Journal of Science, Management and Technology
ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

Device to Device Communication Using Optimized Frequency Spectrum Reuse (OFSR) in Multi-Layered Cellular Network

Ugochukwu Okwudili Matthew[1], Musefiu Aderinola[2], Isiaka Shuaibu[3], Jazuli S. Kazaure[2], John Ohabuiro[2], Ogobuchi Okey Daniel[4], Ubochi C. Nwamouh[5]

[1]Computer Science Department, Hussaini Adamu Federal Polytechnic, Nigeria.

[2]Electrical & Electronics Engineering Department, Hussaini Adamu Federal Polytechnic, Nigeria.

[3]Department of Electrical Electronic Engineering, Universiti of Teknologi, Malaysia.

[4]Department of System and Automation Engineering, Federal University of Lavras, MG, Brazil.

[5]Electrical & Electronics Engineering, Kampala International University, Uganda

*Corresponding Author: macdon4ru2003@gmail.com

Abstract

In a cellular network, Device to Device (D2D) communication faces a number of difficulties, including interference and slow upward and downward linking between device connectivity with base stations. Utilizing optimum frequency spectrum reuse (OFSR), these two issues can be overcome. In order to prevent D2D communication devices on the Evolved Node B (eNB) and cellular user transmitters from interfering with D2D receiver, OFSR is a mechanism where the user reuses the frequency of another cell. The study looks at the problem of spectrum sharing between D2D and cellular communications in a cellular network. Under this network spectrum rationalization, D2D links may access the spectrum that a mobile network operator manages. Each D2D link has the choice of acquiring a sub-band for exclusive usage or gaining access to the sub-bands used by cellular users. Spectrum can also be shared by D2D lines that only use a particular sub-band. One to one hundred (1-100), one to two hundred (1-200), one to three hundred (1-300), and one to four hundred (1-400) users each made up a group (1-400). The system equations were used to represent the network information, such as link gains, noise levels, signal-to-interference-and-noise ratios, and the devices' selected communication mode. Simulations that incorporate D2D communication as an additional communication channel are utilized to demonstrate performance bounds for the cellular system based on the derived equations. When compared to resource allocation technique, the simulation result demonstrates that OFSR has less interference. As can be observed from the simulation results, the throughput in the down link is higher than the throughput in the uplink.

Keywords: Mobile Cellular Network, D2D Communication, Wireless frequency Reuse, Data Transmission Protocol, Spectrum Efficiency

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

1. Introduction

The broadband cellular communication is a key catalyst of electromagnetic spectrum technology and a vital engine for the advancement of disruptive technologies in the electronic society of the twenty-first century(Rejeb & Keogh, 2021). The deployment of 5G network spectrum around the world is expected to result in a situation that at the end of 2020, there will be more mobile-connected devices than there are people on the planet(Nistor & Zadobrischi, 2022). However, in the current frameworks, the frequency spectrum required for broadband cellular networks is insufficient, so it is necessary to propose fresh techniques for a more effective use of the resources already available. In order to transmit to its receiver (DRx) over the device-to-device (D2D) connection, the transmitter of a D2D pair (DTx) does this by using the spectrum of the cellular network. Since D2D pairs and cellular users (CUs) share the same spectrum, there is a requirement for interference management because they could interfere with one another(Zhang et al., 2019). The two most popular interference management strategies in wireless networks are channel (spectrum) allocation and transmit power control schemes(Hossain, Rasti, Tabassum, & Abdelnasser, 2014). A growing concern is the energy efficiency of cellular networks, and D2D communication can lower base station and user power usage. To maintain its quality of service (QoS), a CU will, however, raise its broadcast power when a D2D pair uses its uplink channel(Gour & Tyagi, 2018). Using D2D links as the underlay of a fully used cellular network, (D. Feng et al., 2013) proposes an uplink resource allocation system that maximizes overall network throughput while ensuring QoS for both D2D pairs and CUs. To increase overall throughput in this system, at least one user (the DTx or the CU) transmits at its highest power when a D2D pair uses a CU's uplink frequency(Pawar & Trivedi, 2021).

A distributed power control approach for D2D users is suggested in (Kaufman, Lilleberg, & Aazhang, 2013) for a system model similar to that in (D. Feng et al., 2013), whereby such users can only opportunistically reuse the uplink channels of the CUs when their interference with the base station is smaller. In reality, this compels the CUs to top-up their transmit power levels in order to maintain their throughputs and Signal to Interference & Noise Ratio(SINRs), which may not be feasible in CUs with limited power or may decrease energy efficiency. Therefore, it is desirable to design a new system that maximizes throughput while maintaining QoS for all users and minimizes the increase in uplink transmit power. As an underlay of a fully utilized cellular Long-Term Evolution (LTE), being the wireless broadband communication protocol used by data terminals and mobile devices. With its all internet protocol (IP) network, the LTE standard only supports packet switching(Arnez, Silva, Do Reis, Da Silva, & Damasceno, 2022). Due to the circuit switching used in Global System for Mobile Communication for (GSM), Universal Mobile Telecommunication System(UMTS), and Code Division Multiple Access 2000(CDMA2000) voice calls, carriers will need to redesign their voice call network in order to support LTE(A. Khan, 2020). To that effect, the current paper proposed a brand-new resource allocation strategy for D2D

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

links in this study. By lowering the combined transmit power levels for D2D pairs and CUs while maintaining the necessary QoS for both user types, the associated base station in our proposed approach optimally distributes the uplink resources for each D2D connection. For each cellular user, we assume orthogonal frequency-division multiple access (OFDMA) for the downlink and single-carrier FDMA (SC-FDMA) for the uplink, where the uplink data is dispersed across numerous sub-carriers(Taha, Haci, & Serener, 2022). Similar to (D. Feng et al., 2013), the base station evaluates the minimum required transmit power levels for the D2D pair and any prospective CU partners before determining if admitting the D2D pair as an underlay of the cellular network would not violate either party's QoS criteria.

In line with network reliability, both the quantity of linked devices and the growing number of users within the communication systems have become issues of great concern(Tushar et al., 2021). Consequent upon 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(Ugochukwu O Matthew & Kazaure, 2021),(Kazaure, Matthew, Okafor, & Okey, 2021). This device multiplicity will give rise to high data traffic which has risen exponentially due to online streaming, Internet of Things (IoT) connected data transmission, online gaming and video sharing(Ugochukwu Okwudili Matthew, Kazaure, John, & Haruna, 2021). 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) (Cheng, Huang, & Chen, 2022). The D2D communication can take place either underlay or overlay in-band cellular network or out-band cellular network(Patil & Hendre, 2022). 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 where evolved node-B (eNB) can control D2D users (Ningombam & Shin, 2018). The in-band is subdivided into underlay and overlay communication(Safdar, Ur Rehman, Muhammad, & Imran, 2022). 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 use at different time slots(Li et al., 2022).

Over time, cellular networks have changed, becoming increasingly necessary for devices to interact. In order to manage capacity, offloading cellular traffic has become urgently necessary due to the exponential growth in subscriber numbers. The newest idea in cellular networks is called D2D which facilitates direct communication between devices and networks (such as BS or eNB).

Journal of Science, Management and Technology
ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

Due to the increased data rate of D2D networks, devices can now communicate with very little latency. The D2D communication that uses the same licensed spectrum as cellular communication is known as in-band D2D communication. It can be quite difficult to manage the interferences between cellular and D2D applications in in-band. Algorithms for resource allocation are also quite difficult to create. The radio spectrum for international industrial, scientific, and medical (ISM) radio bands are restricted and cannot be deployed for telecommunications applications(Ahmad et al., 2022). D2D employs unlicensed spectrum (the 2.4 GHz ISM band or the 38 GHz mmwave band) for out-of-band communication, whereas cellular uses licensed frequency provided by the network operator. Cellular and D2D communication do not interfere. D2D users, on the other hand, are impacted by other ISM band users like Wi-Fi and Bluetooth, which is unavoidable.

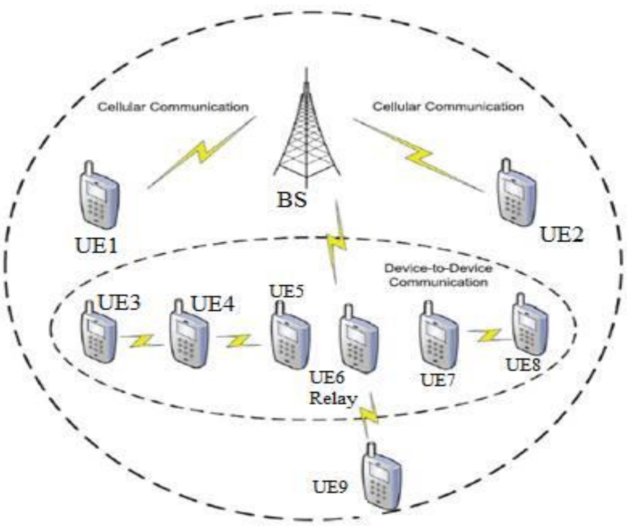

Fig1: Exhibition of cellular uplink communication in cell A to D2D communication in cell B(Sarma, Khuntia, & Hazra, 2022)

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 **Fig 1 above,** it has been shown that D2D user in cell B can make use of same frequency in cell A, this shows that there is no interference between them. Frequency reuse can also be demonstrated by the diagram shown in **Fig 2**. In **Fig 2**, the allocation of sub bands was done with a factor incremental frequency reuse (IFR) factor of 3 while **Fig 3,** illustrated the distribution of sub bands non uniformly to the outer and inner region of the cell.

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

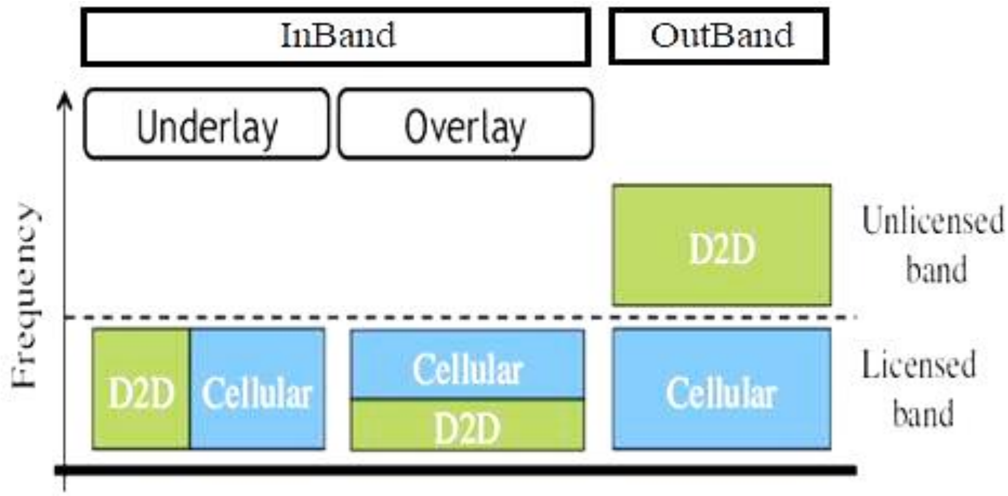

Fig 2: The allocation of sub bands in the D2D Communication Cells(Zhi, Tian, Deng, Qiao, & Lu, 2022)

uses less spectrum, but it is difficult to implement resource sharing between D2D and cellular users. By exploiting spatial diversity, the Underlay D2D improves spectral efficiency(Bhardwaj & Agnihotri, 2018). The allotment of spectrum for in-band and out-of-band D2D and cellular communication is shown in the **Fig 2**. The two types of in-band D2D communication—underlay and overlay—are further divided into two groups.

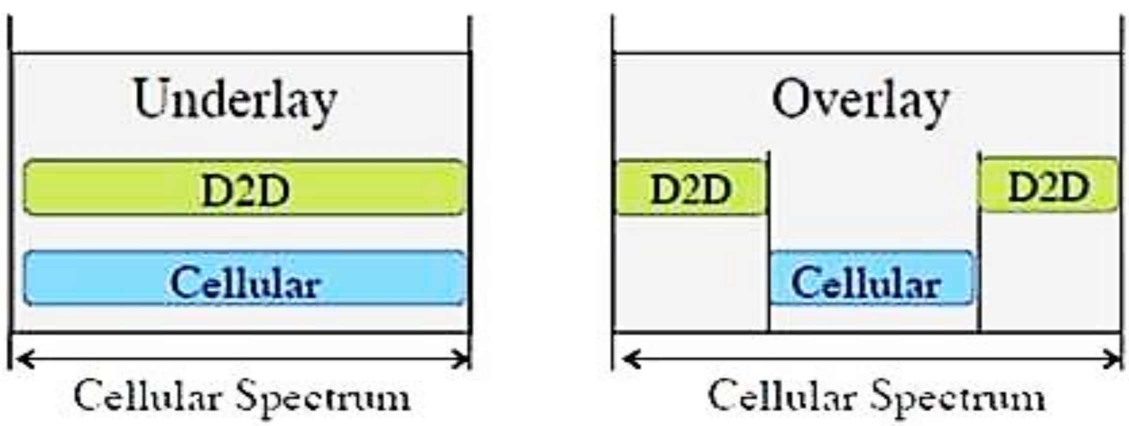

Fig 3: The distribution of sub bands non-uniformly to the outer and inner region of the cell(Sun et al., 2020).

As seen for D2D and cellular links, licensed spectrum is separated into non-overlapping sections in this subtype. Due to the allocation of independent resources, this strategy is relatively straightforward to use. The overlay D2D lessens the possibility of cellular users and D2D users interfering. With this strategy, preventing resource waste demands extra attention. This paper is organized thematically into introduction aims and objectives, related work, the system model with integrated D2D links, discussion of findings and conclusion.

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

2. Aim and Objectives

The aim of the research is to use the optimized frequency spectrum re-use (OFSR) to improve spectrum efficiency in D2D communication. The optimization problem will be solved by being sliced into two smaller problems. The initial step entails determining whether each D2D pair is admissible and obtaining the least transmit power levels for all admissible D2D pairs and their potentially reuse partners that can meet the requirements of each SINR. The second step entails selecting, from among all potential reuse partners' uplink channels, the one that is best for all D2D pairs that are allowed. Specifically, these two objectives were achieved in the current paper:

i. To adequately examine the propagation model in various communication environments with respect to cellular network in D2D communication.
ii. To devise efficient means of reducing interferences on D2D pair whenever necessary in upward and downward device linking.

3. Related Work

Device-to-device (D2D) communication in cellular networks is a new technology that enables two nearby users' devices to connect with one another without the assistance of a base station (BS) or core network delivery infrastructural installation (Kamruzzaman, Sarkar, & Gutierrez, 2022). The D2D communication offers a number of benefits in terms of spectrum efficiency, throughput, latency, power management, coverage expansion, and capacity enhancement by recycling radio resources due to the short communication distance between a D2D pair(Gazestani, Ghorashi, Mousavinasab, & Shikh-Bahaei, 2019). The D2D communication also makes it possible to offer new services including traffic offloading, location-based commercial proximity, content sharing for files, films, or images, gaming, and connectivity expansion(Kamruzzaman, Sarkar, Gutierrez, & Ray, 2019). D2D communication is a crucial enabler technology in the general cellular networks like 4G Long-Term Evolution(LTE), 5G networks and beyond because of these advantages(Malik, Wadhwa, & Khinda, 2020). The number of mobile devices that are connected have increased exponentially during the past ten years, according to the telecom industry estimation(Kim, 2020). As a result of the widespread use of mobile devices and the explosive growth of spectrum-intensive multimedia applications like mobile video streaming, mobile gaming, and social networking, mobile data traffic is continuously increasing. According to Cisco and Ericsson studies, global mobile video traffic is anticipated to expand at a compound annual growth rate of 11% per year from 2016 to 2022(Kim, 2020),(Morley, Widdicks, & Hazas, 2018). With the implementation of the sixth-generation (6G) future networks, this tendency is anticipated to grow even more quickly. The standard cellular network infrastructure may not be able to support high data rate connectivity for new applications because to the massive number of mobile devices and spectrum requirements(Alraih et al., 2022). Heterogeneous networks (HetNets) design has been suggested by business and academic

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

researchers as a potential solution for future wireless networks to help reduce base station congestion. By placing an increasing number of small base stations (SBSs) over the region now covered by macro base stations (MBS), it transforms the conventional single-cellular networks into multitier HetNets. The backhaul cables that connect the MBS and the accompanying SBSs are tightly integrated. The density of SBS deployment allows for improved traffic offloading from MBS to SBS by bringing spectrum access points closer to mobile devices.

In order to connect mobile devices for ubiquitous data transmission when they are too far apart for direct connection, network-assisted D2D communication has recently been proposed. As a matter of fact, mobile device pairs for D2D communications could be placed in various cell regions, with BSs acting as relay nodes, **refer to Fig 1**. A network architecture provides assistance to the relay BSs' cellular spectrum resources, which are then shared for the D2D communication lines(Kim, 2020). In the work of (Nie & Zhao, 2021), 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. While (Ioannou, Vassiliou, Christophorou, & Pitsillides, 2020) utilized 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. Furthermore , (Ioannou, Christophorou, Vassiliou, & Pitsillides, 2022) consolidated on the Distributed Artificial Intelligence (DAI) Framework, which made use of Belief-Desire-Intention extended (BDIx) agents located on D2D Mobile Devices in order to construct D2D communication in a distributed, autonomous, efficient, and adaptable manner. They employed Differentially Private Interactive Algorithm Selection using Pythia (DAIS) Algorithm which 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 surface (RIS) technology was viewed as a promising way to improve D2D communications and maximize the sum rate of the cellular joint optimization(Jia, Yuan, & Liang, 2020). 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 base on D2D vehicle to vehicle (V2V) virtual network communication(Xu et al., 2022). 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 utilisation and better quality of service.

According to (Abbasi-Verki, Yousefi, & Kalbkhani, 2022), power control algorithm was used for power minimization, sum power reduction and increase the resource utilization. Their results of a thorough analysis utilizing the Hungarian matching algorithm to maximize life-energy efficiency demonstrated that their suggested approach boosts cluster-head life and improves

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

energy efficiency in D2D multicast services.. In addition,(Omran & Kadoch, 2019), provided Kuhn mukers technique for D2D communication through the use of channel distribution. Their technique give better energy efficiency and better throughput when used in different network. The design of Elliptic Curve Cryptography(ECC) based public key cryptosystem for D2D communication in 5G Internet of Things(IoT) was conducted by(Seok et al., 2019), 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(Basak & Acharya, 2020). They considered both random base stations and fixed base stations. Their result ascertain that random base stations 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 (T. Feng, Zhang, Tong, & Zhang, 2021), 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 (Hong et al., 2022) 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(Hao, Ni, Li, & Hou, 2018). 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(Bayat et al., 2021). 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 higher 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 (R. Khan, Tsiga, & Asif, 2022) to proposed 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 (FD OMA).In this regard, load balancing and user relay selection in the developing D2D communications have drawn a lot of attention. A D2D relay selection strategy based on link information, for instance, was proposed by the authors(M. Feng, Mao, & Jiang, 2022),(Mach & Becvar, 2022),(Singh, Chattopadhyay, & Ghosh, 2022). Discovering the relay with the best

Journal of Science, Management and Technology
ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

possible link was their objective. Several research introduced the idea of D2D as a potential means of expanding network capacity and admit more computing devices seamlessly. The foundation of D2D is the ability for two or more nearby mobile users to connect directly to one another and communicate without utilizing the base station(Sangaiah, Javadpour, Pinto, Ja'fari, & Zhang, 2022).

4. System Model

In proposing the implementation model , we take into account a multi-cell network in which each cell can only have one user pair (a mobile transmitter and its intended mobile receiver) assigned to a specific frequency channel. At first, every user pair uses the same channel for both uplink and downlink transmissions when communicating in cellular mode. We presume that overlay D2D communication, in particular, preserves the same channel that was assigned for the communication in cellular mode when a user pair switches to D2D mode. We concentrate on the one-way communication between two users, more specifically on the data transmission within a cell from cellular user1 (UE1) to cellular user2 (UE2). Both data and control transmissions take place on the same channel when the user pair UE1 - UE2 converses. The BS has a multi-user multiple-input multiple-output (MU-MIMO) receiver that enables it to receive two concurrent uplink signals on the same channel: the data signals from UE1 and the control signals from UE2. Furthermore, in-band FD operations are possible for BS users as well as mobile users. The SINR is modelled as being equal to the node's transmission power times the attenuation factor. Here, the theoretical framework is offered, with Cell A and Cell B, and concentration of UE1 and UE2, that make up the entirety of the network. According to (Aderinola & Shuaibu, 2022), The Path Loss Model was employed as;

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

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

$$PL_{CB}[dB] = 38.46 + 20 Log10\; d(m) + 0.7d + 18.3n(n+2)(n+1) - 0.46 \quad (2)$$

Signal to noise ratio can be given as

$$SINR_{DL} = PdGdd/\,(No+PcGcd) \quad (3)$$

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

Where

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

$$SINR_{UL} = PdGdd/\,(No+PcuGcud) \quad (5)$$

$$SINRe_{NB} = PcuGcud/\,(No+PdGdc) \quad (6)$$

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

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)

Mathematical expression 1-2 [3]

Mathematical expression 3-6 [4]

Table 1: Simulation-related variables

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

Journal of Science, Management and Technology
ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

5. Results of Simulation

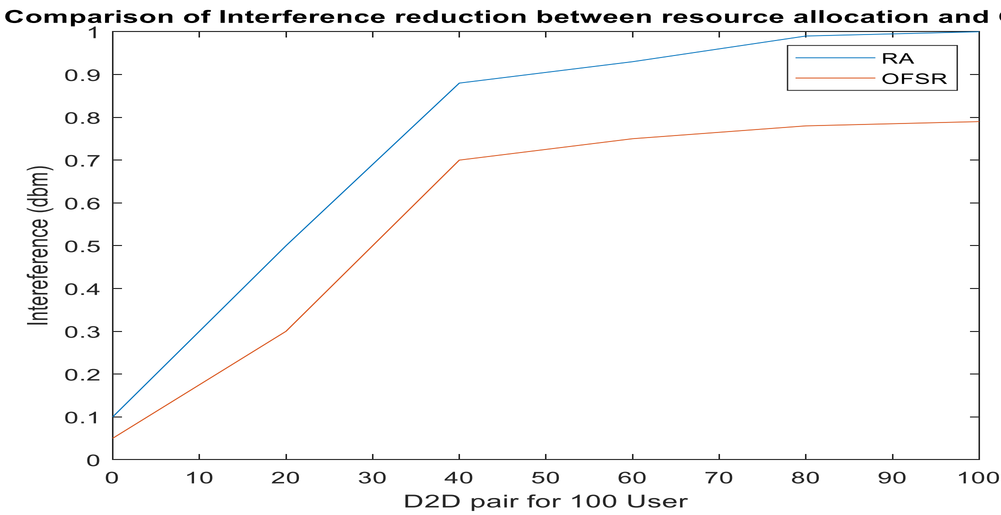

Fig 4 (a) Comparison of resource allocation and OFSR for interference reduction (D2D pair for 100 user)

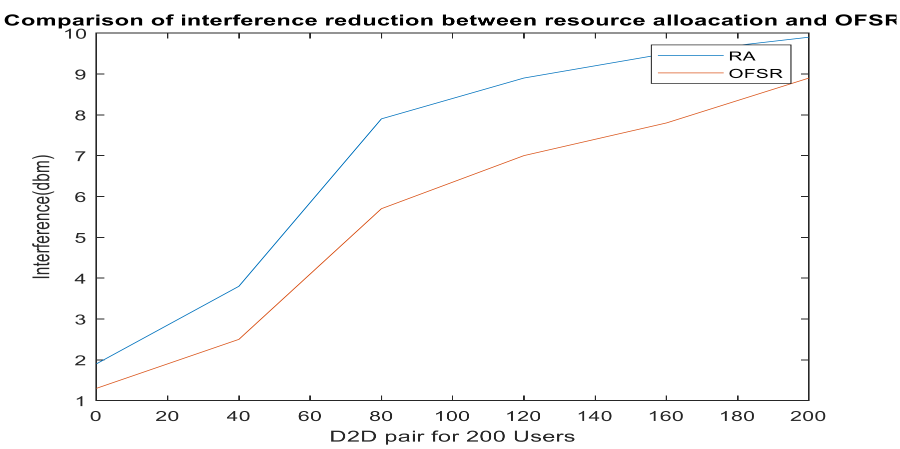

Fig 4 (b) Comparison of OFSR and resource allocation for interference reduction (D2D pair for 200 user)

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

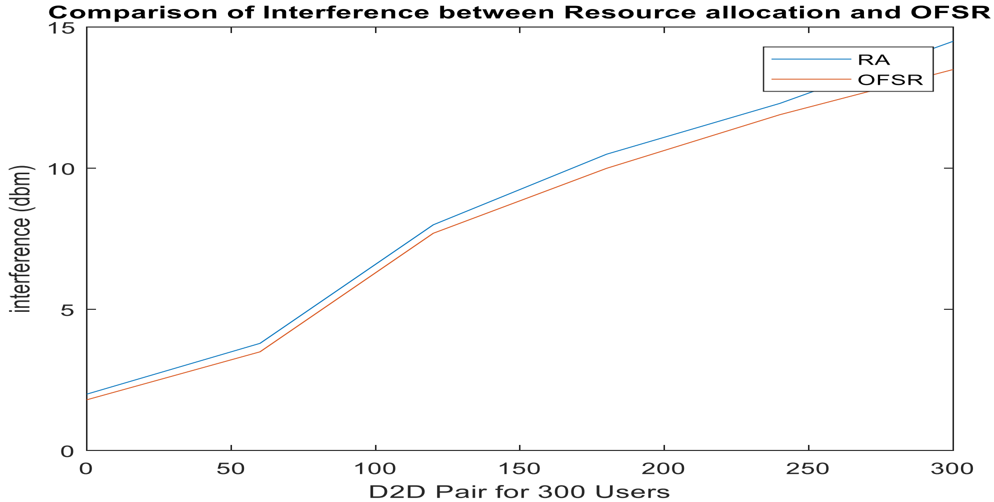

Fig 4(c) Comparison of OFSR and resource allocation for interference reduction (D2D pair for 300 user)

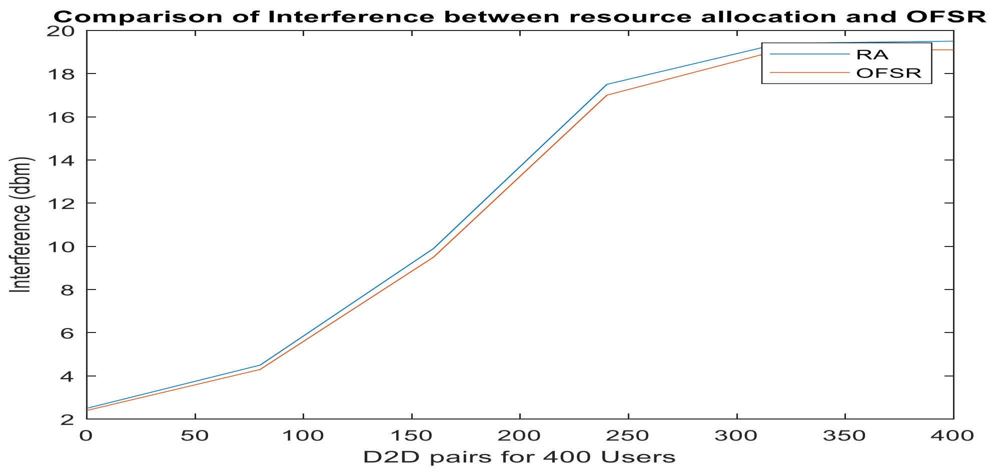

Fig 4(d) Comparison of resource allocation and OFSR for interference reduction (D2D pair for 400 user)

Journal of Science, Management and Technology
ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

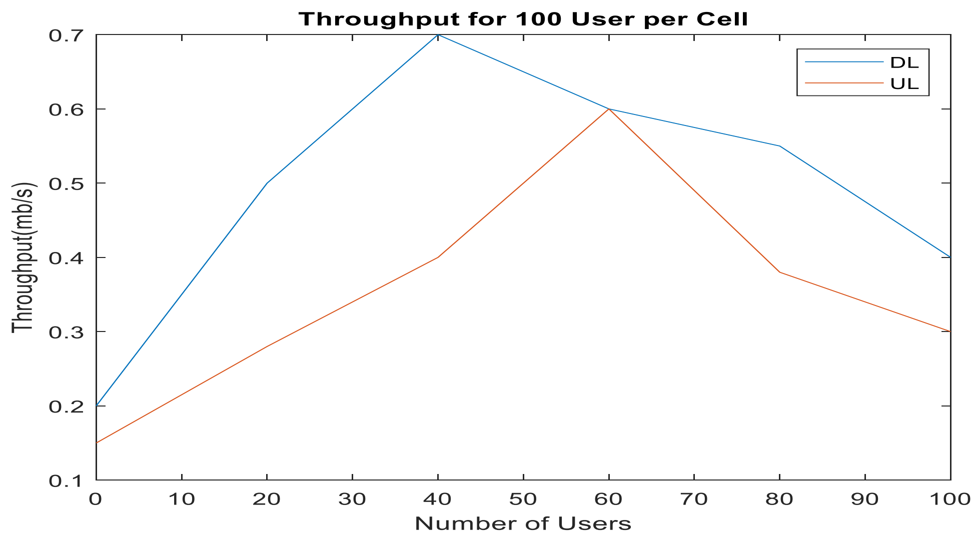

Fig 5(a) The 100 users per cell throughput of the cellular network

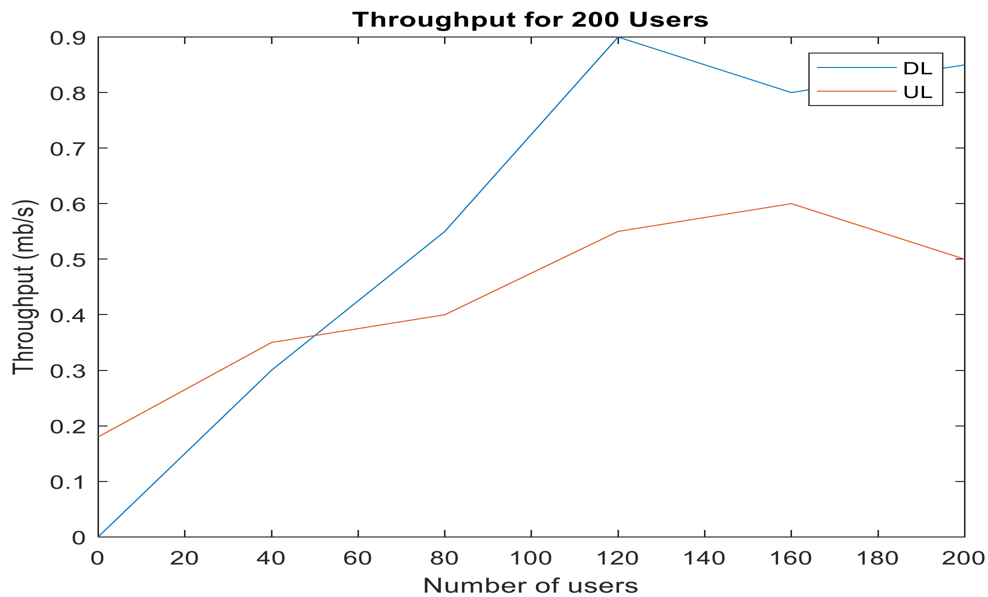

Fig 5(b) The 200 users per cell throughput of the cellular network

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

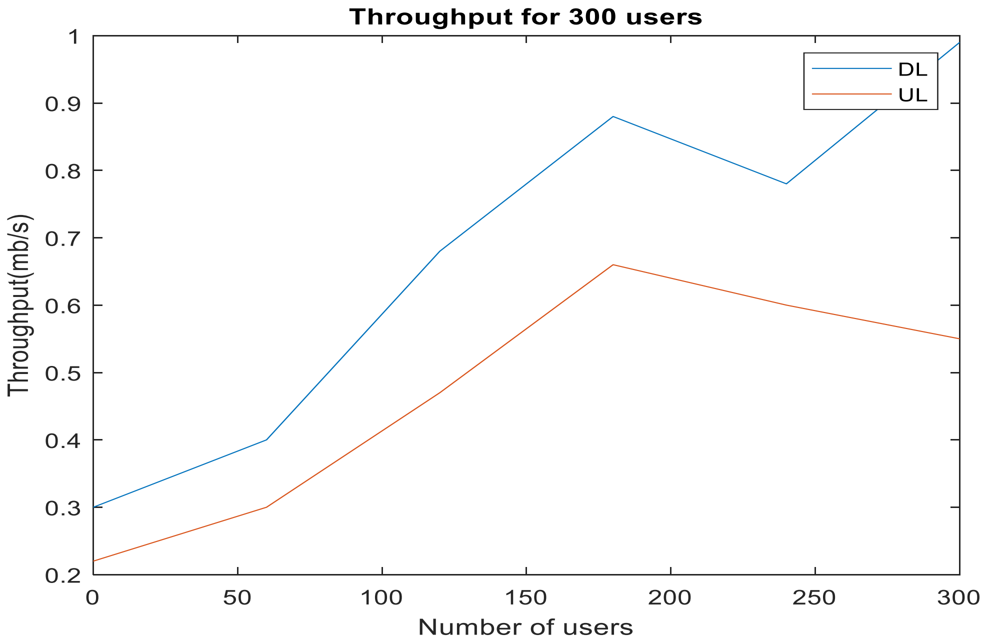

Fig 5(c) The 300 users per cell throughput of the cellular network

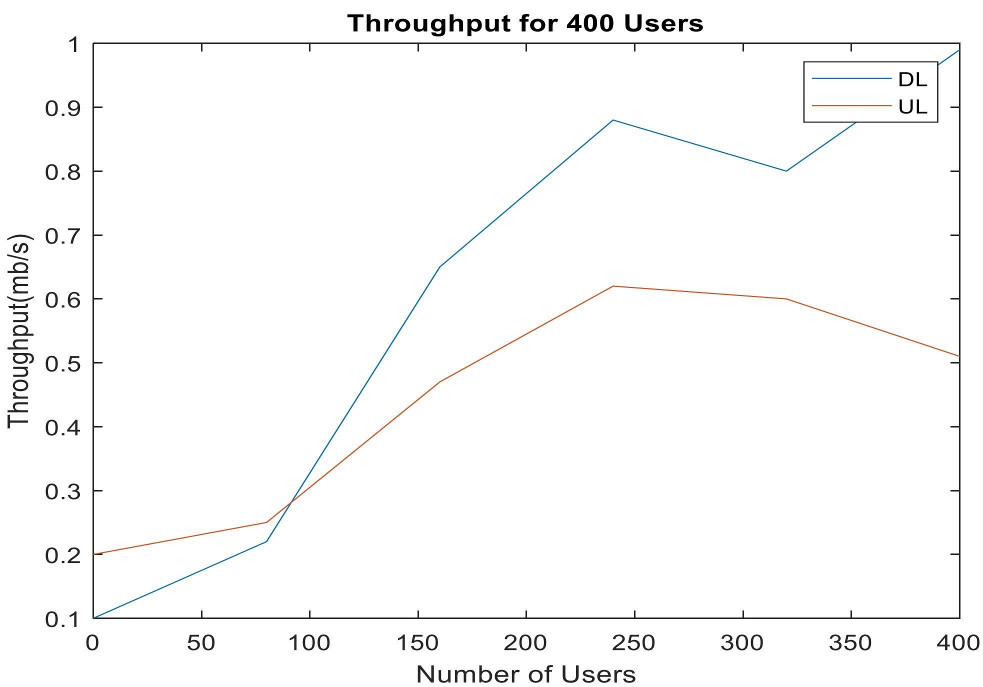

Fig 5(d) The 400 users per cell throughput of the cellular network

6. Discussion of Result

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

The optimized frequency spectrum reuse technique for managing radio frequency resources intelligently can make it possible to use D2D communication in cellular networks. Consideration of the path loss gain (and consequently the physical distance between the concerned users) is the most logical and straightforward method for choosing the communication mode for a pair and reducing interference. The solution can be explained geometrically using this method. However, distance-based solutions do not take into consideration the quality of the actual connection, which can also be impacted by shadowing, fading, and co-channel interference. For the first 100 users, the result in fig. 4(a) compares the interference reduction effects of resource allocation (RA) and optimal frequency spectrum reuse (OFSR). The graph demonstrates that when compared to RA, OFSR has less interference. The same thing holds true for Figures 4(b) and 4(d), when there are 400 users on the cellular network system. The throughput for uplink (UL) and downlink (DL) for the first 100 users is shown in Fig. 5(a). The amounts of throughput for UL and DL were shown in figs. 5(b) through 5(d), and the same thing holds true for them. According to the displayed graph, the DL has a higher throughput in any of the four scenarios.

7. Conclusion

When underlay D2D links are used, the authors of the current research proposed a method for boosting the overall capacity of fully loaded cellular networks while reducing the total uplink transmit power. The paper shown that energy efficiency has increased while maintaining the necessary QoS in terms of SINR for all users. The solved optimization problem was broken down into two smaller problems, with each smaller problem being solved separately. Results from simulations show how our suggested method improves. It has been demonstrated that D2D communication can reduce interference. When the results from OFSR and RA were examined, it was found that OFSR had less interference than RA. In four separate scenarios taken into consideration, the downlink throughput is greater than the uplink throughput. So, the recommended decision criteria are perceived SINR and channel quality. Better system performance results from solutions based on optimization formulations. Due to their intricacy and the additional communication overhead required, they are frequently less useful. This point is made even more clear in multi-cell settings and for the collaborative resolution of the three radio resource management issues. Due to this, the majority of the current research focuses on either offering workable heuristic alternatives or on solving each of these challenges independently.

8. **Acknowledgement**

This research work was supported by U&J Digital Consult Limited with Company registration Number (RC:1692126) Federal Republic of Nigeria under Special Educational Consultancy Services.

Reference

Abbasi-Verki, M., Yousefi, S., & Kalbkhani, H. (2022). Socially-aware and energy-efficient resource allocation and power control for D2D multicast content distribution. Journal of Network and Computer Applications, 204, 103415.

Aderinola, M., & Shuaibu, I. (2022). Application of optimized frequency spectrum reuse (OFSR) for D2D communication in cellular network.

Ahmad, S., Cherif, N., Naseer, S., Ijaz, U., Faouri, Y. S., Ghaffar, A., & Hussein, M. (2022). A wideband circularly polarized CPW-fed substrate integrated waveguide based antenna array for ISM band applications. Heliyon, 8(8), e10058.

Alraih, S., Shayea, I., Behjati, M., Nordin, R., Abdullah, N. F., Abu-Samah, A., & Nandi, D. (2022). Revolution or evolution? Technical requirements and considerations towards 6G mobile communications. Sensors, 22(3), 762.

Arnez, J. J. A., Silva, W. M., Do Reis, R. K. G., Da Silva, L. A., & Damasceno, M. G. L. (2022). SDR 5G NSA Mobile Network and an IMS Core to provide Voice Over IP LTE service. Paper presented at the 2022 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC).

Basak, S., & Acharya, T. (2020). On energy efficient secure routing in multi-hop underlay D2D communications for IoT applications. Ad Hoc Networks, 108, 102275.

Bayat, S., Jalali, J., Khalili, A., Mili, M. R., Wittevrongel, S., & Steendam, H. (2021). Optimal Multi-Objective Resource Allocation for D2D Underlaying Cellular Networks in Uplink Communications. IEEE Access, 9, 114153-114166.

Bhardwaj, A., & Agnihotri, S. (2018). Energy-and spectral-efficiency trade-off for D2D-multicasts in underlay cellular networks. IEEE Wireless Communications Letters, 7(4), 546-549.

Cheng, R.-S., Huang, C.-M., & Chen, H.-H. (2022). MD2DO: A Channel Selection Method for Device to Device Communication Using the Mobile Edge Computing (MEC) Paradigm. Mobile Networks and Applications, 27(1), 15-32.

Feng, D., Lu, L., Yuan-Wu, Y., Li, G. Y., Feng, G., & Li, S. (2013). Device-to-device communications underlaying cellular networks. IEEE Transactions on communications, 61(8), 3541-3551.

Feng, M., Mao, S., & Jiang, T. (2022). Dealing with Link Blockage in mmWave Networks: A Combination of D2D Relaying, Multi-beam Reflection, and Handover. IEEE Transactions on Wireless Communications.

Feng, T., Zhang, J., Tong, Y., & Zhang, H. (2021). Q-learning algorithm in solving consensusability problem of discrete-time multi-agent systems. Automatica, 128, 109576.

Gazestani, A. H., Ghorashi, S. A., Mousavinasab, B., & Shikh-Bahaei, M. (2019). A survey on implementation and applications of full duplex wireless communications. Physical Communication, 34, 121-134.

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

Gour, R., & Tyagi, A. (2018). Channel selection and power allocation for device-to-device enabled cellular networks. IET Communications, 12(15), 1854-1863.

Hao, Y., Ni, Q., Li, H., & Hou, S. (2018). Robust multi-objective optimization for EE-SE tradeoff in D2D communications underlaying heterogeneous networks. IEEE Transactions on communications, 66(10), 4936-4949.

Hong, Z. H., Zhang, L., Li, W., Wu, Y., Zhu, Z., Park, S.-I., . . . Iradier, E. (2022). Frequency-Domain RF Self-Interference Cancellation for In-Band Full-Duplex Communications. IEEE Transactions on Wireless Communications.

Hossain, E., Rasti, M., Tabassum, H., & Abdelnasser, A. (2014). Evolution toward 5G multi-tier cellular wireless networks: An interference management perspective. IEEE Wireless Communications, 21(3), 118-127.

Ioannou, I., Christophorou, C., Vassiliou, V., & Pitsillides, A. (2022). A distributed AI/ML framework for D2D Transmission Mode Selection in 5G and beyond. Computer Networks, 210, 108964.

Ioannou, I., Vassiliou, V., Christophorou, C., & Pitsillides, A. (2020). Distributed artificial intelligence solution for D2D communication in 5G networks. IEEE Systems Journal, 14(3), 4232-4241.

Jia, S., Yuan, X., & Liang, Y.-C. (2020). Reconfigurable intelligent surfaces for energy efficiency in D2D communication network. IEEE Wireless Communications Letters, 10(3), 683-687.

Kamruzzaman, M., Sarkar, N. I., & Gutierrez, J. (2022). A dynamic algorithm for interference management in D2D-enabled heterogeneous cellular networks: Modeling and analysis. Sensors, 22(3), 1063.

Kamruzzaman, M., Sarkar, N. I., Gutierrez, J., & Ray, S. K. (2019). A mode selection algorithm for mitigating interference in D2D enabled next-generation heterogeneous cellular networks. Paper presented at the 2019 International Conference on Information Networking (ICOIN).

Kaufman, B., Lilleberg, J., & Aazhang, B. (2013). Spectrum sharing scheme between cellular users and ad-hoc device-to-device users. IEEE Transactions on Wireless Communications, 12(3), 1038-1049.

Kazaure, J. S., Matthew, U. O., Okafor, N. U., & Okey, O. D. (2021). Telecommunication Network Performances and Evaluation of Radio Frequency Electromagnetic Radiation: Health Effects of the RF-EMR GSM Base Stations. International Journal of Information Communication Technologies and Human Development (IJICTHD), 13(3), 16-37.

Khan, A. (2020). Resource Management in Mobile Networks for Machine-to-Machine Communication. University of Engineering & Technology Peshawar (Pakistan).

Khan, R., Tsiga, N., & Asif, R. (2022). Interference management with reflective in-band full-duplex NOMA for secure 6G wireless communication systems. Sensors, 22(7), 2508.

Kim, S. (2020). Heterogeneous Network Spectrum Allocation Scheme for Network-Assisted D2D Communications. Mobile Information Systems, 2020.

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

Li, J., Wu, D., Yue, C., Yang, Y., Wang, M., & Yuan, F. (2022). Energy-Efficient Transmit Probability-Power Control for Covert D2D Communications With Age of Information Constraints. IEEE Transactions on Vehicular Technology.

Mach, P., & Becvar, Z. (2022). Device-to-Device Relaying: Optimization, Performance Perspectives, and Open Challenges Towards 6G Networks. IEEE Communications Surveys & Tutorials, 24(3), 1336-1393.

Malik, P. K., Wadhwa, D. S., & Khinda, J. S. (2020). A survey of device to device and cooperative communication for the future cellular networks. International Journal of Wireless Information Networks, 27(3), 411-432.

Matthew, U. O., & Kazaure, J. S. (2021). Chemical polarization effects of electromagnetic field radiation from the novel 5G network deployment at ultra high frequency. Health and Technology, 11(2), 305-317.

Matthew, U. O., Kazaure, J. S., John, O., & Haruna, K. (2021). Telecommunication Business Information System and Investment Ecosystem in a Growing Economy: A Review of Telecom Investment in Nigeria. International Journal of Information Communication Technologies and Human Development (IJICTHD), 13(2), 1-20.

Morley, J., Widdicks, K., & Hazas, M. (2018). Digitalisation, energy and data demand: The impact of Internet traffic on overall and peak electricity consumption. Energy Research & Social Science, 38, 128-137.

Nie, X., & Zhao, F. (2021). Pilot allocation and power optimization of massive MIMO cellular networks with underlaid D2D communications. IEEE Internet of Things Journal, 8(20), 15317-15333.

Ningombam, D. D., & Shin, S. (2018). Distance-constrained outage probability analysis for device-to-device communications underlaying cellular networks with frequency reuse factor of 2. Computers, 7(4), 50.

Nistor, A., & Zadobrischi, E. (2022). Analysis and Estimation of Economic Influence of IoT and Telecommunication in Regional Media Based on Evolution and Electronic Markets in Romania. Paper presented at the Telecom.

Omran, A., & Kadoch, M. (2019). Balancing D2D communication relayed traffic offloading in multi-tier HetNets. International Journal of Communications, Network and System Sciences, 12(06), 75.

Patil, P., & Hendre, V. (2022). Device to Device Communication for Next Generation Cellular Network: A Survey ICCCE 2021 (pp. 871-877): Springer.

Pawar, P., & Trivedi, A. (2021). Joint uplink-downlink resource allocation for D2D underlaying cellular network. IEEE Transactions on communications, 69(12), 8352-8362.

Rejeb, A., & Keogh, J. G. (2021). 5G networks in the value chain. Wireless personal communications, 117(2), 1577-1599.

ISSN (Print): 1597-7463; eISSN (Online): 2811-2598, Volume 5, Issue 2 https://dx.doi.org/10.4314/hpjsmt.v5i2.14

Safdar, G. A., Ur Rehman, M., Muhammad, M., & Imran, M. A. (2022). Interference Mitigation in D2D Communication Underlaying LTE-A Network. Interference Mitigation in Device-to-Device Communications, 13-47.

Sangaiah, A. K., Javadpour, A., Pinto, P., Ja'fari, F., & Zhang, W. (2022). Improving quality of service in 5G resilient communication with the cellular structure of smartphones. ACM Transactions on Sensor Networks (TOSN), 18(3), 1-23.

Sarma, S. S., Khuntia, P., & Hazra, R. (2022). Power control scheme for device-to-device communication using uplink channel in 5G mm-Wave network. Transactions on Emerging Telecommunications Technologies, 33(6), e4267.

Seok, B., Sicato, J. C. S., Erzhena, T., Xuan, C., Pan, Y., & Park, J. H. (2019). Secure D2D communication for 5G IoT network based on lightweight cryptography. Applied Sciences, 10(1), 217.

Singh, D., Chattopadhyay, A., & Ghosh, S. C. (2022). To Continue Transmission or to Explore Relays: Millimeter Wave D2D Communication in Presence of Dynamic Obstacles. IEEE Transactions on Mobile Computing.

Sun, K., Wu, J., Huang, W., Zhang, H., Hsieh, H.-Y., & Leung, V. C. (2020). Uplink performance improvement for downlink-uplink decoupled HetNets with non-uniform user distribution. IEEE Transactions on Vehicular Technology, 69(7), 7518-7530.

Taha, D. H., Haci, H., & Serener, A. (2022). Novel Channel/QoS Aware Downlink Scheduler for Next-Generation Cellular Networks. Electronics, 11(18), 2895.

Tushar, W., Yuen, C., Saha, T. K., Morstyn, T., Chapman, A. C., Alam, M. J. E., . . . Poor, H. V. (2021). Peer-to-peer energy systems for connected communities: A review of recent advances and emerging challenges. Applied Energy, 282, 116131.

Xu, C., An, J., Bai, T., Sugiura, S., Maunder, R. G., Wang, Z., . . . Hanzo, L. (2022). Channel Estimation for Reconfigurable Intelligent Surface Assisted High-Mobility Wireless Systems. IEEE Transactions on Vehicular Technology.

Zhang, R., Qi, C., Li, Y., Ruan, Y., Wang, C.-X., & Zhang, H. (2019). Towards energy-efficient underlaid device-to-device communications: A joint resource management approach. IEEE Access, 7, 31385-31396.

Zhi, Y., Tian, J., Deng, X., Qiao, J., & Lu, D. (2022). Deep reinforcement learning-based resource allocation for D2D communications in heterogeneous cellular networks. Digital Communications and Networks, 8(5), 834-842.