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(REVIEW ARTICLE)

Application of optimized frequency spectrum reuse (OFSR) for D2D communication in cellular network

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Abstract

Device to Device (D2D) communication in a cellular network poses some challenges among which are interference and low throughput. These two challenges can be controlled using optimized frequency spectrum reuse (OFSR). OFSR is technique where the user re-uses the frequency of another cell so as to prevent interference of D2D communication devices on the eNB as well as the interference on D2D receiver because of cellular user transmitters. The users were grouped in range of one –one hundred (1- 100), one to two hundred (1 – 200), one to three hundred (1-300) and one to four hundred (1-400). The simulation result obtained shows that OFSR has reduced interference when compared to resource allocation technique. The throughput in the down link is better when compare to the throughput in uplink as seen from the simulation result obtained.

Keywords: D2D; Optimized frequency reuse; Cellular Network; Data Transmission; Spectrum

1. Introduction

Due to the effect on network reliability, both the quantity of linked devices and the growing number of users within the communication systems have become issues of great concern. With the advancement in current mobile communication technologies (6G, 5G,4G and 3G), it is expected that the usage of mobile communications and device connectivity in the sustainable broadband regime would intensify in the nearest future. This device multiplicity will give rise to high data traffic which has risen exponentially due to online streaming, Internet of Things (IoT) data transmission, online gaming and video sharing etc. This poses great challenges to telecommunication industry and research community. One of the promising technologies that can be used to address high data traffic is device to device (D2D) communication. Device to device communication is a technology that allows mobile devices to communicate with one another directly without passing through the base stations (BSs) [1]. D2D communication can take place either underlay or overlay in-band cellular network or out-band cellular network. The difference in in-band and out-band is the frequency spectrum band which used in D2D in in-band mode. All D2D users and cellular users share the same licensed frequency band; therefore evolved node-B (eNB) can control D2D users [2]. The in-band is subdivided into underlay and overlay communication. The spectrum is shared by cellular and D2D users in underlay in-band mode so that both groups can use the same radio resources to communicate simultaneously. This causes interference because it allows multiple users to utilize the same resources. In overlay communication, the spectrum between D2D and cellular user is separated, where portion is used by device to device user, other portion is dedicated to cellular user. In essence a single channel is shared between D2D and cellular user at different time slots [3].In out-band mode, D2D users used unlicensed spectrum such as the

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industrial, scientific and medical (ISM) band for their transmission. This eliminate interference to and fro CUEs but decrease the network control over D2D communications.

Aim

The aim of the research is use Optimized Frequency Spectrum Re-use (OFSR) to improve spectrum efficiency in D2D communication

Objectives

- Examination of the propagation model in various environments
- Reduce interference of D2D pair

2. Optimized Frequency Spectrum Reuse

This is a technique where the user re-uses the frequency of another cell so as to prevent interference of D2D communication devices on the eNB as well as the interference on D2D receiver because of cellular user transmitters. From fig1, it has shown that D2D user in cell B can make use of same frequency in cell A. This shows that no interference between them.

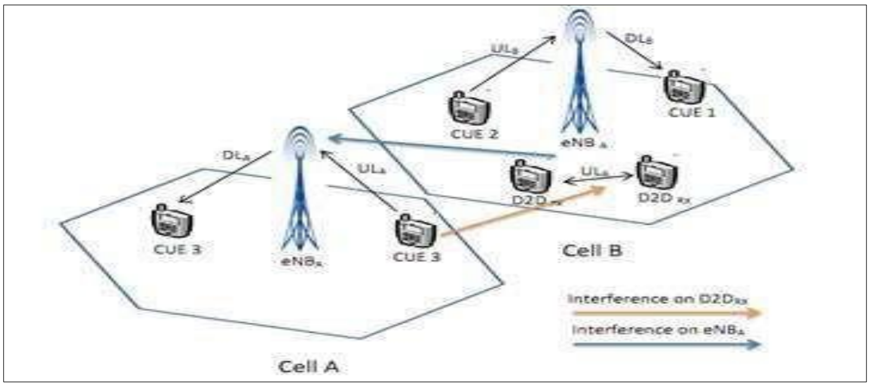

Figure 1 Exhibition of uplink in cell A to D2D communication in cell B [3]

Frequency reuse can also be demonstrated by the diagram shown in fig2.In fig2(a), the allocation sub bands was done with a factor incremental frequency reuse(IFR) factor of 3 while fig 2(b) distributed sub bands non uniformly to the outer and inner region of the cell.

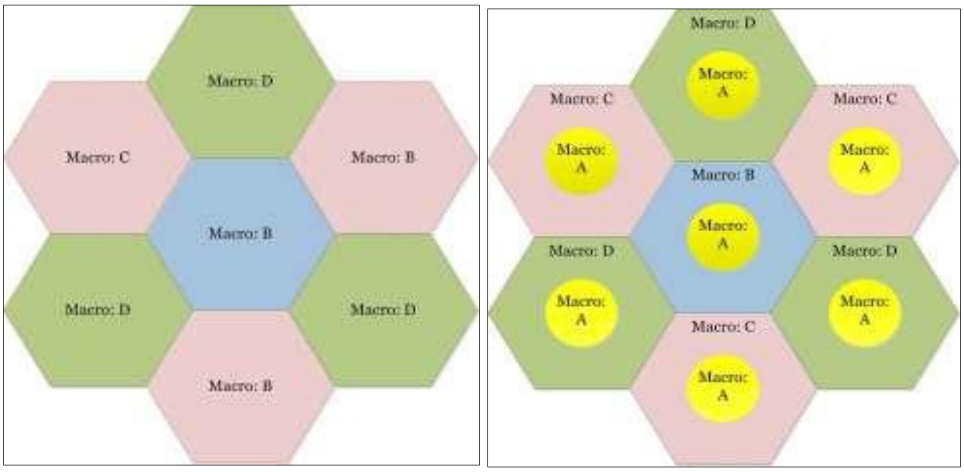

Figure 2 Frequency reuse in micro cellular environment [4]

3. Related Work

In the work of [5], they made use of optimized power control for massive multiple input–multiple out (MIMO) with underlay D2D communication to increase on the spectral efficiency and maximize the product of signal to interference and noise ratio (SINR). By utilizing an orthogonal pilot that can be reused between cells, this was accomplished. [6]uses a distributed intelligent method and a Belief Desire Intention (BDI) intelligent agent to address the problem of D2D communication in a 5G network by avoiding the base station. The Algorithm employed (DAIS) Algorithm made it possible to have data rate and reduced power consumption through transmission mode in D2D. They claim that their simulation result shows high spectral efficiency and low computational load. Reconfigurable intelligent surfaces with power control (RIS) were used in the D2D communication network [7]. The fractional programming was employed to increase energy efficiency and Dinkebach method was employed to control enhanced power improvement. Result of their simulation justifies that RIS contributed to increase in energy efficiency. [8] Carried out investigation on D2D based vehicle to vehicle (V2V) virtual network. They designed a 3-staged layered slicing frame work and Alternating Direction Method of Multipliers (ADMM) based distributed Algorithm. They claim that their work provides better throughput gains, Improve on resource utilization and better quality of service.

According to [9], power control algorithm was used for power minimization, sum power reduction and increase in resource utilization. According to [10], who provided Kuhnmukers technique for D2D communication through the use of channel distribution. Their technique gives better energy efficiency and better throughput when used in different network. The design of ECC based public key crypto system for D2D communication in 5G Internet of Things(IoT) was conducted by [11], where they verified user equipment on 5G Authentication and Key Agreement (5G-AKA) network using Elliptic Curve Digital Signature Algorithm (ECDSA) as a token. When their work was compared to Authenticated Encryption with Associated Data (AEAD) ciphers, it was found that their work shows much more performance and better efficiency. For multi-hop underlay D2D communication, the most effective routing based on trusted connectivity probability was examined [12]. They considered both random base stations and fixed base stations. Their result ascertain that random bases tations show shortest path for connectivity probability between D2D transmitter and receiver, while fixed base station show the optimal path selection location which is needed in 5G IoT for multi-hop D2D communication. According to [13], the paper proposed single-Agent Q-learning and Multi Agent Q-learning Algorithm. Their work show better improvement on quality of service (QoS), energy efficient and power allocation.

The optimal transmit power was found to improve with self-interference cancellation and channel gain by [14] in D2D communication. This was achieved based on iterative algorithm through difference convex (D.C) programming and high SINR approximation algorithm. This produces best result for various boundaries. There were four potential modes that were looked into: full duplex underlay, half duplex underlay, full duplex overlay, and half duplex overlay by [15]. The spectrum efficiency(SE) of the four mode were considered and their result shows that when interference is underlay mode is most appropriate but when self-interference is good, full duplex overlay mode is more applicable. Robust Multi-objective optimization in D2D underlaying heterogeneous network was studied by [16]. Joint optimization and power coordination algorithms were used. When the result were compared with non robust scheme, it was found out that robust scheme produces high energy efficiency and spectral efficiency under cellular user equipment and D2D pair. Due to large bandwidth and energy loss in half duplex relaying, this motivate [17] to propose full duplex relaying and simultaneous wireless information power transfer (SWIPT) technique at D2D transmitter. The energy absorbed at base station was used to send signal to DUEs for better quality of service through the use of interference cancellation technique. Their result show better performance when compared with SWIPT-frequency division octagonal multiple access (FDOMA).

4. System Model

The theoretical background is presented here. The whole network is made up o f Cell A and Cell B. Users indifferent cells are willing to re-use frequency of adjacent cell. Path loss model was used as;

$$PL_{CA}[dB]=15.3+37.6Log_{10}(dm)+S^{out} \qquad (1)$$

Where d is the distance between the transmitter and receiver, and $S^{out}$is factor represent shadowing

$$PL_{CB}[dB]=38.46+20Log10d(m)+0.7d+18.3n(n+2)(n+1)-0.46 \qquad (2)$$

Signal to noise ratio can be given as

$$SINR_{DL}=PdGdd/ (No+PcGcd)………………(3)$$

$$SINR_{DL}=PcGc/(No+PdGcd)………………(4)$$

Where;
Pd = transmit power,
Pc=eNB,
Gdd= D2D Channel gain,
Gcd= interference channel gain,
No=noise

$$SINR_{UL}= PdGdd/(No+PcuGcud)………………(5)$$

$$SINR_{eNB}= PcuGcud/(No+PdGdc)……………….. (6)$$

Where;
Gcud= interference channel gain from eNB to D2D,
Pcu= cellular user transmit power

$$Pd= argmax[Ln ((PdGcd/No+PcGcd)+1)+ Ln((PcGc/No+PdGcd)+1)$$

Mathematicalexpression1-2[3]

Mathematicalexpression3-6[4]

Table 1 Simulation parameters

S/n	Parameter	Values
1	Number of Users	400
2	Spectrum Allocation	40MHz
3	Resource bandwidth	200KHz
4	Number of D2D link per Cell	25
5	Centre Frequency	5GHz
6	Distance Between D2D	150m
7	Transmission Power of cellular user	80mW
8	Transmission power in D2D	0.5mW
9	Transmission power in base station	90dbm
10	Noise spectral density	250dbm/Hz

5. Simulation Result

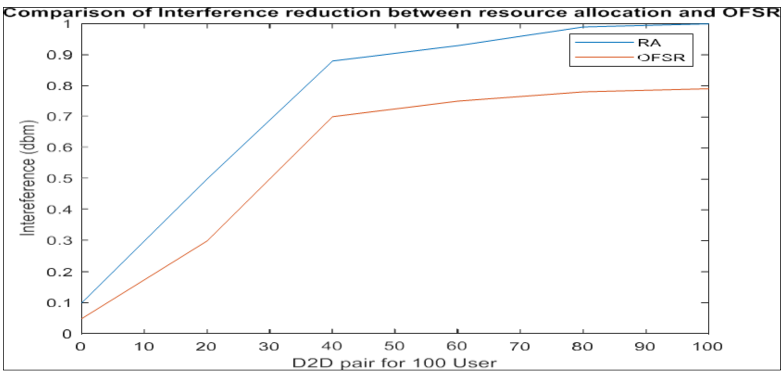

Figure 3a Comparison of interference reduction between resource allocation and OFSR (D2D pair for 100 user)

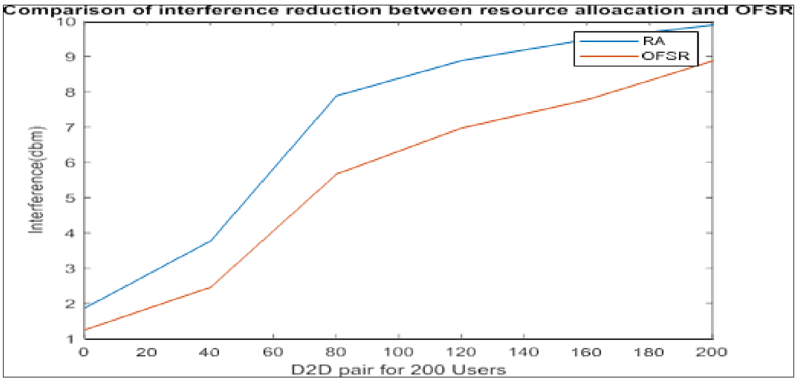

Figure 3b Comparison of interference reduction between resource allocation and OFSR (D2D pair for 200 user)

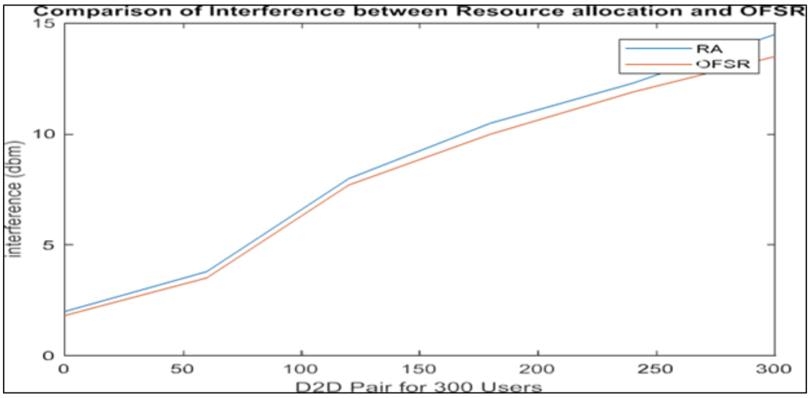

Figure 3c Comparison of interference reduction between resource allocation and OFSR (D2D pair for 300 user)

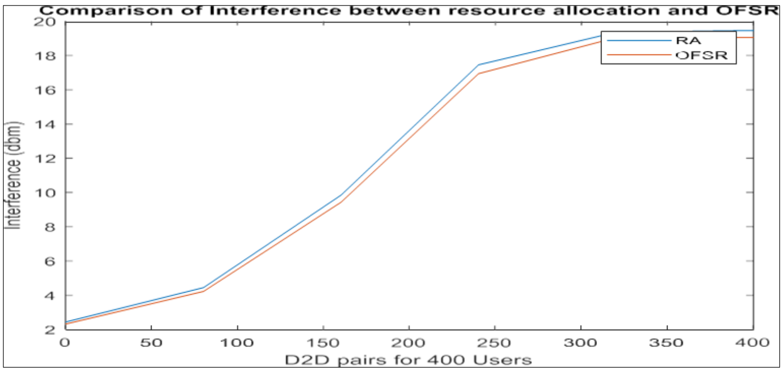

Figure 3d Comparison of interference reduction between resource allocation and OFSR (D2D pair for 400 user)

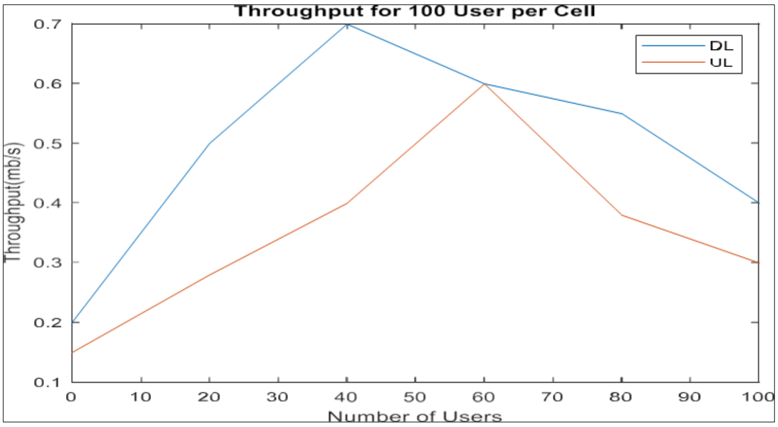

Figure 4a Throughput for 100 user per cell

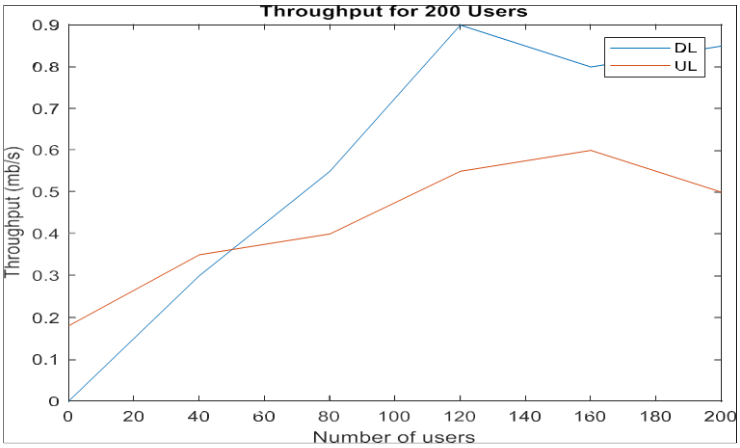

Figure 4b Throughput for 200 user per cell

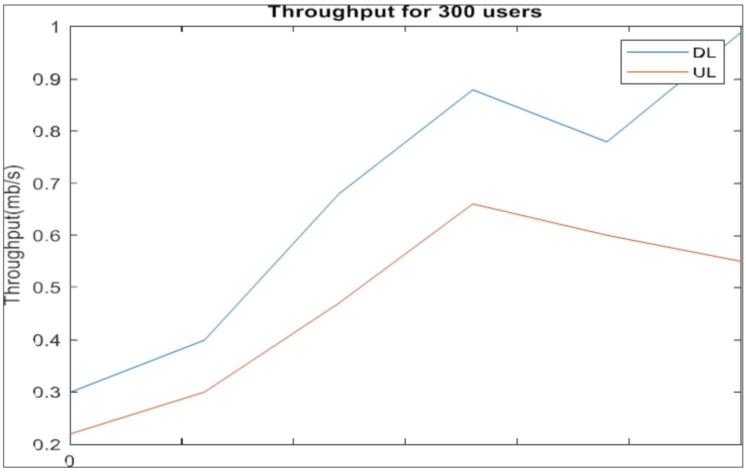

Figure 4c Throughput for 300 user per cell

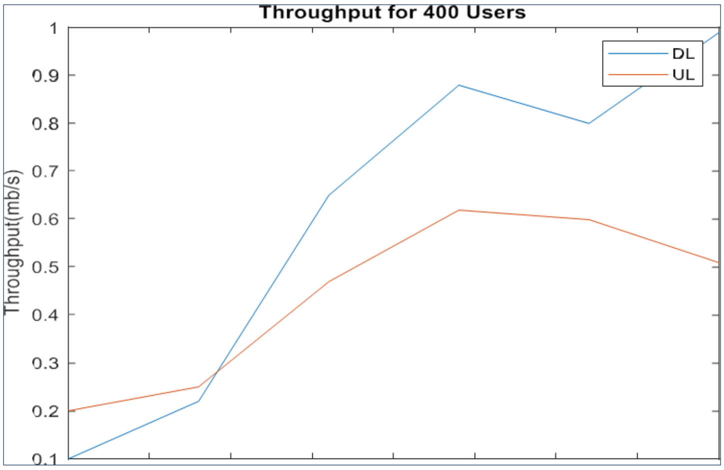

Figure 4d Throughput for 400 user per cell

6. Discussion

The result in fig 3(a) shows the comparison of interference reduction between resource allocation (RA) and optimized frequency spectrum reuse (OFSR) for the first one hundred users. The graph shows that OFSR has reduced interference when compared to RA. The same thing applies from fig 3(b) to fig 3(d) where the number of users increases from two hundred to four hundred.

Fig4(a) shows the throughput for uplink (UL)and downlink(DL)was obtained for the first one hundred users. The same thing applies from fig 4(b) to fig 4(d) where the levels of throughput were shown for UL and DL. The graph shown indicated that the DL has better throughput in any of the four cases.

7. Conclusion

It has been shown that interference reduction can be achieved in D2D communication. The result obtained were compared between OFSR and RA, OFSR has reduction in interference when compared to RA. The throughput in down link is higher than that of uplink in four different cases considered.

Compliance with ethical standards

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Disclosure of conflict of interest

There was no conflict of interest in this work.

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