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Architecture and Emerging Technology of 5G Network

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Abstract— *To contemplate 5G network in the market now. Current technology like OFDMS will work. Moreover, there is no need to have a change in the wireless setup which had come about from 1G to 4G. Alternatively, there could be only the addition of an application done at the fundamental network to please user requirement. This will provoke the package providers to drift for a 5G network as early as 4G is commercially set up. To meet the demands of the user and to overcome the challenges that has been put forward in the 5G system, a drastic change in the strategy of designing the 5G wireless cellular architecture is needed. A general observation of the researchers has shown that most of the researcher use the network 20 percent of the time. In present wireless cellular architecture, for a mobile user to communicate whether they can stay inside or outside, an outside base station presents in the middle of a cell helps in communication. So for inside users to communicate with the outside base station, the signals will have to travel through the walls of the indoors, and this will result in very high penetration loss, which correspondingly costs with reduced spectral efficiency, data rate, and energy efficiency of wireless communication. To overcome this challenge, a new idea or designing technique that has come in to existence for scheming the 5G cellular architecture is to distinct outside and inside setups*

Keywords: *OFDM,Cellular architecture,FP7, Qos*

I. INTRODUCTION

Wireless data traffic has seen creative growth in recent years due to new generation of wireless gadgets (e.g., smartphones) and also due to basic shift in traffic pattern from being data-centric to video-centric. Addressing this fastest growth in wireless data calls for making available radio spectrum as spectrally efficient as possible. In the decade beyond 2020, it will be necessary to support 1000 times1 higher mobile data volume per area into contact with new wireless broadband communication services coming from a large amount of different market segments. These requirements will go beyond the gradual development of IMT-Advanced technologies, which shows the need for a new mobile generation, with certain innovative features with respect to bequest technologies. Although there is no unanimous agreement so far, this seems to be the introduction of the Fifth Generation (5G) technologies. Mobile and wireless communications Enablers for the Twenty-twenty Information Society (METIS) is an integrated research project partly funded by the European Commission under the Framework Programme 7 (FP7) research framework. METIS aims at laying the foundation for the beyond 2020 wireless communication systems by providing the technical encourages needed to address the very challenging requirements foreseen for this time frame. Such a system has to 1) be particularly more efficient in terms of energy, cost and resource utilization than today's systems.

2) more changable to support a significant diversity of requirements (e.g., payload size, availability, mobility, and Quality-of-Service (QoS)) and new scenario use cases, and 3) provide better scalability in terms of number of connected devices, densely deployed access points,energy and cost.

II. MATERIAL AND METHODS

G. Marconi, unlocks the path of wireless communications inrecent day by communicating the letter `S' along a distance of 3Km in the form of three dot Morse code with the help of electromagnetic waves. After wireless communications this inception, have become an important part of present day society.The evolution of wireless begins here [2] and is shown in Fig. 1. It shows the evolving generations of wireless technologies in terms of data rate, mobility, coverage and spectral efficiency.

5g cellular network architecture

To contemplate 5G network in the market now, it is evidentthat the several parts of access techniques in the network arealmost at a still and requires sudden improvement. Currenttechnologies like OFDMA will work for next 50 years.

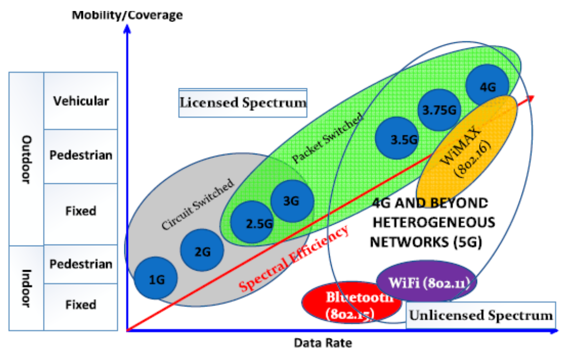


FIGURE 1. Evolution of wireless technologies.

A. RESULTS

A. Backhaul Network Capacity of Ultra-Dense Cellular Networks

The wireless multi-hop relay backhaul scheme of ultra-dense cellular networks is defined as follows: 1) The closest gateway is selected by the small cell BS for receiving backhaul traffic. 2) Two conditions should be satisfied for the small cell BS which is selected for the next hop candidate: 1 the distance between the transmitter and the receiver is less than or equal to the radius of small cell r; 2 the distance between the next hop small cell BS and the gateway is less than the distance between the transmitter and the gateway; 3 when multiple small cell BSs satisfy 1 and 2 , the small cell BS closing the gateway is selected as the next hop candidate; 3) When the distance between the small cell BS and the gateway is less than r, the small cell BS directly transmit backhaul traffic to the gateway without relaying. To avoid the interference from adjacent small cells, the distance of simultaneous transmission small cell BSs is configured to be larger than $(1 + \Delta)$ r, where $\Delta \times r$ is the interference protect distance in 5G ultra-dense cellular networks. Based on our early results in [13], a simple relationship is proposed to estimate the backhaul network capacity of ultra-dense cellular networks as follows: Backhaul network capacity =Y (n) × W k (n) , where n denotes the number of small cell BSs in a macrocell, Y (n) is the average number of simultaneous transmissions in the macrocell, W is the transmission rate of small cell BS, k (n) is the average hop number of wireless backhaul traffic in the macrocell. Without loss of generality, the 5G ultra-dense cellular network with multiple gateways shown in Figure 2 is considered for the following simulation analysis. The macrocell is assumed to be a regular hexagon with 1 km radius. Small cell BSs are scattered following a Poisson point process in a macrocell. All small cells are assumed not to overlap each other in the coverage. Moreover, three gateways are assumed to be symmetrically deployed at top vertices of the hexagon macrocell. The interference safeguard distance is configured as 0.5×r and the transmission rate of small cell BS is normalized as 1 Gbps in the following simulations.

Based on the Monte-Carlo simulation method, the backhaul network capacity and the backhaul energy efficiency of ultra-dense cellular networks are simulated in Figure 3 and Figure 4, respectively. When the radius of small cell r is fixed, the backhaul network capacity with respect to the number of small cell BSs is illustrated in Figure 3(a): the backhaul network capacity first increases with the increase of the number of small cell BSs; after the backhaul network capacity achieves the maximum threshold, the backhaul network capacity decreases with the increase of the number of small cell BSs; in the end, the backhaul network capacity achieves a stationary saturation value when the number of small cell BS approaches to the infinite. When the radius of small cell r is fixed, the backhaul network capacity with respect to the average number of simultaneous transmissions is described in Figure 3(b): considering the interference protect distance _ × r configured by the wireless multi-hop relay backhaul scheme, the maximum average number of simultaneous transmissions decreases with the increase of the radius of small cell when the macrocell coverage is fixed. For example, the maximum average number of simultaneous transmissions is 29, 25 and 19 when the radius of small cell is configured as 100 m, 150 m and 200 m, respectively. The backhaul network capacity increases with the increase of the average number of simultaneous transmissions in the macrocell.

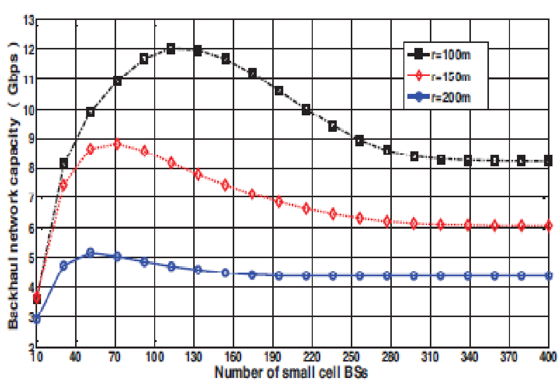
Moreover, the backhaul network capacity approaches to a saturation limit when the average number of simultaneous transmissions is larger than 27, 23 and 15 which correspond to the radius of small cell 100 m, 150 m and 200 m, respectively. When the number of small cell BSs or the average number of simultaneous transmissions is fixed, the backhaul network capacity decreases with increase of the radius of small cells. Based on simulation results in Figure 3(a), the backhaul network capacity will achieve a stationary saturation value when the average number of simultaneous transmissions or the dense of small cell BSs, i.e., the number of small cell BSs in a macrocell is larger than a given threshold. This result provide a guideline for designing the densification of 5G ultra-dense cellular networks.

B. Backhaul Energy Efficiency of Ultra-Dense Cellular Networks

Expect for the backhaul network capacity, the backhaul energy efficiency is another key constrain parameter which restrict the densification of 5G ultra-dense cellular networks. The backhaul energy consumed at the small cell BS is decomposed by the embodied energy EEM and the operation energy EOP [14]. The embodied energy is the energy consumed by all processes associated with the BS production and is accounted for the 20% of the backhaul BS energy consumption in this paper. The operation energy is the energy consumed for the backhaul operation in the lifetime TLifetime and is defined by EOP = POP × TLifetime, where POP is the BS operating power. Without loss of generality, the small cell BS operating power is assumed as the linear function of the small cell BS backhaul transmission power PTX and is expressed as POP = a×PTX+b, where a = 7.84 and b = 71.5 Watt [15]. In general, the BS backhaul transmission power depends on the BS backhaul throughput. To simplify the model derivation, the backhaul transmission power of small cell BS is normalized as PNorm = 1 Watt when the normalization BS backhaul throughput T h0 is assumed as 1 Gbps. Similarly, the small cell BS backhaul transmission power with the average BS backhaul throughput T hAvg is denoted by PTX = PNorm × (T hAvg/T h0), where the average small cell BS backhaul throughput is calculated by the backhaul network capacity [13]. Furthermore, the small cell BS operating power is calculated by POP = a × PNorm × (T hAvg/T h0) + b. In the end, the backhaul energy efficiency of ultra-dense cellular networks is derived by

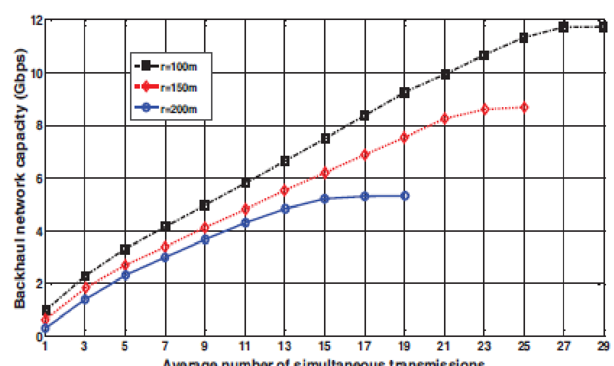
$$\text{Backhaul energy efficiency} = \frac{\text{backhaul network capacity}}{n \times (\text{small cell BS backhaul energy consumption})}$$

Without loss of generality, the lifetime of small cell BS is configured as TLifetime = 5 years. When the radius of small cell r is fixed, the backhaul energy efficiency of ultra-dense cellular networks with respect to the number of small cell BSs is analyzed in Figure 4(a): the backhaul energy efficiency first increases with the increase of the number of small cell BSs; and then, the backhaul energy efficiency decreases with the increase of the number of small cell BSs after the backhaul energy efficiency comes up to the maximum threshold; in the end, the backhaul energy efficiency of ultra-dense cellular networks achieves to a stationary saturation value when the number of small cell BSs approaches to the infinite. When the number of small cell BSs is fixed, the backhaul energy efficiency increases with the increase of the small cell radius when the number of small cell BSs is less than 10. When the number of small cell BSs is larger than or equal to 10, the backhaul energy efficiency decreases with the increase of the small cell radius. When the radius of small cell r is fixed, the backhaul energy efficiency with respect to the average small cell BS throughput is illustrated in Figure 4(b): the backhaul energy efficiency first increases with the increase of the average small cell BS throughput; and then, the backhaul energy efficiency decreases with the increase of the average small cell BS throughput after the backhaul energy efficiency achieves the maximum threshold; in the end, the backhaul energy efficiency of ultra-dense cellular networks achieves to a stationary saturation value when the average small cell BS throughput is larger than 0.35, 0.45 and 0.5 Gbps which correspond to the radius of small cell 200, 150, 100 meters.



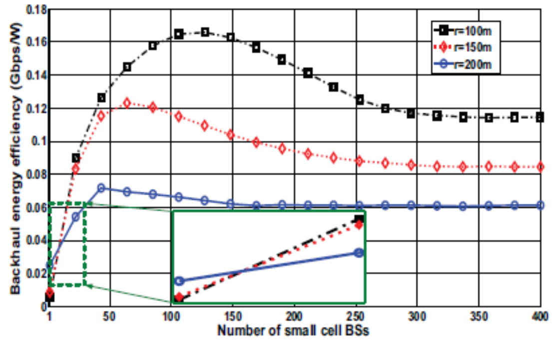
(a)

Fig. 2. Backhaul network capacity of ultra-dense cellular networks: (a) the backhaul network capacity vs the number of small cell BSs



(b)

Fig 3. The backhaul network capacity vs the average number of simultaneous transmissions

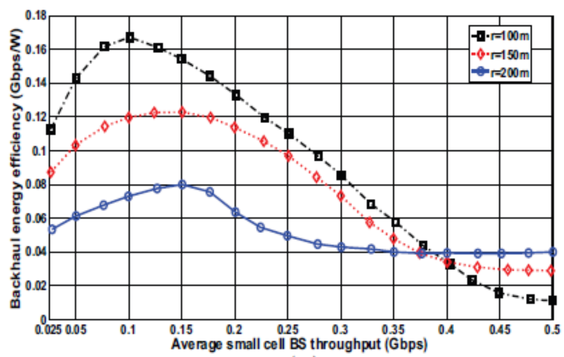


(a)

Fig. 4. Energy efficiency of ultra-dense cellular networks: (a) backhaul energy efficiency vs the number of small cell BSs

III DISCUSSION

As we discussed in the above sections, the emergence of ultra-dense cellular network is motived by massive MIMO antenna and millimeter wave communication technologies. Moreover, the distribution network architecture is a reasonable solution for 5G ultra-dense cellular networks. Compared with results in Table I, it is obvious that the ultra-dense cellular network would bring great changes into future.



(b)

Fig. 5. Energy efficiency of ultra-dense cellular networks (b) backhaul energy efficiency vs average small cell BS throughput.

5G cellular networks. Therefore, the ultra-dense cellular network is one of the most important challenges for future 5G cellular networks. Some potential challenges are presented in the following context. The first challenge is the multi-hop relay optimization in 5G ultra-dense cellular networks. In the distribution network architecture, not only backhaul traffic but also fronthaul traffic needs to be relayed into the destination. The selection of relaying small cell BS should be carefully considered in 5G ultra-dense cellular networks. Hence, the wireless multi-hop routing algorithm is a key challenge for 5G ultra-dense cellular networks. Although the small cell BS equipped with massive MIMO antennas has enough antennas for simultaneously transmitting backhaul traffic and fronthaul traffic, it is another important challenge how to reasonably allocate massive antennas for backhaul and fronthaul transmissions. The small cell coverage of ultra-dense cellular networks is obviously less than the macrocell coverage of conventional cellular networks. For a high-speed mobile user, the user frequently handover in small cells not only increase redundant overhead but also decrease the user experience. Moreover, the wireless transmission of small cell BS equipped with millimeter wave antennas and beamforming technologies has strong directivity, which is to the advantage of high-speed transmission and the disadvantage of covering the high-speed mobile user. The cooperative transmission of small cells is a potential solution for this problem. How to organize adjacent small cells for cooperative transmission is the second challenge for 5G ultra-dense cellular networks. For example, how to dynamically group small cells for seamlessly covering the high-speed mobile user track is an open issue. With the emergence of millimeter wave communication technology for 5G wireless transmission, the beamforming method will be widely used. When the beamforming method is performed by massive MIMO antennas, the computation scale of beamforming method and the computation power of wireless transceivers will be obviously increased by the large scale of signal processing in BS baseband processing systems. Therefore, the proportion between the computation power and transmission power maybe reversed at wireless transceivers adopting massive MIMO antenna and millimeter wave communication technologies. In this case, the computation power can not be ignored for the BS energy consumption. Considering the proportion change between the computation power and the transmission power, the new energy efficiency model need to be investigated for ultra-dense cellular networks with massive MIMO antenna and millimeter wave communication technologies. To face with above challenges in 5G ultra-dense cellular networks, some potential research directions are summarized to solve these issues:

1. The new multi-hop relay scheme and the distribution routing algorithm should be developed for 5G ultra-dense cellular networks.
2. Massive MIMO antennas and millimeter wave communications provide enough resource space for small cell BSs. How to utilize and optimize the resource allocation for BS relaying and self-transmission is a critical problem in 5G ultra-dense cellular networks.
3. The cooperative transmission and backhaul transmission will become two of important directions in future 5G ultra-dense cellular networks.
4. Motived by massive MIMO antenna and millimeter wave communication technologies, the computation power consumed for BS baseband processing systems need to be rethought for 5G ultra-dense cellular networks.

IV CONCLUSION

Until recently, ultra-dense wireless networks have been mainly deployed in parts of network areas, such as indoor and hotspot scenarios. Ultra-dense wireless network are still considered as a complement for cellular networks with centralized network architecture. The massive MIMO antennas and millimeter wave communication technologies enable 5G ultra-dense cellular networks to be deployed in all cellular scenarios. In this paper, the distributed network architecture with single and multiply gateways are presented for 5G ultra-dense cellular networks. Considering the millimeter wave communication technology, the impact of small cell BS density on the backhaul network capacity and the backhaul energy efficiency of ultra-dense cellular networks is investigated. Simulation results indicate that there exists a density threshold of small cells in ultra-dense cellular networks. When the density of ultra-dense cellular networks is larger than the density threshold, the backhaul network capacity and the backhaul energy efficiency of ultra-dense cellular networks will reduce with a further increase in small cell density. These results provide some guidelines for the optimum deployment of 5G ultra-dense cellular networks.

In 2G and 3G mobile communication systems, the wireless communication system has been considered as a noised-limited communication system. With the MIMO antenna technology being adopted in 4G mobile communication systems, the wireless communication system has been transited into an interference-limited communication system. In this paper, it has been shown that there exists a maximum backhaul network capacity corresponding to a given number of small cell BSs in a macrocell, termed by us as the density threshold of ultra-dense cellular network. When the density of ultra-dense cellular networks, measured by the number of small cells per macro-cell, is larger than the density threshold, the backhaul network capacity will reduce with a further increase in the density.

Moreover, a similar bottleneck is also observed in the backhaul energy efficiency of ultra-dense cellular networks. As a consequence, we conclude that the 5G ultra-dense cellular network is a density-limited communication system. How to analytically determine the optimum density of small cell BSs in 5G ultra-dense cellular networks is an open issue. If this is done, a veritable challenge would indeed emerge in the next round of the telecommunications revolution.

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