On the Road to Energy Efficient 5G Mobile Networks

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Abstract: - The seamless and ubiquitous wireless communication anywhere, anytime, anyhow and between anybody and anything is expected to render daily lives easier. This will continue to grow, increasing at the same time, demand on wireless mobile connectivity between people, machines, processes and so on. There is an opinion that this will be achieved by invoking the fifth generation (5G) mobile networks. The aim of this paper is to emphasize the road to energy efficiency as one of the obligatory 5G evolution metrics. In connection with this, energy saving approaches together with energy and information flow among base stations are analyzed in the first part of this paper. Secondly, advances in energy efficiency for wireless networks including 5G mobile systems are explained. Corresponding challenges conclude the presentation.

Key-Words: - 5G mobile networks, energy consumption, energy efficiency, information flow.

1 Introduction

The need for media rich input/output, computation and communication forces users to charge their mobile devices more often. On the other side, network operators have been adding more and more base stations (BSs) to meet a higher service demand. A large portion of the network operators’ operational costs is due to energy consumption of the wireless systems for both mobile users and service providers. The fifth generation (5) infrastructure, when defined as the ultra-broadband network, will be associated with the true revolution into communication field, taking forward new services to everyone and everything. The 5G mobile networks are required to have tremendous spectral efficiency (SE) and energy efficiency (EE) improvement simultaneously. As a result these efficiencies together with cost efficiency have been widely used like three obligatory 5G evolution metrics. In addition, joint energy and communication can maximally save cost by applying both energy cooperation on the supply side and communication operation on the demand side. As for 5G networks, the primary goal is to satisfy a variety of users’ needs in a more energy efficient manner. The question often arises is where the energy can be further saved and what available information in the network can be explored.

The paper is organized as follows. The first part deals with energy saving approach including energy and information flow among base stations. In the second part, the significance of EE for 5G mobile network is analyzed. Finally, the corresponding challenges conclude the paper.

2 Energy Saving Approach

The number of subscribers and thus the increased traffic intensity in cellular networks has moved the limits of capacity and energy consumption because mobile equipment is working in all days of a 24/7/365 regime. On the other hand, energy saving approach is one of the way to improve the efficiency of cellular networks. For network operators, it is difficult to maintain the capacity growth utilize bandwidth, decrease delay and to limit at the same time energy consumption. The following framework has to be taken into account [1]:

a) Deployment-energy tradeoff to balance the deployment cost, throughput and energy consumption in the whole network.

b) Spectrum-energy tradeoff in order to balance the accessible rate and energy consumption of the system.

c) Bandwidth-power tradeoff in order to balance the bandwidth utilized and the required power for transmission.

d) Delay-power tradeoff to balance the average end-to-end delay and the average consumed power in the transmission.

Using these tradeoffs in different research aspects, energy saving approach can be easily obtained. Network infrastructure, sharing and BS sharing off are promising solutions for energy and cost
reduction bringing for mobile operators the decrement of capital and operational expenditures associated with the deployment and the operation of the cellular networks [2]. There exist three types of sharing [3]: passive, active and roaming-based. Passive sharing understands the joint use of sites, masts, building among mobile network operators (MNOs). In active sharing the MNOs share antennas, switches, and backhaul network equipment, while in roaming-based sharing one MNO relies on the coverage of another one on a permanent basis in a region.

3 Energy and Information Flow in Mobile Networks

Applying both energy and communication cooperation maximally save cast can be achieved. Energy cooperation is on the supply side, while communication one is on the demand side. An example of a model of cellular networks with energy and communication cooperation among BSs [4] is shown in Fig. 1.

![Energy and communication cooperation in mobile networks](image)

Fig. 1. Energy and communication cooperation in mobile networks.

The energy trading and sharing is enabled using aggregator. This is upper energy cooperation layer [5]. In principle, aggregators enable to cluster BSs into a finite number of groups. An aggregator serves as an intermediary device to control each group of BSs for the grid. In that case, two-way energy flow between the grid and BS groups will be provided. Communication cooperation serves to a cost saving on the demand side and seeks to minimize the total energy cost by optimally utilizing cheap renewable energy and reliable on-grid energy. In the case of joint operation, the BSs share the energy information by using the two-way information flow through smart meters. The communication information is exchanged through the backhaul connections. It can be seen that the joint energy and communication cooperation is more complex compared to energy or communication operation separately.

4 Advances in Energy Efficiency for Mobile Networks

EE for wireless networks is the metric of interest when taking into account energy consumption. Among other definitions, a satisfactory operational one which was proposed by Lawrence Berkeley National Laboratory says that EE "is using less energy to provide the same service". The ability to adopt the transmission strategy according to the traffic demands will become an important design aspect of EE. Network infrastructure should be regarded as a resource that can be released or occupied on demand. To handle the exponential growth of mobile data traffic while alleviating the huge cost of infrastructure investment, massive multiple-input multiple-output (MIMO), small cells, and device-to-device (D2D) communications have been proposed for Long Term Evolution Advanced (LTE-A) networks. The full application of these technologies could be expected in 5G systems.

Network energy performance is one of a crucial requirement of 5G networks, because of reduced cost ownership and facilities in the process of extensions network connectivity to remote areas. 5G systems with high energy performance should be built on the principle to only be active and transmit when and where needed. To only be active when needed implies an always available approach with dynamic activation on several levels: nodes, functionality, subsystems and components. To only transmit when needed refers in particular to minimized transmissions not directly related to the delivery of user data. To only be active where needed covers the spatial domain of "always available" and may refer both to the same levels as above but with addition of extra dimension to distributed structures.

One of the goals of 5G networks is transmitting as high data rate as possible taking into account users’ need in a more energy efficient manner. In connection with this, it should be noted the importance of identifying where energy can be
Outlines for advances in 5G mobile network technology can be presented in a step by step form (Fig. 2).

Fig. 2. Outlines for advances in 5G mobile networks.

Traditional MIMO systems improve EE because of the array gain, spatial diversity and/or spatial multiplexing gains. On the other side, massive (large-scale) MIMO is a form of multi-user MIMO in which the number of antennas at the BS is much larger comparing to the number of devices per signaling resource. This concept allows for order of magnitude improvement in SE and EE using relatively simple processing [6, 7]. Massive MIMO can increase the capacity 10 times or more and simultaneously improve the radiated EE on the order of 100 times. Finally, a small cell is formed using low-power and low-cost micro, pico and femto BSs. With an improved frequency reuse factor, a small cell is able to enhance SE. At the same time, with reduced distance between the user and the BS, the required transmit power to overcome path loss, fading and noise is also reduced. As a result, both uplink and downlink EE can be improved [8].

There is a great potential for 5G networks to improve both SE and EE, leading toward ultra-dense heterogeneous network (HetNet) environment [9]. As for EE, the deployment of massive MIMO and HetNets for same coverage is still under discussion. Control in HetNets can provide more flexible and higher EE for a large number of small cells, while a massive MIMO cell performs better than a small number of small cells due to its large array gain [10]. By reducing the size of the cell, area SE is increased through higher frequency reuse, while transmit power can be reduced such that the power lost through propagation will be lower. This approach can provide a flexible coverage and improved SE and EE.

An approach to solve the highly dense network problems will be through direct mobile-to-mobile communication in order to either share their radio access connection, or to exchange information. D2D communications can reduce interferences especially in unlicensed frequency bands. Together with small cells, D2D communication will support low-cost architecture. In that way D2D communications can significantly improve EE for devices. Also, more freedom for D2D users in the sense of directly transmission of data, directly reusing the resource of cellular users and by communicating with each other through the BS in the standard way, can be provided [11]. An example of D2D communications in HetNets is shown in Fig. 3.

Fig. 3. An example of D2D communications in HetNets.

Users in cellular networks can transmit data directly to each other. Due to physical proximity, D2D communication provides proximity gain, reuse gain and hip gain. In that way D2D communication improves EE, which is one of significant performance metrics. The main characteristics are: energy constraints, bandwidth constraints, and multihop transmission [12]. In terms of energy constrained networks, the capacity per energy cost over a single link is considered in [13], while the bit per Joule capacity for wireless data delivery is proposed in [14]. For short distance communications, energy cost in the circuit becomes nontrivial, yielding a more complicated issue for the possible power region.

5 Challenges and Conclusion

The integration of new concepts such as massive MIMO, new spectrum bands, ultra-dense networking, direct communications, will allow supporting of the expected increase in the mobile traffic data industry. Main focus of current and future researches is related to the accomplishment of spectral and energy equilibrium, while using perspective radio frequencies in dense heterogeneous environment. Mobile traffic (majority video) is increasing exponentially, while power consumption should be adapted to the traffic...
load. Due to cloud networks, data centers will dominate the power consumption in the network. Future networks are expected to carry 1000 times more mobile data in 10 years, while the energy efficiency is improving only 10 times.

Networks do not only consume energy in transmission in power amplifiers, but also in circuit power (computation), in algorithms and protocols. In small cells, the transmission power is reduced and circuit power starts to dominate. In the case of energy efficiency in 5G networks, there are several research challenges from system/device design and testing to network management. How to enhance the throughput and energy efficiency is still an open issue.

References: