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UTILIZATION OF SC-FDMA AND OFDMA BASED UPLINK AND DOWNLINK RESOURCES IN LTE-A NETWORK ASSISTED DEVICE TO DEVICE COMMUNICATION FOR EFFECTIVE SPECTRUM MANAGEMENT

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ABSTRACT

Increasing data traffic demands high data rates. Device to device communication (D2D) underlying cellular network improves the spectrum utilisation, hence increases the overall cell throughput if we take proper care on two aspects. First one is physical resource block (PRB) allocation between D2Ds and cellular network users (CEs) and the second one is interference avoiding between PRB sharing CE and D2D with controlled transmission power. An efficient allocation of both uplink (UL) and downlink (DL) PRBs simultaneously at a time for D2D underlying LTE-A cellular network along with an efficient power control mechanism is proposed in this paper. To efficiently use the spectrum, which accommodates more number of D2D, we share SC-FDMA based UL and OFDMA based DL, LTE – A PRBs simultaneously. During PRB allocation high priority is given to the UL PRBs for D2D communication and there after DL PRBs are allocated, if no UL PRBs are free or signal to interference and noise ratio (SINR) is high on UL PRB, as peak to average power ratio (PAPR) is low for UL when compared to DL. The propose method uses proportional fair (PF) scheduling algorithm for PRB allocation to guarantee at least cellular or D2D communication to be continued with accepted fairness in worst case scenario. Proposed power control mechanism avoids the interference caused by PRB sharing pairs effectively. Simulation results shows that the proposed PRB allocation and power control techniques improves the overall cell site throughput.

Keywords: LTE-A network, D2D communication, SC-FDMA, OFDMA, PRB sharing, PF scheduling, PAPR.

INTRODUCTION

Telecom engineers are facing many problems for allocating PRB in the available spectrum as numbers of mobile users are increasing in day to day life. To reduce this problem D2D communication plays a vital role as it facilitates direct link between mobile users which helps in improvement of spectrum utilization, extending the network capacity without increasing the transmission bandwidth, throughput, which results in high performance and quality of service (QoS). The main advantage involved in D2D communication is hop gain, proximity of mobile devices which allow reusing of PRBs between cellular and D2D users [1]. LTE-A technology component (D2D communication) facilitate high data rates [2]. Basically, there are two steps in D2D communication.

a) D2D Discovery, which is having Priori discovery in which Networks detects the D2D members before the start of communication and the Posteriori discovery in which network detects the members of D2D with an ongoing communication.
b) D2D communication, which is divided as "In band" in which communication will be in licensed spectrum and the other is "Out band" in which communication takes place in an unlicensed spectrum.

Local area services are examined as popular issues which are needed to be improved and local data rates have been increased drastically due to the reusing of PRBs [3]. With more issues regarding user-driven applications, LTE-A is predicted to have low latency and packet optimized radio access technology [4].

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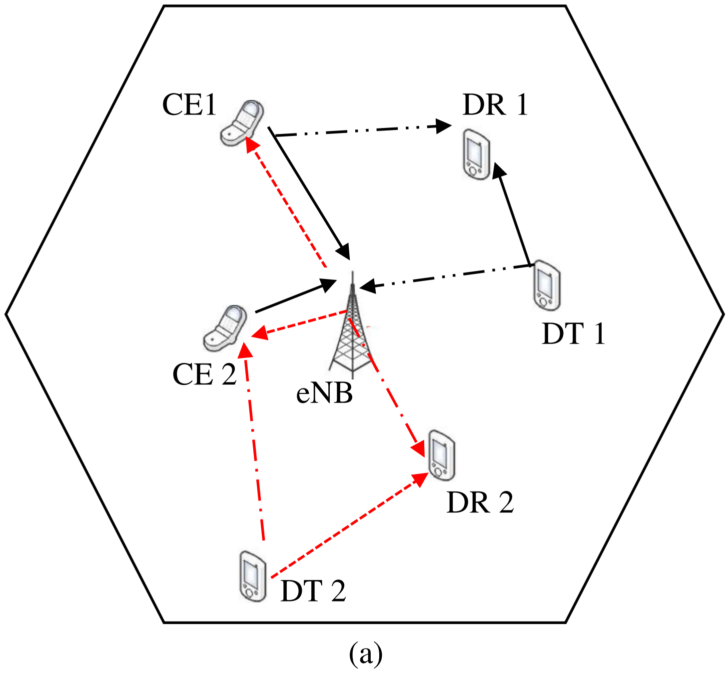

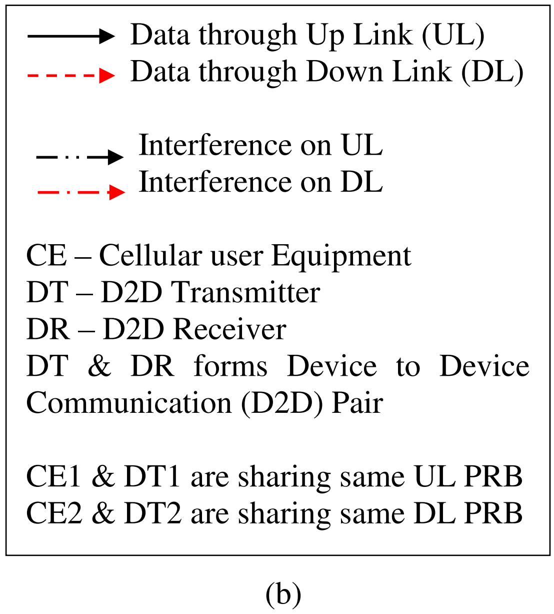

Figure-1. D2D communications. (a) DTs sharing the same UL & DL PRBs of CEs and resulting interference. (b) Notations.

D2D is highly advantageous when some user equipment downloads content through eNodeB (eNB) while other user equipment fetches it through D2D communication from downloaded user and avert congestion at the eNB. D2D communication is having many technical challenges which plays a vital role in networking such as QoS, diminishing of interference, allocation of resources, communication management etc. The applications where D2D involved is offload traffic, context sharing, local advertising and cellular relay.

In order to accommodate D2D communication under LTE-A licenced spectrum, a proper care must be taken to allocate the PRBs & to control the interference caused by the shared PRBs. A generalised scenario where the PRB sharing D2D communication interfering the traditional cellular communication (TCC) is shown in Figure-1(a). Figure-1(b) gives the notations used. In figure-1(a) two CEs operating in LTE-A band feels the interference due to the PRB sharing D2D pairs. In this scenario both UL & DL PRBs are shared. Therefore, UL PRB sharing DT will interfere the eNB & DL PRB sharing DT will interfere the CE. For example, from Figure-1(a) DT1 shares the UL PRB of CEs will cause the interference at eNB & UL transmission of CE1 causes the interference at DR1. Similarly, DT2 shares the DL PRB of CEs will cause the interference at CE2 & DL transmission of eNB causes the interference at DR2. So, interference & PRB allocation is the major issue in D2D communication which must be handled carefully.

The remaining paper is organised as follows. Section 2 gives a detailed survey of research done until on cell site architecture, PRB allocation & Power control. Proposed ICI mitigation with FFR based cell architecture is given in section 3. Section 4 & 5 explains the proposed efficient PRB allocation & power control methods respectively. Section 6 provide the results and discussions. Finally, section 7 concludes the paper.

Literature survey

The research on network controlled D2D communication is gaining popularity. Our survey on literature is mainly concentrated on

Survey on cell architecture

Yiwei Yu *et al* [5], described about Soft Frequency Reuse (SFR) for the analysis of inter cell interference (ICI) in LTE networks in the medium traffic load by increasing the throughput. When the traffic is more than the throughput increases but the cell-centre user performance decreases. Ahmed K I *et al* [6], discussed about the simulations based on Monte-Carlo and the resource allocation scheme that continuously alter the frequency resource share with separation from the eNB for both macro cells and femto cells in order to obtain efficient resource utilization. It can be attained by operating three layers in the cell which need huge number of sectors in a cell, low interference, and splendid frequency reuse. ManliQian *et al* [7] described about 3GPP LTE spectrum in which Soft Frequency reuse algorithm is used to find the number of major and minor sub carriers. An iterative method is used by disintegrating the multi cell into a single cell; number of major and minor sub carriers is calculated first for single cell until there is no change in throughput.

Husam Eldin *et al* [8] discussed about slot allocation scheme for the multi cell OFDMA LTE system, the architecture used is hierarchical, by utilizing the fractional frequency reuse, QOS for secure data forwarding (SDF) in the inner and outer ring cells will be guaranteed. Mahmudur Rahman *et al* [9] used base station level and central controller level to which neighbouring base stations are combined which is known as two level algorithms. A varying interference avoidance scheme is based on inter-cell coordination in order to avert huge inter-cell interference, mainly for cell or sector edge users that are mostly influenced by inter-cell interference, with minimum or no impact on the network throughput. Mahima Mehta *et al* [10] analyses about attaining compromising between the systems area spectral efficiency and the cell edge spectral efficiency. OFDM helps in converting the wide-band frequency-selective channel into various narrow-band sub-channels and transfers over these sub-channels together and each sub-channel looks like a flat fading channel. In multi-user domain, each sub-carrier will perform different fading features to different s users at different time instants.

Yikangs Xiang *et al* [11] analysed the average cell capacity by utilizing different resource reuse schemes. Tri-sector cell layout and individual cell always utilize its maximum total transmission power, which is examined as constant and a static power allocation over the chunks on the available frequency band. Better performance can be achieved by choosing a dynamic cell centre/edge user partitioning. Syed Tariq Shah *et al* [12] proposed FFR based cell architecture with SC-FDMA based resource allocation which has an advantage of low PAPR and improves overall cell throughput. The important design parameter in the cell is the radius of the central sector covers the largest area within the cell assumed to be 63% of the total cell area. In strict FFR consuming the entire frequency band in a single cell is not possible where as soft FFR uses the entire spectrum in a single cell and reuses the same spectrum for the adjacent cells. The overall frequency spectrum is sliced into partitions in such a way that one partition is a combination of two separate sub-bands. Ronald Chang *et al* [13] developed a dynamic FFR with graph-based structure in multi-cell OFDMA networks. The dynamic FFR scheme can improve the cell throughput up to 12% to 33%. High performance is achieved for a 19-cell network with asymmetric cell load. The new graph construction strategy and a colouring method can adapt to varying cell load conditions.

Survey on PRB allocation

UL PRB allocation

Author in [14] discussed UL format is based on the channel condition. The processes of H-ARQ (Hybrid ARQ) used in UL is synchronous i.e. a retransmission is scheduled exactly eight TTI (Transmission Time Intervals) after the previous attempt. Spatial reuse concept is suggested which helps in reducing the required resources in the UL sub-frame. Mohammad Zulhasnine *et al* [15] considered the UL PRB sharing is more beneficial for the system with SC-FDMA. As it is having minimum PAPR when the D2D pair is far distant from the BS. The radio access utilized, enables higher transmit power efficiency for the UEs. Syed Tariq Shah [12] explained the reuse of UL PRBs of conventional cellular user equipment (CUEs) by D2D communication. FFR based architecture and proportional fair (PF) scheduling algorithm is suggested for allocating the resources efficiently and to diminish the interference between CUEs and D2D user equipment (DUEs) by using TDD mode. DUE can use the resources that are not presently used by the CUE in the same region. ShaoyiXu [16] described the Mechanism of near-far interference cancellation scheme in cellular UL spectrum is proposed which is used in an LTE FDD system avoids the issue of PRB allocation and interference. The mechanism of sharing UL spectrum with a cellular Network in a hybrid system is addressed. The frequency bands of UL can be used efficiently by avoiding the harmful interference from cellular networks to D2D transmission.

DL PRB allocation

In [14] DL the processes of H-ARQ are asynchronous, i.e., a retransferring can be expected by the eNB at any TTI (Transmission Time Intervals). Mohammad Zulhasnine *et al* [15] considered PRB allocation for D2D as a MINLP (Mixed Integer Non-Linear Programming). Optimization was achieved using a greedy heuristic algorithm which reduces the interference to the primary cellular networks using channel state information (CSI) but the disadvantage is it cannot prevent signalling overhead. Jorge F. Schmidt *et al* [17] discussed that PRBs are acquired using a time division- multiple-access (TDMA) technique in which BSs will assign individual time slots in orthogonal manner to cellular users. The users of underlay D2D will also access resources on time slot basis, but they transmit in non-orthogonal way which involves the process of slotted ALOHA mechanism. Giri raja C V [18] suggested a dynamic algorithm which is a SNR Based Master-Slave method (SMSDCA) to improve the network resource utilisation. Which involves the concept of dynamic management of clusters and devices for achieving better Quality of Service (QoS). Chen Xu [19] analysed the reverse iterative combinational auction is used as for PRB allocation which helps in achieving an optimal system which leads to a good system sum rate and reducing the latency. The auction will continue until all the D2D links are completed or each channel wins a package. Monowar Hasan *et a*l [20] discussed about chance constraint approach which helps to gain a compact between robustness and optimality. The work behind this paper is to utilize the theory of worst-case resilient optimization to achieve higher end-to-end data rate under link uncertainties for the UEs with lessen QoS requirements while preserving the further receiving relay nodes and D2D UEs from interference. In order to assign PRBs in an organized manner the polynomial time distributed algorithm is described. Lingyang Song [21] described the game theoretic models are favourable for scheming radio resource allocation algorithms to attain stable and efficient solutions by allowing D2D users to access spectrum efficiently and an underlay approach was discussed. Non-cooperative and auction game models are suitable for D2D

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direct communication at the cost of certain signalling overhead. Cooperative game models such as the coalition formation games are suitable for D2D LANs.

Pekka JNIS [3] described about D2D communication radio distributing the identical PRB as the cellular network can contribute to higher capacity (sum rate) when compared to only cellular communication. Cellular Network can receive either uplink or downlink resources from D2D. CSI of all the participated links is accessible at BS so that the PRB allocation decision of D2D users can be controlled centrally by the BS. Arash Asadi [22] explained the architectural view of D2D that looks like a mobile ad-hoc networks (MANET) and Cognitive Radio Networks (CRN). The D2D communication will have high power efficiency of the network by dynamically switching between cellular and D2D modes. Out band D2D is best when compared to in band D2D as interference is less in out band. Interference can be managed efficiently if the D2D users communicate over PRBs that are not used by nearby interfering cellular UEs. PRB allocation for out band D2D simply helps in keeping away of ISM bands which are presently used by other D2D users.

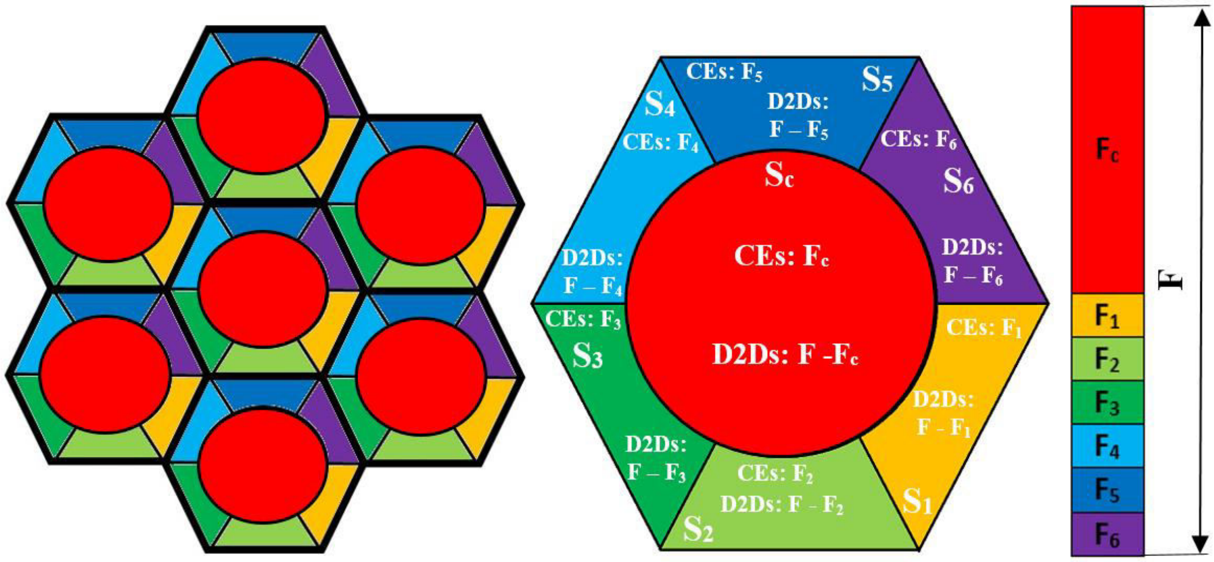
Survey on Power controlling schemes

Shaoyi Xu *et al* [16] used a peculiar method of sharing uplink PRBs in a combined network of cellular and D2D communication by tracking the intrusive cellular users using near-far interference method. Which reduces the interference and increases the resource allocation. Pekka jnis *et al* [3] gave proper mechanism for power control by reusing the cellular frequencies without any interface. The maximum power can be calculated using the UL power and SINR can be diminished at the same instant of time. The D2D communication can be done in low interference - limited network without reducing the performance of the already existed cellular network and author also made a study on the gain of the D2D communication in a single cell. Syed Tariq Shah *et al* [12] proposed power control in D2D communication. This also uses the mechanism which does not guarantees the SINR for the cellular network and maintains the SINR at the minimum. The author also lightens up the throughput of all the devices and also increases the cell capacity. Gbor Fodor et.al [23] proposed about three types of gain. Proximity gain of user equipment due to which the user equipment gets high data rates. Reuse gain due to which the resource can be used at the same time by more users. Hop gain which refers to the single link in the D2D communication. The transmission scheme OFDM is considered. Power control algorithms and proper mode selection should be done for realizing the reuse gain and the proximity gain.

Namyoon Lee *et al* [24] described about random network model for D2D communication. Which is inside the cellular system & utilizes the concept of centralized and distributed power control algorithms. The main aim of the centralized algorithm is to affect the cellular users to have acceptable coverage by reducing the interference due to the D2D user. In distributed power control algorithm, many analytical expressions are derived which are used to control the on/off power control scheme, due to the both algorithms the throughput of the cellular network can be increased, however the distributed power algorithm does not assure the reliable cellular network. Yanfang Xu *et al* [25] graved about the channel allocation problem in a single cell when more number of D2D pairs want to communicate with each other. Author used Hungarian algorithm to increase the number of D2D pairs by neglecting the interference from D2D pairs. Wei Wang *et al* [26] controls the D2D power dynamically by considering the delay in data transmission between D2D pairs. Author uses average cost Markov decision process and closed-form approximate priority function to control power dynamically and is less in complexity. Solves well known Bellman equation to obtain the optimal control policy. Efficiently reduces the average transmit power as well as the average delay of the D2D data transmission. Gbor Fodor et.al [27] proposed SINR based distributed power control algorithm which targets D2D underlying cellular network. Subject to a sum-rate constraint, the overall cell site power is reduced by distributed power control. Augmented Lagrangian Penalty Function (ALPF) method was used to set an optimal SINR target, which used to evaluate the performance of distributed power control algorithm.

Proposed Inter Cell Interference Mitigation technique with SFFR based cell architecture

A hexagonal cell site is sectored to handle the increased traffic by using dedicated directional antennas. A site with frequency reuse factor (FRF) =1 results in more inter cell interference (ICI) [28]. Cell sectoring and frequency reuse techniques are used to avoid ICI. Soft frequency reuse (SFR) and Fractional frequency reuse (FFR) are the two popular frequency reuse techniques. The variants of SFR and FFR are discussed in [29-32].



(a) (b)

Figure-2. Proposed cell architecture for Inter Cell Interference mitigation: (a) FFR based seven cell architecture (b) Proposed cell sectoring and PRB allocation (c) Division of available frequency bands in each cell

To address this problem, we divide each cell site in to two sectors called central or inner sector (CS) and edge or outer sector (ES). Further the ES is divided in to six slots and named as S_1, S_2, S_3, S_4, S_5, and S_6. Therefore, the total number of sector in each cell is equal to 7. Besides cell sectoring, we use strict fractional frequency reuse (SFFR) method to allocate the frequency bands to the sectored cell regions or zones. Based on strict FFR [33, 34], CS has a FRF of 1 and ES has a FRF of N. Entire frequency band in each cell site is divided in to seven bands, where F_c (centre frequency) occupies large portion and the remaining is divided in to six bands and are named $F_1, F_2, F_3, F_4, F_5, F_5$, as shown in figure-2(c). Among these seven bands F_c is allotted to the CS (S_c) and the remaining six bands (F_1 to F_6) are assigned to six edge sectors (S_1 to S_6) as shown in Figure-2(b). Figure-2(a) gives proposed strict FFR based seven cell architecture. Area of the CS is a parameter which effects the performance of the entire cell site. According to the [35], we consider the radius of the CS is 63% of entire cell area. The proposed cell site architecture reduces the interference at the cell edges called inter cell interference (ICI), as there is a large spatial separation between the ES which are using same frequency. The proposed Inter Cell Interference mitigation mechanism based on sectoring and SFFR is shown in figure-2.

Cellular network controlled D2D communication is developed as show in the Figure-1. D2D pairs share the common PRBs that are being used by the CEs. The allocation of PRBs for D2D communication is controlled and managed by the eNB. As per the proposed cell architecture, D2D pairs in respective sector uses the entire frequency band F except a band F_x which is used by the CEs in that respective sector (i.e., $F - F_x$), where F_x is a band of frequencies which are being used by the CEs. For example, in sector S_2 CEs uses F_2 whereas D2D pairs uses the entire frequency band (F) except F_2, i.e., $F_c + F_1 + F_3 + F_4 + F_5 + F_6$. Each PRB in a frequency band (F_x) constitutes a UL & DL PRBs as pair. Through this, every sector in cell site has a chance to uses the entire frequency, including CEs and D2D pairs. Which increases the entire cell throughput.

Proposed PRB allocation scheme

This section contains two parts. Considered system model is discussed first and PRB allocation scheme later.

System model

PRB allocation scheme for network controlled D2D communication underlying LTE-A Network uses FFR. We assume that ICI is very less and is neglected due to the efficiently designed cell site architecture. LTE-A FDD frame type-1 [36] is considered here. We focus on scenario where the CE and D2D pairs share both UL & DL PRB simultaneously in order to support the vast number of autonomous D2D communications in parallel with traditional cellular communication (TCC).

The proposed scheme works as follows. We consider a cell site with total number of CEs are equal to C_N, and D2D pairs equal to D_N. Throughout this paper a D2D pair compromises a DT and its corresponding DR. Two UEs are paired as a D2D pair by a D2D peer discovery process [23, 37, 38]. We assume the network is in full buffer mode where all users want to communicate. A set of CEs and D2Ds are defined as C = {1, 2, 3, …, C_N} & D = {1, 2, 3, …, D_N} respectively. Procedure explained in 3GPP Rel-9 [39] to find the location services (LCS) are used to find the location of a particular CE or DT or DR in which region or sector they are resides in. We also define F_{cd} (c ∈ C and d ∈ D) as a PRB sharing pair which contains one CE and one D2D pair. At any

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instant in a cell each PRB is shared by one F_{cd} only and this F_{cd} is not in same sector, because CEs in each sector uses the frequency band that is not used by D2Ds in that sector. Two D2D pairs never use a same PRB at a time; therefore we can neglect the interference between two D2D pairs. User equipment & eNB calculate the channel gains as given in [12]. Channel gain between CE, DT, DR & eNB and their notations are given the Figure-3.

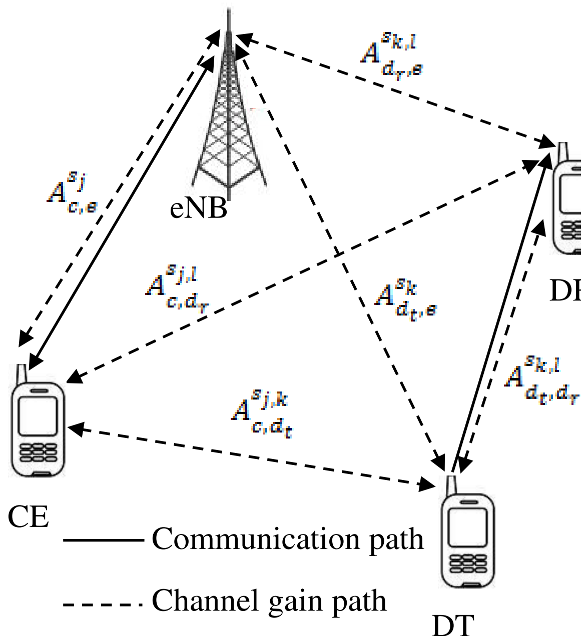

Figure-3. Channel gain between CEs, D2Ds and eNB.

In Figure-3 $A^{s_{k,l}}_{d_t,d_r}$ represents the channel gain between DT & DR located in sector k & l respectively and $A^{s_j}_{c,e}$ represents channel gain associated with CE resides in j^{th} sector & eNB. Similarly, remaining notations can be easily understood. From Figure-3 we can note that DT & DR in a D2D pair may or may not be in same sector i.e. $k \neq l$ & $k = l$ where $j, k \text{ and } l \in s_c, s_1, s_2, \cdots s_6$.

PRB allocation

Proposed efficient PRB allocation scheme allocates both UL & DL PRBs for D2D communication without effecting the TCC. Proposed algorithm assigns high priority to UL PRBs and low priority to DL PRBs. Assignment of priority to UL & DL PRBs is considered from the conclusion of [17]. The main advantage of sharing both UL & DL is the availability of more bandwidth (BW) for D2D communication (UL BW + DL BW) besides with a great challenge on maintaining quality of service (QoS) to TCC. When we are sharing both UL & DL PRBs of TCC with D2D pairs, then eNB, CE and DR may feel interference from D2D transmission over UL & DL PRBs respectively as shown in figure-1. We use PF scheduling algorithm with proposed allocation method to maintain guaranteed user fairness.

In general, there will be a specific DL PRB associated with every UL PRB. In this context "a PRB assigned to a CE by eNB" means a UL & its corresponding DL (by default) is assigned to a CE. eNB divides the entire BW in to sub-channels then assigns each sub-channel (UL & DL pair) to a CE for which PF metric value (λ) is high when compared to others. PF scheduling algorithm targets to achieve maximum log utility function$\sum_u \log R_u$. Where R_u is the mean throughput of a user 'u' in previous transmission time interval (TTI). The PF metric value of a user 'u' over a PRB 'n' can be calculated as $\lambda_{u,n} = \frac{r_{u,n}}{R_u}$. Where $r_{u,n}$ is the throughput at current TTI that can be achievable for a user 'u' over a PRB n. Where $n \in F_c, F_1, F_2, \cdots F_6$. eNB calculates the λ of CE 'c' in j^{th} sector over n^{th} UL & DL PRB using the following equations

$$\lambda^{s_j}_{c,nU} = 1 + \frac{r^{s_j}_{c,nU}}{R^{s_j}_{c,nU}} \tag{1}$$

and

$$\lambda^{s_j}_{c,nD} = 1 + \frac{r^{s_j}_{c,nD}}{R^{s_j}_{c,nD}} \tag{2}$$

Where $r^{s_j}_{c,nU}$ & $r^{s_j}_{c,nD}$ is throughput achievable on 'n^{th}' PRB of UL & DL respectively for a CE 'c' resides in sector 'j' in current TTI and $R^{s_j}_{c,nU}$ & $R^{s_j}_{c,nD}$ is mean throughput of a CE 'c' resides in sector 'j' on 'n^{th}' PRB of UL & DL respectively in previous TTI. Similarly, eNB calculates λ for every D2D pair (d) over n^{th} PRB of UL & DL separately as given below in equation (3) & (4) respectively.

$$\lambda^{s_{k,l}}_{d,nU} = 1 + \frac{r^{s_{k,l}}_{d,nU}}{R^{s_{k,l}}_{d,nU}} \tag{3}$$

&

$$\lambda^{s_{k,l}}_{d,nD} = 1 + \frac{r^{s_{k,l}}_{d,nD}}{R^{s_{k,l}}_{d,nD}} \tag{4}$$

Where $s_{k,l}$ represents that DT & DR resides in sector k & l respectively. The r, R values mainly depend on the channel gain & SINR value of a particular path as shown in figure-3. The r, R values can be calculated from the equation (4) given below.

$$r^s_{u,n} \text{ or } R^s_{u,n} = \sum B_{sub} \log_2(1 + SINR^s_{u,n}) \tag{5}$$

Where B_{sub} is the Band width of sub carrier and $SINR^s_{u,n}$ is SINR of user 'u' on n^{th} PRB resides in a sector s. Based on the measured λ of CEs & D2D pairs, eNB forms the UL PRB sharing pairs ($F^U_{c,d}$) if and only if the product of $\lambda^{s_j}_{c,nU}$ & $\lambda^{s_{k,l}}_{d,nU}$ is high for a same PRB n. Similarly, eNB forms the DL PRB sharing pairs ($F^U_{c,d}$) if and only if the product of $\lambda^{s_j}_{c,nD}$ & $\lambda^{s_{k,l}}_{d,nD}$ is high for a same

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PRB 'n'. Where every CE is operating on UL & DL PRBs simultaneously whereas D2D pair operates on either UL or DL PRB. As high priority is given to UL PRBs as mentioned earlier, eNB tries to share UL PRBs first. If all UL PRBs are pre-occupied or the product of PF metric value is low for a D2D & every CE, then eNB try to make PRB sharing pair on DL PRBs. As this process makes computational overhead at eNB but improves overall cell site throughput drastically. Improvements in parallel processing techniques may reduce this computational overhead at eNB.

Proposed power control scheme

SINR of communication path between eNB, CE & D2D is used to control the power of DT which effectively reduces the interference. No modifications are suggested in TCC. CEs transmission power will be controlled by the eNB based on the CQI. Whereas the DTs transmission power will be controlled based on the SINR of CEs & D2D pairs. Based on the received signal strength DRs intimate the CQI to eNB. Based on that information eNB decides the DTs transmission power level by considering the CE transmission power, distance between the eNB & PRB sharing pair, DT & DR and distance between PRB sharing CE & DT using LCS. P_{max} is considered as the maximum allowable DT transmission power i.e., $P_{d_t}$is in between [0, P_{max}]. The transmission power of DT over UL ($P_{d_t,U}$) & DL ($P_{d_t,D}$) PRBs can be calculated using

$$P_{d_t,U} = \begin{cases} \frac{P_c^{s_j} A_{d_t,e}^{s_k}}{A_{d_t,e}^{s_k}\gamma_{c,U}} - \frac{N_0}{A_{d_t,e}^{s_k}} & if\ SINR_{c,U}^{s_j} < \gamma_{c,U}\ and\ SINR_{d,U}^{s_{k,l}} \geq \gamma_{d,U}\ or\ \min[\hat{C}_U, \widehat{D}_U] = \hat{C}_U \\ \frac{\gamma_{d,U} P_c^{s_j} A_{c,d_r}^{s_{j,l}}}{A_{d_t,d_r}^{s_{k,l}}} + \frac{\gamma_{d,U} N_0}{A_{d_t,d_r}^{s_{k,l}}} & if\ SINR_{c,U}^{s_j} \geq \gamma_{c,U}\ and\ SINR_{d,U}^{s_{k,l}} < \gamma_{d,U}\ or\ \min[\hat{C}_U, \widehat{D}_U] = \widehat{D}_U \\ P_{max} & if\ SINR_{c,U}^{s_j} \geq \gamma_{c,U}\ and\ SINR_{d,U}^{s_{k,l}} \geq \gamma_{d,U} \end{cases} \quad (6)$$

And

$$P_{d_t,D} = \begin{cases} \frac{P_e A_{d_t,c}^{s_{k,j}}}{A_{d_t,c}^{s_{k,j}}\gamma_{c,D}} - \frac{N_0}{A_{d_t,c}^{s_{k,j}}} & if\ SINR_{c,D}^{s_j} < \gamma_{c,D}\ and\ SINR_{d,D}^{s_{k,l}} \geq \gamma_{d,D}\ or\ \min[\hat{C}_D, \widehat{D}_D] = \hat{C}_U \\ \frac{\gamma_{d,D} P_e A_{d_r,e}^{s_l}}{A_{d_t,d_r}^{s_{k,l}}} + \frac{\gamma_{d,D} N_0}{A_{d_t,d_r}^{s_{k,l}}} & if\ SINR_{c,D}^{s_j} \geq \gamma_{c,D}\ and\ SINR_{d,D}^{s_{k,l}} < \gamma_{d,D}\ or\ \min[\hat{C}_D, \widehat{D}_D] = \widehat{D}_D \\ P_{max} & if\ SINR_{c,D}^{s_j} \geq \gamma_{c,D}\ and\ SINR_{d,D}^{s_{k,l}} \geq \gamma_{d,D} \end{cases} \quad (7)$$

Where$\gamma_{c,D}$, $\gamma_{c,U}$ & $\gamma_{d,D}$, $\gamma_{d,U}$ are threshold values of SINR for CE & D2D pairs over DL & UL PRBs respectively. $P_{d_t}^{s_k}$, $P_{d_c}^{s_j}$ & P_e are the transmission power of DT, CE & eNB located in respective sectors 's'. N_0 is the white noise power. 'A' is the channel gain as explained in section 4.1. $\hat{C}_U, C_D, \widehat{D}_U, \widehat{D}_D$ are SINR & threshold SINR (γ) difference of CE & D2D pair over UL & DL PRBs respectively and are defined as

$$\hat{C}_U = SINR_{c,U}^{s_j} - \gamma_{c,U} \quad (8)$$

$$\hat{C}_D = SINR_{c,D}^{s_j} - \gamma_{c,D} \quad (9)$$

$$\widehat{D}_U = SINR_{d,U}^{s_{k,l}} - \gamma_{d,U} \quad (10)$$

and

$$\widehat{D}_D = SINR_{d,D}^{s_{k,l}} - \gamma_{d,D}. \quad (11)$$

SINR values of PRB sharing pair can be calculated using

$$SINR_{c,U}^{s_j} = \frac{P_c^{s_j} A_{c,e}^{s_j}}{N_0 + P_{d_t}^{s_k} A_{d_t,e}^{s_k}} \quad (12)$$

$$SINR_{c,D}^{s_j} = \frac{P_e A_{c,e}^{s_j}}{N_0 + P_{d_t}^{s_k} A_{d_t,c}^{s_{k,j}}} \quad (13)$$

$$SINR_{d,U}^{s_{k,l}} = \frac{P_{d_t}^{s_k} A_{d_t,d_r}^{s_{k,l}}}{N_0 + P_c^{s_j} A_{d_t,c}^{s_{j,l}}} \quad (14)$$

and

$$SINR_{d,D}^{s_{k,l}} = \frac{P_{d_t}^{s_k} A_{d_t,d_r}^{s_{k,l}}}{N_0 + P_e A_{d_t,e}^{s_l}}. \quad (15)$$

RESULTS AND DISCUSSIONS

Efficiency of the proposed method is verified by conducting extensive simulations on Mat Lab. Simulations are done based on varying number of D2D pairs in the cell site. Table-1 gives the considered simulation parameters. Each simulation, with varying number of D2D pairs in a cell site, is of 100 TTIs duration. Figure-4 shows that the utilisation of both UL & DL PRBs at a time for D2D communication improves the overall cell site throughput when compared with others.

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Table-1. Simulation parameters.

Parameters	Value
Number of CEs per cell (C_N)	30
Carrier frequency	2.0 GHz
UL & DL bandwidth	5 MHz each
Total number of Resource blocks on UL & DL	25 each
Maximum UE transmission power (Pmax)	24 dBm [40]
Sub channel bandwidth	180 KHz
Channel model	20-tap typical urban channel model [41]
Path loss exponent (alpha)	3.5
Transmission time interval (TTI)	1 msec
Antenna Gain of eNB	15.0 dB
Antenna Gain of UE	4.0 dB
eNB's Transmission power	43 dBm [42]
Noise power density	-174 dBm

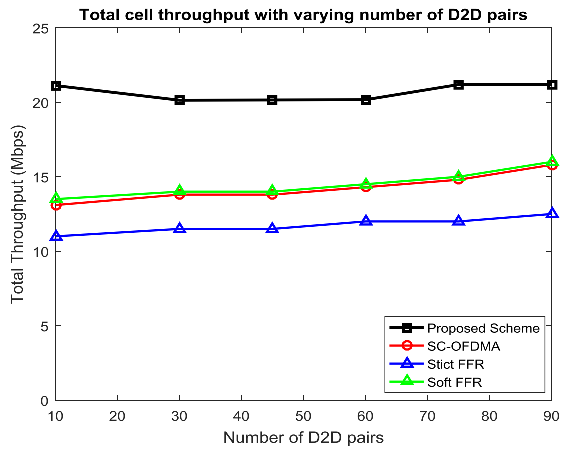

Figure-4. Cell site throughput. Entire cell site throughput Vs changing number of D2D pairs.

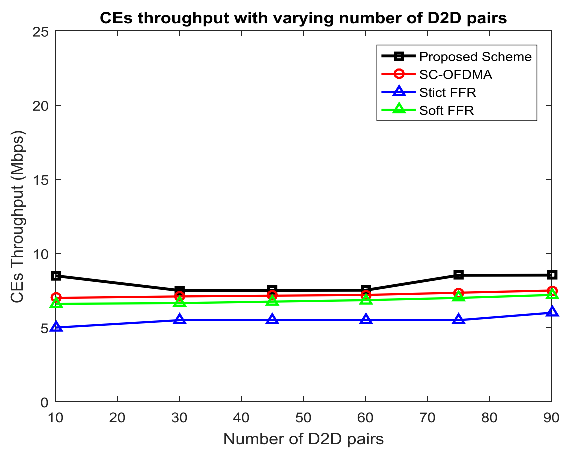

Figure-5. CEs throughput. CEs throughput Vs changing number of D2D pairs

The proposed method also improves the CEs throughput drastically as the interference between the CEs & D2Ds are efficiently reduced with proposed power control mechanism. We can observe in figure-5 the CEs throughput is unaffected even the number of D2D pairs are as high as 90. Whereas D2Ds throughput is high as shown in figure-6 when compared with CEs throughput. PAPR Vs changing number of D2D pairs graph shown in Figure-7 proves that the PAPR of proposed method over UL is low compared with other for both CEs and D2Ds.

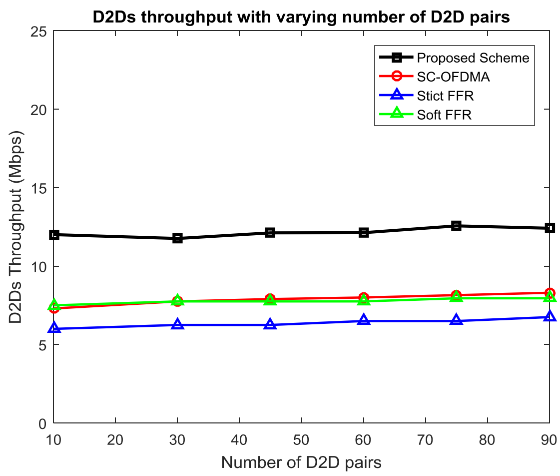

Figure-6. D2Ds throughput. D2Ds throughput Vs changing number of D2D pairs.

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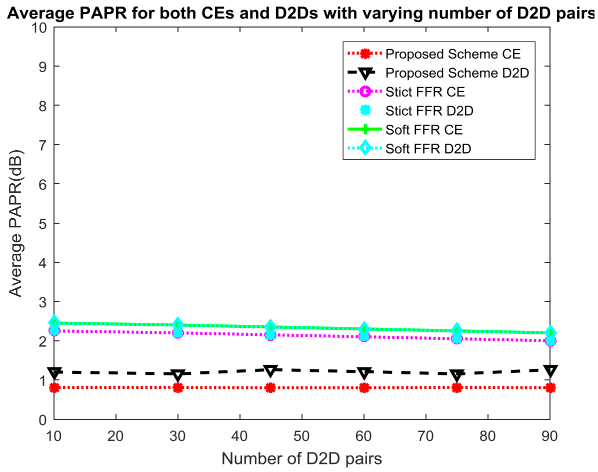

Figure-7. Average PAPR. Average PAPR Vs changing number of D2D pairs.

Figure-8 shows the Jain's fairness indices for both CEs and D2D pairs. Which proves that both CEs and D2Ds both are served with better fairness.

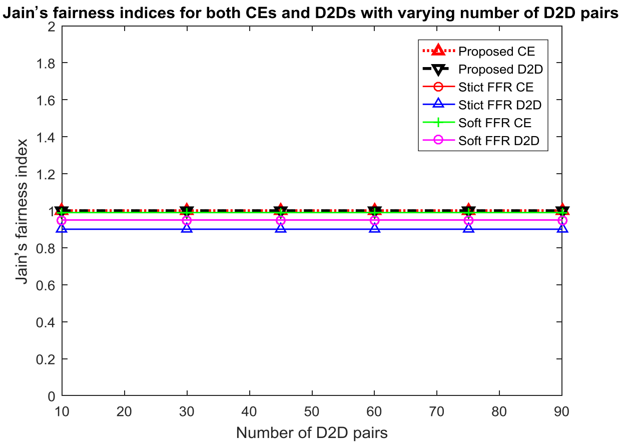

Figure-8. Jain's Fairness index. Jain's fairness indices Vs changing number of D2D pairs

CONCLUSIONS

UL & DL PRB allocation to accommodate more number of D2D candidates without effecting the traditional cellular communication is presented in this paper. To reduce the interference between eNB, CE & D2D pair (due to PRB sharing) an efficient power controlling mechanism is also presented. Use of strict FFR with cell sectoring at cell edge eliminates inter cell interference effectively. Utilisation of well-known proportional fair resource scheduling algorithm guarantees the cellular users fairness besides maintaining the acceptable D2D communication fairness. The proposed SINR based power control method effectively reduces the interference between PRB sharing pairs. Only D2D transmission power is controlled by eNB so as to ensure that there are no changes in cellular user communication. Simulation results shows that more number of D2D communication requests can be served without compromising the cellular user throughput. D2D communication using UL & DL PRBs simultaneously provides efficient spectrum utilisation and improves overall cell throughput drastically.

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