

Review of Heterogeneous Wireless Fusion in Mobile 5G Networks: Benefits and Challenges

Yuan Gao^{1,2,3(✉)}, Ao Hong², Quan Zhou², Zhaoyang Li², Weigui Zhou², Shaochi Cheng¹,
Xiangyang Li¹, and Yi Li^{3,4(✉)}

¹ China Defense Science and Technology Information Center, Beijing, China

² Xi Chang Satellite Launch Center, Xichang, China

³ State Key Laboratory on Microwave and Digital Communications, National Laboratory for Information Science and Technology, Tsinghua University, Beijing, China
yuangao08@tsinghua.edu.cn

⁴ The High School Affiliated to Renmin University of China, Beijing, China
liyi@rdcz.cn

Abstract. The 5th generation wireless network has become popular in recent days, the system could provide higher transmission speed, lower latency, enhanced spectrum efficiency and energy efficiency. However, the improvements are mainly focused on mobile base stations such as large scale MIMO, full duplex, etc. The resources of integrated multi-functional mobile terminals are wasted. In this work, we discuss the fusion technology in 5G wireless networks, to make full utilization of multi-functional terminals, the fusion of 5G, Wi-Fi, ZigBee, Bluetooth will greatly increase the transmission speed and reduce the latency, both benefits and challenges are summarized. In heterogeneous architecture, simulation results indicate that the fusion of mobile terminals could increase system capacity and reduce transmission latency significantly.

Keywords: Wireless fusion · Mobile terminal · Heterogeneous networks · 5G

1 Introduction

In the past five years, the rapid development of mobile communication technology has brought changes in the communications industry, especially the number of mobile terminals and processing ability has been greatly improved. The 2016 National Science and Technology R & D program focused on “broadband communications and networking” has mentioned that, to speed up the establishment process of the fifth generation mobile communication (5G) systems and further improve the transmission speed and efficiency of the wireless network is the major mission of the upcoming 5 years. In order to meet growing demand of customers for QoS, 3GPP LTE Advanced Pro (LTE Rel.14) [1, 2] and the 5G IMT-2020 white paper are network architecture and key technologies for future mobile communication systems were discussed, especially the ultra-high dense networks with Device to Device communication (D2D), which could improve the transmission rate and reduce transmission delay of technical breakthroughs [3].

As an important method to enhance the transmission rate, many researchers tried to optimize the transmission schemes in base station side, such as using distributed antenna systems (DAS), base stations cooperation (CoMP), large-scale MIMO, etc., which could significantly enhance the user's transmission speed. However, these improvements are mainly in the base station side, the multi-functional mobile terminals are omitted and the resources are wasted. Considering the amount of mobile terminals are large with satisfied performance, so how to make full use of such integrated wireless transmission methods becomes a new chance [5].

Current researches on D2D collaborative technology has been discussed for a long time [6]. Researches on Cooperative D2D communication contains two major aspects:

D2D relay system: In order to shorten the distance between the base station and the target user, users located between base stations and target users will be considered as relay node, data is transmitted to destination via point to point transmission, and such operation could help reduce the loss of long-distance transmission. The main contribution of such problems are summarized in reference [7–10], where the joint optimization of relay selection and resource allocation in single-hop and multi-hop scenario. Traditional solution is to form a continuous convex optimization problem and find out optimal relay nodes and optimal resource allocation policy. There are still problems remaining in this scenario, such as the assumption of ideal channel estimation and mobility.

D2D cooperative multi-functional terminal design: This is the most complex research in D2D, including the cooperative node selection [11], selection of cooperative scheme [12, 13], the optimization of cooperative transmission design (including power allocation [14], bandwidth allocation [15–18] and optimization of spectral efficiency [19, 20]) as well as constraint cooperating scenarios optimization design [21] and other studies. The above references are mainly about the selection of cooperative terminals using information of UE position, transmission power, etc. in multi-UE scenario, and then perform cooperative resource allocation and transmission optimization. The above-mentioned problems can be solved by modeling and solving the typical convex optimization problem, and then get the optimal solution. The literature [22, 23] considered the fusion between UE terminals, that is, different types of traffic need different bandwidth and power resources, and how to make full use of system resources and improve system capacity becomes the major target.

The rest of this paper is organized as follows: in part 2, we introduce the wireless fusion technology in 5G related networks, both architecture and principle are discussed; in part 3, we discuss the advantage and challenge in wireless fusion, the advantages include spectrum efficiency and energy efficiency, the challenges are mainly about the interface and heterogeneous networks architecture, practical simulation results are also discussed in this part; in part 4, conclusions are presented and further discussion are planned.

2 Wireless Fusion in 5G Mobile Networks

The construction of 5G wireless network will mainly increase transmission speed and reduce latency to satisfy the need of users. Current 3GPP specifications do not restrict the utilization of multi-functional terminals, so there are some chances to improve system performance by using the multi-functional mobile terminals.

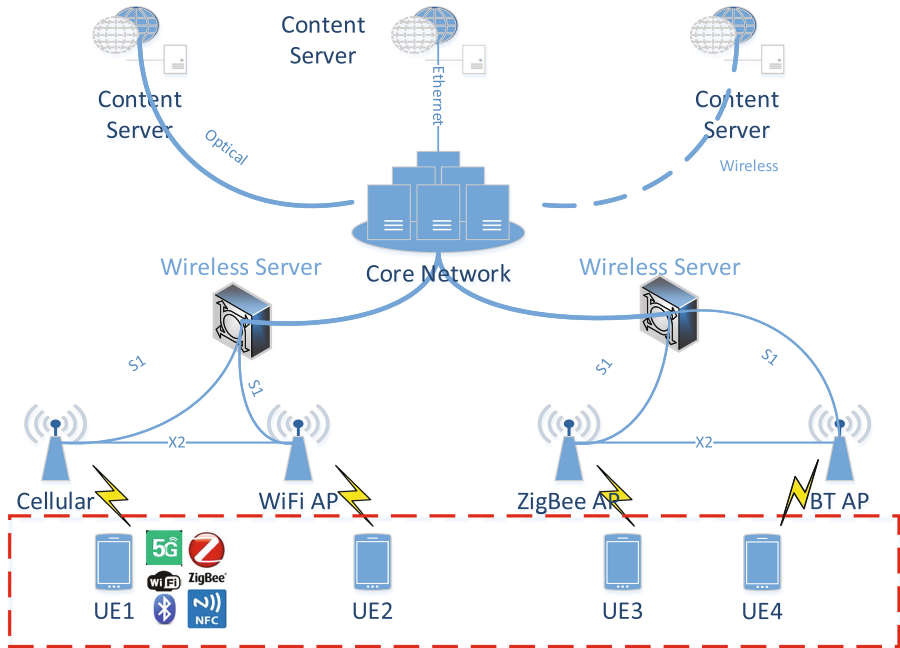


Fig. 1. Network architecture of heterogeneous network with multi-functional mobile terminals, varieties of transmission technology are integrated together in one terminal and chances are introduced in such scenarios.

As shown in Fig. 1, the heterogeneous network architecture may support many types of base stations and service mode, which serve the minorities of users. To tackle the different types of services, many mobile terminals support multi-functional services by installing multi-functional antennas and software defined radio and signal processing core, such as 5G cellular networks, the 802.11 family Wi-Fi (2.4 GHz and 5 GHz), Bluetooth 4.2, ZigBee, NFC and so on. Because such service providers are all connected to Internet cloud service, so the effects of different service base stations are the same, the only differences are the QoS and cost. Typically, users use only one of the transmission methods at the same time, e.g. using the cellular network when making a phone call or SMS, free Wi-Fi for high speed download or online video, Bluetooth or ZigBee for some specific point to point transmission scenarios. However, the decision that which method (s) is selected to perform transmission not only depend on the network providers, but also the prices and QoS (such as 802.11n Wi-Fi could afford 300Mbps in general,

5G cellular network could provide the maximum speed of 1 Gbps when paying some fees, Bluetooth version 4.2 is 60 Mbps, etc.).

In fact, the UE terminal that supports multiple transmission mode is common in recent wireless systems, and the current operator-centric network operation mode causes a waste of system resources in UE terminals. The UE terminal cannot perform better scheduling according to the actual needs of the traffic under the constraint of quality of service requirements (QoS) or money. So wireless fusion technology is proposed to make full use of the terminal resources and reduce the load of traditional base stations.

3 Benefits of Wireless Fusion in SE and EE

The fusion of multi-functional terminals brings the chance to utilize all the types of wireless transmission at a proper way. For example, when target user is located at the coverage of 5G wireless network, he will find out the balance between charge and transmission speed while only one transmission mode could be selected. However, when wireless fusion is enabled, users could receive signal from multiple types of base stations, that means, when users are requiring a large video clip, traditional method using 5G will cost much money when there is no Wi-Fi coverage, when fusion is enabled, this video clip would be divided into multiple slices and provided by different types of providers at the same time, so the target user will receive satisfied QoS in a very low cost.

Such fusion technology will enable the transmission from multiple functional antennas at the same time, so from the terminal side of view, it is a proper and workable method. But there is much work to do at the network operator side.

To describe the benefits of the fusion technology, we make some simple but promising simulations to quantize the benefits of the wireless fusion under the widely used system level simulation platform. Simulation parameters and assumptions are listed in Table 1.

Considering the ultra-dense network in 5G scenario, we take SCME urban micro as channel model. The carrier frequency is set to 2.2 GHz according to LTE-R14, the antenna configuration is set to 8 by 8 at the most, and 2 by 2 MIMO is configured in regular, the configuration is dynamically changed according to channel environment. The number of typical 5G base stations is set to 7 with 3 sectors per cell, the affiliated service nodes such as Wi-Fi and Bluetooth are deployed in conjunction with the primary 5G base stations. The bandwidth for 5G transmission is 100 MHz and the inter site distance is 50 meters.

For system level simulation platform, the mapping from link level to system level is set to EESM and the speed of users is set to 1 m/s in average and the density is set to 3 UE/cell. Note that the channel state information is assumed global to reduce the complexity of the evaluation, and higher order modulation is not adopted because complex signal processing method such as ML detector is not considered.

Table 1. Simulation parameters and assumptions according to our SL simulation platform.

Name	Value
Channel model	SCME, urban micro
Carrier frequency	2.2 GHz
Tx antenna	8 (maximum)
Rx antenna	8 (maximum)
Transmit power	38 dBm
BS number	7
Sectors per BS	3
Users in simulation	3 per cell
Bandwidth	100 MHz
SL to LL mapping	EESM
Inter-site distance	50 m
Pathloss model	$L = 128.1 + 37.6\log_{10}(R)$
Shadowing Std	4 dB
HARQ scheme	CC
AMC table	QPSK($R = \{1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5\}$) 16QAM($R = \{1/2, 3/5, 2/3, 3/4, 4/5\}$)
UE Sig processing	MMSE
Max Re-trans times	4
UE speed	1 m/s
Channel estimation	Ideal
Simulation TTIs	2000

3.1 Benefits in Spectrum Efficiency

Spectrum efficiency is the key technique to evaluate the system performance. In 5G related works, the spectrum efficiency is the leaf of the 5G flower. In 5G communication systems, the bandwidth resource becomes prosperous when carrier aggregation, high frequency transmission and full duplex transmission technology are adopted.

The spectrum efficiency is defined the fraction of transmission capacity and the bandwidth. In previous version of LTE related systems, due to the limitation of transmission capacity, the spectrum efficiency is limited. When wireless fusion is adopted, the maximum capacity will increase due to the allocation of multi-functional antennas, user could acquire information from different types of service nodes. In Fig. 2, we make a comparison of spectrum efficiency between HSDPA, LTE, LTE-A, 5G (LTE-Rel 14) and 5G with fusion. The x-axis is the index of different technologies and the y-axis is the spectrum efficiency in bit/s/Hz. The spectrum efficiency is gradually increased along with the advance of wireless transmission technology, in 5G fusion method, the additional frequency is not taken into account, so the benefits in spectrum efficiency is a little bit higher than 5G. In real transmission systems, the fusion with 2.4Ghz public spectrum will not introduce additional spectrum waste to 5G systems.

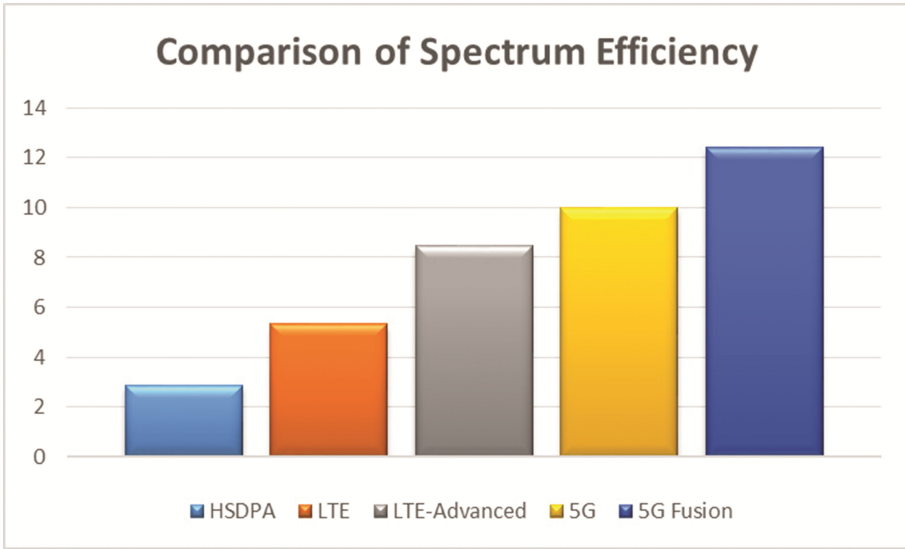


Fig. 2. Comparison of Spectrum Efficiency.

So in this way, the wireless fusion could increase system spectrum efficiency by introducing additional spectrum resources to this system and make full use of the limited resources to achieve higher transmission rates.

3.2 Benefits in Energy Efficiency

The energy efficiency is defined in bit/Joule, where this parameter reflect the fact that how much energy will be consumed to transmit a single bit information. The energy efficiency becomes key technique in 5G communication system because the increasing amount of base stations and the terrible electricity consumption in current wireless networks.

To increase the energy efficiency, the most effective way is to reduce the energy consumption of base stations. Traditional researches on EE are mainly focused on how to turn down idle base stations, which is proved effective in current 5G architectures. However, the on-off control of base stations meet the bottleneck of EE, because the energy consumption could not be reduced any more. So we are trying to increase the ability of per usage of electric power to transmit information as much as possible.

In wireless fusion technology, a large video clip will be divided into many parts, and these parts could be transmitted through different method. For example, within 1 min, the 5G network could transmit 60 Gbit at the most, but with the help of Wi-Fi and Bluetooth, this value could be increased to 100 Gbit.

In Fig. 3, we make a comparison of different types of transmission and power. The x-axis is the index and the y-axis is the energy efficiency. It is clear that the EE will increase when transmit power is low at the same scenario. That means, the cell-edge user will not affect the EE in a significant way. With the advance of transmission

technology, the energy efficiency increases at a low speed, but the 5G system has brought significant changes in EE for the on-off control of base stations are introduced. The wireless fusion help increase the EE in advance, because the time consumption to serve a practical traffic is reduced, so the leisure time of the 5G base station is increased, by utilizing the on-off control of base stations, the EE will be increased.

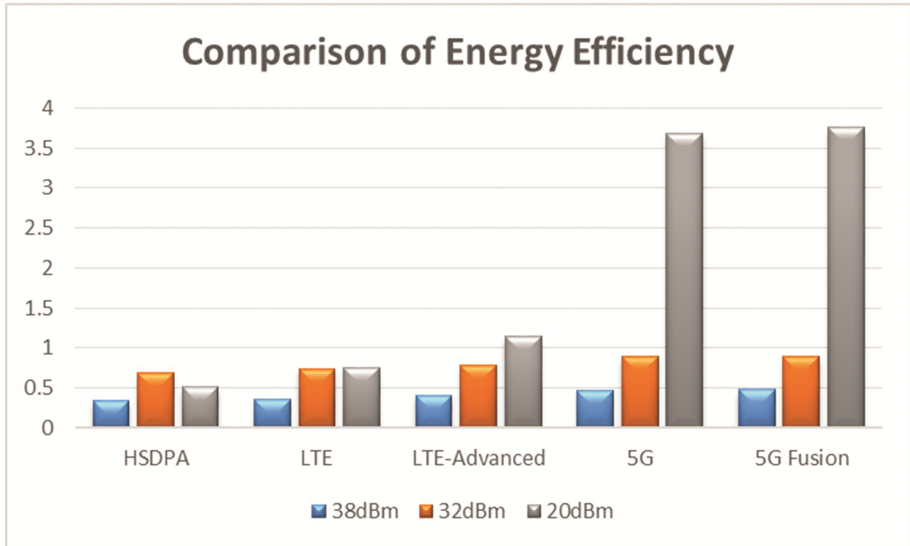


Fig. 3. Comparison of Energy Efficiency.

4 Conclusion

In this paper, we discuss the wireless fusion in 5G related networks as a review. First of all, we point out the fact that the ability of integrated multi-functional terminal are wasted for only one transmission method could be selected at one time, then we propose the possible wireless fusion technology in heterogeneous architecture to enhance the system capacity. Evaluation under the system level simulation has been given both in SE and EE.

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