data shown in tables 3.4(a) and (b) were obtained.

Table 3.4(a): Distributed Balancing Algorithm

Percentage of Mobiles in Outage (%)	0	5	10	15	20	25	30	35	40	45	50

Table 3.4(b): Distributed Balancing Algorithm

No. of Mobiles in Cell	10	15	20	25	30	35	40	45	50	55	60

The data values in table 3.3(a) are then plotted against those data values in table 3.3(b). Similarly, the data values in table 3.4(a) are plotted against those in table 3.4(b).

IV. RESULTS AND DISCUSSION

The process of characterization was earlier shown in tables 3.1 and 3.2 where an area of the simulation was taken to be 2000m x 2000m while the number of nodes varies from 0 to 160. Numerical results were used to clearly represent a normal geographical environment with all the parameters shown in table 3.1. These parametric data were used in evaluations as subsequently carried out. The relationship between the outage probability and power control exponent is shown in the graph of Figure 4.

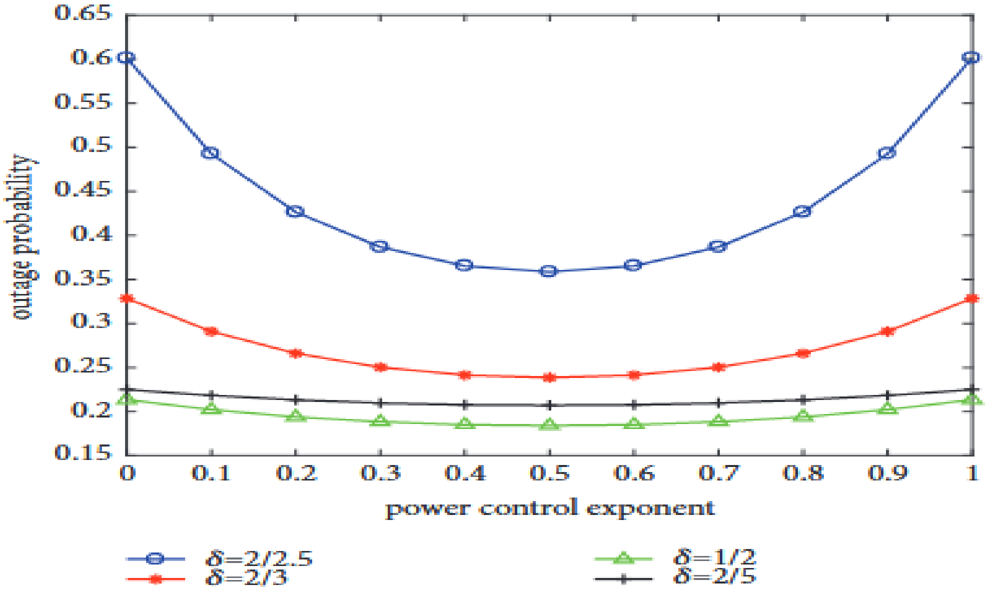

Figure 4: Power control exponents *w* versus outage probability.

The graph of Figure 4 has a bearing on the path loss shown in table 3.2 for different environments. In this graph of Figure 4, the path loss exponent, α, was taken as $2 < \alpha < 6$. Four different values of α were taken. These are

$\alpha_1 = 2.5$;

$\alpha_2 = 3$;

$\alpha_3 = 2$ and

$\alpha_4 = 5$.

The different environments for wireless channel are represented by different parameters. In Figure 4.1, the minimization of the outage probability is achieved more readily with the more effective PC-OPA considering a VANET environment. Given that w is the power control exponent, w = 0 is used to represent maximum transmission power while w = 1 denotes channel inversion or operation overload, which is undesirable.

The different performance gains achieved in terms of output probability can be deduced from the graph of Figure 4, arising from the characterization. Thus, at $w = 0.5$ a significant performance gain was achieved in terms of the outage probability irrespective of the radio environment, while $w = 0$ and $w = 1$ are seen to be comparable, which is high cumulative interference and outage probability in the receiver. This simulation is meant to establish the effectiveness of the proposed power control schemes.

The plotted graphs are shown in Figures 5 and 6.

The results of the data generated from the simulation of Figure 3 were collated and tabulated as shown in tables 3.3(a) and 3.3(b) for distance based power allocation control algorithm as well as tables 3.4(a) and 3.4(b) for distributed balancing power allocation control algorithm. These are later used in plotting the graphs relative to each as shown in Figures 5 and 6.

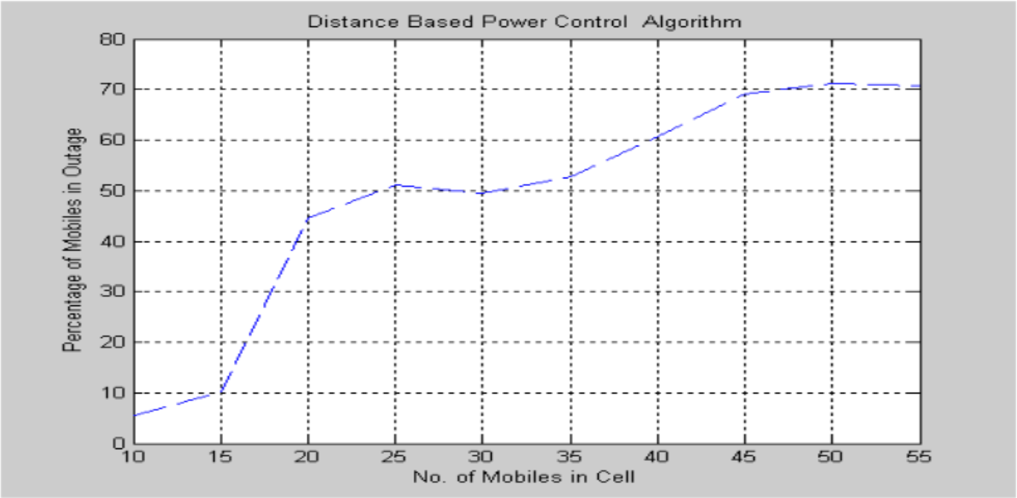

Figure 5: Outage Percentage of Mobiles in Outage versus No .of Mobiles in Cell

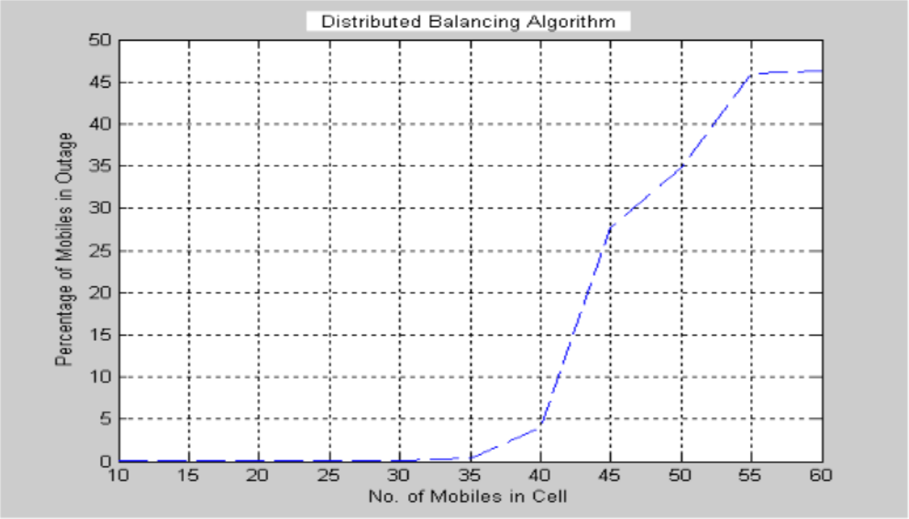

Figure 6: Outage Percentage of Mobiles in Outage versus No .of Mobiles in Cell

The plotted graphs are shown in Figures 5 and 6. However, the data in tables 3.3(a) and 3.3(b) as well as those in tables 3.4(a) and 3.4(b) were used in plotting the graphs. The simulation results show that the outage probability of the Distance Based Power Control Algorithm decreased by 23% and the throughput increased by 25%, compared to Distributed Balancing Power Control Algorithm. Further analyses are as follows.

For the Distance Based Power Control Algorithm,

Given the Mobile Number in Cell	50
Corresponding Percentage of Mobiles in outage	72

For the Distributed Balancing Power Control Algorithm,

Given the Mobile Number in Cell	50
Corresponding Percentage of Mobiles in outage	35

The above summary shows that while the distance based PCA presented a higher throughput shown by the percentage of mobiles in outage, the distributed balancing PCA showed a lower throughput. This means that a better radio resource management can be achieved by using distributed balancing power allocation control algorithm as a technique.

Summary of Results

The summary of the results is as follows:

At $\alpha_1 = 2.5$, $\delta_1 = \frac{2}{2.5} = 0.8$

At $\alpha_2 = 3$, $\delta_2 = \frac{2}{3} = 0.67$

At $\alpha_3 = 2$, $\delta_3 = \frac{2}{2} = 1$

At $\alpha_4 = 5$, $\delta_4 = \frac{2}{5} = 0.4$

Outage Probability

Distance based power allocation control algorithm: decrease of 23%.

Distributed balancing power allocation control algorithm: decrease of 20%.

Throughput

Distance based power allocation control algorithm: increase of 25%.

Distributed balancing power allocation control algorithm: increase of 30%.

Thus, distributed balancing power allocation control algorithm showed a better radio resource management technique among the two.

V. Conclusion

From the results and discussions presented, it is obvious that the distributed balancing power allocation control algorithm showed a better radio resource management technique when compared to the distance based power allocation control algorithm. Thus, it is advised to implement this radio resource management when spectrum implementation is being configured.

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