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A REVIEW OF ANALYSIS OF ENERGY EFFICIENCY FOR 5G TECHNOLOGY USING MILLIMETER WAVE WIRELESS COMMUNICATIONS

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ABSTRACT: Fifth generation (5G) wireless networks will target at energy and spectrum efficient solutions to cope with the increasing demands in capacity and energy efficiency. To achieve this joint goal, dense networks of small cells (SCs) are expected to overlay the existing macro cells. In parallel, for the SC connection to the core network, a promising solution lies in a mesh network of high capacity millimeter wave backhaul (BH) links. We considered 5G architecture, spectrum efficiency than the state-of-the-art in 3GPP scenarios.

KEYWORDS: *Fifth generation, energy efficiency, millimeter wave.*

I. INTRODUCTION

Energy consumption has become a primary concern in the design and operation of wireless communication systems. Indeed, while for more than a century communication networks have been mainly designed with the aim of optimizing performance metrics such as the data-rate, throughput, latency, etc., in the last decade energy efficiency has emerged as a new prominent figure of merit, due to economic, operational, and environmental concerns. The design of the next generation (5G) of wireless networks will thus necessarily have to consider energy efficiency as one of its key pillars. Indeed, 5G systems will serve an unprecedented number of devices, providing ubiquitous connectivity as well as innovative and rate-demanding services. It is forecast that by 2020 there will be more than 50 billion connected devices [1], i.e. more than 6 connected devices per person, including not only human type communications, but also machine-type communications. The vision is to have a connected society in which sensors, cars, drones, medical and wearable devices will all use cellular networks to connect with one another, interacting with human end-users to provide a series of innovative services such as smart homes, smart cities, smart cars, tele-surgery, and advanced security. Clearly, in order to serve such a massive number of terminals, future networks will have to dramatically increase the provided capacity compared to present standards. It is estimated that the traffic volume in 5G networks will reach tens of Exabytes (10006 Bytes) per month. This requires the capacity provided by 5G networks to be 1000 times higher than in present cellular systems [2]. Trying to achieve this ambitious goal relying on the paradigms and architectures of present networks is not sustainable, since it will inevitably lead to an energy crunch with serious economic and environmental concerns. three times more connected devices than our global population in 2020 to deal with these demands, energy and spectrum efficient wireless solutions, able to offer high capacity, are needed the nature of fifth generation (5G) wireless networks is expected to be heterogeneous, consisting of a dense network of small cells (SCs) deployed on the top of the existing macro cells [2].

The benefits of the dense SC deployment are threefold. Firstly, the user comes closer to its serving base station (BS), which results in higher signal-to interference-plus-noise ratio (SINR), and thus, higher capacity as well as lower mobile battery consumption. Secondly, frequency reuse can be applied among SCs that are located far from each other, hence offering higher area spectrum efficiency. Thirdly, millimeter wave (mm Wave) is favored to offer high capacity wireless backhaul (BH) links, i.e., set of links between the BSs and the core network. This is mainly due to two reasons: 1) the connection of each SC to the core by fiber is highly cost-inefficient and 2) the anticipated short BH link length among Neighboring SCs will result in line-of-sight (LOS) opportunities, essential for good mm Wave coverage. In particular, most macro cells are already connected through fiber to the core. Therefore, exploiting the existing connection and providing core connectivity to SCs through it with the use of mm Wave, a mesh BH network of LOS mm Wave links is expected, where each SC will forward its traffic to its neighbors, selecting among a broad set of alternative paths, to reach the core. This topology combines the mm Wave benefits with the mesh networking advantages. On the one hand, mm Wave offers high spectrum availability, and consequently, high capacity links. In addition, the very small mm Wave wavelength enables higher antenna gains, resulting in highly directional links. Therefore, mm Wave is able to compensate the higher path loss experienced at higher frequencies [3].

On the other hand, mesh networking can increase reliability and redundancies through self-forming and self-healing in case of a BH link failure [2]. In this context of hyper-dense 5G heterogeneous networks with complicated BH topologies, selecting the serving BS of a user equipment (UE), becomes challenging, as it impacts both the network and UE performance. Hence, new low-complexity UE association and BH traffic routing algorithms are needed, able to maximize the network energy and spectrum efficiency. However, the majority of user association algorithms proposed so far focus on the performance optimization of the access network (AN), i.e., the links between the UEs and their serving BSs. Specifically, LTE-Advanced (LTE-A) employs two metrics: the reference signal received power (RSRP) and the reference signal received quality (RSRQ) [4]. Equivalently, the best-SINR algorithm connects a UE to the BS with the highest received power. Although the aforementioned criteria maximize the spectrum efficiency, they do not maximize the network throughput, as few UEs connect to SCs. This limitation was overcome by range expansion (RE), where a bias was applied for signals originated by SCs [5]. Thereby, the connections with SCs were favored, resulting in load balancing between SCs and macro. Finally, in the extreme biasing case, a UE connects to the BS with the lowest experienced path loss, i.e., minimum path loss (MPL) [6]. MPL achieves the highest offloading to SCs at the expense of low spectrum efficiency. On the other hand, there are few works that consider the BH conditions in the user association decision. In particular, [7] proposes a user association analytical framework, which jointly considers the AN and BH. Specifically, spectrum efficiency, base station load, BH link capacity and topology, as well as different types of traffic are taken into account. In [8], the authors study the joint problem of user association and resource allocation, considering the resource consumption. and the energy budget of BSs, as well as the maximum BH capacity.

However, in all these BH-aware approaches, there is no study of energy consumption, and hence, their high performance in terms of energy efficiency cannot be ensured. To this end, in [9] the authors study the aforementioned problem focusing on the energy and spectrum efficiency maximization of a network with tree BH links. Specifically, the in [9] selects among the BSs that maximize the network spectrum efficiency, while taking into account the number of BH link hops to reach the core network. Nevertheless, due to the simplicity of the applied criterion, its high energy efficiency in scenarios with heterogeneous BH links, i.e., links that differ in length, allocated bandwidth, or even in applied frequency, cannot be ensured. Therefore, in [10], the authors proposed a solution that takes into account the amount of power consumed in each BH link, thereby relaxing the limitation of homogeneous BH links. Still, in both works, the proposed solutions focus on tree topologies, where a single BH link route is available for each SC. However, in such 5G networks consisting of mesh BH links, the BH routing problem is another challenge that should be jointly considered. Therefore, in this paper, we study the joint problem of user association and BH traffic routing with the aim of maximizing the energy and spectrum efficiency of the network, while guaranteeing the UE quality of service (QoS). A low-complexity UE association which is able to provide good tradeoffs between the two competitive objectives. Moreover, in order to demonstrate the benefits of load balancing in the performance, two different cases are studied, i.e., with or without load balancing. Finally, the proposed algorithm is compared with existing solutions.

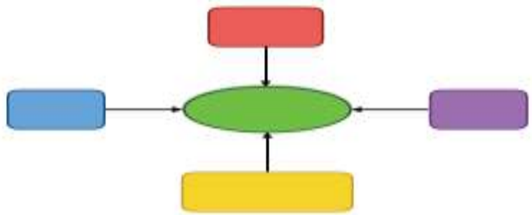

Fig.1: Energy-efficient 5G technologies.

We focus to improve network energy efficiency by a factor 1000with respect to the 2010 state of the art reference network. The consortium published a technology roadmap and announced its final results in its “Green Meter” research study [9]. Additionally, the Groupe Speciale Mobile Association (GSMA) demands, by 2020, a reduction of CO2 emissions per connection of more than 40%. These fundamental facts have led to introducing the notion of bit-per-Joule energy efficiency, which is defined as the amount of information that can be reliably transmitted per Joule of consumed energy, and which is a key performance indicator for 5G networks [6], [7] (see also [10]–[12] as some of the first papers introducing the notion of bit-per-Joule energy efficiency). As illustrated in Fig. 1, most of the approach useful for increasing the energy efficiency of wireless networks can be grouped under four broad categories as follows.

a) Resource allocation. The first technique to increase the energy efficiency of a wireless communication system is to allocate the system radio resources in order to maximize the energy efficiency rather than the throughput. This approach has been shown to provide substantial energy efficiency gains at the price of a moderate throughput reduction

b) Network planning and deployment. The second technique

is to deploy infrastructure nodes in order to maximize the covered area per consumed energy, rather than just the covered area. In addition, the use of base station (BS) switch on/ switch-off algorithms and antenna muting techniques to adapt to the traffic conditions, can further reduce energy consumptions

c) Energy harvesting and transfer. The third technique is to operate communication systems by harvesting energy from the environment. This applies to both renewable and clean energy sources like sun or wind energy, and to the radio signals present over the air.

d) Hardware solutions .The fourth technique is to design the hardware for wireless communications systems explicitly accounting for its energy consumption and to adopt major architectural changes, such as the cloud-based implementation

Resource Allocation

As energy efficiency has emerged as a key performance indicator for future 5G networks, a paradigm shift from Throughput-optimized to energy- efficient-optimized communications has begun. A communication system’s radio resources should no longer be solely optimized to maximize the amount of information that is reliably transmitted, but rather the amount of information that is reliably transmitted per Joule of consumed energy. Compared to traditional resource allocation schemes, this requires the use of novel mathematical tools specifically tailored to energy efficiency maximization. A survey of this topic is provided in [13].

II. NETWORK PLANNING AND DEPLOYMENT

In order to cope with the sheer number of connected devices, several potentially disruptive technologies have been proposed for the planning, deployment, and operation of 5G networks.

A. Dense networks

The idea of dense networks is to deal with the explosively increasing number of devices to serve by increasing the amount of deployed infrastructure equipment. Two main kinds of network densification are gaining momentum and appear as very strong candidates for the implementation of 5G networks.

1) Dense Heterogeneous Networks: Unlike present network

deployments which uniformly split a macro-cell into a relatively low number of smaller areas each covered by a light base-station, dense heterogeneous networks drastically increase the number of infrastructure nodes per unit of area A very large number of heterogeneous infrastructure nodes ranging from macro BSs to femtocells and relays are opportunistically deployed and activated in a demand-based fashion, thus leading to an irregularly-shaped network.

Massive MIMO: If the idea of dense networks is to density the number of infrastructure nodes, the idea of massive MIMO is to densify the number of deployed antennas. In massive MIMO, conventional arrays with only a few antennas fed by bulky and expensive hardware are replaced by hundreds of small antennas fed by low-cost amplifiers and circuitry. The research interest in such a technology has been spurred which observed how, owing to the law of large numbers, large antenna arrays can average out multi-user interference. This happens provided the so-called favorable propagation condition holds, which has been experimentally validated in the overview works However, massive MIMO systems also come with several challenges and impairments. First of all, deploying a very large number of antennas points in the direction of very large systems, for which a microscopic analysis is usually too complex. Instead, system analysis and design must be performed based on the limiting behavior of the network, a task which is usually accomplished by means of random matrix theory In addition, massive MIMO systems are characterized by a more difficult channel estimation task, due to a more severe pilot contamination effect, and to more significant hardware impairments. Contributions to address these challenges have mainly focused on traditional performance measures the energy efficiency of massive MIMO systems have started appearing only very recently. As far as energy efficiency is concerned, massive MIMO has been shown to reduce the radiated power by a factor proportional to the square root of the number of deployed antennas, while keeping the information rate unaltered However, this result applies to an ideal, single-cell massive MIMO system only, and without taking into account the hardware-consumed power. In the aggregate effect of hardware impairments in massive MIMO systems.

Device-to-device (D2D) communications. While in a conventional network user devices are not allowed to directly communicate, D2D communications refer instead to the scenario in which several co-located (or in close proximity) devices can communicate directly using a cellular frequency and being instructed to do so by the BS. D2D techniques have a profound impact on the system energy efficiency since direct transmission between nearby devices may happen at a much lower transmit power than that needed for communication through a BS that can be far away. Additionally, they are a powerful offloading strategy since they permit releasing resources at the BS that, through proper interference management, can be used for supporting other users. The impact of D2D communications on the energy efficiency.

mmWave cellular. The use of frequency bands above 10GHz,mmWaves while increasing the available network bandwidth, is considered in this as a strategy to offload traffic from the sub-6GHz cellular frequencies for short-range (up to 100-200 m) communications in densely crowded areas. Future wireless technology will need to harness the massively unused mmWave spectrum to meet the projected acceleration in mobile traffic demand. Today, the available range of mmWavebased solutions is already represented by IEEE 802.11ad (WiGig), IEEE 802.15.3c, WirelessHD, and ECMA-387 standards, with more to come in the following years. In we will comment on the hardware challenges that the use of mmWave poses. Studies on the impact of mmWaves on the energy efficiency of future 5G.

III. ENERGY HARVESTING AND TRANSFER

Harvesting energy from the environment and converting it to electrical power is emerging as an appealing possibility to operate wireless communication systems. Indeed, although this approach does not directly reduce the amount of energy required to operate the system, it enables wireless networks to be powered by renewable and clean energy sources two main kinds of energy harvesting have emerged so far in the context of wireless communications.

Environmental energy harvesting. This technique refers to harvesting clean energy from natural sources, such as sun and wind. Comprehensive surveys on this approach.

Radio-frequency energy harvesting. This technique refers to harvesting energy from the radio signals over the air, thus enabling the recycling of energy that would otherwise be wasted. In this interference signals provide a natural source of electromagnetic-based power Surveys on this approach.

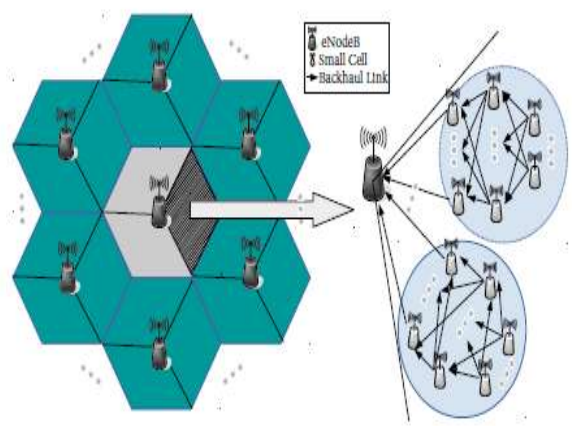

Fig.2: System model

Wireless communications in millimeter-wave (mm-wave) bands (from around 24 GHz to 300 GHz) is a key enabler for multi-gigabits per second (Gbps) transmission [11]In contrast to conventional wireless communications in sub- 6 GHz bands, many appealing properties, including the abundant spectral resources, lower component costs, and highly directional antennas, make mm-wave communications attractive for future mobile communications standards. As an important metric for evaluating the quality of service (QoS), low latency plays a crucial role in the forthcoming fifth generation (5G) mobile communications [4]–[6], especially for various delay-sensitive applications, e.g., high-definition television (HDTV), intelligent transport system, vehicle-to everything (V2X), machine-to-machine (M2M) communication, and real-time remote control. The overall delay in wireless communications consists of four components as follows [7], [8]: propagation delay (time for sending the one bit to its designated end via the physical medium), transmission delay (time for pushing the packet into the communication medium in use), processing delay (time for analyzing a packet header and making a routing decision), and queuing delay (the time that a packet spends in the buffer or queue, i.e., waiting for transmission). Normally, the overall delay for queuing system is dominantly determined by the queuing delay, while the contributions by the other types of delay are nearly negligible. Thus, for low-latency buffer-aided systems, the major task is to largely decrease the queuing delay.

In recent years, many efforts from different aspects have been devoted to low-latency mm-wave communications. In [14], several critical challenges and possible solutions for delivering end-to-end low-latency services in mm-wave cellular systems were comprehensively reviewed, from the perspectives of protocols at the medium access control (MAC) layer, congestion control, and core network architecture. By applying the Lyapunov technique for the utility-delay control, the problem of ultra-reliable and low-latency in mm-wave-enabled massive multiple-input multiple-output (MIMO) networks was studied in [9]. Regarding hybrid beam forming in mm-wave MIMO systems, a novel algorithm for achieving the ultra-low latency of mm-wave communications was proposed in where the training time can be significantly reduced by progressive channel estimations. Furthermore, for systems with buffers at transceivers, the probabilistic delay for point-to-point mmwave communications is analyzed in where the delay bound is derived based on network calculus theory. Due to unprecedented data volumes in mm-wave communications, the transceivers for many applications are commonly equipped with large-size buffers, such that the data arrivals that cannot be processed in time will be temporarily queued up in the buffer until corresponding service is provided. Hence, the low-latency problem for mm-wave communications with buffers can be interpreted as a delay problem in queuing systems, equivalently. By queuing theory, it is known that the key idea for effectively reducing the queuing delay is to keep lower service utilization. That is, the average arrival rate of data traffic should be less than the service rate of server as much as possible. Commonly, low service utilization can be fulfilled mainly through two distinct methods: offloading arrival traffic and improving the service capability. In a wireless network, offloading arrival traffic can be realized by adopting the traffic dispersion scheme, and service enhancement can be realized by adopting the network densification scheme. Traffic dispersion stems from the application of distributed antenna systems (DASs) or distributed remote radio heads (RRHs) in mm wave communications, and network densification is motivated from the trend of dense deployment for mm-wave networks.

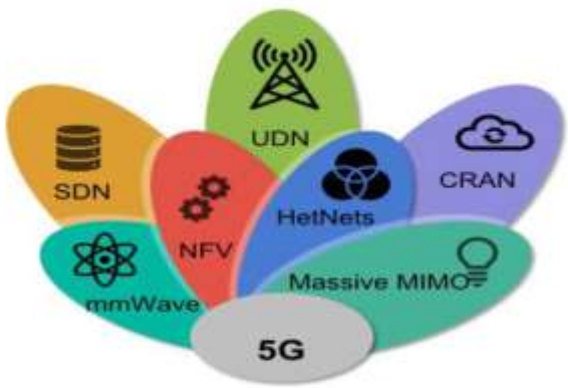

Fig.3: Outline of technologies analysed for energy efficiency in this survey.

Roughly, the traffic dispersion scheme applies the "divide-and conquer" principle, which enables parallel transmissions to fully exploit the spatial diversity, such that a large single queue (or large delay, equivalently) can be avoided. On the other hand, the network densification scheme departs from reducing the path loss, via shortening the separation distance between adjacent nodes, such that the end-to-end service capability can be improved. Clearly, both the traffic dispersion and network densification schemes are promising and competitive candidates for low latency mm-wave communications. Though there are many research contributions in low-latency communications based on above two principles, the existing literature focus on either the dispersion scheme or multi-hop relaying scheme It is not clear yet which scheme can provide better delay performance. For designing or implementing mm-wave networks, it is essential to explore the respective strengths of traffic dispersion and network densification, and know their applicability and capability for realizing low-latency mm-wave networks. Moreover, a combination of traffic dispersion and network densification, termed as "hybrid scheme", is worthy of study. Intuitively, the hybrid strategy takes advantages of both traffic dispersion and network densification, and potentially.

Due to the ever-increasing data traffic, fifth generation (5G) wireless networks call for sustainability in terms of capacity growth. To that end, the dense deployment of small cells (SCs), overlaid on the existing macrocell forming a heterogeneous network (HetNet), is expected to play a key role. When a dense SC network is deployed, the SC radius is reduced, shorter distance between user equipments (UEs) and SCs and thus higher signal-to-interference-plus-noise ratio higher area spectral efficiency (bps/Hz/m2). Despite the aforementioned benefits, the high number of SCs complicates their direct connection to the core network. Fiber backhaul (BH) links are prohibitive in this case due to their high deployment cost Hence, a promising solution lies in exploiting the existing connection between the eNB site and the core network (mainly fiber), and to provide core network connectivity to SCs through the eNB site Still, in order to connect the SCs to the eNB site, new cost-efficient and high capacity wireless BH solutions are required. To that end, the use of millimeter wave (mmWave) is favored, due to its high bandwidth availability, able to provide high capacity BH [21]. It has been shown, however, that mmWave can provide good coverage for distances shorter than 200 m, otherwise, links may not be established Given that the eNB radius is typically on the order of 500 m, a multi-hop architecture is needed, to allow each SC to reach the eNB site In this 5G context, user association problem, which impacts both the network and user performance, becomes even more challenging, since it directly affects the traffic that passes through each BH link and thus its energy consumption. Nevertheless, traditional user association algorithms only consider the radio access network (AN), i.e., the links between UEs and their serving base stations (BSs)1.

In LTE-Advanced (LTE-A), user association is based on the reference signal received power (RSRP) and reference signal received quality (RSRQ). The first measures the average received power over the resource elements that carry cell-specific reference signals within certain bandwidth, while the latter measures the portion of pure reference signal power over the total power received by the UE. [3]. although these metrics maximize the instantaneous SINR of UEs [4], it has been shown that they do not increase the overall throughput significantly, since few UEs are connected to SCs [5]. Hence, range expansion (RE) was motivated, where a bias is introduced in the case the signal comes from a SC, thus favoring the UE association with SCs [15]. In this case, although a UE may be associated with a BS not providing the best SINR, better load balancing is achieved between eNB and SCs. However, the network topology changes stress the need for new BH-aware strategies, which will consider both BH capacity and energy impact.

IV. CONCLUSION

Wireless communications are undergoing a rapid evolution, wherein the quest for new services and applications pushes for the fast introduction of new technologies into the marketplace. Operators are just now starting to make initial profits from their deployed LTE networks, and already 5G demos and prototypes are being announced. Moreover, the wireless communications industry has begun to design for energy efficiency. this survey, energy efficiency has gained in the last decade its own role as a performance measure and design constraint for communication networks, but many technical, regulatory, policy, and business challenges still remain to be addressed before the ambitious 1000-times energy efficiency improvement goal can be reached. We hope that this paper provide high energy efficiency. Two different BH routing approaches were considered, i.e, with or without load balancing. The proposed low complexity algorithm was compared with existing solutions and it was be able to provide good trade-offs between the two competitive objectives. Finally, our results demonstrate the high gains of load balancing in lower BH power consumption, and thus, better BH resource utilization. As future work, we will compare the proposed approaches with optimal solutions obtained through analytical methods. Despite their high complexity, the optimal solutions will be valuable to further prove the gains of the proposed low-complexity approaches.

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