

# Research on Dynamic Channel Capacity Allocation Algorithms in 5G Networks

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**Abstract.** Fifth-generation (5G) mobile technology, characterized by ultra-low latency, ultra-high transmission speeds, and ultra-large bandwidth, are widely utilized in various fields such as civilian communication, telemedicine, and military technology. Currently, the construction of 5G networks has transitioned from the theoretical stage to a phase of rapid practical application. 5G mobile communication systems, smart interconnectivity, and related technologies have been widely adopted in the civilian sector. However, the development of 5G networks towards broader application scopes and deeper application depths still faces multiple challenges, including the dense construction of base stations, allocation of spectrum resources, network information security, and device compatibility, among others. This paper focuses on the issue of spectrum resource allocation, specifically discussing various algorithms for dynamic channel capacity allocation, such as Proportional Fairness (PF), Adaptive Modulation and Coding (AMC), and Network Slicing (NS). It provides accurate explanations of the improvements made to these algorithms as well as their new applications. This paper provides scientific references for professionals and offers a comprehensive overview of 5G dynamic channel capacity research for amateur readers.

**Keywords:** 5G network; PF; AMC; NS.

## 1. Introduction

Due to its characteristics of ultra-large mobile broadband, ultra-reliable low-latency communication, ultra-high transmission rates, and massive machine-type communication, 5G is experiencing continuous growth in user scale. According to Ericsson's regular mobile report released in November 2023, over 280 service providers worldwide are offering commercial 5G services. This widespread adoption indicates the rapid growth of 5G technology. Forecasts predict that by 2029, global 5G mobile users are expected to reach 5.3 billion, suggesting a significant shift towards 5G in the coming years. With its powerful performance features, 5G can provide a wide range of applications such as virtual reality, high-precision intelligent manufacturing, smart city transportation, and aerospace services [1]. 5G offers strong technical support for various industries, driving them towards digital and intelligent innovation. For example, in smart manufacturing, 5G's low latency and high reliability enable real-time monitoring and control of production processes. In autonomous driving, 5G's high-speed data transmission allows vehicles to communicate with each other and with infrastructure in real-time, enhancing safety and efficiency.

However, despite its numerous application advantages, 5G faces significant technical difficulties and development challenges. Compared to 4G, which operates at lower frequency bands, 5G utilizes higher frequency carrier signals, resulting in greater bandwidth and faster data transmission speeds, but also shorter propagation distances and reduced penetration capabilities. This necessitates the deployment of dense small cell bases in both urban and rural areas to ensure high-quality coverage. The application of MIMO technology in 5G requires large-scale new hardware and advanced antenna technologies, leading to high infrastructure costs and ongoing maintenance expenses. While 4G commonly operates within the frequency range of 800 MHz to 2.6 GHz, 5G frequently utilizes bands from 600 MHz to 40 GHz. The introduction of more frequency bands increases spectrum resources but also presents new challenges in spectrum utilization and management, particularly in high-density environments such as sports venues, shopping malls, and smart transportation scenarios. The powerful capabilities of 5G allow for simultaneous access by multiple users and the transmission of

large data volumes. While this enhances network efficiency, it also poses severe challenges. For information security, the increased number of connected devices and data flow creates more potential entry points for network attacks. In terms of device compatibility, ensuring that a wide range of devices can effectively utilize 5G's advanced features requires significant technological adaptations and device upgrades.

Given these challenges, efficient spectrum resource allocation is crucial for maximizing 5G's potential. This paper focuses on spectrum resource allocation issues, specifically discussing the advantages of PF, AMC, and NS in dynamic channel capacity allocation within 5G networks, and anticipates future application prospects. These technologies play key roles in addressing the complex demands of 5G networks.

## 2. Dynamic channel capacity allocation algorithm and optimization algorithm

### 2.1. PF Algorithm

Proportional Fairness algorithm is an effective frequency resource allocation strategy in wireless network communication. PF can maximize the overall efficiency of the system while equitably allocating resources to users and make more resources available to higher-priority target users [2]. Li et al. present association control algorithms based on optimal proportional fairness. With the association control algorithms, the total throughput of the network can be 2.3 times greater than the max-min fair allocation and is better than the default user-AP association method in the 802.11 standard [3].

#### 2.1.1 Application of PF and its reformation in 5G

Device-to-Device (D2D) communication is a new type of communication mode that is directly connected to devices to achieve the huge data transmission rate, extremely low power consumption and extremely low latency required by 5G networks [4]. Fig. 1 shows D2D.

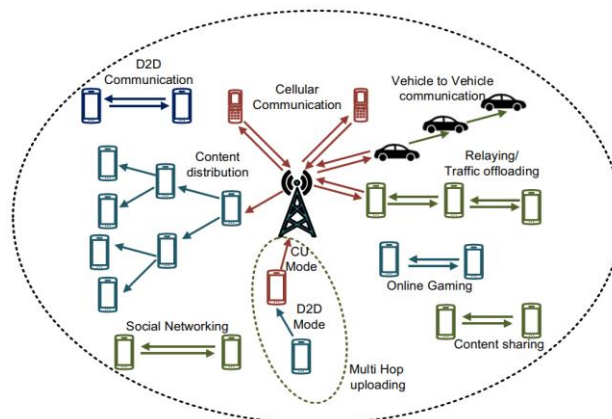


Fig. 1 D2D cellular communication model [4]

However, D2D will bring serious co-channel interference problem, which makes channel capacity allocation face challenges. Yu et al. achieve efficient power control and resource allocation that make the network achieve maximum throughput [5]. Ban et al. propose the centralized scheduling method and distributed scheduling method to avoid co-channel interference [6]. The studies mentioned above primarily focus on channel throughput, without considering fairness. Li et al. have proposed a new joint power control and resource scheduling scheme for underlay D2D communication [7]. They establish a proportional fair resource allocation problem by optimizing the sum of all users' proportional fair functions, and propose a resource allocation algorithm with low computational difficulty and low consumption. Through this algorithm, the Quality-of-Service levels of all D2D users and cellular users can be maintained simultaneously and the throughput and fairness of the system can be significantly improved. Therefore, the PF algorithm can solve the problem of co-channel interference in complex cases, and ensure the throughput and fairness of the network.

Millimeter wave (mmWave) communication is used in 5G communication, especially industrial 5G communication, because of its ultra-large bandwidth and extremely low interference characteristics. At the same time, mmWave communication has some shortcomings, such as easy to block obstacles, serious signal attenuation, short wavelength and low coverage rate, which bring great troubles to the actual use [8]. Medium access control (MAC) layer is an important part of the mmWave communication. Ma et al. study the effective utilization of PF algorithm in MAC layer and propose enhanced proportional fair scheduler which not only improves the priority of users under bad channel conditions, but also speeds up the reaction time under fluctuating channel conditions [9].

### 2.1.2 Summary of PF algorithm

PF algorithm is widely adopted in 4G and 5G networks to maximize system throughput while ensuring user fairness. The improved PF algorithm is also used to solve the problem of co-channel interference in D2D and MAC scheduling in mmWave communication.

## 2.2. AMC Algorithm

AMC is a technique that dynamically adjusts modulation and coding schemes in wireless communication systems. The AMC can dynamically adjust the modulation mode and coding rate according to the quality of the channel to optimize the data transmission efficiency and improve link spectrum utilization.

### 2.2.1 Application of AMC and its reformation in 5G

Extensive research has been conducted on 5G technology to achieve breakthrough data transmission rates. 5G networks can achieve data transfer rates exceeding 1Gb/s, with peak rates reaching around 10Gb/s. In specific scenarios the data transmission rate can reach 20Gb/s or even higher [10]. High data rates require more spectrum resources. However, due to technical reasons, frequency bands above 6 GHz and mmWave communication have not been widely used, while the spectrum below 6 GHz faces congestion or overuse due to limited resources. AMC algorithm optimizes data transmission rates through dynamic modulation, improving spectrum efficiency. As a result, it has become one of the main dynamic channel capacity algorithms in 5G communication. The AMC algorithm is often combined with a variety of algorithms to obtain various levels of modulation and coding. The paper explores the application of AMC algorithm in large-scale MIMO systems using online deep learning (ODL) algorithms. Compared to traditional OLLA, the deep learning-based AMC technology demonstrates a 10% to 20% increase in user throughput in a full-buffer scenario [11]. Due to the characteristics of 5G network, AMC classifier is required to have high accuracy and short calculation time. Hermawan et al. propose an algorithm called IC-AMCNet, which is an enhanced convolutional neural network-based automatic modulation classification network designed for determining the modulation type of wireless signals [12]. Fig. 2 shows a comparison of the classification accuracy of different algorithms with SNR distributed from -20dB to +18 dB.

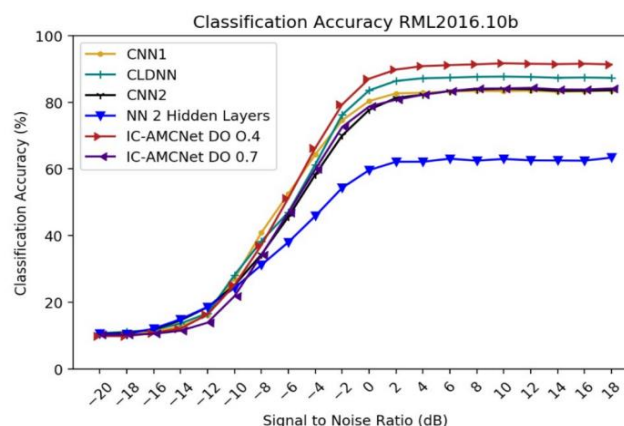


Fig. 2 Classification accuracy of different algorithms in signal to noise ratio [12]

**Table 1.** Computing time comparison [12]

Algorithms	CNN1	CLDNN	CNN2	NN	ICAMCNet
Computing time (ms)	0.0165	0.1109	0.0910	0.0029	0.0048

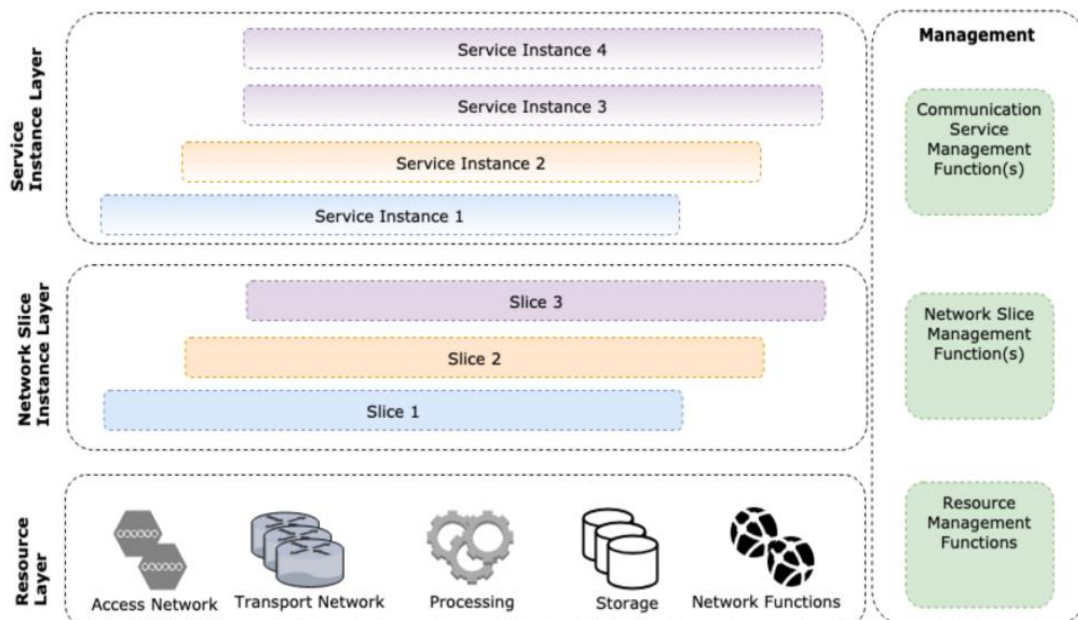
Table 1 shows the computing time in different algorithms. According to Fig. 2, when the SNR is approximately 10 dB, IC-AMCNet achieves the highest accuracy (91.70%) with a dropout value of 0.4. Additionally, as shown in Table 1, the computation time of IC-AMCNet is only 0.0048 ms. Simulation results show that the algorithm significantly outperforms previous methods in both classification accuracy and computation time, and meets the estimated latency standards for beyond 5G communication.

**2.2.2 Summary of AMC algorithm**

Adaptive Modulation and Coding algorithm is one of the main algorithms in 5G communication system. Recent advancements include integrating AMC with deep learning for improved throughput performance and combining AMC with enhanced convolutional neural network for gaining high accuracy with low latency. By combining different intelligent algorithms, AMC algorithm makes a great contribution to the development of future 5G networks.

**2.3. NS**

Network slicing stands out as a game-changing innovation poised to revolutionize future communication networks. It uses virtualization technology to separate and allocate physical resources (such as bandwidth, computing, and storage), thereby dividing the physical network into multiple logically independent virtual networks. Each slice has specific network functions and resource configurations, allowing it to provide specialized services for different application scenarios, such as ultra-high bandwidth applications (video streaming), low-latency applications (autonomous driving), and massive IoT (Internet of Things) devices. Fig. 3 shows the overall architecture in NS.

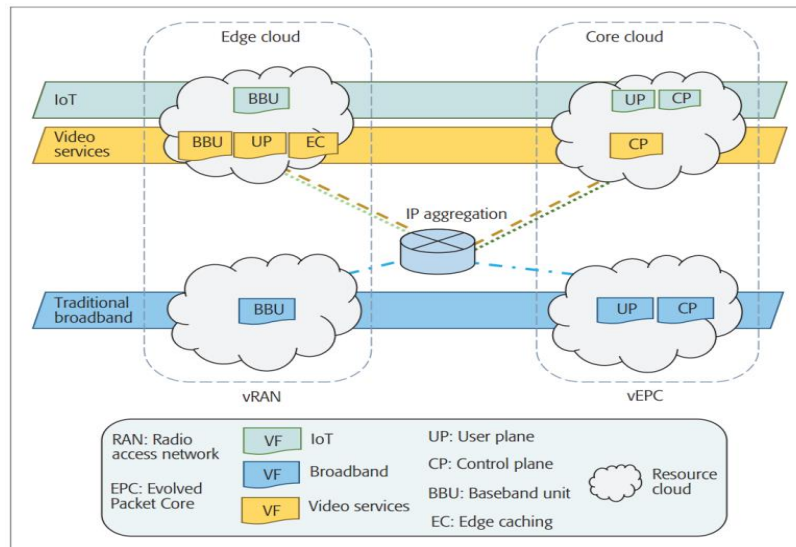


**Fig. 3** Overall architecture in network slicing [13]

**2.3.1 Realization and challenges of NS**

NS is primarily implemented through two key technologies: Software-Defined Networking (SDN) for network allocation, and Network Functions Virtualization (NFV) for service provisioning. Using SDN routers, virtual links can be established more easily. SDN enables administrators to remotely configure the physical network, allowing them to allocate resources on demand for network slices. Virtual nodes deliver specific network functions, akin to physical nodes in traditional networks.

Virtual nodes can be implemented as Virtual Network Functions (VNFs) running on standard hardware, thereby creating cloud infrastructure [14]. Fig. 4 shows an example of NS and VNFs.



**Fig. 4** Network slices supporting indicative applications with diverse requirements. Each slice consists of different VNFs, which can be placed on different physical network domains [14]

In a network composed of SDN routers and NFV capabilities, slices can be quickly instantiated and reconfigured according to varying dynamic needs. This approach enables 5G networks to simultaneously meet the diverse requirements of multiple professional communication networks, supporting parallel multi-user scenarios.

While NS effectively addresses 5G network needs and offers substantial user benefits, it also grapples with numerous challenges. Security issues in network slicing are one of the key areas of focus. Olimid et al. discuss several major security concerns in network slicing, such as the security of the network slice life cycle at different stages, intra-slice security, and inter-slice security [13]. It also discusses end-to-end security, AI-based self-defense mechanisms for network slicing, and methods for implementing strict isolation. Another challenging aspect is the resource management issues in network slicing. The paper proposes a method for optimizing neural networks with evolutionary features to address the dynamic network slicing problem [14]. In the 5G domain, NS still faces urgent challenges such as fairness between slices and heterogeneous demands for achieving true commercial and industrial applications.

### 2.3.2 Summary of NS

NS has attracted significant attention in 5G research for its ability to create independent virtual networks supporting parallel multi-user applications. NS is primarily implemented through NFV and SDN, but faces numerous challenges in practical applications. However, its implementation and use are expected to bring groundbreaking advancements to future 5G networks and even the 6G domain.

## 3. Conclusion

This article focuses on the spectrum resource allocation issue, specifically discussing the applications of Proportional Fairness (PF), Adaptive Modulation and Coding (AMC), and Network Slicing (NS) in dynamic channel capacity allocation for 5G networks. It examines how PF maximizes system throughput while ensuring fairness in spectrum allocation. Additionally, it discusses PF's advantages in Device-to-Device (D2D) communication and its applications in microwave communication. Moving on to another important technology, AMC is a dynamic modulation and coding technique used in wireless communication systems. The AMC algorithm optimizes data transmission rates through dynamic modulation, thereby improving spectral efficiency. This article emphasizes the combination of AMC technology with deep learning algorithms. The IC-AMCNet

proposed by Hermawan et al. achieves high classification accuracy and low computation time. NS is an innovative technology for future 5G applications that utilizes virtualization techniques to separate and allocate physical resources (such as bandwidth, computing, and storage). This effectively divides the physical network into multiple logically independent virtual networks. This approach allows 5G networks to simultaneously meet the diverse needs of multiple specialized communication networks, supporting parallel multi-user scenarios. However, NS technology currently faces various challenges, including inter-slice security, intra-slice security, and resource management for network slicing. With the integration of artificial intelligence technologies and deep algorithms into 5G network resource allocation algorithms, new methods for optimal spectrum resource allocation and channel capacity distribution will continue to emerge. As issues such as dense base station construction, spectrum resource allocation, network security, and device compatibility are addressed, the application of 5G technology will become more widespread. Future 5G will not be limited to experimental phases or restrictive application scenarios. Instead, it will fully leverage its superior performance advantages to make breakthrough contributions in areas such as smart cities, autonomous vehicles, and remote healthcare, ultimately improving human quality of life.

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