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High-throughput Data Offloading Scheme in The Coexistence Environment of 5G Cellular Network and WiFi 7

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Abstract

In order to meet the demand of data growth and overcome the problem of expensive and shortage of cellular network spectrum resources, heterogeneous network is recognized as one of the promising network technologies to solove the problems. Among them, the data offloading technology has been widely studied. However, most of the literature considers the traditional WiFi protocols (such as IEEE 802.11g, IEEE 802.11ac, IEEE 802.11n) and 4G networks. In a dense environment, future released IEEE 802.11be standards and 5G strategic deployment plans will take a big step forward in wireless network communication technology with high and reliable throughput and network performance.In the coexistence environment of WiFi and 5G network, the original data offloading strategy can no longer meet the needs of the new network scenario, so the new data offloading scheme should be combined with the new characteristics of 5G and WiFi communication technology. This plays an important role and is of a practical significance for the 5G deplpoyment, the efficient application of the next-generation WIFI networks, and the development of the Internet of Things.

Keywords

WiFi 7; IEEE 802.11be; 5G Cellular Network; OFDMA.

1. Introduction

Mobile data traffic has exploded with the growing demand for wireless access and the widespread use of various rich media outlets. According to the Cisco survey data, the global monthly mobile data traffic will reach 77EB in 2022, and nearly 1ZB per year[1]. The Internet is popularized on a large scale, the mobile Internet is widely used, and the Internet of Things is deeply applied in all walks of life. Mobile and wireless communications have subsequently undergone major technological changes, including Wireless Personal Area Networks (WPAN), Wireless Local Area Network (WLAN), wireless city area networks and wireless wide area networks.

WiFi networks based on the IEEE 802.11 standard [2] are widely used due to their support for user mobility, flexible deployment, strong scalability, and low maintenance costs. More than 60% of the mobile data traffic is diverted to the WiFi networks. With the continuous extension of large traffic and low latency applications such as 4K/8K HD video, AR/VR, online games and online video conferencing, people put higher demand for the throughput and latency of dense WiFi networks. To this end, the IEEE TGbe working group will focus more on multi-AP scenarios, using AP collaboration technology to develop the next generation of WiFi 7 standards, namely IEEE 802.11be, and plans to release in May 2024 [3]. The 7th-generation WiFi standard plans to use higher frequency (6 GHz), greater bandwidth (320 MHz), more antennas (16 MIMO), and higher-order modulation technology (4096-QAM) to increase the peak throughput to 4 timesof the sixth-generation WiFi[4]. Networks based on IEEE 802.11be standards are also known as Extremely High Throughput (EHT) networks. Theoretical research and application deployment

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of new technologies and new features in WiFi 7, including multi-user channel access, spatial reuse, heterogeneous network, etc., have become the research hotspot and cutting-edge technologies in recent years.

Cellular network technology has been continuously improved and innovated, so that the data transmission rate has been significantly improved. The fifth-generation cellular mobile communication system (5G) was put into operation in some Chinese cities in 2019. However, the surge in mobile smart devices has strained the limited cellular network spectrum resources, and the explosion of wireless data traffic has also posed challenges for network operators. The current communication network capacity has been difficult to support the explosive growth of data traffic, and the cellular network is difficult to guarantee the high-quality communication needs of users. In order to meet the demand of data growth and overcome the high cost and shortage of cellular network spectrum resources, the academia and industry have proposed various solutions. Multiple heterogeneous networks present in the mobile Internet are recognized as one of the promising network technologies[3]. It uses the advantages of different networks to solve the problems of cellular traffic overload and spectrum resource shortage, improve the throughput of the network, increase resource utilization and improve the service quality of users, and bring better experience for users. The solution in heterogeneous networks is to offload data services from Long Term Evolution (LTE) to license-free frequency bands, such as 2.4 GHz industrial, scientific, and medical (ISM) frequency bands and 5 GHz license-free National Information Infrastructure (UNII) frequency bands, to improve cellular network capacity efficiently, and work at a low cost.

At present, most of the heterogeneous networks composed of LTE and WiFi consider both 4G cellular networks and traditional WiFi networks. There are four main solutions in the heterogeneous network. That is LTE and WiFi: LTE-U technology (LTE-Unlicensed) [5], LAA technology (License Assisted Access) [6], LWA technology (LTE + WiFi Link Aggregation) [7], and offloading technology [8]. In a dense environment, WiFi 7, which introduces new technology, will coexist with immature 5G networks, and it is still in many ways to improve. Combined with the new WiFi 7 technologies and new mechanisms, such as multi-RU operation, operate based on trigger frames, designing reasonable and highly efficient user allocation and data offloading scheme in the time dimension has become an important research point. It includes user allocation and association scheme for throughput optimization, and data offloading scheme for throughput optimization. This is of an important role and practical significance for the 5G planning, the efficient application of the next-generation WIFI networks, and the development of the Internet of Things.

2. Research State and Future Development Tendency

With the rapid development of wireless technology, the application scenarios of WiFi (universities, shopping malls, high-speed rail stations, office buildings, etc.) and LTE system (4G technology) emerge. The problems of resource allocation and data offloading have become two important contents in the coexistence network of WiFi and LTE system.

2.1. Resource Allocation Schemes in a WiFi and LTE Coexistence Environment

With the continuous development of wireless network technology, more and more mobile devices can transmit their data in the range of both WiFi and LTE simultaneously. In both WiFi and LTE coexistence environments, terminals with WiFi interfaces and cellular interfaces need to consider which network to select for data transfer. If most terminals connect to one of these networks, it can cause uneven resource allocation in coexistence environments, thus causing problems such as network overload or channel idle. How to connect with dual-interface users in the WiFi and LTE coexistence environment is particularly important. Researchers have studied user allocation strategies in coexisting environments, considering how to design

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reasonable user allocation schemes to improve performance indicators (e. g., throughput, energy efficiency).

G. Yu et al.[9] proposed that heterogeneous networks integrating a variety of wireless access technologies is a promising technology to allocate resources in heterogeneous networks to maximize the energy efficiency of each user in the system while ensuring the user QoS requirements. H. Beyranvand et al [10] studied heterogeneous networks centered on user data to assess WiFi and LTE maximum aggregate throughput by probabilistic analysis and validation simulations. S. Navaratnarajah et al. [11] propose an adaptive random wireless access selection scheme for the dual region coverage scenarios of LTE and WiFi, allowing users to choose which network to access to according to the load of the two networks and their own performance requirements. In order to meet the growing demand for data, Ajami. A et al.[12] studied the coexistence environment of WiFi and LTE. They allocated the resources of license-free band to users in LTE to achieve high user transmission. And then, they modeled the base station, access point and user positions into independent Poisson point processes, derived the throughput of uplink and downlink, and proved that WiFi and LTE system can achieve perfect coexistence on license-free band.

2.2. Data Offloading Scheme in a WiFi and LTE Coexistence Environment

In the coexistence environment of WiFi and LTE system, the researchers propose to offload some users in the LTE system to WiFi, and to use the advantages of WiFi to relieve the pressure of LTE. LTE does not consider the technical compatibility with WiFi. But the technology of data offloading help the LTE cellular network to expand the system capacity in an efficient and low-cost way[13]. Therefore, the problem of data offloading in the coexistence environment of WiFi and LTE has attracted wide attention at home and abroad. According to literature [14][15], research scholars work to optimize data offloading strategies for capacity, cost, and energy consumption.

Most of the literature considers traditional WiFi protocols (such as IEEE 802.11g, IEEE 802.11ac, IEEE 802.11n) and 4G networks. In a dense environment, future released IEEE 802.11be standards and 5G strategic deployment plans will take a big step forward in wireless network communication technology with high and reliable throughput and network performance. Therefore, when the user is in the coexistence environment of WiFi and 5G network, the original data offloading strategy will no longer meet the needs of the new scenarios. Thus the new data offloading scheme should be combined with the new characteristics of 5G and WiFi communication technology.

2.3. Summary of the Research Status

The fifth-generation mobile Communication System (5G) [16] which will operate on the same license-free frequency band with WiFi. Whether many coexistence solutions can be directly applied is questionable questions. Research on the WiFi 7 standard faces not only intensive deployment, but also challenges from new 5G cellular networks using license-free frequency bands.

Therefore, in the face of new environments and new features, we need to study the efficient resource scheduling schemes. Besides, we also have to pay attention on how to share the spectrum resources with the 5G network to improve the overall performance of the network. The above is also the main motivation for the research of data offloading schemes.

3. Main Research Content

Heterogeneous networks offloading data transmission services from Long Term Evolution (LTE) to license-free frequency bands, improving the capacity of the cellular network efficiently and at a low cost. As a result, the development of the new WiFi 7 standard also faces the problem of

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coexisting with cellular networks in the 5 GHz band, including 5G cellular networks just into use. In a heterogeneous network composed of cellular and WiFi, uninstallation technology is regarded as a promising solution to uninstall data transmission services from cellular networks into WiFi using the respective advantages of WiFi and cellular networks.

Reasonable user allocation and offloading policies of LTE-WiFi heterogeneous networks are very important. While protecting the business of WiFi users, we can find the optimal number of uninstall users, allocate reasonable resources for the two types of users, and design a reasonable RU resource allocation scheme for each terminals. To complete the offloading strategy, most operators have deployed their own WiFi, which will cause more WiFi overlapping area further exacerbate the collision and interference problems in the intensive deployment, and bring more challenges to the development of the next generation of WiFi development. LTE-U (discontinuous transmission) adopts duty ratio method. It will keep silent in certain time periods, i.e. LTE in some periods, and WiFi in some periods. The technology of LAA uses the post-start mechanis, which can improve throughput and maintain fair coexistence with WiFi. According to the new feature of multi-user simultaneous transimission in WiFi 7, we have to study the impact of LTE-U / LAA on the WIFI network on the shared 5GHz frequency band resources. To complete the efficient data transmission on LTE-U / LAA and WiFi, time scheduling needs to be well planned, such as the duty cycle allocation scheme of LTE-U in the coexistence environment.

3.1. User Offloading Scheme

When the cellular network traffic overload, it will cause a large delay in the network. Combining the new technologies of the next generation of WiFi with 5G, we have to consider how to offinstall user data transmission services under the constraints of QoS indicators (such as throughput, latency, system capacity, and cost) for cellular users and WiFi users. If excessive user competition in the WiFi network, uninstalling WiFi users to LAA / LTE-U to the license-free frequency band will lead to a sharp performance decline. Hence, how to shares part of the license-free frequency band resources to LAA / LTE-U to achieve a win-win situation for the WiFi network is of great importance.

3.2. The RU Resource Allocation Scheme

After the offloading is completed in the heterogeneous network, the AP will add new users on the basis of the original users. These original users also use the IEEE 802.11be protocol. Considering the different data access characteristics of unloaded users and original users, a reasonable resource allocation algorithm should be designed to ensure that the overall throughput is as high as possible under different QoS requirements. In the dense environment after offloading, it will cause interference and collision that cannot be ignored. Therefore, it is necessary to combine the BSS color technology in WiFi to study the RU resource allocation under multi AP circumstances. In addition, on the basis of extensive research on the new features of next-generation WiFi, and the modeling and analysis results of MU-OFDMA performance indicators, it provides a foundation for LTE-U/LAA channel time allocation of different source terminals in the coexistence environment of 5G networks and next-generation WiFi.

3.3. User Association Issues

After giving the user allocation scheme and the user offloading scheme between the WiFi and 5G coexistence environment, the rapidly changing user mobility problems should be addressed. From the perspective of the coexistence environment of 5G and WiFi, most outdoor users are mobile. When users connect to 5G network or WiFi network for data transmission, machine learning and game theory will seek the best and fairest connection mode for maximizing the network performance.

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4. Conclusion

The use of data offloading technology in a heterogeneous network to reduce the pressure on the cellular network is to uninstall the data transmission services in the cellular carrier to their own deployed WiFi. Since LTE system and WiFi system are operate on the same band, the data offloading have to consider the new technology in the 7th generation IEEE 802.11be standard. WiFi 7 introduces OFDMA based multi-RU operation, which is very suitable for dense environments. The data offloading scheme should consider how to allocate new resources to uninstalled users and original users, how to rationally use RU, and improve the overall throughput of WiFi and cellular network as much as possible.

User allocation scheme in the WiFi and 5G coexistence environment is used to solve the network association problems (connect to 5G or WiFi for communication). Due to the continuous development of 5G and WiFi technologies, it is foreseeable that the nationwide 5G networks and the WiFi 7 proposed by IEEE organizations will achieve comprehensive mutual coverage. Within the overlapped coverage range, how to allocate the users between the two types of networks to maximize the throughput by considering their economic cost, energy consumption, network throughput and other factors becomes more and more important.

The WiFi and 5G coexistence environment is used to solve the contradiction between the operator spectrum scarcity and the explosive growth of network traffic. Due to the explosive growth of data traffic. It is difficult for 5G network to expand their spectrum capacity for data transmission. The WiFi uses free license-free spectrum resources, which can uninstall some 5G users to the WiFi network to alleviate the spectrum resource shortage of cellular wireless access. Consider the number of user access to WiFi and 5G networks, we have to uninstall paid 5G users to indoor WiFi networks to relieve the pressure on cellular networks.

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