Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

A Comprehensive Review of D2D Communication in 5G and B5G Networks

Owais Muhammad[1], Hong Jiang[2], Bilal Muhammad[3], Mushtaq Muhammad Umer[4], Naeem Muhammad Ahtsam[5], Samuel Akwasi Danso[6]

[1,4]Ph.D. Scholar, School of Information Engineering, Southwest University of Science and Technology, Mianyang, 621010, China.

[2]Professor, School of Information Engineering, Southwest University of Science and Technology, Mianyang, 621010, China.

[3]Scholar, School of Software Engineering, Northeastern University, Shenyang, 110167, China

[5]Ph.D. Scholar, School of Information and Software Engineering, University of Electronic Sciences and Technology, Chengdu, 610000, China.

[6]HOD, Computer engineering department, Ghana Communication Technology University, Accra, Ghana

pingtoowais@gmail.com, jianghong@swust.edu.cn*, Muhammadbilalbsse@gmail.com, umer449@gmail.com, Muhammadahtsam1@outlook.com, sdanso@gctu.edu.gh

DOI: 10.5281/zenodo.10185013

ABSTRACT

The evolution of Device-to-device (D2D) communication represents a significant breakthrough within the realm of mobile technology, particularly in the context of 5G and beyond 5G (B5G) networks. This innovation streamlines the process of data transfer between devices that are in close physical proximity to each other. D2D communication capitalizes on the capabilities of nearby devices to communicate directly with one another, thereby optimizing the efficient utilization of available network resources, reducing latency, enhancing data transmission speed, and increasing the overall network capacity. In essence, it empowers more effective and rapid data sharing among neighboring devices, which is especially advantageous within the advanced landscape of mobile networks such as 5G and B5G. The development of D2D communication is largely driven by mobile operators who gather and leverage short-range communications data to propel this technology forward. This data is vital for maintaining proximity-based services and enhancing network performance. The primary objective of this research is to provide a comprehensive overview of recent progress in different aspects of D2D communication, including the discovery process, mode selection methods, interference management, power allocation, and how D2D is employed in 5G technologies. Furthermore, the study also underscores the unresolved issues and identifies the challenges associated with D2D communication, shedding light on areas that need further exploration and development.

Keywords: 5G, B5G, D2D, Power Allocation, Interference.

Cite as: Owais Muhammad, Hong Jiang, Bilal Muhammad, Mushtaq Muhammad Umer, Naeem Muhammad Ahtsam, & Samuel Akwasi Danso. (2023). A Comprehensive Review of D2D Communication in 5G and B5G Networks. *LC International Journal of STEM*, *4*(3), 25–46. https://doi.org/10.5281/zenodo.10185013

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

INTRODUCTION

The widespread adoption of digital applications like online video streaming, video conferencing, and cloud computing has given rise to a pressing need for wireless communication technologies that offer high-speed data transmission and minimal latency. In an era where users expect seamless and real-time experiences, high-speed wireless communication is crucial to ensure smooth video streaming and responsive video conferences. Simultaneously, low latency is imperative to minimize delays in data transmission, providing users with instantaneous and frustration-free interactions with their digital applications, and ultimately enhancing the overall quality of the digital experience (Nguyen et al., 2022). Meeting these demands for high-speed, low-latency wireless communication represents a significant challenge for the forthcoming 5G technology, which incorporates network slicing and aggregation as part of its framework. Notably, the 3rd Generation Partnership Project (3GPP) introduced D2D communication, which provides proximity-based services and was first described as 4G technology in Release 12. D2D communication effectively addresses the evolving needs of 5G networks, providing a potential solution to the demands of high-speed, low-delay data transmission essential for modern digital applications and services (Kar & Sanyal, 2020; Lin et al., 2014). D2D communication creates a direct connection that optimally utilizes the licensed spectrum, allowing nearby devices or users within a cellular network to communicate directly with each other without the need for relaying information through a central Base Station (BS) (Zhao et al., 2019). The promise of IoT (Internet of Things) devices lies in their ability to seamlessly connect with each other, independent of human intervention, a concept referred to as Machine to Machine (M2M) communications. This is important in the context of 5G-M2M communication within IoT, where M2M refers to a wireless communication mechanism for sharing local information involving one or more devices that do not require direct human involvement. D2D communication, a crucial component of this landscape, offers numerous benefits such as reduced latency, improved spectral efficiency, enhanced reliability, and increased system capacity. It's important to note that this emerging technology is a fundamental part of the 5G network, a departure from previous 4G technology, which didn't incorporate D2D communication (Jaafar et al., 2019).

Emerging technologies are reshaping how people share information, particularly in the realms of mobile computing and wireless communication. The typical cellular mobile environment, on the other hand, is still reliant on infrastructure. In this configuration, mobile users' connectivity is limited by the BS coverage region, and direct communication between mobile devices is not possible (Nwazor & Ugah, 2022). Contemporary communication technologies must possess the capability to transmit data when required via suitable network connections and exhibit the adaptability to enhance network capabilities. D2D communication is seen as a favorable approach that empowers mobile devices to communicate directly with each other, eliminating the necessity for access points or base stations (BSs) (Areqi et al., 2023). Wireless local area networks, wireless personal area networks, and analogous technologies are utilized for direct communication without the need for an allocated licensed frequency band. This approach provides the advantage of energy-efficient communication at a cost-effective rate, rendering it an appealing choice for a wide range of applications. (Doan et al., 2019; Mach et al., 2015; Wu et al., 2020). Opting for unlicensed frequency bands for communication may not always be the optimal decision, particularly when contemplating potential interference challenges. Conversely, D2D communication within a licensed frequency band presents benefits like regulated interference, heightened energy efficiency, and more effective utilization of the available spectrum resources. This makes it a highly attractive choice for direct communication within the context of 5G technology (Malik et al., 2020; Salih et al., 2020).

In a conventional cellular system, the standard practice involves routing all communication through base stations (BSs), and it generally does not allow devices to establish direct communication with one another. This dependence on centralized infrastructure can result in constraints concerning efficiency and adaptability in specific communication situations (Gismalla et al., 2022). D2D communication is engineered to capitalize on the close physical proximity of devices, thereby strengthening signal reception. This is especially advantageous in regions with limited network coverage. To create a comprehensive communication ecosystem, D2D should seamlessly complement conventional cellular network services. A pivotal element in D2D design is the effective allocation of resources, encompassing energy and radio spectrum, between D2D communication and traditional cellular networks. Striking the right balance in resource allocation is critical for maximizing network performance and ensuring a harmonious coexistence between these two communication modes (Hayat, Ngah, Kaleem, et al., 2020). D2D communication provides numerous advantages, notably improved content privacy and robust anonymity. These advantages arise from the absence of central data storage, thereby mitigating the risk of data exposure. Moreover, D2D communications hold promise in enhancing fairness in resource allocation, accelerating data transmission speeds, conserving energy, and diminishing communication latency. These attributes collectively contribute to a more efficient and responsive network (Feng et al., 2014). Furthermore, the performance of D2D communication experiences a substantial boost as system throughput increases and spectrum reuse is optimized through the direct routing of D2D traffic. This heightened efficiency in resource utilization results in remarkable enhancements in D2D communication capabilities (Nwazor & Ugah, 2022). D2D communication efficiently alleviates the load on cellular networks by diverting traffic away from infrastructure-based routes and facilitating direct D2D transmissions. This approach results in several advantages, including reduced transmission delay, energy conservation, and higher data transmission rates, making it a valuable addition to wireless communication systems (Wang & Yan, 2017). Standalone D2D communication has its limitations as it solely relies on links managed by individual devices, lacking the capacity for centralized channel management and relaying. On the other hand, network-assisted D2D leverages some control from the base station (BS) and operator-managed links but still faces challenges in fully maintaining channel selection and relay functions. Consequently, there is a pressing need for comprehensive research and attention to effectively manage interference in D2D communication, especially in scenarios where both standalone and network-assisted D2D approaches are in use (Chakraborty & Rodrigues, 2020).

To effectively implement D2D communication technology, there are numerous challenges that must be solved. Complex resource management techniques, effective device discovery (DD) methodologies, the creation of clever mode selection algorithms, and the creation of efficient mobility management practices are a few examples. Despite several research initiatives aimed at improving spectral efficiency and interference control in D2D communications, comprehensive studies addressing various aspects of D2D communications, including their requirements and problems, are conspicuously lacking. This underlines the need for a more in-depth examination of D2D communication in order to fully comprehend its complexity. The authors carried out a thorough examination that looks at both the well studied and less extensively studied facets of D2D interactions. This research should shed light on both areas where there is a lack of research and those where there is an abundance of it (Jameel et al., 2018). A survey was conducted by the authors (Gandotra & Jha, 2016; Pedhadiya et al., 2019), who concentrated on case studies and technology that improve direct-to-direct communication. The study also explores D2D communications-related issues such resource allocation, interference mitigation, and power distribution. This research likely provides valuable insights into the technologies and strategies that enable D2D communication, while also addressing critical technical challenges in this field.

To provide a comprehensive understanding of the fundamental principles within the D2D communication and its associated problems in light of recent advancements, an in-depth analysis of existing literature is essential. The primary aim of this paper is to provide readers with a foundational resource that delves into a range of challenges, potential solutions, recent innovations, and ongoing issues in D2D communications. In contrast to previous reviews, as illustrated in Table 1, we have organized prior research and challenges in the realm of Specific fields of D2D communication, namely DD, interference management, power allocation, and mode selection. These domains are recognized as pivotal elements in the quest to enhance network optimization and grasp the intricacies of D2D communication (Zhang et al., 2018).

Unlike previous surveys and reviews that have covered all these topics as a whole, this study takes a different approach. It specifically delves into recent developments within the D2D communication field, with a focus on identifying problem areas, exploring the methods and techniques proposed to address these problems, and critically assessing the limitations of these solutions. Additionally, the research also analyzes emerging challenges in D2D communications. Essentially, it offers a detailed and up-to-date exploration of the specific issues, potential solutions, and evolving challenges in the realm of D2D communication.

Table 1: A summary of previous relevant reviews

References	Challenges			
	Device Discovery	Interference Management	Resource allocation and power allocation	Mode Selection
(Ansari et al., 2017)	✓	✓		
(Gismalla et al., 2022)		✓	✓	✓
(Siddiqui et al., 2021)		✓		
(Salim et al., 2023)			✓	
(Alibraheemi et al., 2023)		✓	✓	
(Asadi et al., 2014)			✓	
(Raghu & Kiran, 2022)		✓		
(Islam & Kwon, 2022)			✓	
(Jameel et al., 2018)		✓	✓	
(Kumar Jadav et al., 2022)			✓	
(Noura & Nordin, 2016)		✓		
(Gandotra & Jha, 2016)	✓		✓	
(Zhang et al., 2018)	✓			
(Hayat et al., 2021)	✓		✓	
Proposed	✓	✓	✓	✓

The primary goal of this review paper is to provide readers with the latest research developments in the field of D2D communications, including optimal solutions, their results, and restrictions. Specifically, this paper aims to make the following contributions:

- Outlining a thorough literature assessment of current developments in particular D2D fields, including the mode selection procedures designed for D2D applications, interference control, power allocation strategies, and discovery processes.
- Spotlighting areas of research problems and difficulties that demand more consideration and possibly future study. This aspect of the paper aims to identify and underline the aspects of D2D communications that require additional exploration and innovation.

The paper is organized as follows in its subsequent sections: Section 2 conducts an extensive examination and evaluation of D2D DD methods, and Section 3 furnishes a thorough summary of interference control approaches in D2D communication. Section 4 discusses power allocation schemes in D2D communications, followed by a discussion of mode selection schemes and recent advancements in Section 5. The paper then explores challenging issues in D2D communication in Section 6. Finally, Section 7 serves as the conclusion, summarizing key observations and findings drawn from the preceding sections, providing readers with a cohesive understanding of the current state and challenges in the D2D communication landscape.

Device Discovery

Device discovery in wireless communication, crucial for 5G, occurs when devices send signals via a base station to locate nearby devices. This process can be centralized, where a central entity like a base station manages it, or distributed, with devices autonomously discovering each other. The decision depends on the particular use cases and the requirements of the network (Vaishnav et al., 2022). These categories serve as the foundation upon which all other approaches and functions in the system are built. They lay the groundwork for classifying and designing diverse approaches, maintaining consistency and congruence with the system's goals. (Yan et al., 2017). A central entity, commonly located at an access point or base station, plays an important role in allowing device interaction in centralized device discovery (DD). When a gadget wishes to connect with other devices nearby, it broadcasts this intention to the base station. The base station then collects critical information, including channel conditions, power levels, and interference management rules, all of which are tailored to the system's individual requirements. This centralized strategy allows for efficient device detection coordination and resource allocation. Predefined protocols govern the extent to which the base station participates in device discovery. Devices are not permitted to begin DD independently with other devices when the base station is fully engaged. Instead, the base station regulates and facilitates all discovery signals transmitted between devices. In this case, devices use the base station's already broadcast discovery signals to begin the DD process.

In cases when the base station's function is constrained, devices can emit discovery signals without obtaining prior clearance from the base station. This suggests that the gadgets will have more autonomy throughout the discovery process. This differential in engagement levels with the base station provides for greater flexibility in how device discovery is handled inside the network. However, the BS is responsible for transmitting critical information like as the Signal-to-Interference Noise Ratio (SINR) and path gain for each device. This information is crucial for the BS to assess the feasibility of communication for each device. Subsequently, the BS requests both devices to initiate the communication process, ensuring that the conditions are favorable and communication is viable for all

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

parties involved. This coordinated approach helps optimize and facilitate effective D2D communication within the network (Fodor et al., 2016).
In decentralized device discovery, devices are permitted to find other devices independently of the base station. Devices utilize control signals at varying time intervals with the goal of recognizing nearby devices. However, the dispersed mode has a number of difficulties, including synchronization problems, interference, and the strength of the discovery signals. Due to this, it is generally believed that in-band device identification is more efficient in D2D design. There have been many different in-band and out-of-band categories for device detection systems presented. Network-assisted discovery, beacon-based discovery, and DD fall under the in-band category, whilst other methods fall under the out-of-band category. For a detailed comparison of these DD schemes in D2D communications, please refer to Table 2, which provides a summary of their characteristics.

Table 2: Comparing device discovery methods in D2D communication

Reference	Method	Objective
(Chour et al., 2017)	VANET	Improve latency, power efficiency, and throughput
(Mosbah et al., 2019)	Discovery algorithm	Improve network utilization and time required for discovery
(Zhang et al., 2017)	Random back-off procedure	Improve latency
(Li et al., 2018)	Sequential estimation scheme	Improve latency and power efficient
(Hayat, Ngah, Hashim, et al., 2019)	Device discovery algorithm	Improve latency and energy efficient
(Hayat, Ngah, & Zahedi, 2019)	A device discovery technique is proposed	Energy efficient
(Hayat, Ngah, & Mohd Hashim, 2020)	Discovery algorithm	Fast Discoverability
(Swain & Murthy, 2020)	Proposed device discovery scheme	Fast Discoverability
(Kaleem et al., 2019)	D2D discovery maximization algorithm	Improves Energy-efficient and Fast Discoverability
(Hayat et al., 2021)	Sector Scanning Algorithm	Improves Energy-efficient and Fast Discoverability

Latest Developments in Discovering Devices

The significance of D2D communication in next-gen cellular networks is highlighted, emphasizing its role in proximity-based services. It discusses the challenge of peer discovery in D2D and introduces a novel approach, a self-organized mobility-aware device discovery mechanism (SMDD), utilizing self-organization and mobility awareness. SMDD significantly enhances peer discovery rates, cluster formation times, and energy efficiency compared to other algorithms (Kumari & Tyagi, 2022). The authors presented a technique for discovering energy-efficient devices that were designed for public safety purposes. The designers of this system accommodate for concurrent user access to resources and overcome important limits associated with overlay interference in D2D networks. The outcomes of this approach are noteworthy, resulting in the discovery of a substantial number of energy-efficient devices while also boosting the overall count of DD compared to static or random back-off patterns (Kaleem et al., 2019). A D2D DD approach in which a device initiates the discovery of neighboring devices. They discuss static device discovery outside the network and investigate the timing of these discoveries. Another author also developed a mathematical model that can be applied to mobile D2Ds. To validate their findings, they conducted Monte-Carlo simulations (Jaffry et al., 2019). The authors (Kaleem et

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

al., 2020) introduced a time-efficient, full-duplex device discovery system for public safety applications within the D2D framework. This system leverages the IB-FD (In-Band Full-Duplex) framework and places a strong emphasis on improving SE and reducing the delay associated with DD in public safety scenarios. The proposed framework allows for the transmission mode to switch from half-duplex to full-duplex. Through simulations, the results were verified and compared to a conventional random-access technique. The outcome of these simulations revealed that employing the public safety priority method led to approximately 37 percent reduction in device discovery time compared to the random-access technique. In a 5G heterogeneous network, an authentication mechanism designed for D2D communication and privacy-preserving DD. Elliptic-Curve Diffie-Hellman approaches, the authors provided an authentication strategy that combines identity-based procedures with built-in privacy protection for device identification. The performance analysis of this scheme demonstrated its capability to safeguard privacy with optimal efficiency (Sun et al., 2019). The author (Kaleem et al., 2018), proposed a full-duplex DD system for a D2D network, with a focus on public safety applications and prioritization. The study's findings revealed that in-band full-duplex operation is more effective in efficiently utilizing radio resources when compared to half-duplex operation. Additionally, the suggested approach was observed to reduce device discovery time by approximately 37 percent. The author introduces an innovative device discovery method for in-band D2D communication, which utilizes a Cell Sector Scanning Algorithm in scenarios involving random walk and velocity-based movement. The study divides the coverage area into 8 sectors, optimizing the utilization of radio resources for proximity-based device discovery. The proposed algorithm is characterized by speed, precision, and energy efficiency at both the device and network levels. It notably enhances the quality of discovery by more than 20% compared to linear estimation and reduces energy consumption by 24%, especially in densely populated areas, while maintaining adaptability to changing environmental conditions (Hayat et al., 2021).

Interference Management

Cellular user interference poses a significant challenge in D2D communication. This interference occurs when both cellular users and D2D pairs utilize the same cellular resources, resulting in interference issues. The type of interference varies depending on the operation mode of the D2D network, whether it's in an uplink or downlink scenario. In both situations, D2D users may encounter interference from within their own cell (referred to as intracellular interference) or from neighboring cells (known as intercellular interference). This interference can degrade the quality of transmissions by compromising the SINR, which is a crucial factor in determining successful data transmission (Annur et al., 2021). In this section, several interference management techniques are discussed. There are three basic categories that these methods fall under interference coordination, interference avoidance, and interference cancellation. Table 3 provides a concise summary of these interference management approaches in the context of D2D communications.

Table 3: An overview of interference management in D2D communication

Reference	Method	Objective	Channel	Interference Type
(Aslam et al., 2019)	Game theory	Interference management	Uplink	Decentralized
(Doumiati et al., 2019)	Topological interference management	Low computation complexity	Uplink and downlink	Centralized
(Liu et al., 2016)	Stackelberg game	Interference management and resource allocation	Uplink	Centralized

(Raziah et al., 2022)	Low-energy adaptive clustering hierarchy	Interference management and power control	Uplink and downlink	Decentralized
(Yang, Cheng, et al., 2017)	Graph theory-based	Energy efficiency	Uplink and downlink	Distributed
(Shamaei et al., 2023)	Poisson Point Process	Resource allocation	Uplink and downlink	Distributed
(Shamaei et al., 2018)	Matching theory-based algorithm	Resource allocation and low complexity	Downlink	Distributed
(Kamruzzaman et al., 2022)	Dynamic algorithm	Minimize the interference	Uplink	Distributed
(Zhao et al., 2018)	Greedy-based algorithm	Minimize the interference and low computation complexity	Uplink	Centralized

Latest Developments in Interference management

Avoiding Interference

To eliminate conflicts between D2D and cellular connections, interference avoidance techniques are used. Because of its responsiveness to traffic needs and minimal control overhead, they chose a distributed approach for interference control. They developed a completely distributed random-access protocol for D2D connections in cellular networks. Interferes are prevented from sending signals near D2D receivers using this approach of interference avoidance. The results show that the suggested distributed D2D scheme beats the conventional technique by a large margin, despite the fact that the simulation only included device locations following a Poisson point process (Kong, 2020). In this study, they introduced a multiuser D2D system known as MD2D that allows simultaneous D2D transmissions. To tackle interference across multiuser D2D environments, they utilized Multiple-Input Multiple-Output. The system assesses different antenna combinations to determine their ability to eliminate interference between pairs and then employs a bucket-based degree of freedom method to configure antenna usage effectively for interference elimination. The results of this approach indicate a remarkable 87.39 percent improvement in throughput compared to traditional interference avoidance schemes, and in large-scale simulations, the improvement reaches up to 218.84 % (Chiu et al., 2016). In order to handle interference in D2D communication, the author presents a novel power control method based on the Low-energy adaptive clustering hierarchy protocol. It outperforms the traditional fixed power control method and a modified version (MFPC) in terms of reducing interference and improving signal quality (Raziah et al., 2022). The authors proposed a radio resource allocation strategy for multihop D2D connections, with an emphasis on interference avoidance approaches in LTE-A networks. Their goal was to apply the concepts of single-hop D2D technology to multi-hop D2D communications. According to their findings, when these proposed techniques and appropriate power control are used, established D2D networks may efficiently reuse cellular frequency bands while reducing interference to cellular communication (Dubey et al., 2022).

Interference Coordination

Inband D2D communication benefits greatly from interference coordination techniques. Coordination and monitoring are principally provided by the Base Station in the Centralized Interference Coordination system, which plays a critical role in interference management. However, because D2D nodes actively engage in the coordination process, the demand for considerable monitoring from the BS is eliminated by the Decentralized Interference Coordination system. These interference coordinating approaches are critical for lowering interference between cellular and D2D networks, ultimately improving the overall performance and quality of communication in such networks. The authors employed full-duplex communication in a D2D communication environment but faced interference challenges when devices operated in full-duplex mode. To address this, they introduced a graph-coloring-based resource-sharing scheme as a solution to jointly optimize the system with minimal complexity. This scheme was implemented to enhance spectrum utilization in D2D communication (Yang, Zhang, et al., 2017). The author's proposed method introduces a decentralized approach for managing both interlayer and intralayer interferences. It leverages the pricing concept, utilized by the BS to control inter-layer interference, while intralayer interference is managed through game theory (Aslam et al., 2019). The author presents an interference coordination scheme for D2D communication networks using an improved Stackelberg model. It combines resource allocation and power control, employing a Deep Q Network (DQN) to optimize the system. This approach enhances QoS for cellular users while effectively managing interference in D2D communication networks, outperforming similar algorithms (Xinzhou Li et al., 2023).

Cancellation of Interference

Interference cancellation techniques are methods that utilize advanced decoding and coding strategies to eliminate or mitigate interference signals at either the DUE or CUE. These techniques are employed to improve the overall capacity and efficiency of cellular networks. By effectively reducing or canceling out interfering signals, the network can handle more users and data traffic simultaneously, leading to enhanced network performance and capacity. The author introduced an interference mitigation algorithm that leverages a guard zone and enables successive interference cancellation at Base Stations (BSs). In this approach, D2D users are required to switch to the standard cellular mode when they are within a defined geographical area within a cell. The scheme's results show an increase in UE average throughput and the probability of successful data transmission for UE, showcasing the effectiveness of the proposed approach in improving network performance (Lv et al., 2016). This study presents a practical resource allocation framework based on matching theory with externalities by reducing cellular and D2D communication interference, and increasing network throughput. It models user equipment positions and achieves stable resource allocation with near-optimal network performance at a low computational cost (Shamaei et al., 2023). A cooperative NOMA approach is introduced, incorporating Weak User Beam-Matching and Strong User Beam-Matching equalizers to eliminate interference. It utilizes D2D Channel State Information sharing, a novel power allocation strategy and introduces Bit Error Rate as a performance metric. Simulation results show substantial improvements in both the sum rate and Bit Error Rate compared to other non-cooperative schemes (Al-Wani et al., 2021). A dynamic approach based on distance is described to reduce interference and offer QoS for both cellular and D2D communication links. The results demonstrate a significant enhancement in outage probability, with a 35% improvement in eNB links and a remarkable 49% improvement in SCeNB links when compared to conventional neighbor-based methods (Kamruzzaman et al., 2022). This research paper delves into interference cancellation within the framework of relay-assisted D2D communication. It integrates two interference cancellation models into the analysis of transmission capacity. The study explores the enhancements in performance that interference cancellation can offer and analyzes how different parameters interact to affect network performance. Furthermore, the paper investigates two hybrid interference cancellation models, shedding light on their effects in various scenarios and the trade-offs they entail (Amodu et al., 2021). To eliminate mutual interference and increase performance, an interference mitigation approach is developed. For resource-sharing links, this technique recommends using orthogonal precoding vectors. Using this interference cancellation technology reduces the chance of outages and boosts the overall capacity for cellular and D2D user equipment that shares these resources. The adoption of precoding techniques, according to the research, enhances outage performance and system capacity (Tsegay et al., 2020). The usage of a two-way decode-and-forward relay node in D2D communication is investigated in this work. It assesses the likelihood of asymmetric and symmetric outages using various approaches such as beamforming and

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

interference cancellation. The findings demonstrate that a lot of factors influence system performance, including the deployment of a high number of antennas at the base station, which can considerably lower the likelihood of a cellular connection going down (Ni et al., 2018).

Power Allocation

Power allocation in wireless communication refers to the dynamic adjustment of transmission power levels for base stations and user equipment with the purpose of enhancing connection capacity by improving signal strength while balancing the risk of interference amongst devices using the same resources. Efficient power allocation algorithms are crucial for conserving energy resources, particularly in battery-powered devices, and for ensuring overall service quality in wireless networks (Thakre & Pokle, 2022). The distribution of radio resources is one of these tactics, which is used to govern how various users or devices connect to the wireless network. Resource allocation is crucial in meeting the immediate increase in resource demand. To enhance the overall efficiency and capacity of the system, it's essential to focus on resource utilization and joint optimization, as these factors contribute significantly to improving the system's throughput and capacity, ensuring a better user experience and network performance (Kebede et al., 2022). Resource allocation techniques and various power allocation strategies emphasize the significance of integrating power allocation and mode selection in conjunction with link adaption strategies to provide optimal system performance. Power allocation algorithms can be broadly categorized into two types: centralized and distributed. In centralized algorithms, the base station takes on the responsibility of making decisions regarding resource allocation and power allocation, whereas in distributed algorithms, this responsibility lies with the user equipment. An example of a centralized algorithm is LTE power control, which demonstrates how power allocation decisions are made by the network infrastructure to optimize the wireless communication system's performance (Hussain et al., 2020). Creating a structured power allocation algorithm for wireless communication necessitates considering key parameters such as maximum transmit power and the target-received power per resource block, how many resources there are, and path loss are all factors. These parameters are pivotal in designing an efficient power allocation strategy. Table 4, on the other hand, likely provides a summary of power allocation challenges and possible solutions in D2D communications, serving as a valuable reference for researchers and engineers in this field.

Table 4: A summary of power allocation problems and possible solutions

Reference	Method	Objective
(Huang et al., 2020)	Power allocation mechanisms	Energy efficiency
(Zhai et al., 2017)	Graph theory	Power allocation and energy efficiency
(Zeb et al., 2021)	Graph theory	Spectrum and energy efficiency
(Kai et al., 2020)	Joint subcarrier and Power allocation scheme	Power allocation
(Xu et al., 2018)	Particle Swarm Optimization	Improve throughput
(Rashed et al., 2020)	Factor-graphs and Message-Passing Algorithm	Power allocation
(Gao et al., 2019)	Sequential Geometric Programming	Energy efficiency
(Omidkar et al., 2022)	Reinforcement learning	Energy efficiency and spectrum sharing

(Najeh & Bouallegue, 2023)	Dynamic Stackelberg game	Power allocation

Recent Developments in Power Allocation

The D2D communication technique has interference issues that affect its benefits. To mitigate interference, various methods like resource allocation, power allocation, signal processing, and mode selection have been proposed. These methods aim to enhance the coexistence of D2D and cellular communication, making D2D more effective in wireless networks. The power allocation for D2D communications was optimized by the authors using an interior point technique. To reduce computational complexity, they approximated the interior point method. The outcomes indicate that this approach, with reduced computational complexity, can still achieve near-optimal throughput for D2D communication (Wang et al., 2017). The study introduces two methods for allocating power in D2D communications, focusing on determining both transmit power and power splitting ratios. Additionally, the research presents two pricing strategies designed to maximize social utility, considering both D2D and cellular communications. Simulation results confirm the effectiveness of these methods and strategies. Notably, the research shows that the pricing strategies are efficient and energy-saving, while the power allocation mechanism can adapt well to the mobility of D2D users (Huang et al., 2020). The primary issue highlighted in the study is the non-convexity of sum-rates maximization when subject to power constraints. The authors underscore this challenge by framing the power allocation model as a potential game. To address this issue, they introduce two iterative algorithms that leverage the convergence properties of potential games. These proposed solutions outperform traditional rate maximization schemes because they lead to solutions that align more closely with the local maxima of the objective function (Abrardo & Moretti, 2016). The study, employing graph theory, highlights the complexity of optimizing power and spectrum allocation in D2D networks. It presents a two-phase algorithm that minimizes resource usage and transmission power while meeting QoS requirements. Additionally, dynamic frequency reuse strategies are proposed, showing better results than existing methods in terms of spectrum and energy efficiency under network outage constraints (Zeb et al., 2021). Through a network-centric strategy, the goal of the study is to improve EE for both CUEs and DUE. To achieve this, the authors propose a price-based cost function for DUE to ensure CUE uplink transmission. The results of their testing indicate that the proposed scheme exhibits fast convergence and provides a superior solution for both network-centric and user-centric EE optimization problems (Ding et al., 2016). The author proposed a new method to enhance energy efficiency in an IoT network with energy harvesting and simultaneous wireless information and power transfer. It combines time switching for D2D users and power splitting for IoT users. The study addresses an optimization problem that considers various factors, and it's solved through reinforcement learning and convex optimization. Simulation results demonstrate the method's superior performance and significant energy efficiency improvements through spectrum sharing in D2D communication (Omidkar et al., 2022). The authors present an innovative algorithm named the "modified mixed strategy algorithm" designed for power allocation, with the goal of enhancing the efficiency and cost-effectiveness of power transmission. Experimental findings indicate that the modified mixed strategy algorithm surpasses a baseline model that doesn't employ any power allocation method. This indicates that the proposed algorithm is more effective in the management of power resources (Rahma et al., 2022).

Mode Selection

Within a D2D cellular network, user equipment has the capacity to establish direct communication with the base station, offering distinct advantages such as reduced latency and enhanced network throughput. Nonetheless, this capability also brings forth fresh challenges pertaining to resource allocation and potential network congestion. Moreover, network administration becomes more complex when multiple pieces of user equipment utilize various communication modes, including direct, hybrid, or other modes of communication (Chen et al., 2020). Table 5 provides a concise summary of issues associated with the selection of communication modes in D2D communication, along with proposed solutions. User equipment typically has four communication modes at its disposal.

- Pure cellular mode is utilized in scenarios characterized by limited resources and significant network interference, often resulting from the absence of D2D communication. In this mode, D2D users are unable to directly transfer their data between each other. Instead, all data traffic is routed through the cellular network, which can lead to higher interference levels and reduced efficiency in certain scenarios (Ali & Ahmad, 2017).
- In the Partial cellular mode, user equipment (UE) can communicate through the base station without sharing the co-channel spectrum with other UEs engaged in direct D2D communication. This mode enables UEs to utilize the cellular network infrastructure for their communication needs, which can help manage interference issues and maintain efficient network operations.
- The Dedicated mode permits user equipment (UE) to establish direct communication with other UEs using specifically allocated spectrum resources. In this mode, UEs have their dedicated frequency bands or channels for communication, which can provide more efficient and interference-free direct connections between UEs (Doppler et al., 2010).
- The Underlay mode enables both D2D users and cellular users to use the same uplink and downlink resources within the network. In this mode, they coexist and use the available spectrum simultaneously, allowing for efficient use of resources but requiring effective management to prevent interference and maintain network performance (Zhang et al., 2015).

Table 5: A summary of mode selection in D2D communication

Reference	Method	Objective
(Bithas et al., 2019)	Greedy heuristic algorithm	Improves sum rate
(Hou & Chen, 2020)	Resource allocation algorithm-based mode selection.	Maximize the throughput
(Tian et al., 2019)	resource allocation and relay selection scheme	Maximize transmission data rates
(Han et al., 2020)	Concave-convex procedure algorithm	Spectrum efficiency and transmit power
(Galanopoulos et al., 2020)	Proximal algorithm	Spectrum allocation and mode selection
(Jeon et al., 2020)	Graph-theory	Improves sum rate
(Ioannou et al., 2021)	Transmission mode selection approach	Spectral efficiency
(Bithas et al., 2019)	Greedy heuristic algorithm	Improves sum rate
(J. Li et al., 2019)	Quasi-convex optimization algorithm	Maximize system throughput

Modern Developments in Mode Selection

For the purpose of choosing a D2D communication method, the author offers a resource allocation technique. Users are grouped according to where they are, communication channels are assigned according to priority, and resource distribution is optimized. The technique successfully increases throughput for consumers, according to simulation data (Hou & Chen, 2020). The author introduces an optimal strategy for mode selection in socially conscious D2D communications, emphasizing social reciprocity and link rate improvement for effective content sharing. It uses total unimodularity attributes to create online solutions through linear programming algorithms. However, the paper doesn't cover mode selection for different popularity distributions or individual QoS constraints (Wu et al., 2018). Another author proposed spectrum allocation and mode selection in a heterogeneous network with macro and pico base stations for D2D communication. It aims to strike a balance between power efficiency and user data rates. The paper offers two solutions: a centralized one and a distributed one using the proximal algorithm, with the distributed approach being more efficient. Simulations confirm the effectiveness of the method under various channel conditions, providing insights into complexity, convergence, and real-world implementation for future wireless networks (Galanopoulos et al., 2020). In a D2D network, selecting effective communication modes for user equipment pairs presents difficulties with regard to mode variety, capacity optimization, and effective sharing of uplink channels among cellular users. The authors propose an optimal mode selection algorithm for multipair and multimode D2D networks, aiming to maximize capacity through the selection of three modes: direct D2D, relay D2D, and local route mode. This problem can be represented as an integer programming issue, and it presents a key challenge in D2D communication optimization (Chen et al., 2019). The author introduces a mode selection scheme for D2D cellular networks, focusing on maintaining service quality while addressing interference and using realistic channel information. It employs Markov-chain theory to analyze single-user scenarios, reducing mode switching and improving efficiency. In multi-user contexts, a joint mode selection, resource allocation, and scheduling algorithm, powered by a greedy heuristic, enhances sum-rate performance (Bithas et al., 2019). The author addresses D2D communication in cellular networks, optimizing throughput and user satisfaction. It introduces a mode selection and resource allocation approach based on geographic data and prioritizes resources. User satisfaction is measured using the Mean Opinion Score index. The paper presents a multi-objective optimization problem to maximize system throughput and user satisfaction, ultimately achieving higher user satisfaction at a minor cost to overall system throughput (Xiukui Li et al., 2023). This study focuses on optimizing mode selection and transmit power allocation for D2D communication in cellular networks. It addresses the challenge of coexistence between direct D2D and device-infrastructure-device (DID) modes, which can cause interference. The research formulates a joint optimization model and employs a deep neural network (DNN) to find near-optimal solutions with lower computational complexity compared to an exhaustive search. Simulation results demonstrate the DNN's effectiveness in achieving improved network performance (Ron & Lee, 2022).

D2D Communication Challenges

The D2D communication within 5G comes with various challenges related to interference management, spectrum allocation, security, scalability, quality of service, energy efficiency, standardization, regulatory adherence, and network segmentation. It is crucial to tackle these challenges to fully harness the potential of D2D communication in 5G settings. The forthcoming discussion will shed light on the outstanding issues and hurdles.

Device Discovery challenges

As continuing open research concerns, certain difficulties in device discovery are emphasized.

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

Multi-cell Device Discovery

Device discovery can present notable difficulties, especially when a device from a different cell within the cellular network is on the move. This situation prompts concerns regarding the distribution of radio resources and the beneficiaries of this mobility, highlighting the intricacies associated with handling such situations. The authors have introduced a multi-cell device discovery approach as a potential solution. This approach may necessitate cooperation between the core network and BS. Consequently, it is crucial and of paramount significance to put forward a scheduling mechanism for the efficient management of discovery signals (Areqi et al., 2023; Hayat et al., 2018).

Synchronization

In D2D communication, synchronization is typically achieved between the devices in the system and the base station, where the BS sets the time frames and schedules. Nevertheless, a complication arises during device discovery when secondary devices linked to primary devices are situated beyond the base station coverage area. In this asynchronous discovery scenario, the devices must constantly search for nearby devices, which can consume significant resources and potentially hinder efficiency (Karatalay, 2022).

Discovery Messages Frequencies

Synchronizing devices and managing discovery frequencies are critical challenges in D2D communication. The volume of discovery messages impacts D2D performance, and interference can arise due to device distribution. On the other hand, a low number of messages can lead to outdated information about neighboring devices. To address this, an appropriate scheduling scheme is needed to optimize discovery message frequencies and balance performance and interference (Swain & Murthy, 2020).

Interference Management Challenges

This paper also points out interference management challenges in 5G D2D communications for future research.

D2D in mmWave Communication

An essential feature that has garnered significant attention in 5G cellular networks is communication in the mmWave band (Niu et al., 2019). There is a strong expectation that in future 5G cellular networks, mmWave mesh networks will supplant the conventional copper or fiber-based structures, providing mesh-like connectivity and rapid deployment capabilities (Al-Hazemi et al., 2019). High data speeds are offered by mmWave communication in 5G networks, however, due to unusual propagation properties, interference control difficulties are also present. In order to support simultaneous D2D communications in mmWave 5G networks, interference control strategies that take direction into account are required, as existing efforts have mainly focused on resource-sharing algorithms (Feng et al., 2022).

Ultra-Reliable Low Latency Communication

Ultra-Reliable Low Latency Communication (URLLC) holds a pivotal role in handling interference in D2D communication. It guarantees the high reliability and low-latency of D2D communication while efficiently managing interference to uphold the overall network's performance. The emergence of B5G URLLC applications within modern heterogeneous networks has presented opportunities for optimization. Nevertheless, interference challenges arising from uncoordinated wireless networks and innovative technologies can impact the performance of URLLC systems. Interference challenges within URLLC systems, with a specific focus on contemporary designs and technologies for B5G and

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

forthcoming 6G networks. It provides a comprehensive overview and offers guidance for future research in this field (Adeogun et al., 2022; Siddiqui et al., 2023).

Power allocation challenges

Numerous challenges in the domain of power allocation have been identified and can be considered as reference points for future research.

Transmission Power

Ensuring that D2D device transmission power is appropriately regulated is of utmost importance. It's essential that the transmission power is not too low to achieve high-quality D2D links (X. Li et al., 2019). Minimizing transmission power is essential for preserving equipment battery life. Researchers focus on achieving optimal power allocation, which can be categorized into dynamic and static power allocation. Static power allocation maintains a constant transmission power, while dynamic allocation allows power adjustment based on device proximity. Effective power management is particularly crucial in uplink transmission to reduce co-channel interference and the near-far effect (Barik et al., 2019). Setting an upper power level restriction for D2D users can help a network maintain the quality of service for cellular customers. To reduce interference in underlaying D2D cellular networks, an efficient power control method is essential. It is consistently important to determine the ideal power level for D2D links, ensuring minimal interference and preserving the quality of these links. This approach helps balance the coexistence of D2D and cellular communication while upholding QoS standards for all users in the network (Sun et al., 2018).

Several small networks or a single large network

Resource management challenges, particularly power control, are directly influenced by the number of users in the network. In small networks, power and frequency resources can be efficiently managed. However, as the user base continues to expand, it becomes increasingly challenging for a single network to accommodate all users. The growing number of antennas, complex decoding processes, large overhead for Channel State Information (CSI) feedback, and intricate precoding metrics can lead to network performance degradation. Key issues that should be addressed include determining the maximum number of users allowed in the network, resource allocation methods within subnetworks, and the decision-making process, whether it is centralized or distributed. These challenges are central to managing resource allocation effectively in large and complex networks (Liu et al., 2019; Wang et al., 2018).

Model selection challenges

The following section underscores several research challenges related to mode selection in D2D communication.

Dynamic Mode Selection

Most research primarily deals with static network scenarios, particularly in downlink situations where the base station serves as the intermediary for D2D communication. It's evident that dynamically switching modes, whether through brute force or heuristics, can sometimes lead to suboptimal enhancements in network performance. These findings highlight the need for a more comprehensive mode selection strategy capable of dynamic adaptation in real-world scenarios (Ioannou et al., 2022).

Overhead for Mode Selection

The mode selection process, which includes both channel estimation and control signaling, can add a large amount of overhead. The channel estimate is based on the Channel State Information (CSI) of the links. However, if the CSI becomes obsolete, network performance might suffer significantly. In essence, reducing the overhead associated with mode selection is critical for extending the device's

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

operating lifetime. This reduction in overhead may lead to more efficient and prolonged device operation (Eslami et al., 2023).

Conclusion

D2D communication offers several benefits over traditional cellular networks and is seen as a very promising paradigm for future network development. This study examines existing D2D technologies in-depth, addressing topics such as device detection, interference management, power allocation, and mode selection. The analysis indicates outstanding concerns and prospective future research directions in the ever-changing field of D2D communication. While D2D technology is new, a large body of study has revealed several research challenges and areas for further development. The primary objective of this extensive review is to offer a well-defined grasp of D2D technologies, underlying principles, areas of research yet to be explored, and the potential future directions in the field of D2D communication.

CONFLICT OF INTEREST

All authors declare no conflict of interest

REFERENCES

Abrardo, A., & Moretti, M. (2016). Distributed power allocation for D2D communications underlaying/overlaying OFDMA cellular networks. *IEEE Transactions on Wireless Communications*, *16*(3), 1466-1479.

Adeogun, R., Berardinelli, G., & Mogensen, P. E. (2022). Enhanced interference management for 6G in-X subnetworks. *IEEE Access*, *10*, 45784-45798.

Al-Hazemi, A. M., Al-Mekhlafi, A. A., & Shaddad, R. Q. (2019). Densification of 5G heterogeneous cellular wireless network based on millimeter-wave communication. 2019 First International Conference of Intelligent Computing and Engineering (ICOICE),

Al-Wani, M. M., Sali, A., Awad, S. D., Salah, A. A., Ding, Z., Noordin, N. K., . . . Leow, C. Y. (2021). Interference cancellation via D2D CSI sharing for MU-MISO-NOMA system with limited feedback. *IEEE Transactions on Vehicular Technology*, *70*(5), 4569-4584.

Ali, S., & Ahmad, A. (2017). Resource allocation, interference management, and mode selection in device-to-device communication: a survey. *Transactions on Emerging Telecommunications Technologies*, *28*(7), e3148.

Alibraheemi, A. M. H., Hindia, M. N., Dimyati, K., Izam, T. F. T. M. N., Yahaya, J., Qamar, F., & Abdullah, Z. H. (2023). A Survey of Resource Management in D2D Communication for B5G Networks. *IEEE Access*, *11*, 7892-7923.

Amodu, O. A., Othman, M., Noordin, N. K., & Ahmad, I. (2021). Transmission capacity analysis of relay-assisted D2D cellular networks with interference cancellation. *Ad Hoc Networks*, *117*, 102400.

Annur, R., Subri, F., Jalil, N. A., & Ponnusamy, V. (2021). Review on Secure Device to Device Communications in LTE. 2021 International Conference on Computer & Information Sciences (ICCOINS),

Ansari, R. I., Chrysostomou, C., Hassan, S. A., Guizani, M., Mumtaz, S., Rodriguez, J., & Rodrigues, J. J. (2017). 5G D2D networks: Techniques, challenges, and future prospects. *IEEE Systems Journal*, *12*(4), 3970-3984.

Areqi, M. A., Zahary, A. T., & Ali, M. N. (2023). State-of-the-art device-to-device communication solutions. *IEEE Access*.

Asadi, A., Wang, Q., & Mancuso, V. (2014). A survey on device-to-device communication in cellular networks. *IEEE Communications Surveys & Tutorials*, *16*(4), 1801-1819.

Aslam, S., Alam, F., Hasan, S. F., & Rashid, M. (2019). Decentralized interference mitigation technique for D2D networks using game theory optimization. 2019 29th International Telecommunication Networks and Applications Conference (ITNAC),

Barik, P. K., Singhal, C., & Datta, R. (2019). DAMS: D2D-assisted multimedia streaming service with minimized BS transmit power in cellular networks. *Computer Communications*, *144*, 149-161.

Bithas, P. S., Maliatsos, K., & Foukalas, F. (2019). An SINR-aware joint mode selection, scheduling, and resource allocation scheme for D2D communications. *IEEE Transactions on Vehicular Technology*, *68*(5), 4949-4963.

Chakraborty, C., & Rodrigues, J. J. (2020). A comprehensive review on device-to-device communication paradigm: trends, challenges and applications. *Wireless Personal Communications*, *114*(1), 185-207.

Chen, C.-Y., Sung, C.-A., & Chen, H.-H. (2019). Capacity maximization based on optimal mode selection in multi-mode and multi-pair D2D communications. *IEEE Transactions on Vehicular Technology*, *68*(7), 6524-6534.

Chen, L., Deng, N., & Wei, H. (2020). Performance analysis of D2D and cellular coexisting networks with interference management. *IEEE Access*, *8*, 82747-82759.

Chiu, S.-L., Lin, K. C.-J., Lin, G.-X., & Wei, H.-Y. (2016). Empowering device-to-device networks with cross-link interference management. *IEEE Transactions on mobile computing*, *16*(4), 950-963.

Chour, H., Nasser, Y., Artail, H., Kachouh, A., & Al-Dubai, A. (2017). VANET aided D2D discovery: Delay analysis and performance. *IEEE Transactions on Vehicular Technology*, *66*(9), 8059-8071.

Ding, J., Jiang, L., & He, C. (2016). Energy-efficient power control for underlaying D2D communication with channel uncertainty: User-centric versus network-centric. *Journal of Communications and Networks*, *18*(4), 589-599.

Doan, K. N., Van Nguyen, T., Shin, H., & Quek, T. Q. (2019). Socially-aware caching in wireless networks with random D2D communications. *IEEE Access*, *7*, 58394-58406.

Doppler, K., Yu, C.-H., Ribeiro, C. B., & Jänis, P. (2010). Mode selection for device-to-device communication underlaying an LTE-advanced network. 2010 IEEE wireless communication and networking conference,

Doumiati, S., Assaad, M., & Artail, H. A. (2019). A framework of topological interference management and clustering for D2D networks. *IEEE Transactions on Communications*, *67*(11), 7856-7871.

Dubey, R., Mishra, P. K., & Pandey, S. (2022). An energy efficient scheme by exploiting multi-hop D2D communications for 5G networks. *Physical Communication*, *51*, 101576.

Eslami, L., Mirjalily, G., & Davidson, T. N. (2023). Joint Mode Selection and Resource Allocation for D2D and Femtocell Users in Dense Heterogeneous Networks with Full Frequency Reuse. *IEEE Transactions on Vehicular Technology*.

Feng, D., Lu, L., Yuan-Wu, Y., Li, G. Y., Li, S., & Feng, G. (2014). Device-to-device communications in cellular networks. *IEEE Communications Magazine*, *52*(4), 49-55.

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*, *21*(8), 6746-6759.

Fodor, G., Roger, S., Rajatheva, N., Slimane, S. B., Svensson, T., Popovski, P., . . . Ali, S. (2016). An overview of device-to-device communications technology components in METIS. *IEEE Access*, *4*, 3288-3299.

Galanopoulos, A., Foukalas, F., & Khattab, T. (2020). Energy efficient spectrum allocation and mode selection for D2D communications in heterogeneous networks. *IEEE Transactions on Signal and Information Processing over Networks*, *6*, 382-393.

Gandotra, P., & Jha, R. K. (2016). Device-to-device communication in cellular networks: A survey. *Journal of Network and Computer Applications*, *71*, 99-117.

Gao, X., Yang, K., Yang, N., & Wu, J. (2019). Energy-efficient resource block assignment and power control for underlay device-to-device communications in multi-cell networks. *Computer Networks*, *149*, 240-251.

Gismalla, M. S. M., Azmi, A. I., Salim, M. R. B., Abdullah, M. F. L., Iqbal, F., Mabrouk, W. A., . . . Supa'at, A. S. M. (2022). Survey on device to device (D2D) communication for 5GB/6G networks: Concept, applications, challenges, and future directions. *IEEE Access*, *10*, 30792-30821.

Han, L., Zhang, Y., Li, Y., & Zhang, X. (2020). Spectrum-efficient transmission mode selection for full-duplex-enabled two-way D2D communications. *IEEE Access*, *8*, 115982-115991.

Hayat, O., Ngah, R., Hashim, S. Z. M., Dahri, M. H., Malik, R. F., & Rahayu, Y. (2019). Device discovery in D2D communication: A survey. *IEEE Access*, *7*, 131114-131134.

Hayat, O., Ngah, R., Kaleem, Z., Hashim, S. Z. M., & Rodrigues, J. J. (2020). A survey on security and privacy challenges in device discovery for next-generation systems. *IEEE Access*, *8*, 84584-84603.

Hayat, O., Ngah, R., & Mohd Hashim, S. Z. (2020). Performance analysis of device discovery algorithms for D2D communication. *Arabian Journal for Science and Engineering*, *45*, 1457-1471.

Hayat, O., Ngah, R., & Mohd Hashim, S. Z. (2021). Sector scanning algorithm (SSA) for device discovery in D2D communication. *International Journal of Electronics*, *108*(1), 45-66.

Hayat, O., Ngah, R., & Zahedi, Y. (2018). Cooperative GPS and neighbors awareness based device discovery for D2D communication in in-band cellular networks. *Int. J. Eng. Technol*, *7*(2.29), 700-703.

Hayat, O., Ngah, R., & Zahedi, Y. (2019). In-band device to device (D2D) communication and device discovery: A survey. *Wireless Personal Communications*, *106*, 451-472.

Hou, G., & Chen, L. (2020). D2D communication mode selection and resource allocation in 5G wireless networks. *Computer Communications*, *155*, 244-251.

Huang, J., Xing, C.-c., & Guizani, M. (2020). Power allocation for D2D communications with SWIPT. *IEEE Transactions on Wireless Communications*, *19*(4), 2308-2320.

Hussain, F., Hassan, S. A., Hussain, R., & Hossain, E. (2020). Machine learning for resource management in cellular and IoT networks: Potentials, current solutions, and open challenges. *IEEE Communications Surveys & Tutorials*, *22*(2), 1251-1275.

Ioannou, I., Christophorou, C., Vassiliou, V., & Pitsillides, A. (2021). Performance evaluation of transmission mode selection in D2D communication. 2021 11th IFIP International Conference on New Technologies, Mobility and Security (NTMS),

Ioannou, I. I., Christophorou, C., Vassiliou, V., Lestas, M., & Pitsillides, A. (2022). Dynamic D2D Communication in 5G/6G Using a Distributed AI Framework. *IEEE Access*, *10*, 62772-62799.

Islam, T., & Kwon, C. (2022). Survey on the state-of-the-art in device-to-device communication: A resource allocation perspective. *Ad Hoc Networks*, 102978.

Jaafar, W., Ajib, W., & Elbiaze, H. (2019). Caching optimization for D2D-assisted heterogeneous wireless networks. 2019 IEEE 30th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC),

Jaffry, S., Zaidi, S. K., Shah, S. T., Hasan, S. F., & Gui, X. (2019). D2D neighborhood discovery by a mobile device. ICC 2019-2019 IEEE International Conference on Communications (ICC), Jameel, F., Hamid, Z., Jabeen, F., Zeadally, S., & Javed, M. A. (2018). A survey of device-to-device communications: Research issues and challenges. *IEEE Communications Surveys & Tutorials*, *20*(3), 2133-2168.

Jeon, H.-B., Koo, B.-H., Park, S.-H., Park, J., & Chae, C.-B. (2020). Graph-theory-based resource allocation and mode selection in D2D communication systems: The role of full-duplex. *IEEE Wireless Communications Letters*, *10*(2), 236-240.

Kai, C., Wu, Y., Hu, X., & Huang, W. (2020). Joint subcarrier and power allocation in D2D communications underlaying cellular networks. 2020 IEEE Wireless Communications and Networking Conference (WCNC),

Kaleem, Z., Khan, A., Hassan, S. A., Vo, N.-S., Nguyen, L. D., & Nguyen, H. M. (2020). Full-duplex enabled time-efficient device discovery for public safety communications. *Mobile Networks and Applications*, *25*, 341-349.

Kaleem, Z., Qadri, N. N., Duong, T. Q., & Karagiannidis, G. K. (2019). Energy-efficient device discovery in D2D cellular networks for public safety scenario. *IEEE Systems Journal*, *13*(3), 2716-2719.

Kaleem, Z., Yousaf, M., Hassan, S. A., Vo, N.-S., & Duong, T. Q. (2018). Priority-Based device discovery in public safety D2D networks with full duplexing. International Conference on Heterogeneous Networking for Quality, Reliability, Security and Robustness,

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.

Kar, U. N., & Sanyal, D. K. (2020). A critical review of 3GPP standardization of device-to-device communication in cellular networks. *SN Computer Science*, *1*(1), 37.

Karatalay, O. (2022). *Energy-Efficient Synchronization and Resource Allocation Strategies for Device To-Device Communications*. McGill University (Canada).

Kebede, T., Wondie, Y., Steinbrunn, J., Kassa, H. B., & Kornegay, K. T. (2022). Multi-carrier waveforms and multiple access strategies in wireless networks: Performance, applications, and challenges. *IEEE Access*, *10*, 21120-21140.

Kong, P.-Y. (2020). Cellular-assisted device-to-device communications for healthcare monitoring wireless body area networks. *IEEE Sensors Journal*, *20*(21), 13139-13149.

Kumar Jadav, N., Gupta, R., & Tanwar, S. (2022). A survey on energy-efficient resource allocation schemes in device-to-device communication. *International Journal of Communication Systems*, *35*(8), e5112.

Kumari, R., & Tyagi, D. K. (2022). Self-organised Mobility aware Device Discovery for Ultra-dense D2D Communication Network. 2022 IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS),

Li, B., Guo, W., Liang, Y.-C., An, C., & Zhao, C. (2018). Asynchronous device detection for cognitive device-to-device communications. *IEEE Transactions on Wireless Communications*, *17*(4), 2443-2456.

Li, J., Lei, G., Manogaran, G., Mastorakis, G., & Mavromoustakis, C. X. (2019). D2D communication mode selection and resource optimization algorithm with optimal throughput in 5G network. *IEEE Access*, *7*, 25263-25273.

Li, X., Chen, G., Wu, G., Sun, Z., & Chen, G. (2023). D2D Communication Network Interference Coordination Scheme Based on Improved Stackelberg. *Sustainability*, *15*(2), 961.

Li, X., Sun, Y., Zhou, L., Xu, Y., & Zhou, S. (2019). A resource allocation scheme based on predatory search algorithm for ultra-dense D2D communications. Wireless and Satellite Systems: 10th EAI International Conference, WiSATS 2019, Harbin, China, January 12–13, 2019, Proceedings, Part II 10, Li, X., Zhang, J., & Liu, X. (2023). Mode Selection and Resource Allocation for D2D Communications with Tradeoff of Throughput and User Satisfaction. *IEEE Transactions on Communications*.

Lin, X., Andrews, J. G., Ghosh, A., & Ratasuk, R. (2014). An overview of 3GPP device-to-device proximity services. *IEEE Communications Magazine*, *52*(4), 40-48.

Liu, Y., Wang, R., & Han, Z. (2016). Interference-constrained pricing for D2D networks. *IEEE Transactions on Wireless Communications*, *16*(1), 475-486.

Liu, Y., Wang, Y., Sun, R., & Miao, Z. (2019). Distributed resource allocation for D2D-assisted small cell networks with heterogeneous spectrum. *IEEE Access*, *7*, 83900-83914.

Lv, S., Xing, C., Zhang, Z., & Long, K. (2016). Guard zone based interference management for D2D-aided underlaying cellular networks. *IEEE Transactions on Vehicular Technology*, *66*(6), 5466-5471.

Mach, P., Becvar, Z., & Vanek, T. (2015). In-band device-to-device communication in OFDMA cellular networks: A survey and challenges. *IEEE Communications Surveys & Tutorials*, *17*(4), 1885-1922.

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.

Mosbah, A. B., Hammami, S. E., Moungla, H., Afifi, H., & Kamal, A. E. (2019). Enhancing Device-to-Device direct discovery based on predicted user density patterns. *Computer Networks*, *151*, 245-259.

Najeh, S., & Bouallegue, A. (2023). Power Allocation in Device-to-Device Communications based-Stackelberg Game Theory. 2023 International Wireless Communications and Mobile Computing (IWCMC),

Nguyen, T. N., Nguyen, V. S., Nguyen, H. G., Tu, L. T., Van Chien, T., & Nguyen, T. H. (2022). On the performance of underlay device-to-device communications. *Sensors*, *22*(4), 1456.

Ni, Y., Zhao, J., Wang, Y., & Zhu, H. (2018). Beamforming and interference cancellation for D2D communication assisted by two-way decode-and-forward relay node. *China Communications*, *15*(3), 100-111.

Niu, Y., Yu, L., Li, Y., Zhong, Z., Ai, B., & Chen, S. (2019). Device-to-device communications enabled multicast scheduling with the multi-level codebook in mmWave small cells. *Mobile Networks and Applications*, *24*, 1603-1617.

Noura, M., & Nordin, R. (2016). A survey on interference management for device-to-device (D2D) communication and its challenges in 5G networks. *Journal of Network and Computer Applications*, *71*, 130-150.

Nwazor, N. O., & Ugah, V. K. (2022). Device-To-Device (D2D) Data Communications in 5g Networks. *no. February*, 0-4.

Omidkar, A., Khalili, A., Nguyen, H. H., & Shafiei, H. (2022). Reinforcement-Learning-Based Resource Allocation for Energy-Harvesting-Aided D2D Communications in IoT Networks. *IEEE Internet of Things Journal*, *9*(17), 16521-16531.

Pedhadiya, M. K., Jha, R. K., & Bhatt, H. G. (2019). Device to device communication: A survey. *Journal of Network and Computer Applications*, *129*, 71-89.

Raghu, T., & Kiran, M. (2022). A survey on device to device communications. 2022 International Conference for Advancement in Technology (ICONAT),

Rahma, N., Suparta, I., Adriansyah, N., & Prabowo, V. (2022). A Modified of Mixed Strategy Algorithm for Power Allocation on D2D Underlay Communication. *Journal of Computer, Electronic, and Telecommunication (COMPLETE)*, *3*(1).

Rashed, S. K., Asvadi, R., Rajabi, S., Ghorashi, S. A., & Martini, M. G. (2020). Power allocation for D2D communications using max-min message-passing algorithm. *IEEE Transactions on Vehicular Technology*, *69*(8), 8443-8458.

Logical Creations Education Research Institute
LC INTERNATIONAL JOURNAL OF STEM
E-ISSN: 2708-7123
Web: www.lcjstem.com | Email: editor@lcjstem.com
Volume-04 | Issue-03 | September-2023

Raziah, I., Yunida, Y., Away, Y., Muharar, R., & Nasaruddin, N. (2022). A New Adaptive Power Control Based on LEACH Clustering Protocol for Interference Management in Cooperative D2D Systems. *IEEE Access*, *10*, 113513-113522.

Ron, D., & Lee, J.-R. (2022). Learning-based joint optimization of mode selection and transmit power control for D2D communication underlaid cellular networks. *Expert Systems with Applications*, *198*, 116725.

Salih, A. A., Zeebaree, S., Abdulraheem, A. S., Zebari, R. R., Sadeeq, M., & Ahmed, O. M. (2020). Evolution of mobile wireless communication to 5G revolution. *Technology Reports of Kansai University*, *62*(5), 2139-2151.

Salim, M. M., Elsayed, H. A., & Abdalzaher, M. S. (2023). A survey on essential challenges in relay-aided D2D communication for next-generation cellular networks. *Journal of Network and Computer Applications*, *216*, 103657.

Shamaei, S., Bayat, S., & Hemmatyar, A. M. A. (2018). Interference management in D2D-enabled heterogeneous cellular networks using matching theory. *IEEE Transactions on mobile computing*, *18*(9), 2091-2102.

Shamaei, S., Bayat, S., & Hemmatyar, A. M. A. (2023). Interference-Aware Resource Allocation Algorithm for D2D-Enabled Cellular Networks Using Matching Theory. *IEEE Transactions on Network and Service Management*.

Siddiqui, M. U. A., Abumarshoud, H., Bariah, L., Muhaidat, S., Imran, M. A., & Mohjazi, L. (2023). URLLC in Beyond 5G and 6G Networks: An Interference Management Perspective. *IEEE Access*.

Siddiqui, M. U. A., Qamar, F., Ahmed, F., Nguyen, Q. N., & Hassan, R. (2021). Interference management in 5G and beyond network: Requirements, challenges and future directions. *IEEE Access*, *9*, 68932-68965.

Sun, J., Zhang, Z., Xiao, H., & Xing, C. (2018). Uplink interference coordination management with power control for D2D underlaying cellular networks: Modeling, algorithms, and analysis. *IEEE Transactions on Vehicular Technology*, *67*(9), 8582-8594.

Sun, Y., Cao, J., Ma, M., Li, H., Niu, B., & Li, F. (2019). Privacy-preserving device discovery and authentication scheme for D2D communication in 3GPP 5G HetNet. 2019 International Conference on Computing, Networking and Communications (ICNC),

Swain, S. N., & Murthy, C. S. R. (2020). A novel collision aware network assisted device discovery scheme empowering massive D2D communications in 3GPP LTE-A networks. *Computer Networks*, *169*, 107071.

Thakre, P. N., & Pokle, S. B. (2022). A survey on power allocation in pd-noma for 5g wireless communication systems. 2022 10th International Conference on Emerging Trends in Engineering and Technology-Signal and Information Processing (ICETET-SIP-22),

Tian, C., Qian, Z., Wang, X., & Hu, L. (2019). Analysis of joint relay selection and resource allocation scheme for relay-aided D2D communication networks. *IEEE Access*, *7*, 142715-142725.

Tsegay, M. B., Dhaka, K., & Bhattacharjee, R. (2020). Interference Cancellation in Multiple D2D Underlaying LTE Cellular Networks. 2020 4th International Conference on Computer, Communication and Signal Processing (ICCCSP),

Vaishnav, A., Swain, A. R., & Lenka, M. R. (2022). Device Discovery Approaches in D2D Communication: A Survey. 2022 OITS International Conference on Information Technology (OCIT),

Wang, H., Ding, G., Wang, J., Wang, S., & Wang, L. (2017). Power control for multiple interfering D2D communications underlaying cellular networks: An approximate interior point approach. 2017 IEEE International Conference on Communications Workshops (ICC Workshops),

Wang, M., & Yan, Z. (2017). A survey on security in D2D communications. *Mobile Networks and Applications*, *22*, 195-208.

Wang, X., Zhang, Y., Leung, V. C., Guizani, N., & Jiang, T. (2018). D2D big data: Content deliveries over wireless device-to-device sharing in large-scale mobile networks. *IEEE Wireless Communications*, *25*(1), 32-38.

Wu, D., Zhou, L., Cai, Y., & Qian, Y. (2018). Optimal content sharing mode selection for social-aware D2D communications. *IEEE Wireless Communications Letters*, *7*(6), 910-913.

Wu, H., Gao, X., Xu, S., Wu, D. O., & Gong, P. (2020). Proximate device discovery for D2D communication in LTE advanced: Challenges and approaches. *IEEE Wireless Communications*, *27*(4), 140-147.

Xu, J., Guo, C., & Zhang, H. (2018). Joint channel allocation and power control based on PSO for cellular networks with D2D communications. *Computer Networks*, *133*, 104-119.

Yan, Y., Zhang, B., & Li, C. (2017). Opportunistic network coding based cooperative retransmissions in D2D communications. *Computer Networks*, *113*, 72-83.

Yang, T., Cheng, X., Shen, X., Chen, S., & Yang, L. (2017). QoS-aware interference management for vehicular D2D relay networks. *Journal of Communications and Information Networks*, *2*(2), 75-90.

Yang, T., Zhang, R., Cheng, X., & Yang, L. (2017). Graph coloring based resource sharing (GCRS) scheme for D2D communications underlaying full-duplex cellular networks. *IEEE Transactions on Vehicular Technology*, *66*(8), 7506-7517.

Zeb, J., Hassan, A., & Nisar, M. D. (2021). Joint power and spectrum allocation for D2D communication overlaying cellular networks. *Computer Networks*, *184*, 107683.

Zhai, D., Sheng, M., Wang, X., Sun, Z., Xu, C., & Li, J. (2017). Energy-saving resource management for D2D and cellular coexisting networks enhanced by hybrid multiple access technologies. *IEEE Transactions on Wireless Communications*, *16*(4), 2678-2692.

Zhang, J., Deng, L., Li, X., Zhou, Y., Liang, Y., & Liu, Y. (2017). Novel device-to-device discovery scheme based on random backoff in LTE-advanced networks. *IEEE Transactions on Vehicular Technology*, *66*(12), 11404-11408.

Zhang, Y., Shen, Y., Jiang, X., & Kasahara, S. (2018). Mode selection and spectrum partition for D2D inband communications: A physical layer security perspective. *IEEE Transactions on Communications*, *67*(1), 623-638.

Zhang, Z., Hu, R. Q., Qian, Y., & Papathanassiou, A. (2015). D2D communication underlay in uplink cellular networks with fractional power control and fractional frequency reuse. 2015 IEEE Global Communications Conference (GLOBECOM),

Zhao, G., Chen, S., Qi, L., Zhao, L., & Hanzo, L. (2019). Mobile-traffic-aware offloading for energy- and spectral-efficient large-scale D2D-enabled cellular networks. *IEEE Transactions on Wireless Communications*, *18*(6), 3251-3264.

Zhao, L., Wang, H., & Zhong, X. (2018). Interference graph based channel assignment algorithm for D2D cellular networks. *IEEE Access*, *6*, 3270-3279.