D2D communication for mobile nodes in 5G networks

A Thesis Submitted in Partial Fulfilment of the Requirements

for the Degree of

Bachelor of Technology

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CERTIFICATE

It is certified that the work contained in the thesis entitled " D2D communication for mobile nodes in 5G networks " has been carried out by **Nitin Shyam Gupta (Roll no: 20CS8144), Sahil (Roll no: 20CS8038) and Aditya (Roll no: 20CS8033)** under the guidance of **Prof. Tanmay De,** the data reported here in is original and this work has not been submitted elsewhere for any other Degree or Diploma.

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ABSTRACT

Device-to-Device (D2D) communication has emerged as a promising technology for improving the efficiency and capacity of wireless networks. In D2D communication, mobile devices communicate directly with each other without routing through the base station, thereby reducing network congestion and latency. However, the performance of D2D communication networks can be affected by the mobility of the nodes.

This paper presents an approach for D2D communication in networks where the nodes are moving. We investigate the impact of node mobility on the performance of D2D communication networks.

Our study provides insights into the impact of node mobility on the performance of D2D communication networks and highlights the need for mobility-aware D2D communication protocols. The findings of this research can inform the development of efficient and reliable D2D communication protocols for mobile devices, which can enhance the overall performance of wireless networks.

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1. INTRODUCTION

1.1 INTRODUCTION OF D2D COMMUNICATION

Device-to-Device (D2D) communication in cellular networks is defined as direct communication between two mobile users without Base Station as an intermediary. It is generally non-transparent to the cellular network, and it can occur on the cellular frequencies (i.e., inband) or unlicensed spectrum (i.e., outband).

Next-generation cellular networks need high capacity, power efficiency, and guaranteed Quality of Service (QoS). To achieve these goals D2D communication is an important technology for fifth-generation applications. In general, D2D is a technique used to connect devices with each other without the need for communication infrastructure, for example, access points (AP) and base stations (BS). In simpler terms, device-to-device (D2D) communication commonly refers to a type of technology that enables devices to communicate directly with each other without communication infrastructures such as access points (APs) or base stations (BSs). Bluetooth and WiFi-Direct are the two most popular D2D techniques. With the emergence of machine-to-machine (M2M) applications, D2D communication has assumed a very pivotal role. It facilitates the discovery of devices that are closer to each other and enables direct communication between them. This results in improved communication quality and reduces energy consumption and communication delays.

In a traditional cellular network, all communications must go through the BS even if communicating parties are in range for proximity based D2D communication. Communication through BS suits conventional low data rates mobile services such as voice calls and text messaging in which users are seldom close enough for direct communication. However, mobile users in today's cellular networks use high data rate services (e.g., video sharing, gaming, proximity-aware social networking) which could potentially be in the range for direct communications (i.e., D2D). Hence, D2D communications in such scenarios can greatly increase the spectral efficiency of the network. The advantages of D2D communications go beyond spectral efficiency; they can potentially improve throughput, energy efficiency, delay, and fairness.

D2D can deal in an integrated way with various techniques to improve Network performance such as the Internet of Things (IoT), Vehicle-to-Vehicle (V2V) Technology, Artificial Intelligence (AI), millimeter Waves (mmW) Technology, the other hand, may encounter many difficulties that must be taken into account. When implementing D2D technology, there is interference between centralized users (CUs) and distributed users (DUs) because they share the same resources in the same area. Other problems facing D2D technology such as peer discovery, delivery, management of radio resource allocation, optimization, and security issue in addition to energy consumption. Thus, many researchers and mobile operators have paid attention to D2D to enhance network performance without breaching any of the requirements of the service.

D2D aims to use the physical range of communication devices to increase the signal of mobile devices in a dispersed environment. To complement each other, D2D connections must work with cellular network services. The crucial factor to consider when designing D2D is the sharing of resources, in terms of power and spectrum, between D2D and cellular connectivity. Among the benefits that can be obtained from D2D is that it maintains the privacy of the content and anonymity. Because the central storage unit is not responsible for storing shared information. D2D communications can improve energy efficiency, productivity, fairness, and delay. This report represents a review of a set of proposed solutions aimed at improving security in D2D communications.

1.2 TYPES OF D2D COMMUNICATION

INBAND AND OUTBAND COMMUNICATION

InBand D2D Communication: In this type, both cellular communication and D2D use the same licensed spectrum. There is interference between D2D and cellular uses which is very challenging to handle. Moreover, resource allocation algorithms are very complex to develop.

OutBand D2D Communication: In this type, D2D uses unlicensed spectrum (2.4 GHz ISM band or 38 GHz mm-wave band) whereas cellular uses licensed spectrum as given by the network operator. There is no interference issue between cellular and D2D. However D2D users are affected by other ISM band users of wifi and bluetooth which is uncontrollable.

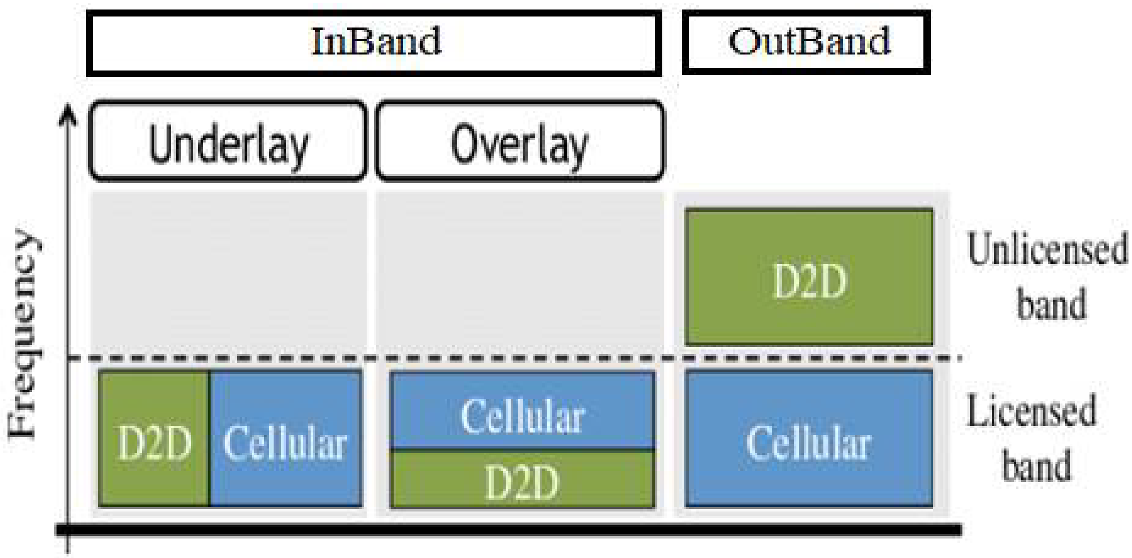


Fig 1.1 : InBand and OutBand

UNDERLAY AND OVERLAY COMMUNICATION

InBand D2D communication is further categorized into two types viz. Underlay and Overlay as described below.

Underlay D2D communication

- In this subtype, the licensed spectrum is not divided for D2D and Cellular use.
- The technique is more spectrum efficient, but it is challenging to implement resource allocation between D2D and Cellular users.
- The Underlay D2D increases spectral efficiency by utilizing spatial diversity.

Overlay D2D communication

- In this subtype, the licensed spectrum is divided into non-overlapping parts as shown for D2D and cellular links.
- This technique is very simple to implement due to separate resource allocations.
- The overlay D2D reduces the chances of interference between D2D and cellular users.
- This technique requires more focus on avoiding the wastage of resources.

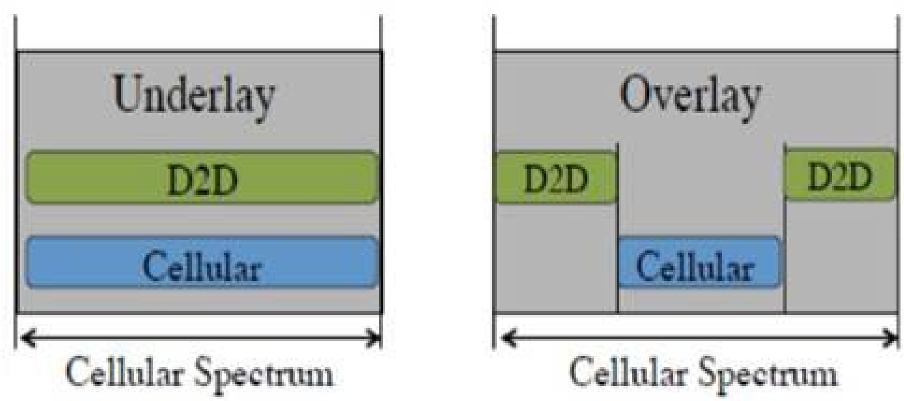


Fig 1.2: UNDERLAY AND OVERLAY

1.3 IDEA OF D2D MULTICASTING

Device-to-device (D2D) multicasting is a communication technique where data is transmitted simultaneously from one device to multiple nearby devices, without the need for an intermediary network. It is an efficient way to deliver content to multiple users in a local area, and can be used in various applications such as video streaming, file sharing, and gaming.

D2D multicasting utilizes the proximity and connectivity of nearby devices to create a direct communication link, which can improve the efficiency of data transfer and reduce network congestion. This approach can also enhance the reliability of data transmission, as the data can be transmitted via multiple paths and devices.

Research in D2D multicasting has been growing, and various approaches have been proposed to optimize the performance and efficiency of this technique. For example, researchers have proposed using network coding to improve the throughput of D2D multicasting, as well as developing algorithms to optimize the selection of devices for multicasting.

D2D multicasting has the potential to revolutionize local content delivery and improve the user experience in various applications. However, there are still some challenges to be addressed, such as interference management and ensuring the security and privacy of the transmitted data.

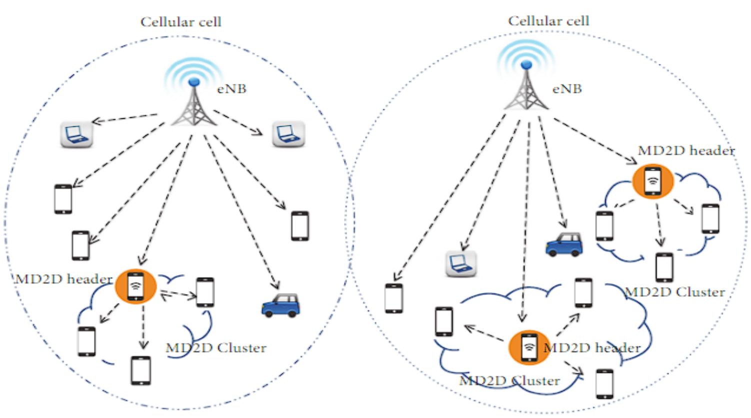


Fig 1.3: Multi-Casting

2. LITERARY SURVEY

The purpose of this literature survey is to provide an overview of the research conducted on device-to-device (D2D) communication and clustering in wireless networks. The survey aims to identify the benefits and challenges of these technologies, as well as the current state of research and future directions. The results of the survey will be used to gain insights into the use of D2D communication and clustering in wireless networks and provide recommendations for future studies.

The literature survey will be conducted using academic databases such as IEEE Xplore, ACM Digital Library, and Google Scholar. The survey will include research papers, journal articles, conference proceedings, and book chapters published between 2015 and 2022.

D2D Communication:

A number of studies have focused on the use of D2D communication in wireless networks. Research has shown that D2D communication can improve network efficiency, reduce latency, increase bandwidth, and enhance security. Some of the challenges associated with the deployment of D2D communication include interference with existing networks, security concerns, integration with existing systems, regulatory barriers, and lack of standardization.

Underlay D2D Communication:

Research in this area has explored various techniques to enable efficient underlay D2D communication while maintaining the quality of service for both D2D and cellular users. Studies have investigated resource allocation strategies, such as power control and frequency allocation, to mitigate interference and ensure coexistence with cellular users. Furthermore, advancements in spectrum sharing technologies, such as cognitive radio and dynamic spectrum access, have been proposed to improve spectral efficiency and accommodate the growing demand for wireless communication. Despite its potential benefits, underlay D2D communication faces challenges such as interference management, spectrum scarcity, and coordination among devices. Addressing these challenges requires innovative solutions in resource management, interference mitigation, and spectrum utilization to harness the full potential of underlay D2D communication in wireless networks.

Overlay D2D Communication:

Research in overlay D2D communication has focused on developing efficient routing algorithms, neighbor discovery mechanisms, and network formation protocols to enable seamless communication among devices. Moreover, studies have explored the integration of overlay D2D communication with existing wireless technologies, such as WiFi and Bluetooth, to create heterogeneous networks with enhanced coverage and connectivity. However, overlay D2D communication also presents challenges, including network scalability, routing overhead, and energy consumption. Overcoming these challenges requires innovative approaches in network optimization, protocol design, and energy-efficient communication mechanisms to realize the full potential of overlay D2D communication in wireless networks.

D2D Clustering:

Research has also been conducted on the use of D2D clustering in wireless networks. D2D clustering can improve network efficiency, reduce latency, increase bandwidth, and enhance security. The challenges associated with the deployment of D2D clustering are similar to those of D2D communication. Some studies have proposed solutions to these challenges, such as the use of cognitive radio technology, dynamic spectrum access, and distributed resource allocation.

Future Directions:

Future research in D2D communication and clustering could focus on addressing the challenges associated with deployment, such as interference with existing networks, security concerns, and lack of standardization. Studies could also explore the potential benefits of D2D communication and clustering in different types of wireless networks, such as cellular networks, ad hoc networks, and internet of things (IoT) networks.

3. PROJECT DESCRIPTION

Work is done on various software over here, such as:

3.1 Software Utilized

Python

Python is a high-level, general-purpose programming language. Its design philosophy emphasizes code readability with the use of significant indentation. Python's flexibility allows it to be utilized for a multitude of purposes, whether it's scripting, automation, data analysis, machine learning, or building robust web applications.

The Python interpreter, which executes Python code, is predominantly written in C. This choice of implementation language offers a balance between performance, portability, and ease of interfacing with other systems and libraries.

Python's popularity stems from its open-source nature and strong community support. The language is maintained by the Python Software Foundation, ensuring its continuous development and improvement. Python's release cycle follows a predictable pattern, with major updates occurring approximately every 18-24 months with its current version being python 3.12.

Windows

Windows 10 is a widely used operating system developed by Microsoft, renowned for its versatility and user-friendly interface. Built on a foundation of robustness and security, Windows 10 provides a stable platform for a diverse range of applications and workflows. Its intuitive graphical user interface (GUI) simplifies navigation and enhances productivity, making it accessible to users of all skill levels.

The core components of Windows 10 are primarily developed using C and C++, allowing for high performance and compatibility with a vast array of hardware and software. Major feature updates are released biannually, introducing new functionalities, enhancements, and security improvements to ensure a modern and secure computing experience. The latest version of Windows 10 is version 22H2.

3.2 Initialization

First, the N number of nodes are allocated randomly over a 500 x 500 area. Then, the nodes are grouped into clusters for D2D communication. The 0^{th} node is considered as the base station. Clustering is done based on the number of resource blocks available and the minimum pairing distance. Overlapping clusters need to be allocated different resource blocks to prevent interference. Each of the resource blocks have been denoted with a different color in the NS2 simulator. An example allocation and clustering of 100 nodes is given below.

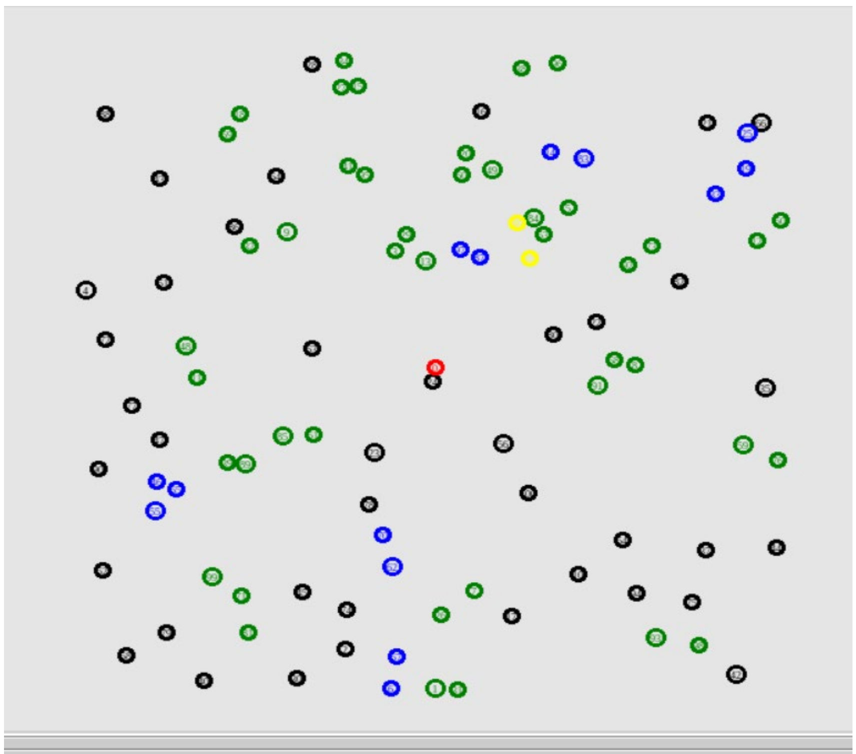


Fig 3.1: Simulation of Users

After this, data rate is calculated to each of the clusters by considering the data rate of the longest distance node from the cluster head. Then, mobility is assigned to the cluster nodes. All the nodes move with constant velocity to a randomly chosen destination coordinate. Mobility implementation is explained using the figures given below.

Before mobility:

Let us consider a simple 5G network with 3 clusters.

Here, each circle represents a cluster. Cluster heads are represented in blue and cluster members are represented in orange

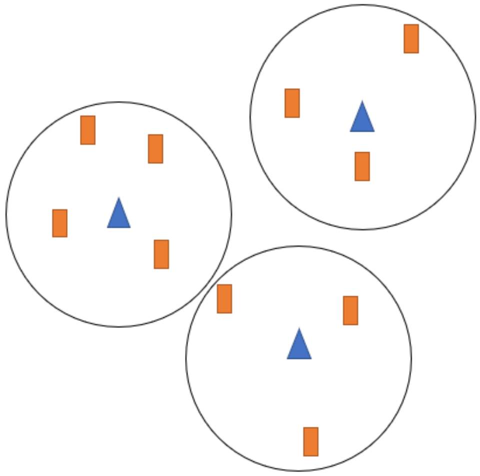


Fig 3.2: Initial Clustering of Users

After mobility:

Here, a few nodes have now moved from their initial positions to their final positions denoted by arrows.

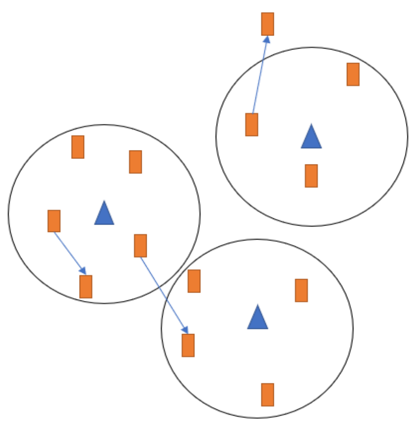


Fig 3.3: Clusters after mobility

After mobility, many of the nodes are getting a very low data rate (lesser than the threshold data rate of the network) from their respective cluster heads due to increased distance from cluster head. So they are removed from their respective clusters. Now hand-off is done for these nodes using our approach. In traditional hand off management, we consider only distance metric and try to add that node to the nearest cluster that provides the suitable data rate. But, in our approach, we consider the energy consumed by a cluster head when the node is added to that particular cluster and we try to minimize the consumed energy and also get the suitable data rate for each cluster.

4. MOTIVATION

In recent years, 5G communication is an emerging technology due to which devices can enjoy the benefit of fast access to the cellular spectrum. Several works have been done in 5G D2D communication but when the nodes are mobile, then it is a challenging issue to successfully implement the D2D communication and to establish communication between devices as they will change their positions. This is the motivation behind our work. We want to investigate the impact of mobility on D2D communication.

The exponential growth of wireless communication and data traffic, high demands for broadband mobile wireless communications, and the emergence of new wireless multimedia applications and services constituted the critical drivers to the development of the Long-Term Evolution-Advanced (LTE-A) network. One of the main challenges of LTE-advanced is to recover the local-area services and enhance spectrum efficiency, increase data rate and reduce the energy consumed by the network. To achieve those goals technical capabilities are required. Device to Device (Device to Device (D2D) communications is a new technology that offers wireless peer-to-peer services and improves spectrum utilization in LTE-advanced networks. D2D communications were initially proposed in cellular networks as a new paradigm to enhance network performance. The motivation for D2D comes directly from the user requirements and D2D communications will serve specific future needs.

5. PROPOSED APPROACH

For initial allocation of nodes:

Random numbers are generated for the X and Y coordinates of N number of nodes in such a way that the range of X,Y is [0, 500] and the distance between two nodes is at least 10 meters. The coordinates generated are stored in text files so that they can be accessed later to run the simulations and take the results.

For initial allocation of clusters:

Clusters are formed from the allocated nodes by randomly selecting cluster heads from the nodes and keeping the minimum pairing distance as 30m. All the nodes within the minimum pairing distance of the cluster head that are not already allocated to any other cluster are allocated to the cluster head. The clustering is done in such a way that overlapping clusters are allocated different resource blocks to prevent interference.

For assigning mobility to cluster nodes:

For all the cluster nodes, the final coordinates for mobility are chosen randomly in such a way that they can travel there from the initial coordinates with a given velocity within a given time. Also, minimum distance criteria between nodes should be maintained. The coordinates of the destination for all nodes are stored in text files so that they can be accessed later to run the simulations and take the results.

For resource block allocation:

We use resource blocks for transmitting signals. We are working on 3 resource blocks. Allocation proceeds sequentially while ensuring signal-to-interference-plus-noise-ratio at the receiver. We have to minimize this interference from other transmitters in the same resource block. A threshold of 6 decibels is enforced, indicating resource block allocation only to transmitters whose receivers achieve SINR >= 6dB.

SINR= $(P_t \cdot g \cdot d_{ij}^{(-\alpha)} \cdot |h_0|^2 \cdot \delta) / (\sigma^2 + I_e)$

were,

P_t is the transmit power (20 dB),

g is the channel gain (-33.58 dB),

d_{ij} is the distance between nodes transmitter i and receiver j,

α is the path loss exponent (4),

h_0 is the modulus of the channel gain (1),

δ is the signal power factor (4 dB),

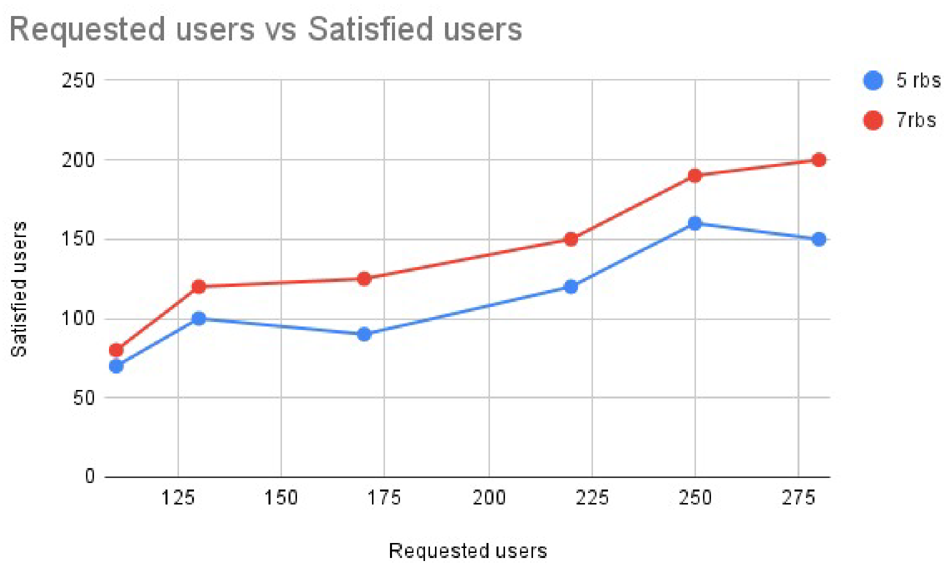
σ is the noise power (σ^2 having value of -107 dBm),

I_e is the interference from other sources.

6. RESULTS AND ANALYSIS

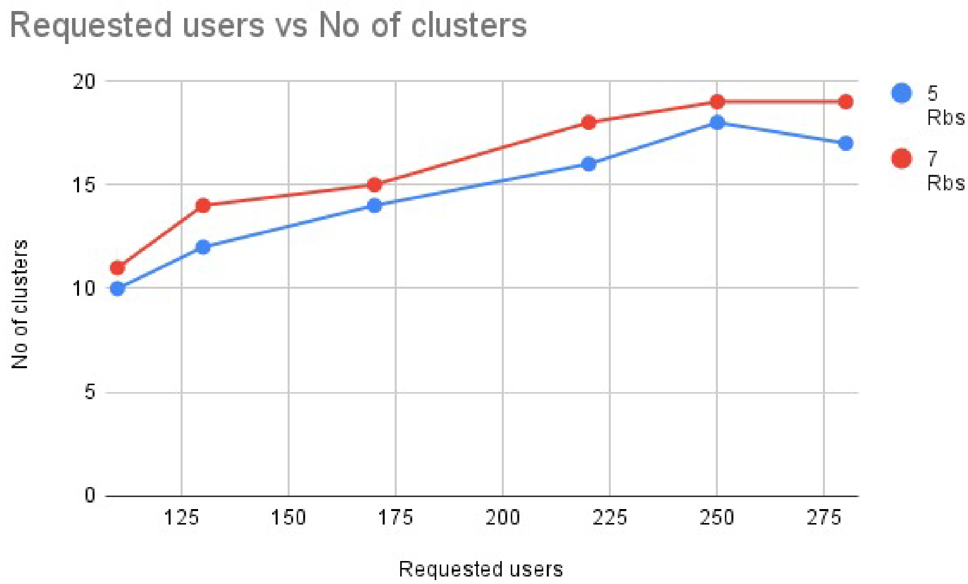
In our experimentation, we deployed nodes in 500*500 area initiating with 150 nodes and incrementing 50 nodes for every 2 seconds ,i.e. for every time slot until 6 time slots resulting in 400 nodes.

Figure 6.1: Served nodes vs. Number of Nodes



The plot in
Figure 6.1 illustrates the comparison between Requested users, representing boundary users located farther from the base station and seeking signal access, and Satisfied users, indicating those users able to receive signal after the application of our algorithm for varying number of resource blocks that are used to transmit signal. This plot is generated with a D2D radius constraint of 80. After observing the plot, it is evident that as the number of resource blocks allocated for signal transmission increases, the number of satisfied users also increases

Figure 6.2 : Requested users vs No of clusters



The plot in Figure 6.2 presents the relationship between the number of requested users, representing boundary users located farther from the base station and seeking signal access and the number of clusters formed using the DBSCAN algorithm for varying number of resource blocks used for signal transmission. This plot is generated with a D2D radius constraint of 80. The plot reveals that as the number of resource blocks increases, the number of clusters formed using DBSCAN also increases.

7. CONCLUSIONS

The proposed approach was thoroughly evaluated through various analyses, including an examination of the number of satisfied users concerning the varying number of requested users and D2D radius. As the number of requested users increases across different resource block utilization levels, we observed a corresponding increase in the number of satisfied users and clusters. This outcome underscores the effectiveness of our methodology, where a higher number of resource blocks facilitate greater signal reach, consequently enhancing user satisfaction across diverse clusters and yielding improved algorithmic results.

Furthermore, with the escalation in the total number of users, there was a parallel increase in the number of served users. This trend can be attributed to the higher user density, fostering the formation of more clusters, and accommodating a greater number of users within each cluster. Consequently, there was a notable rise in the total number of satisfied users.

The significance of our methodology lies in its strategic allocation of resources, particularly in optimizing power consumption by strategically assigning boundary users to relay signals from cellular users unable to receive direct signals from the base station. This approach not only enhances connectivity and coverage but also addresses challenges faced by nodes beyond the initial coverage area. Ultimately, our project offers a robust solution for efficient resource block allocation, minimizing interference and enabling effective multicasting and communication clustering in wireless networks.

8. FUTURE SCOPE

Numerous studies have explored the realm of 5G Device-to-Device (D2D) communication. However, when nodes are mobile, implementing D2D communication becomes a formidable challenge due to the dynamic nature of node positions. Our forthcoming focus will delve into this aspect, investigating the profound impact of mobility on D2D communication. Such insights are crucial, given the pivotal role D2D communication is poised to play in emerging technologies such as Vehicle-to-Vehicle (V2V) communications, mmWave technology, social D2D networks, energy harvesting, and Simultaneous Wireless Information and Power Transfer (SWIPT).

Beyond mere exploration, our aim is to devise solutions that amplify the number of users capable of leveraging device-to-device communication concurrently, all while ensuring affordability. Addressing the multifaceted challenges in this domain is paramount. We are committed to refining our approach to adapt to dynamic environments, paving the way for real-world deployment of our hypothetical model.

Our journey doesn't end here. We envision extending this project to explore the implications of mobile users on the next frontier of cellular networks, including the anticipated 6G technology. This iterative process underscores our dedication to advancing the boundaries of knowledge and innovation. Rest assured, our efforts in network simulation will persist, driving us towards a future where mobile communications are seamlessly integrated into our everyday lives.

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