ACADEMY JOURNAL OF SCIENCE AND ENGINEERING
Available online @
www.academyjsekad.edu.ng
AJSE 17 (1) 2023
Original Research

AN IMPROVED POWER CONTROL SCHEME FOR INTERFERENCE MITIGATION IN D2D NETWORKS

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Abstract

As the steep growth in mobile data traffic continues to gain lots of attention in recent years, discussions of the next generation of mobile networks - the fifth generation (5G), have gained significant traction both in the academia and industry. In addition to more capacity, stringent requirements for improving energy efficiency, decreasing delays, and increasing reliability have been envisioned in 5G. Many solutions have been put forward, one of them being Device-to-Device (D2D) communications where users in proximity can communicate directly with one another. Interference management between Cellular User Equipment (CUE) and D2D user Equipment (DUE) is one of the most critical issues when D2D is introduced to cellular network because D2D users share the same licensed spectrum with cellular users. This work considers an overlaying network scenario where an energy efficient D2D Power Control Scheme (DPCS) was developed for the mitigation of co-tier interference, which recorded a 14.81% energy conservation against the Power Control Scheme 1 (PCS1). The obtained results show the efficacy of the algorithm in significantly mitigating co-tier interference scenarios in the D2D network.

Keywords: Data rate, D2D, Interference, Power Control, User Equipment.

1.0 INTRODUCTION

With an ever-growing number of connected devices using the cellular network (Safaei, 2017), service providers are faced with the challenge of improving spectrum reuse, throughput, energy consumption, coverage, and reduction of end-to-end latency. Network performance would be driven up if closely located user pairs are allowed direct communication with each other, rather than through the traditional Up-link and Down-link communication channels of the Base Stations (BS). Additionally, the creation of new peer-to-peer services and location-based applications would all be driven by an efficient Device-to-Device (D2D) communication system, which incidentally, is one of the identified enabling technologies

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for the next generation cellular network, 5G. This, of course, comes with its challenges, chief among which is interference between the User Equipment (UEs). With enabled Device to Device communication between devices in proximity, there would be an introduction of interference between D2D User Equipment (DUEs) and other D2D Users, known as Co-Tier Interference, as well as interference between D2D users and traditional Cellular User Equipment (CUEs), the Cross-Tier Interference.

In this work, a Power Control Scheme was developed to mitigate co-tier interference in the D2D network, and the performance of the scheme was evaluated through simulations on MATLAB and compared with the work of Rana *et.al*, (2021), as well as a non-controlled scenario.

2.0 INTERFERENCE MANAGEMENT

Interference is an undesired signal picked up by neighbouring receivers. It has a mathematical relationship with signal-to-interference-plus-noise ratio (SINR), throughput and transmit power as expressed in equations (1) to (4) below:

$$Interference \propto transmit\ Power \quad (1)$$

$$Interference \propto \frac{1}{throughput} \quad (2)$$

$$Interference \propto \frac{1}{SINR} \quad (3)$$

$$Interference \propto \frac{transmit\ power}{SINR * throughput} \quad (4)$$

Enabling D2D links within a cellular network pose a big threat of interference to the cellular links in the network. Interference can be mitigated through mode selection, optimum resource allocation, and power control. Setting the maximum transmit power limits of the D2D transmitter is an effective technique of limiting the interference between DUEs and CUEs. A general scenario of interference in D2D underlayed cellular networks is depicted in Figure 1:

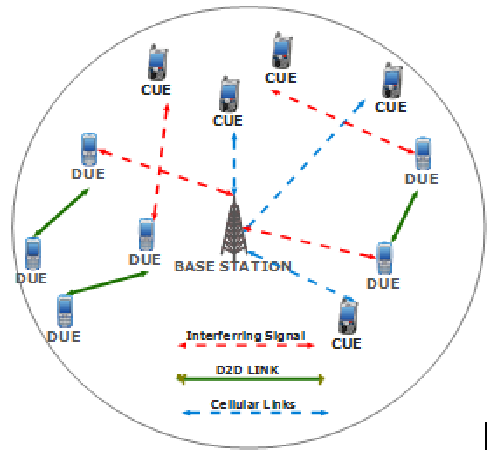


Figure 1: An interference scenario in D2D underlayed cellular network.

Some interference mitigation techniques are briefly described below.

Bandwidth Allocation

The easiest way to coordinate the cross-tier interference between the cellular and device tier is to use bandwidth allocation, which will simplify the interference between DUEs and CUEs. Shami *et al.* (2019) use bandwidth allocation, where the spectrum band was divided into two parts, as shown in Figure 2. One part would be dedicated to CUEs and the other part would be assigned to DUEs. However, dedicated channels for D2D communication will lead to inefficient use of the available channels depending on the number of D2D terminals and the proportion of available spectrum for them.

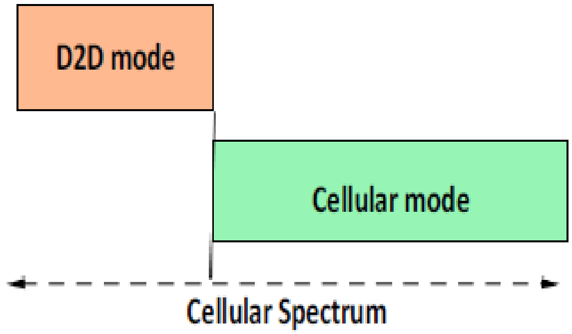


Figure 2: Spectrum Allocation

Power Control

Although higher transmit power of D2D users can provide wider coverage and better signal quality, it can, at the same time, cause tremendous interference to the cellular network. The power control (PC) mechanism is one approach to deal with cross-tier interference generated from DUEs to the cellular network for both the uplink (UL) and the downlink (DL) case, as well as the co-tier interference between DUEs in a two-tiered cellular network with D2D communication. It coordinates the interference imposed by DUEs to the cellular network and the interference from a DUE to a neighbouring DUE by controlling the transmit power levels of DUEs to improve system capacity, coverage, and reduce power consumption. To meet these goals, PC schemes aim at maximizing the transmit power and at the same time limiting the generated interference.

Mode Selection

It is possible to avoid the effect of cross-tier interference between the cellular and D2D user or co-tier interference among DUE with a proper mode selection (MS) algorithm. Although D2D candidates may be in range for direct communication with each other, it may not be optimal for them to work in D2D mode because of the interference imposed on DUE or CUE. In this sense, D2D MS algorithm decides on the optimal communication mode so that the overall network throughput is maximized and the QoS requirements of the communication links are satisfied. Each of the communication modes affects the amount of interference between cellular users and D2D users or between multiple DUEs.

2.1 Related Works

Swetha and Murthy (2017) proposed the resource management scheme in overlay D2D network where bandwidth is allocated to D2D overlay devices by the base station, based on the bandwidth resource blocks earmarked for D2D mode. The challenge is the maximization of the reserved bandwidth if not optimally utilized. When the resource block assigned for D2D mode is exhausted the base station assigns subsequent UE to CUE mode. Equations (5) and (6) were used to compute both line of sight (LOS) and non-line of sight (NLOS) pathlosses for the transmissions.

$$P_{LOS} = 65 + 21log_{10}(d) \quad (5)$$

$$P_{NLOS} = 71.1 + 34log_{10}(d) \quad (6)$$

Simple MS could be performed based on the path loss, received signal strength over the D2D link or the distance between the terminals. However, these schemes do not reflect exact channel quality or interference issues. MS has been performed based on the channel quality.

A more sophisticated MS strategy was proposed by Doppler *et al*. (2010), which takes the link quality of both D2D and cellular users, the interference situation (cross-tier interference from DUE to cellular network) for each possible mode. The MS strategy proposed in Doppler *et al*. (2010) is as follows. Initially, the D2D terminals send probing signals to each other and estimate the received signal powers. Then, the D2D terminal estimate interference plus noise power in both uplink and downlink. Next, the obtained information is sent to the evolved Node B (eNB), when it can decide about the amount of resources it would allocate to the DUE in UL/DL based on cellular load as well as the maximum transmit power of DUE for the different direct modes. Then, eNB estimates the expected SINR for each communication mode and the expected throughput based on SINR and available amount of resources for each communication mode. Finally, the communication mode with the highest throughput is selected. The result of the study provides an improvement of 50% in sum-rate with limited interference to the cellular network. However, PC was not considered in this scheme and it was assumed that the BS has all the Channel State Information (CSI) available to choose the best resource sharing mode.

Different from the other works in this section, the authors of Lei *et al*. (2014), considered a dynamic MS procedure to limit the cross-tier interference between cellular and D2D users. They proposed three routing modes (D2D, cellular and hybrid) for D2D communications underlaying cellular networks and then combined them with different resource allocation restrictions to result in seven communication modes to model both the semi-static and dynamic mode selection using Discrete Time Markov Chain (DTMC).

Generally, distance between the D2D users and cellular users is considered for mode selection (Wen, *et al*., 2012). Also, distance between cellular user and the BS is an important parameter for selection of the communication mode in the network, thus avoiding interference. Jänis, *et al*. (2009) introduced MIMO transmission schemes for interference avoidance, resulting in a great enhancement of SINR. Due to interfering signals, the received signal contains three components - Desired signal, Outside interference signal, and D2D interference signal.
Interference at the receiver must be minimized so that a higher value of SINR is achieved. This can be achieved by Modulation and Coding Scheme (MCS), which supports error-free reception of information. The D2D interference signals can be reduced, but interference from outside sources is hard to avoid.

Zhou, *et al*. (2015) considered a D2D underlaying communication network for interference cancellation, along with the transmission powers for maximizing the utility of the network. Significant gains are enjoyed by the users in terms of spectral efficiency. Wang, *et al*. (2012) proposed a novel interference coordination scheme for improving system throughput and efficient resource utilization in a multicast D2D network. Guo *et al*. (2015) concentrated on managing interference between D2D users and cellular users by discussing the range of an Interference Suppression Area (ISA) which classifies the strength of the interference between the cellular and D2D users and influences the system performance. Adequate adjustment of the range of ISA can help achieve optimal system performance.

Interference management using network coding is discussed in Wang, *et al*. (2015). In a cellular system with users undergoing cellular communication, along with D2D multicast communication, both sharing the same spectrum, the interference scenarios are evaluated in Wang, *et al*. (2012). Interference in such a scenario can be mitigated by power control, followed by optimal resource allocation. Thus, different approaches were adopted by different researchers for interference mitigation between D2D links and cellular links.

In this work, a Power Control scheme was developed to mitigate the incidence of co-tier interference in the D2D tier of the network.

3.0 METHODOLOGY

3.1 Research System Model

The research system model as shown in Figure 3 captures transmission in cellular communication. It gives an illustration of D2D communication between a D2D user equipment (DUEs) and communication between a cellular user equipment (CUE) and its serving base station.

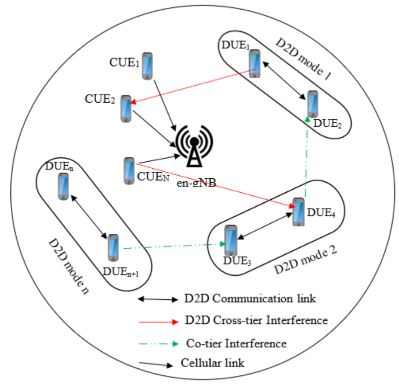


Figure 3: Research System Model

The simulation of the schemes on MATLAB was guided by the research system parameters in Table 1.

Table 1: System Parameters

No.	Parameter	Value
1.	Minimum transmit power of UE (DUE and CUE)	0 dBm
2.	Maximum transmit power of UE (DUE and CUE)	23 dBm (Rana *et al*., 2021)
3.	System bandwidth	60 MHz
4.	Carrier frequency	2.6 GHz (Rehman 2020)
5.	Thermal noise density	-174 dBm/Hz (Rana *et al*., 2021)
6.	Number of macrocells	1
7.	Number of D2D pairs	1 – 10
8.	Initial transmit power of CUE and DUE	20 dBm
9.	Target D2D distance	10m
10.	Target SINR for DUEs	0 dB

3.2 D2D Power Control Scheme

The D2D power control scheme (DPCS) was implemented by UEs in D2D communication mode regulating the use of scarce power resources for an optimal interference mitigation. In DPCS, the UE does not start transmitting with their maximum transmit power, rather a set initial transmit power. The UEs in D2D communication computes CUE and DUE path losses, Channel gain, SINR, average DUE transmit power, data rate and average data rates respectively.

The block diagram of the power control scheme for mitigating co-tier interference in D2D communication is presented in Figure 4.

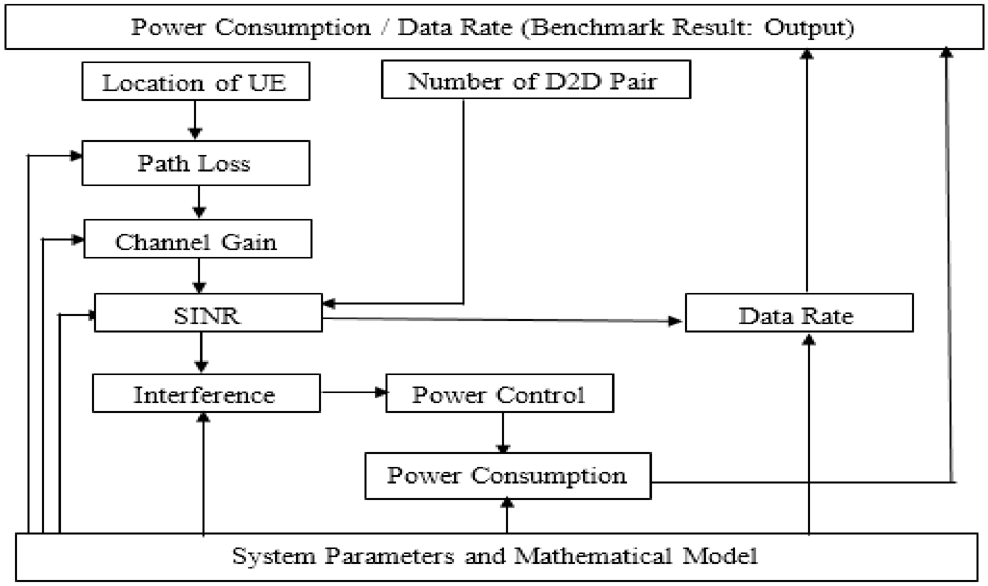


Figure 4: Block Diagram of Power Control Algorithm

The block diagram in Figure 4 shows the various blocks of the power control scheme. The Interference block determines interference in the network based on the quality of signal received. The target SINR, is compared with the computed SINR to determine the level of interference. Equations (7) and (8) mathematically expresses the decision-making process of interference block (Dawar *et al*., 2021; Rana *et al*., 2021)

$$\lambda = SINR_{computed} - SINR_{target} \quad (7)$$

$$if\ \lambda = \begin{cases} < 0 & interference\ is\ high, assign\ \ \Delta = +0.5 \\ > 0 & interference\ is\ low, assign\ \ \Delta = -0.5 \\ = 0 & threshold\ interference\ \ assign\ \ \Delta = 0 \end{cases} \quad (8)$$

where λ is the difference between computed and target SINR, and Δ is a step power factor.

Based on the outcome of the interference block, the power control block adjusts the transmit power of UE using power step value, and power control model in equation (5) (Dawar *et al*., 2021; Rana *et al*., 2021; Hassan and Gao 2019).

$$P_{tx} = max\left(P_{min,}\ min\ ((P_{tx} + \Delta), P_{max})\right) \quad (9)$$

Where;

P_{tx} = transmit power of UEs
P_{min} = Minimum transmit power
P_{max} = Maximum transmit power of UEs

The power consumption block computes the average power consumption of each DUE in the network using equation (10). An array of transmit power used by transmitting UEs at different positions and instances was used to get the average transmit power.

$$P_{DUEs}^{Average} = \frac{\sum_{i=1}^{i=L}(\sum_{NDUE=1}^{NDUE=n}(P_{tx}^{1} + P_{tx}^{2} + \cdots + P_{tx}^{n}))}{L \times n} \quad (10)$$

Where;

$P_{DUEs}^{Average}$ = average power consumed by DUE
P_{tx}^{n} = transmit power of n^{th} DUE
n = last number of DUE
L = last number of iterations
$\sum_{NDUE=1}^{NDUE=n}(P_{tx}^{1} + P_{tx}^{2} + \cdots + P_{tx}^{n})$ = Summation of all DUEs transmit power

The data rate block, when considering the power control scheme compute data rate and average data rate using mathematical model captured in equations (11) and (12) respectively (Sihan *et al.*, 2019; Budhiraja *et al.*, 2018; Adejo *et al.*, 2020).

$$D_{D2D}^{PS} = Bwlog_2(1 + SINR_{rx}) \quad (11)$$

$$D_{Average\_D2D}^{PS} = \frac{\sum_{i=1}^{i=L}(\sum_{NDUE=1}^{NDUE=n}(D_{D2D1}^{PS} + D_{D2D2}^{PS} + \cdots + D_{D2Dn}^{PS}))}{n \; X \; L} \quad (12)$$

Where;

$D_{Average\_D2D}^{PS}$ = average DUE data rate
Bw = system bandwidth
$\sum_{i=1}^{i=L}(\sum_{NDUE=1}^{NDUE=n}(D_{D2D1}^{PS} + D_{D2D2}^{PS} + \cdots + D_{D2Dn}^{PS}))$ = Summation of DUE data rate

The system output block displays the computed DUE SINR, average DUE data rate and DUE average transmit power. Figure 5 is the flowchart of the power control scheme for co-tier interference mitigation in Macro-D2D HetNet.

The flowchart in Figure 5 also expresses the power control scheme. Where one was assigned to *i*, which stands for the initial number of iteration and *L* stands for the maximum number of iterations. The iteration controls the number of D2D pair distance and number of D2D pair that would be used in the simulation of the scheme. The program executes at different D2D pair distance and number of D2D pair until the number of iterations exceed the value of *L*. When the iteration stops.

The program computes the average power consumption, and average data rate considering DUE transmit power, and data rate during each iteration. The pseudocode for the power control scheme used for mitigating co-tier interference in D2D communication is captured in Table 2

Table 2: Pseudocode of D2D Power Control Scheme

PSEUDOCODE OF POWER CONTROL SCHEME FOR D2D COMMUNICATION
1. Booting of UEs
2. Load input variables
3. Set initial transmission power
- $P_t = P_{initial}$

4. Compute:
   - UE path loss using (7) and (8)
   - D2D SINR using (11)
5. First decision:
   - $SINR_{D2D} >= SINR_{CUE} \begin{cases} Yes: then\ SINR_{D2D} > SINR_{target} \\ No: then\ SINR_{CUE} > SINR_{target} \end{cases}$
6. Second decision:
   - $SINR_{D2D} > SINR_{target} \begin{cases} Yes: then\ \Delta = -0.5 \\ No: then\ SINR_{D2D} < SINR_{target} \end{cases}$
7. Third decision:

   $SINR_{D2D} < SINR_{target} \begin{cases} Yes: then\ \Delta = 0.5 \\ No: then\ \Delta = 0 \end{cases}$
8. Control iteration:
   - Increase counter:

     $i = i + 1$
   - Check for limit:

     $i <= L$
9. Compute:
   - Average transmit power of DUE using (10)
   - DUE data rate using (11)
   - Average data rate using (12)
10. Output:
    - Average transmit power of DUE
    - DUE SINR
    - DUE data rate
    - DUE average data rate

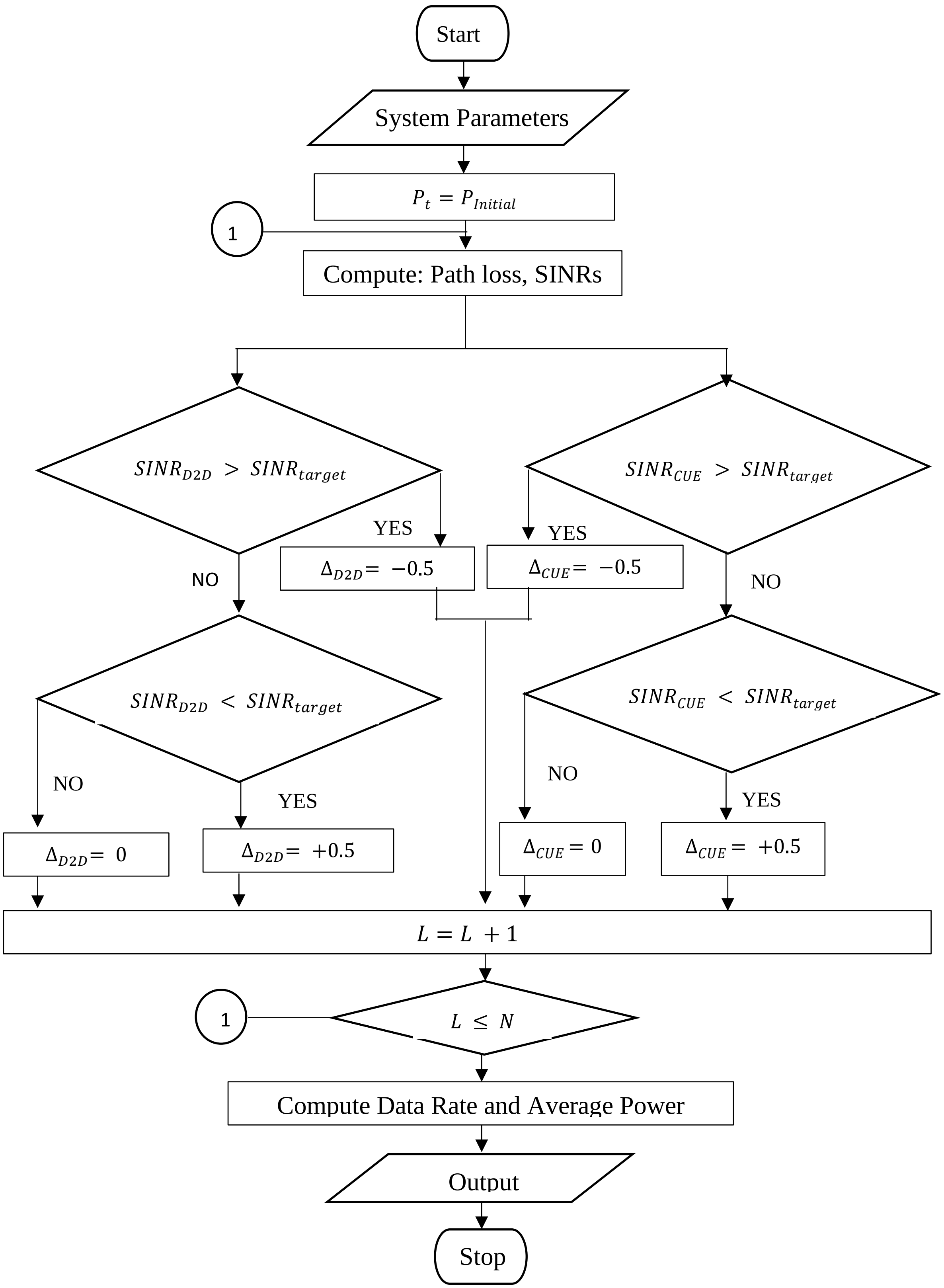
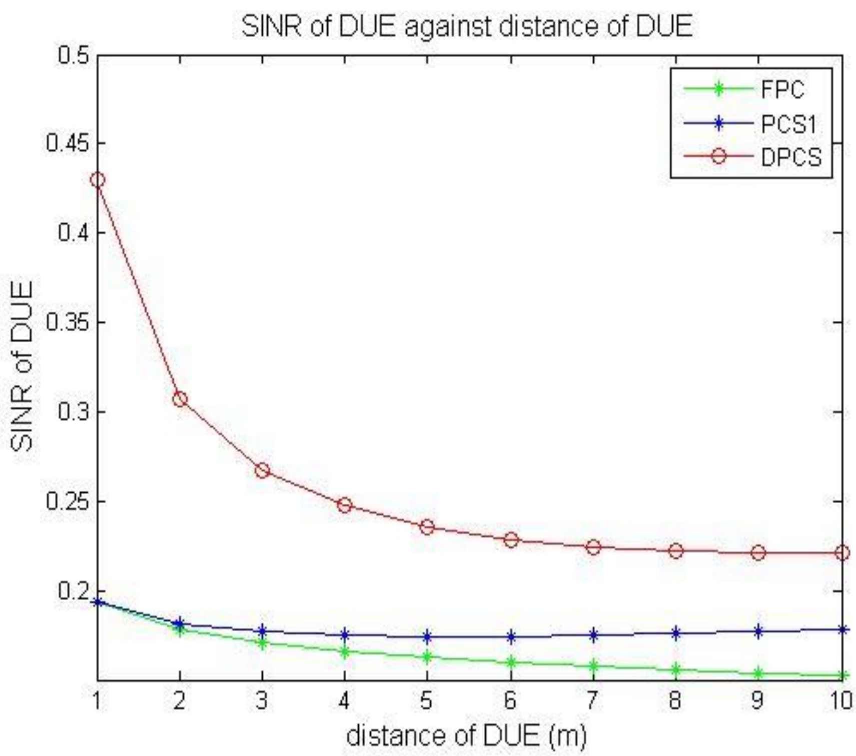


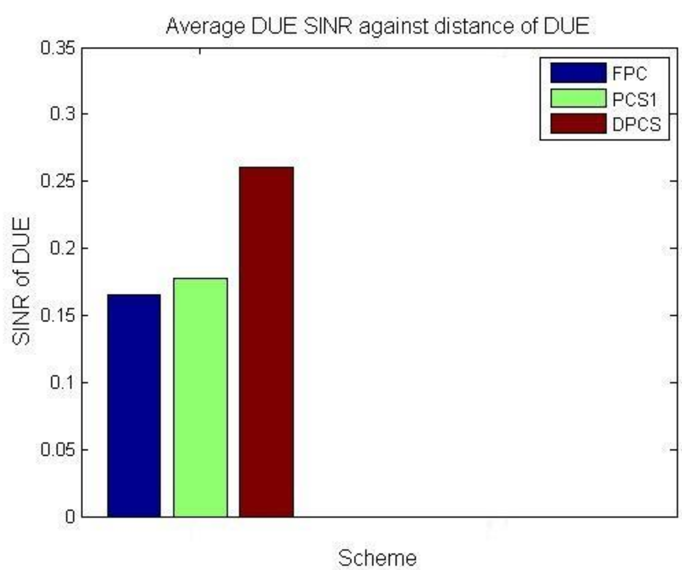
Figure 5: Flowchart of D2D Power Control Scheme

4.0 RESULTS

The D2D power control scheme (DPCS) for co-tier interference mitigation in D2D communication was simulated and the performance presented in Figures 6 – 15.



a. Benchmarked DPCS performance of DUE SINR when DUE distance was varied.



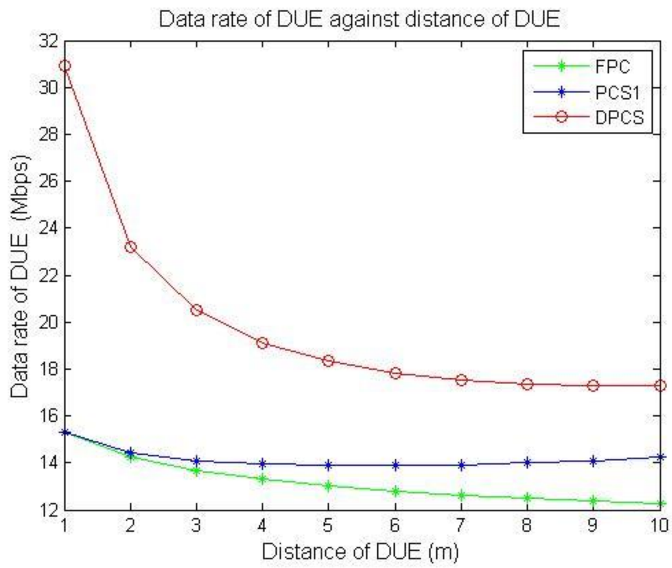
b. Average DPCS performance of DUE SINR when DUE distance was varied

Figure 6: Benchmarked SINR of PCS1 based on varied DUE distance

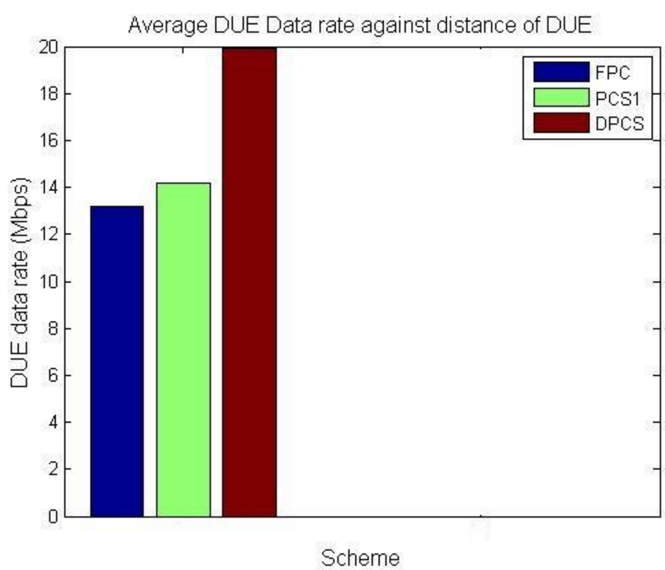
The DUE SINR performance of FPC, PCS1 and DPCS when DUE distance was varied as presented in Figure 6a indicates that DPCS had better DUE SINR. At DUE distance ranging from 1 – 10 m DPCS DUE data rate was better than that of FPC by 55.81 %, 41.94 %, and 37.04 %, 32.00%, 33.33 %, 30.43 %, 27.27 %, 31.82 %, 31.82 %, and 31.82 % respectively. And better than PCS1 at DUE distance of 1 – 10 m by 55.81 %, 41.94 %, 33.33 %, 32.00 %, 29.17 %, 26.09 %, 22.73 %, 18.18 %, 18.18 %, and 18.18 % respectively.

The average DUE SINR of FPC, PCS1 and DPCS when DUE distance was varied as presented in Figure 4.10b stood at 0.16, 0.18 and 0.26 respectively. Hence, DPCS DUE SINR when DUE distance varied, was better than that of FPC and PCS1 by 38.46 % and 30.77 % respectively.

The DUE data rate performance of DPCS when DUE distance was varied was plotted and presented in Figure 7.



a. Benchmarked DPCS DUE data rate when DUE distance was varied

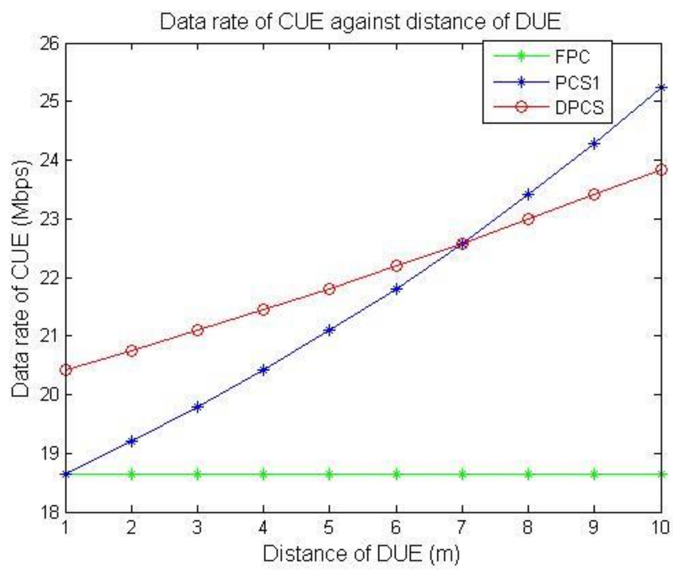


b. Benchmarked DPCS DUE data rate when DUE distance was varied

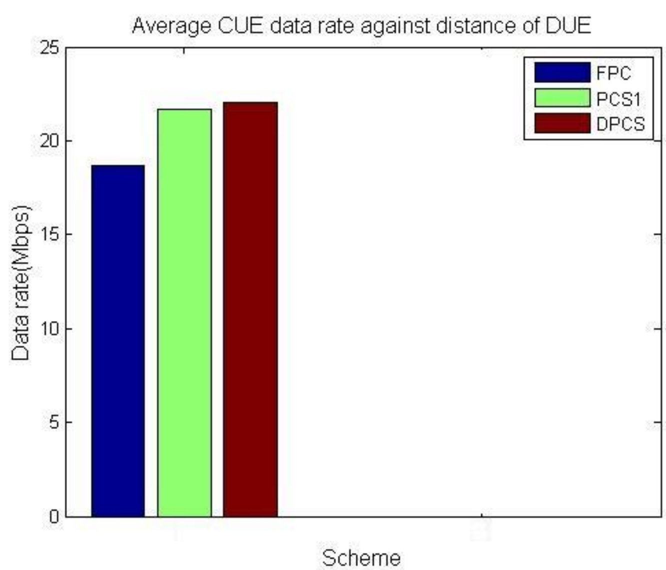
Figure 7: Benchmarked DPCS DUE data rate based on varied DUE distance

From Figure 7, DPCS had better DUE data rate at different DUE distances. At DUE distance ranging from 1 – 10 m, DPCS had DUE data rate that outperformed that of FPC by 50.57 %, 38.61%, 33.32 %, 30.48%, 29.07 %, 28.06 %, 27.85 %, 27.97 %, 28.37 %, and 29.03 %, respectively. And that of PCS1 by 50.57 %, 37.66 %, 31.22 %, 27.08 %, 24.24 %, 22.11 %, 20.49 %, 19.26 %, 18.36 %, and 17.56 % respectively. As shown in Figure 4.11b, the average DUE data rate of FPC, PSC1 and DPCS when DUE distance was varied stood at 13.21 Mbps, 14.1 Mbps, and 19.93 Mbps respectively. When DUE distance was varied, DPCS had an average DUE data rate which was better than that of FPC and PCS1 by 33.72 % and 22.73 % respectively.

The plotted performance of DPCS scheme when DUE distance was varied in terms of CUE data rate is presented Figure 8.



a. **Benchmarked DPCS CUE data rate when DUE distance was varied**.



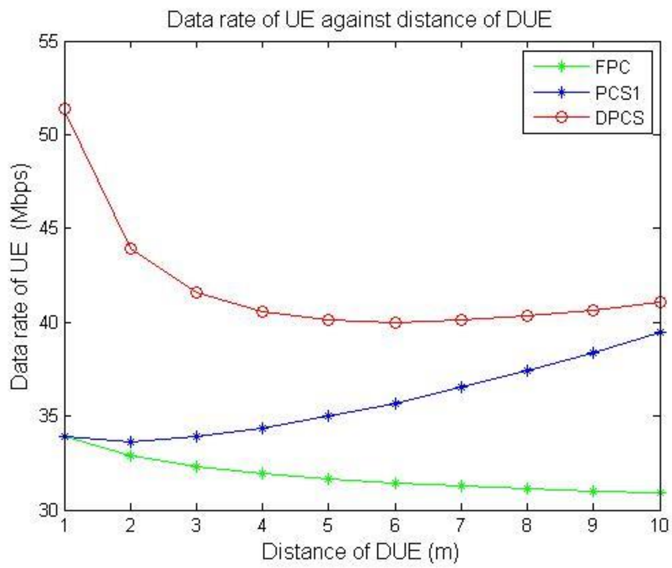
b. **Benchmarked average DPCS CUE data rate when DUE distance was varied.**

Figure 8: Benchmarked DPCS CUE data rate based on varied DUE distance

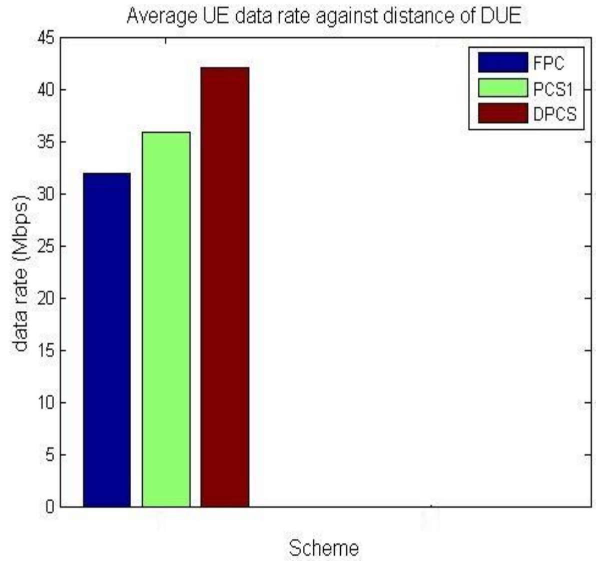
From Figure 8a, DPCS had the best CUE data rate at DUE distance of 1 – 6 m. While at DUE distance of 8 – 10 m, PCS1 had the best CUE data rate. PCS1 and DPCS had same DUE data rate at DUE distance of 7m. But when DUE distance was varied from 1 - 6 m, DPCS had CUE data rate that outperformed that of FPC by 8.72 %, 10.17 %, 11.62 %, 14.50 %, 14.53 %, and 16.00 %, respectively. Also, DPCS had CUE data rate that outperformed that of PCS1 by 8.72%, 7.47 %, 6.16 %, 6.37 %, 3.30 %, and 1.71 %. At DUE distance of 8 – 10 m, PCS1 CUE data rate outperformed that of FPC by 20.34 %, 23.26 %, and 26.18 % respectively. And outperformed DPCS by 1.79 %, 3.66 %, and 5.58 % respectively.

The result of average CUE data rate of FPC, PCS1 and DPCS when DUE distance was varied as presented in Figure 8b gave 18.64 Mbps, 21.65 Mbps, and 22.09 Mbps respectively. DPCS CUE data rate considering DUE distance was better than that of FPC and PCS1 by 15.62 % and 1.99 % respectively.

The plot of DPCS UE data rate performance when DUE distance was varied is presented in Figure 9. Where Figure 9a gives the UE data performance at each DUE distance and Figure 9b gives the average UE data rate performance.



a. Benchmarked DPCS UE data rate when DUE distance was varied.



b. Average DPCS UE data rate when DUE distance was varied.

Figure 9: Benchmarked DPCS UE data rate based on varied DUE distance

According to results plotted in Figure 9a, DPCS had the best UE data rate when DUE distance was within 1 – 10 m.
At DUE distance ranging from 1 – 10 m, DPCS had UE data rate that outperformed that of FPC by 33.92 %, 25.15 %, 22.29 %, 21.25 %, 21.06 %, 21.37 %, 21.97 %, 22.81 %, 23.75 %, and 24.82 %, respectively: and outperformed PCS1 by 33.92 %, 23.40 %, 18.49 %, 15.28 %, 12.83 %, 10.77 %, 8.95 %, 7.26 %, 5.58 %, and 3.94 % respectively.

The average UE data rate of FPC, PCS1 and DPCS stood at 31.86 Mbps, 35.83 Mbps and 41.98 Mbps respectively.

FPC, PCS1 and DPCS average power consumption of DUE at varying DUE distance was computed; and the result presented in Figure 10.

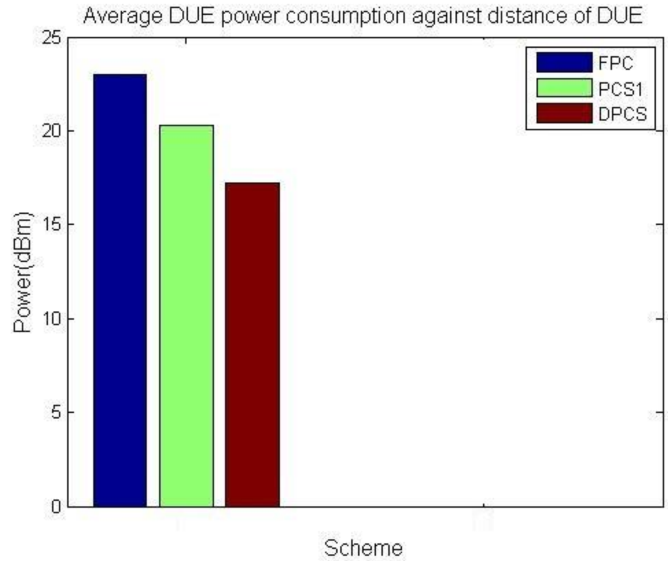
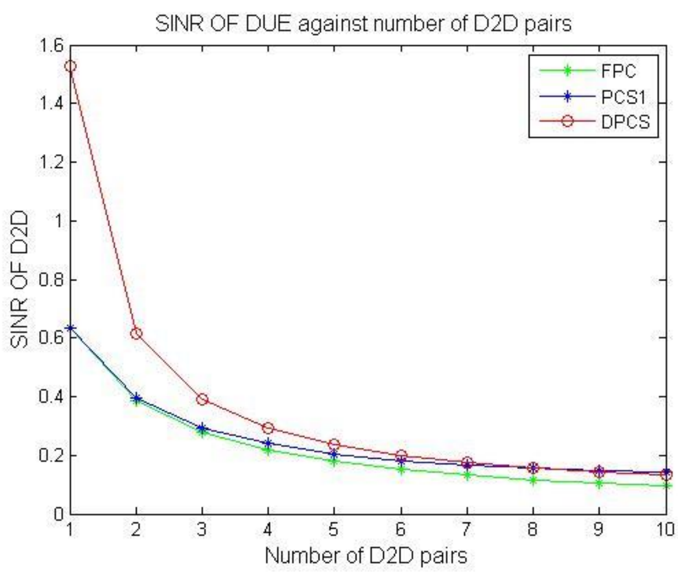
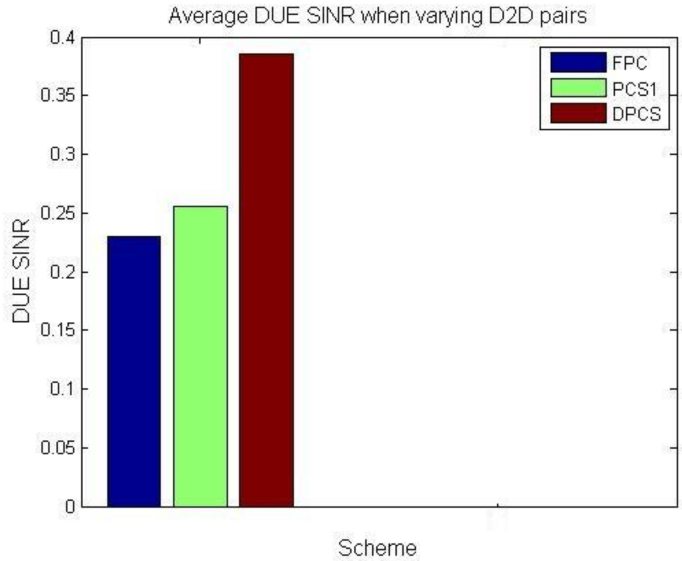


Figure 10: Benchmarked DPCS Average DUE power against DUE distance.
The average UE power consumption of FPC, PSC1 and DPCS stood at 23.00 dB, 20.25 dB and 17.25 dB respectively.

The DPCS performance in terms of DUE SINR when number of D2D pairs was varied is presented in Figure 11.



a. Benchmarked DPCS SINR of DUE when number of D2D pair was varied

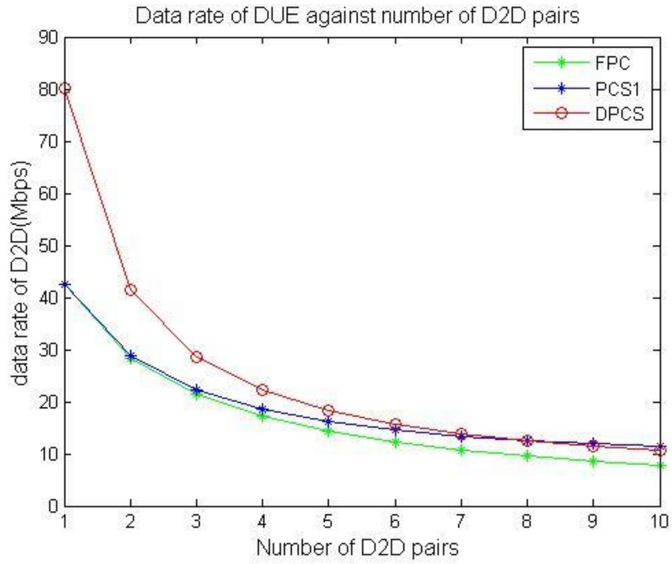


b. An average DPCS SINR of DUE when number of D2D pair was varied.
Figure 11: Benchmarked DPCS DUE SINR on varied D2D Pair

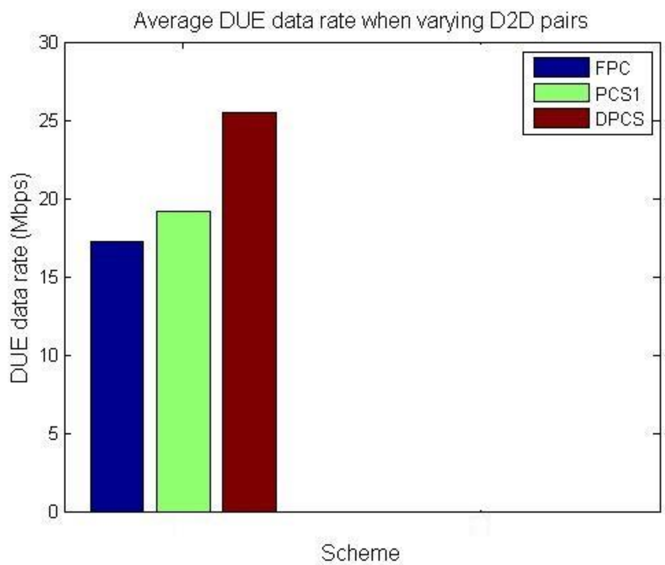
From Figure 11, when number of D2D was varied from 1 – 8 pairs, DPCS had the best DUE SINR when compared to FPC and PCS1. At 9 and 10 D2D pairs, PCS1 had the best DUE SINR compared to that of FPC and DPCS.

At 1 – 8 D2D pairs, DPCS have DUE SINR that outperformed that of FPC by 58.83, 36.07, 28.21, 24.14, 25.00, 25.00, 23.53, and 25.00. At 1 – 6 D2D pairs, DPCS DUE SINR outperformed that of PCS1 by 58.82 %, 36.07 %, 25.64%, 17.24%, 16.67%, and 10.00% respectively. At 7 and 8 D2D pairs, DPCS and PCS1 had the same DUE SINR of 0.17 and 0.16 respectively. At 8 and 9 D2D pairs, PCS1 DUE SINR outperformed that of FPC by 33.33 %, 35.71 % respectively; and that of DPCS by 6.67 % and 7.14 % respectively.
Results of average DUE SINR of FPC, PCS1 and DPCS when DUE was varied as presented in 4.15b, gave 0.23, 0.26 and 0.39. Hence, the average DUE SINR of DPCS was higher compared to that of FPC and PCS1 by 41.03 % and 33.33 % respectively.

The DUE data rate performance at different number of D2D pairs is presented in Figure 12.



a. Benchmarked DPCS DUE data rate when number of D2D pairs was varied

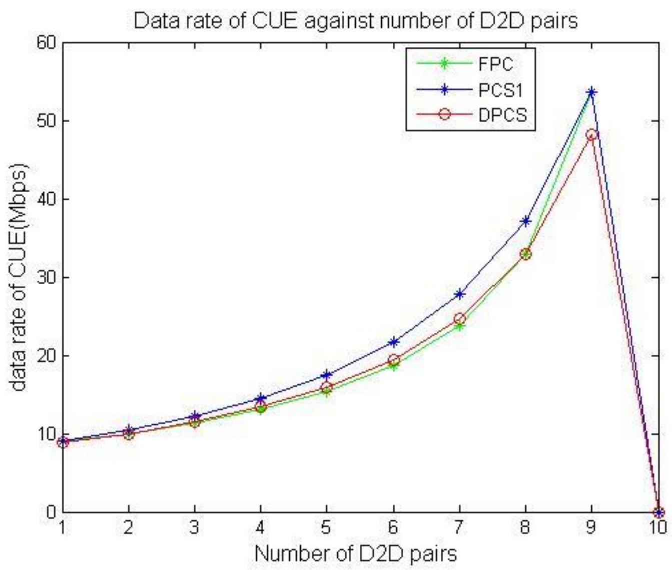


b. Average DPCS DUE data rate when number of D2D pairs was varied

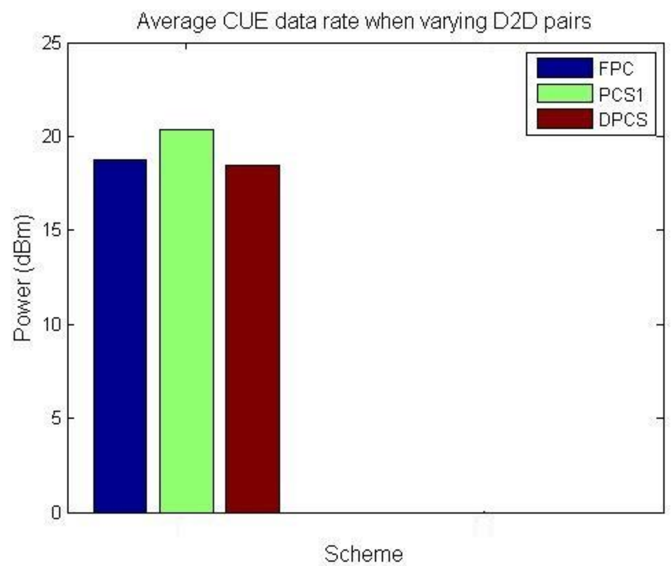
Figure 12: Benchmarked DPCS DUE data rate based on varied D2D pairs.

From Figure 12, at 1 – 8 D2D pairs, DUE data rate of DPCS was better that of FPC by 46.96 %, 31.43 %, 25.36 %, 22.72 %, 22.11 %, 21.92 %, 22.64 %, and 23.66 % respectively. And better than that of PCS1 by 46.96 %, 30.41 %, 21.97 %, 16.21 %, 11.66 %, 7.65 %, 3.97 %, and 0.24 % respectively. At 8 and 9 D2D pairs, PCS1 had DUE data rate that outperformed that of FPC by 25.02 % and 31.88 % respectively; and higher than that of DPCS by 3.53 % and 7.14 % respectively.

The result of average DUE data rate of FPC, PCS1 and DPCS at varying number of D2D pairs gave17.26 Mbps, 19.20 Mbps and 25.48 Mbps respectively. The average DUE data rate of DPCS is better than that of FPC and PCS1 by 32.26 %, and 24.65 % respectively.
The CUE data rate performance at different D2D pairs is presented in Figure 13.



a. Benchmarked DPCS CUE data rate when number of D2D pairs was varied



b. Average DPCS CUE data rate when number of D2D pairs was varied

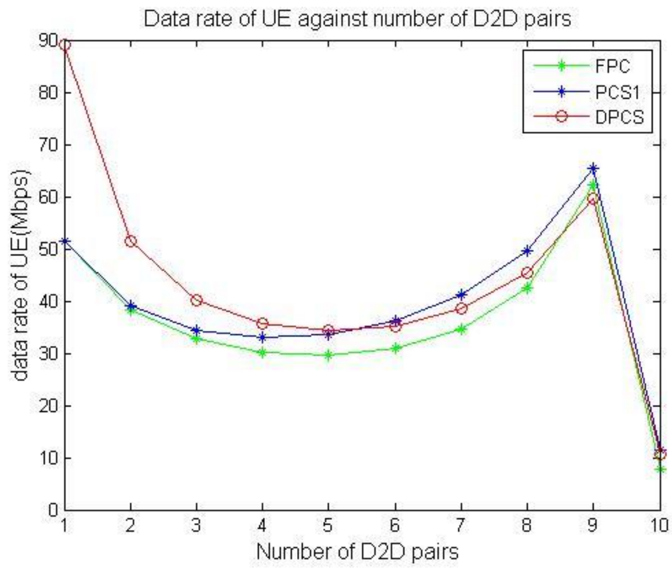
Figure 13: Benchmarked DPCS CUE data rate based on varied D2D pairs

From Figure 13, when number of D2D pairs was 10, CUE data rate of FPC, PCS1 and DPCS were all 0.0 Mbps, because all UEs were in D2D mode. And when number of D2D pair was varied from 2 – 8 pairs, the CUE data rate of PCS1 was better than that of FPC by 3.47%, 6.84%, 9.78%, 12.36%, 14.07%, 14.41%, and 11.72% respectively. At 1 and 9 D2D pairs, DPCS and FPC had same data rate of 8.96 Mbps, and 53.54 Mbps.

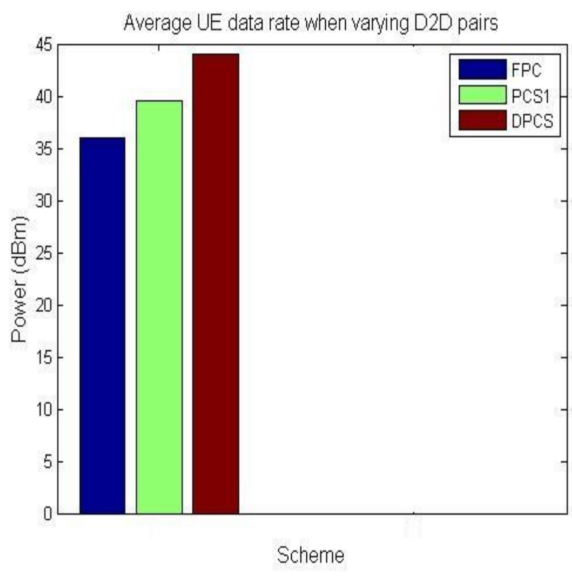
The CUE data rate of PCS1 at varying number of D2D pairs ranging from 1 – 9, was better than that of DPCS by 1.79 %, 3.47 %, and 5.28 %, 7.00 %, 3.47 %, 10.20 %, 11.35 %, 11.72 % and 10.03 % respectively.

The average DUE data rate of FPC, PCS1 and DPCS at varying number of D2D pairs in Figure 4.17b stood at 18.73 Mbps, 20.35 Mbps and 18.47 Mbps respectively. The average PCS1 average DUE data rate at varying number of D2D pairs outperformed that of FPC and DPCS by 7.96 % and 9.24 % respectively.

The DPCS UE data rate performance at different number of D2D pairs is presented in Figure 14.



a. Benchmarked DPCS UE data rate when number of D2D pairs was varied



b. Average DPCS UE data rate when number of D2D pairs was varied

Figure 14: Benchmarked DPCS UE data rate based on varied D2D pairs

From Figure 14, when number of D2D pair varied from 1 – 5, DPCS UE data rate outperformed that of FPC by 42.15 %, 25.31 %, 18.54 %, 15.27 %, and 13.53 %, and performed better than PCS1 UE data rate by 42.15 %, 23.79 %, 14.07 %, 7.26 %, and 1.81 %, respectively.

The average UE data rate of FPC, PCS1 and DPCS when number of D2D pairs was varied as seen in Figure 14b gave 35.99 Mbps, 39.55 Mbps and 43.95 Mbps respectively. Average UE data rate of DPCS at varied number of D2D pairs performed better than that of FPC and PCS1 by 18.11 % and 10.01 % respectively.

The average DUE power consumption at different number of D2D pairs is presented in Figure 15.

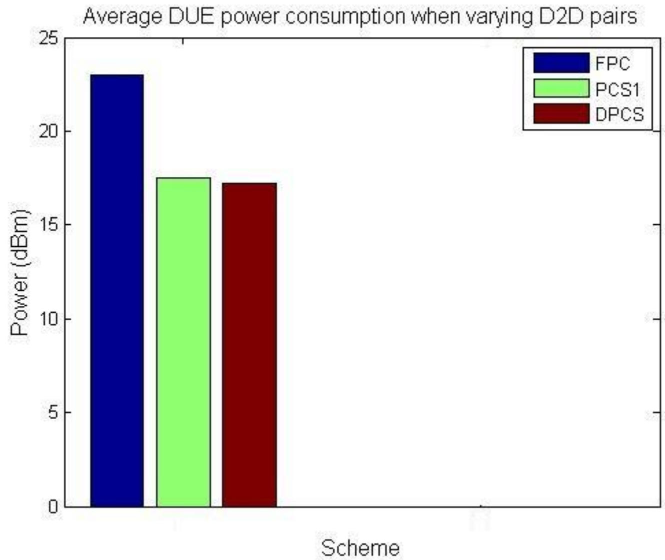


Figure 15: Benchmarked DPCS average power consumption based on varied D2D pairs.

From Figure 15, the average power consumed by DUEs based on Fixed Power Control FPC, PCS1 and DPCS schemes was 23.00 dBm, 17.50 dBm and 17.25 dBm respectively, which indicates a 1.43% and 25% power efficiency of the DPCS over the PCS1 and FPC schemes respectively.

From Figure 15, the average power consumed by DUEs based on Fixed Power Control FPC, PCS1 and DPCS schemes was 23.00 dBm, 17.50 dBm and 17.25 dBm respectively, which indicates a 1.43% and 25% power efficiency of the DPCS over the PCS1 and FPC schemes respectively.

5.0 CONCLUSION

In this work, a D2D Power Control Scheme (DPCS) was developed to mitigate the incidence of co-tier interference in the D2D tier of the network. The Power control Scheme starts with a low initial transmit power by UEs, thereby conserving energy and reducing interference. The DPCS lead to the attainment of 14.81% energy conservation when compared with the work of Rana *et. Al*, (2021). Therefore, DPCS mitigated the problem of co-tier interference, while improving system throughput by 10.01% against that of Rana *et.al*, (2021) and 18.11% against an uncontrolled scenario, while increasing energy conservation by 1.43% and 25% over the PCS1 and FPC schemes respectively in the D2D tier.

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