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Enhancing Throughput in 5G Networks: A Systematic Study and Optimization Strategies

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Abstract: The advent of 5G technology has ushered in a new era of mobile communication, promising ultra-fast internet speeds, low latency, and massive connectivity. As the demand for high quality video streaming, augmented reality, and Internet of Things (IoT) applications continues to surge, researchers have focused on enhancing the throughput of 5G networks to cater these content rich demands. This research paper, aimed at improving throughput of 5G networks. To address the challenges posed by the increasing data requirements, researchers have turned to innovativesolutions, among which Device-to-Device (D2D) communication has emerged as a promising approach. D2D communication fosters direct interaction between devices, optimizing spectrum efficiency, reducing latency, and mitigating network congestion. Drawing from recent advancements in D2D communication, this paper examines its role in 5G networks and its potential to elevatethroughput to unprecedented levels. Moreover, the study delves into the associated challenges, such as security issues, mobility management, and handoff procedures, aiming to shed light on the future prospects and areas of improvement. Through a systematic analysis of existing research works, this paper outlinesto improvise the throughput of 5G networks.By leveraging the potential of D2D communication and exploring innovative research directions, 5G networks can unlock their fullcapabilities, revolutionizing the way we experience and interact with the ever-expanding digital world.

Keywords: *Device-to-Device (D2D), Spectrum efficiency, Quality of service.*

1. Introduction

Over the past few years, the rapid advancement of mobile communication technologies has transformed the way we interact with the digital world. The introduction of 5G (fifth generation) wireless systems stands as a pivotal milestone in this evolution, promising a quantum leap in wireless connectivity and opening up a realm of possibilities for the future of communication. With the proliferation of smart devices, the Internet of Things (IoT), and the ever increasing demand for high-bandwidth applications, 5G networks have emerged as a critical enabler of the digital age . The concept of 5G networks is built upon a foundation of unprecedented speed, low latency, and massive connectivity, allowing for the seamless exchange of data and information across a diverse range of devices and applications. Unlike itspredecessors, 5G is not merely an incremental improvement but represents a holistic transformation of the cellular communication landscape, redefining the very essence of connectivity. At the core of the 5G revolution lies a convergence of cutting-edge technologies including advanced radio access techniques, state-of-the-art antenna designs, network virtualization, and software-defined networking These innovations collectively empower 5G networks to support an array of applications that were previously considered unattainable, such as streaming ultra-high definition videos and engaging in augmented and virtual reality autonomous vehicles, remote healthcare, and smart city initiatives. As the number of connected devices continues to soar exponentially, traditional cellular networks face mounting challenges to accommodate the ever-increasing data demands. 5G networks address these challenges through higher bandwidth capacity, improved spectrum utilization, and enhanced network densification, resulting in a significant boost to overall networkperformance and efficiency.

Moreover, 5G networks are not confined solely to terrestrial communication Unmanned Aerial Vehicles (UAVs), widely recognized as drones have emerged as a novel element in the 5G ecosystem, presenting opportunities for aerial base stations, access points, and relays. The integration of UAVs into 5G networks extends network coverage to previously underserved areas, complements existing terrestrial infrastructure, and opens up new avenues for emergency communication and disaster response scenarios. In this research paper, we delve into the realm of 5G net works, exploring their key features, underlying technologies, and the transformative impact they wield on the world of information and communication technology. We aim to shed light on the vast potential of 5G networks and the diverse opportunities they present for enhancing our digital connectivity.Additionally, we discuss the challenges that accompany this paradigm shift, addressing issues of security, privacy, and the dynamic

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interplay between emerging technologies and legacy systems. By gaining a comprehensive understanding of 5G networks and their multifaceted implications, we can pave the way for a future where seamless communication, data driven innovations, and unparalleled connectivity converge, revolutionizing the way we live, work, and interact with technology.

Through this exploration, we hope to contributeto the ongoing discourse surrounding 5G networks and ignite further research and development endeavours to harness their full potential.

2. Related Works

In [1], the authors focused on improving the communication and efficiency of a network of Unmanned Aerial Vehicles (UAVs) called a UAV swarm. A UAV swarm is a group of heterogeneous (different types) UAVs working together for various tasks. To enhance the communication among these UAVs, the authors propose a method inspired by cell communication. The main objective of the research is to increase the feasibility and throughput of the communication within this heterogeneous UAV swarm network . Feasibility refers to the practicality and achievability of the communication, while throughput is the rate at which data can be transmitted throughthe network To achieve their goal, the authors devise a methodcalled ”cell wall construction”. This construction acts as a means of intercommunication between the different UAVs in the swarm network.
In order to enhance the throughput, the authors represent the optimization of the diverse UAV swarm network as an ”edge colouring problem.” In graph theory, an edge colouring problem involves assigning colors to the edges of a graph such that no two adjacent edges have the same colour. Bysolving this problem, the authors can optimize the way the UAVs use different communication channels, thus enhancing the overall throughput. The research introduces a novel and optimal edge colouring solution to tackle this problem, going beyond conventional approaches.

Additionally, the proposed method incorporates collision mitigation, which ensures that data transmission time slots are efficiently allocated to prevent collisions between UAVs and, in turn, reduce delays. The authors verify the effectiveness of their proposed approaches through evaluation, demonstrating that their methods can reduce the generation of time slots and extend the connections within the UAV swarm network. This means that the communication between different UAVs becomes more efficient and moreover, the paper highlights the benefits of their proposed solution over existing hierarchical and central architectures. The authors demonstrate that their method can provide a morerobust and feasible throughput for communication between the UAV swarm network, indicating better overall performance. Overall, the research contributes to the deployment of UAV swarm networking and promotes massive collaboration and cooperation between UAVs on a large scale. This could have implications for various applications, such as surveillance, datacollection, or coordination in complex missions that involve different types of UAVs.

In [2], The focus of this study is on energy efficiency in Device-to-Device (D2D) communication systems, which play a crucial role as an essential component of the 5G network. The authors propose two schemes called DU-CP and DU- DCP for the HetNet (Heterogeneous Network) underlying the 5G network. The goal is to evaluate and analyse the performance of these schemes in terms of energy efficiency and network throughput. The researchers use optimization techniques called Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) to find near optimal solutions for the formulated scheme. These optimization methods help in efficiently allocating resources and improving the overall performance of the D2D communication system. The results of the evaluation show that the DU-DCP access scheme outperforms the DU-CP access scheme in terms of network throughput. In other words, using DU-DCP leads to better data transmission rates in the network. Additionally, the study demonstrates that the DU-DCP scheme is more energy-efficient compared to the DU-CP method. This means that the DU-DCP approach consumes less energy while maintaining or even improving the network’s performance.

Furthermore, the researchers compare the performance of PSO and GA in optimizing energy efficiency and network throughput. They find that the Genetic Algorithm produces better results for the DU-DCP method compared to the Particle Swarm Optimization, achieving an almost 13% higher energy efficiency. This indicates that GA is more effective in optimizing the parameters for energy-efficient data transmission. To validate the proposed method’s effectiveness, the authors compare it with three other schemes in terms of throughput and energy efficiency. The results show that the DU-DCP strategy, especially when combined with GA, performs significantly better than the other compared methods.

Device-to-Device (D2D) communication as an emerging technology in 5G networks, offering increased convenience to traditional cellular users [3]. The paper focuses on the user’s mode selection during D2D communication and introduces both an optimal and a sub-optimal resource allocation algorithm.

In scenarios with a large number of users and a complex system model, the sub-optimal resource allocation algorithm is proposed as a cost-effective and efficient alternative. Simulation results demonstrate that the methods proposed in the paper significantly enhance system throughput and provide users with a better overall experience. It also acknowledges that as the number of users increases in the future, channel resources will become scarcer, making it necessary to multiplex cellular network resources. However, this resource multiplexing can lead to interference between users, degrading the user experience. Moreover, in a multi-cell environment, allowing multiple D2D pairs to share the same resource block adds complexity and computational overhead to the system model. Addressing the challenges of interference, resource allocation, and computational efficiency in multiplexing D2D communication will be the focus of future research.

In [4], proposes a collaborative flight path planning approach, CARLO, for non-dedicated drones in congested cells to enhance network throughput during parcel delivery missions. Drones adjust altitude to improve energy efficiency and LoS propagation with BTS. High-capacity drones boost throughputbut reduce energy efficiency due to short residence times. Limitations exist as non-dedicated drones prioritize parcel delivery, achieving only local optimality. Future work will ad-dress base placement and optimal drone number to overcome these challenges

3. System Model

Figure 1 depicts our system model illustrating a 5G network architecture that incorporates Device-to-Device (D2D) communication .

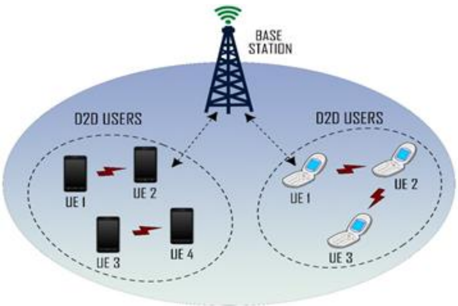

Fig. 1. 5G scenario

Base Stations (BS): These are the central nodes of the 5G network that provide wireless communication coverageto a specific area, often referred to as cells.

Base stations actas access points for connecting devices to the 5G network. In the diagram, you will see multiple devices represented,such as smartphones, tablets, or other types of user equipment.These devices are the end-users' devices that connect to the5G network for communication and data services. D2D communication refers to direct communication between nearby devices without the need to relay through a base station. Inthe diagram, you may see some devices connected to each other directly using lines or arrows, indicating D2D links. This enables devices to exchange data or information directly when they are in proximity to each other, enhancing communication efficiency and reducing reliance on the base station.

The diagram may also depict the interaction between base stations and D2D-enabled devices. For instance, a device may use D2D communication when it is withinthe coverage area of a base station but still prefer to communicate directly with nearby devices for certain tasks, such as file sharing or collaborative applications. The diagram illustrates how base stations are strategically placed to ensure seamless coverage and connectivity for devices throughout the network area. D2D communication can complement traditional cellular communication, especially in crowded or congested areas, improving data rates and overall network performance. Overall, the diagram is likely demonstrating how D2D communication is integrated into the 5G network architecture, showing the interactions between base stations and devices and highlighting the benefits of among nearby devices to enhance communication efficiency, throughput and user experience.

4. 5G Throughput Optimization

To achieve high 5G throughput, let's analyse the 5G frame structure . The maximum data rate transmitted within a single resource block during one slot is determined through our calculations. A resource block consists of 12 subcarriers, and assuming a 30KHz structure, we have 360KHz for one resource block.

- Number of Subcarriers: 12
- Number of Symbols: 14
- Data Symbols: 11
- Total Data Resource Elements: 132 (12 x 11)
- Maximum Bits per Symbol: 7.4063 (256QAM)
- Data carried in one Resource Block over one slot: 977 Bits in 0.5ms

Assuming a 5G bandwidth of 200MHz:

- Number of Resource Blocks in 200MHz: 555 (551 used, 4 RBs as guard)
- Number of Slots available in one second: 2000 (1000 ms / 0.5ms)
- Downlink Slots: 1600
- Maximum Number of MIMO layers: 4
- The 5G Throughput can be calculated as follows:
- Throughput = 977 bits x 551 RBs x 1600 slots x 4 layers / 1024 / 1024 = 3285 Mbps.

To achieve high throughput in 5G, it is crucial to optimize and increase the values of CQI, MCS, and MIMO layers more MIMO layers lead to improved throughput, and higher MCS values enhance the data transmission rate. Additionally, managing the Bit Error Rate is essential as higher BER can negatively impact the overall throughput. By carefullyconsidering and optimizing these parameters, 5G systems can maximize their data transmission efficiency and achieve high throughput performance.

5G Parameters	**Influences on 5G throughput**
• CQI (Channel Quality Indicator)	• Increasing CQI values improves throughput
• MCS (Modulation and Coding Scheme)	• Higher MCS values lead to enhanced throughput
• MIMO layers (Multiple-Input Multiple-Output)	• More MIMO layers contribute to higher throughput
• Bit Error Rate (BER)	• Higher BER reduces overall throughput

Table1: 5G Parameters

5. Algorithm for 5G Throughput Optimization

- Start
- Read input1 from the user (5G channel Bandwidth)
- Read input2 from the user (Subcarrier spacing in KHz)
- Read Mimo Layers from the user (Number of MIMO layers)
- Read Choice from the user (0 for CQI, 1 for MCS)
- Read Index from the user (CQI Index: 0-15 or MCS Index: 0-27)
- Read BlerTarget from the user (Block error rate percentage)
- Calculate the number of subcarriers (x) in the channel: x = input1 * 1000 / (input2 * 12).
- Calculate the number of available Physical Resource Blocks (PRBs):

  NumPRBS = x - 4

  NumPRBS = floor(NumPRBS)
- Display "Available number of PRBs is NumPRBS".
- Set Dlslots to 1600.
- Define arrays SpecEffMcs and SpecEffCqi for spectral efficiency values.
- Determine the spectral efficiency (y) based on the user's Choice and Index:
- If Choice is 0, set y to SpecEffCqi[Index].
- If Choice is 1, set y to SpecEffMcs[Index].
- Calculate the Transport Block size (TbSize): TbSize = 132 * y
- Round down the TbSize to the nearest integer: Tbsize = floor(TbSize).
- Calculate the Maximum Throughput for the given configuration:
- Throughput = TbSize * NumPRBS * Dlslots * MimoLayers
- * ((100 - BlerTarget) / 100) / 1000 / 1000
- Display "Maximum Throughput for this configuration is Throughput".
- End

6. Result

In the below Fig.2, we observe clear trends and patterns that shed light on the system's behaviour under different conditions. Notably, certain configurations demonstrate higher throughputrates. Achieving high throughput in 5G is influenced by in- creasing the values of CQI and MIMO layers. Similarly, we observed that higher values of MCS and MIMO layers also lead to improved throughput. These parameters play a crucial role in optimizing 5G throughput. Additionally, we noticed that Bit Error Rate (BER) also impacts the throughput; as the BER increases, it reduces the overall throughput. Therefore, optimizing CQI, MCS, MIMO layers, and managing BER are all essential considerations for maximizing 5G throughput.

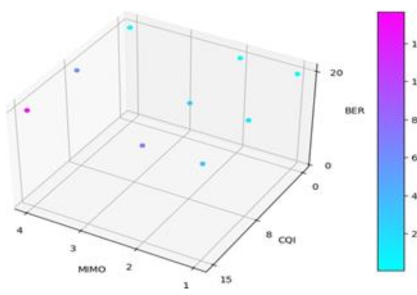

Fig. 2. Throughput versus CQI MIMO

In Fig.2. our analysis demonstrates that a higher throughput is achieved when the bandwidth of 100 subcarriers in a 30 MIMO (Multiple Input Multiple Output) system is set to 4, and the Channel Quality Indicator (CQI) is 15. The results, as depicted in the diagram above, clearly illustrate the impact of these parameter settings on achieving improved data transfer rates.

In Fig.3., the investigation reveals that setting the bandwidth of 100 subcarriers in a 30 MIMO system to 4, along with using Modulation and Coding Scheme (MCS) 27, leads to a higher throughput. The diagram presented above effectively illustrates the substantial impact of these specific parameter configurations on achieving superior data transfer rates.

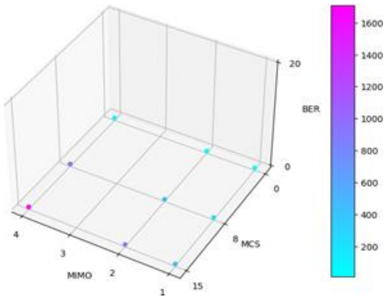

Fig. 3. Throughput versus CQI MCS

In Fig.4., our findings demonstrate that a higher throughput is achieved when the bandwidth of 100 subcarriers in a 30 MIMO system is set to 4, and the Channel Quality Indicator (CQI) is 15, along with achieving a Bit Error Rate (BER) of 0. The diagram presented above provides a clear illustration of the significant impact of these specific parameter settings on improving data transfer rates.

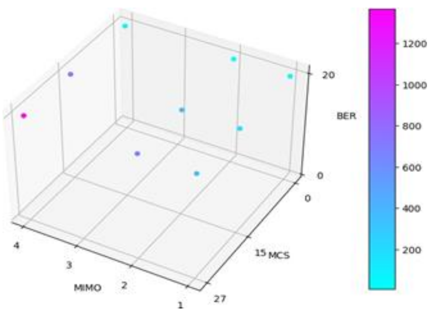

Fig. 4. Throughput versus CQI, MIMO, BER

In Fig.5., the results indicate that setting the bandwidth of 100 subcarriers in a 30 MIMO system to 4, along with using Modulation and Coding Scheme (MCS) 27 and achieving a Bit Error Rate (BER) of 0, leads to a higher throughput. The diagram provided above clearly illustrates the significant impact of these specific parameter configurations on improving data transfer rates.

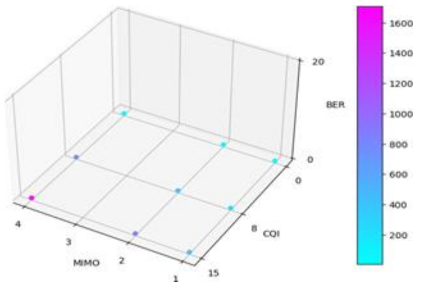

Fig. 5. Throughput versus CQI MCS, BER

6. Conclusion

The key to increasing the throughput of 5G systems lies in optimizing several critical parameters. By enhancing the values of Channel Quality Indicator (CQI) and employing multiple- input and multiple-output (MIMO) layers, we observed a substantial improvement in throughput. Additionally, higher values of Modulation and Coding Scheme (MCS) and MIMO layers were also found to positively impact data transfer rates. Managing the Bit Error Rate (BER) is equally crucial, as a higher BER negatively affects the overall throughput. Thus, a comprehensive approach that focuses on optimizing CQI, MCS, MIMO layers, and controlling BER emerges as essential for achieving maximum 5G throughput.

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