Energy efficiency for 5G mobile communications

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Rezumat. *Scopul acestui articol este de a prezenta aspecte tehnice privind eficiența energetică în cadrul rețelelor de comunicații mobile 5G. În acest articol se realizează o comparație între caracteristicile principale ale tehnologiei 4G și ale tehnologiei viitoare 5G. De asemenea, sunt precizate soluții pentru rețele „verzi" de comunicații mobile 5G.*
Cuvinte cheie. *Sistem, comunicații, tehnologie, rețea, energie, eficiență.*

Abstract: *This paper is presenting technical aspects about energy efficiency for 5G mobile communications networks. In this paper is accomplished a comparison between the main features of 4G technology and the future 5G technology. Also, are specified solutions for „green" 5G mobile communications networks.*
Keywords. *System, communications, technology, network, energy, efficiency.*

1. PRELIMINARY ASPECTS

Energy consumption is a main and very important factor in the large scale deployment of mobile networks. It is known that more than 0,5% of the world's total energy is used by the mobile networks [1]. Thereby reducing energy consumption in 5G mobile networks is a major issue in designing and developing them taking into account the environmental needs but also the network maintenanace.

In 5G mobile communications networks will be improved data transfer speed, scalability, connectivity and not least energy efficiency. This can be defined as the number of bits that can be transmitted per Joule of energy, where the energy is considerated over the whole network, including [2]:

- Potentially legacy cellular technologies;
- Radio access networks;
- Core networks;
- Data centres.

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Obviously, every effort to increase energy efficiency must be made without degrading network performance. Global mobile Suppliers Association (GSA) considers that the value of the performance minimum parameters that will define 5G are those in the Table 1 [3]. Some of the this values are specified relative to LTE performance. Thereby, it is estimated that the value of energy efficiency for 5G will be an improvement of more than 90% over LTE.

Table 1. **Performance minimum parameters for 5G [3]**

Parameter	Value
Latency in the air link	< 1 ms
Latency end-to-end (device to core)	< 10 ms
Connection density	100x compared with LTE
Area capacity density	1 $Tbit/s/km^2$
System spectral effiency	10bit/s/Hz/cell
Peak throughput (downlink) per connection	10Gbit/s
Energy efficiency	>90% improvement over LTE

Table 2. **Comparison between 4G and 5G technologies [4]**

Technology/Features	4G	5G
Data bandwith	2 Mbit/s to 1 Gbit/s	1 Gbit/s and higher
Standards	Single unified standard	Single unified standard
Technology	Unified IP and seamless combination of broadband, LAN/WAN/PAN and WLAN	Unified IP and seamless combination of broadband, LAN/WAN/PAN and WLAN and WWWW
Services	Provides dynamic information access, wearable devices	Provides dynamic information access, wearable devices with AI capabilities
Applications	Provides high definition streaming and some additional features such as multimedia newspaper and ultrabroadband Internet access	Includes large phone memory, dialling speed and much more. We can connect 5G cell phones with laptop to have broadband Internet access.
Bandwidth per frequency channel	Up to 100 MHz	Up to 28GHz
Detection or avoid of the error	Are used concatenated codes for error detection	The high quality of service based on policy to avoid error
Multiple access	CDMA	CDMA and BDMA
Core network	Internet	Internet
Handoff	Horizontal and vertical	Horizontal and vertical
Energy efficiency	For 5G is an important improvement compared to 4G	

From a user point of view, the differences between current 4G systems and 5G system include [4]:

- Increased maximum throughput;
- **Lower battery consumption**;
- Better coverage and high data rates available at cell edge;
- Multiple concurrent data transfer paths;
- Around 1 Gbit/s data rate in mobility;
- Better cognitive radio (CR)/software defined radio (SDR) security;
- Worldwide wireless web (WWWW), wireless based web applications that include multimedia capability beyond 4G speeds;
- More applications combined with artificial intelligence (AI);
- Low infrastructure deployment costs involving cheaper traffic fees.

In Table 2 is achieved a comparison between 4G technology and the future 5G technology [4].

2. PRESENTATION OF SOLUTIONS FOR „GREEN" 5G MOBILE COMMUNICATIONS NETWORKS

Energy efficiency has an important role in mobile communication on device side. Furthermore, increasing energy efficiency imposed a longer battery life.

For 5G devices the battery life shall be significantly increased [2]:

- At least 3 days for a smartphone;
- Up to 15 years for a low cost MTC device.

One of the main issues for the future mobile networks is to reduce power consumption. Most power consumption of cellular networks comes from base stations (BS) because they consume more than 60% of the power. Therefore it is very important to reduce power consumption in BS.

In a real situation for a mobile network if the load increased, then coverage will decrease and if the load decreased, then coverage will increase. In order to reduce the power consumption, the network topology can be designed so that as the load decreased BSs begin to cover more locations. In this situation some of the BSs can be stopped [5].

A key factor for network infrastructure is the need for high energy performance. In this regard it is desired to reduce overall network energy consumption while appearing massive increases of traffic and users number.

Also it is crucial to improve energy performance to data transmissions. For this it is necessary to have a more user-centric system in which the transmissions can be specifically tailored to the intended receiver in a flexible and adaptable way. Starting from the perspective of application, a user-centric system implies an increased precision in resource allocation according to applications needs. The latter contributes to the determination of the tolerable delays that indirectly influencing how aggressive energy-saving mode may be used in the underlying hardware equipment [6].

User-centric RANs can be realised by directional transmissions that are specific to users, by example beamforming.

It is known that advanced antenna techniques play an important role for mobile communications. Thus, from the energy performance perspective, advanced antenna techniques provide several benefits. Higher data rates enable more time for sleep mode utilisation by the equipments. Also an increased system capacity allows that in the future the extreme traffic to be realised without a corresponding densification of the network.

The high energy performance of 5G networks will be based on two design techniques [6]:

a) To only be active and transmit when needed;
b) To only be active and transmit where needed.

The main technologies used to obtain high energy performance of 5G networks include:

- Ultra-lean design;
- Advanced beamforming techniques;
- Separation of user-data and system-control planes on radio interface;
- Virtualized network functionality and cloud technologies.

Ultra-lean design is based on the design principle to *„only transmit when needed"* and it refers to the minimization of any transmissions that do not directly related to the provision of user data.

The main benefits of ultra-lean design in terms of energy performance are:

1) It provides more time without transmission, compared with existing cellular technologies and in this time the equipment can be in sleep mode;

2) The longer periods without transmission enable equipment to have more extensive or deeper, sleep-mode levels.

That technique called to *„only transmit where needed"* is the most interesting multi-antenna technique for the high energy performance of networks. This means to use a large number of antenna elements for very selective beamformed transmission.

The benefits of selective beamforming include [6]:

✓ Decreased interference which enables reduced overall transmission power in networks;

✓ Extended service coverage which provides high data rates in sparse deployments of networks.

Separating user-data and system-control plane functionality is important in order to achieve an superior energy performance. This separating in the radio interface allows:

- Separate scaling of user-plane capacity;
- Fundamentaln system-connectivity functionality.

In the Figure 1 is shown that a separation of system-control plane and user-data plane allows full utilization of advanced antenna systems [6].

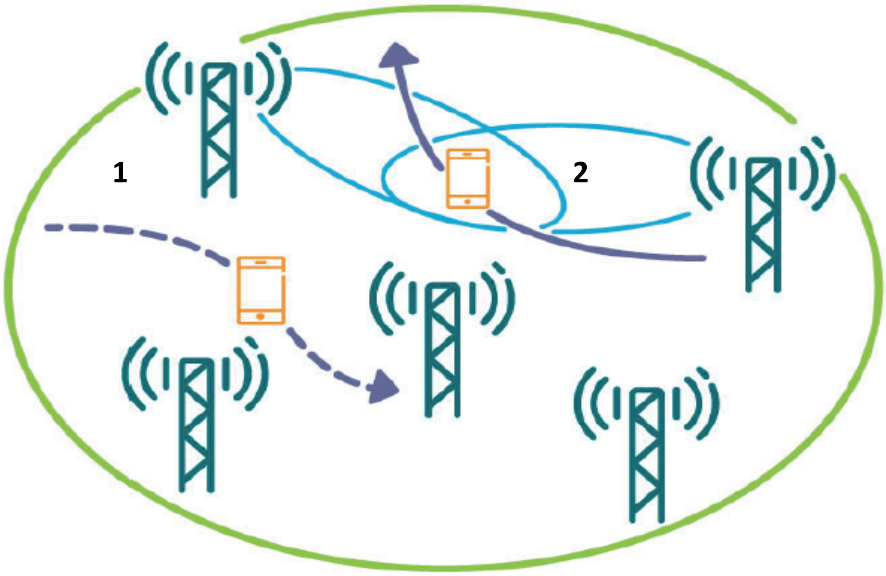

Figure 1. Separation of system-control plane (1) and user-data plane (2) allows full utilization of advanced antenna systems [6].

User data can be transmitted by a dense layer of access nodes, which can be activated on demand. At the same time system information is delivered only by an overlaid layer, on which devices initially access the system. All of them are related to the design principles – to *„only transmit when and where needed"*.

Combining ultra-lean design with separation of user-data and system-control planes allows a greater degree of user-centric network optimization of the active radio links in the 5G network.

For designing systems (also 5G systems) with a higher degree of abstraction, which improves network flexibility and enables the concept of network slicing can be used important tools like virtualized network functionality (VFN) and cloud technologies.

For some of the VFN, higher centralization in larger data centers enables [6]:

- ✓ Better infrastructure scaling;
- ✓ Less computational redundancy;

Therefore they can improve the energy consumption footprint.

On the other hand the cloud infrastructure can provide flexible deployment and runtime functionality enabling the functions to run at best place and time based on requirements for high energy performance [6].

Mobil traffic in mobile communications neworks will increase exponentially and the power consumption should be adapted to the traffic load. However, the power consumption in the networks will be dominated by the data centres, due to cloud networks. It is assumed that the future networks will transmit 1000 times more mobile data in 10 years, while the energy efficiency will improved only 10 times [7].

A high energy performance of the network is essential due [6]:

- ❖ Contributing to reducing operational cost;
- ❖ It is a driver for better nodes and network dimensioning;
- ❖ It is a part of the general operator target to provide wireless access in a sustainable and more resourse-efficiency way.

Also, one can say that will be essential that 5G networks to transmit as high data rate as possible taking into account users' need in a more energy efficient manner. In addition it is important to identify where the energy can be saved.

It must be mentioned that networks do not only consume energy in transmission in power amplifiers, but also in [7]:

⇨ Circuit power (computation),

⇨ Algorithms;

⇨ Protocols.

The transmission power for small cells is reduced and circuit power starts to dominate.

Any of the above mentioned aspects may be considered design solutions for „green” 5G mobile communications networks.

Referring to the energy efficiency of 5G networks there are still several research problems from system and device design but also from testing to network management.

Improving energy efficiency for 5G networks remains an open issue.

3. CONCLUSIONS

Energy efficiency has an important role in mobile communication on device side. Furthermore, increasing energy efficiency imposed a longer battery life.

One of the main issues for the future mobile networks is to reduce power consumption and it is very important to reduce power consumption in BS because they consume more than 60% of this total power.

A key factor for network infrastructure is the need for high energy performance and this will be based on two design techniques:

a) To only be active and transmit when needed;

b) To only be active and transmit where needed.

The main technologies used to obtain high energy performance of 5G networks include:

- Ultra-lean design;
- Advanced beamforming techniques;
- Separation of user-data and system-control planes on radio interface;
- Virtualized network functionality and cloud technologies.

It will be essential that 5G networks to transmit as high data rate as possible taking into account users' need in a more energy efficient manner. In addition it is important to identify where the energy can be saved. It must be mentioned that networks do not only consume energy in transmission in power amplifiers, but also in circuit power (computation), algorithms and protocols.

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Acronyms

Acronym	Signification
4G	4^{th} Generation
5G	5^{th} Generation
AI	Artificial Intelligence
BDMA	Beam Division Multiple Access

Acronym	Signification
BS	Base Station
CDMA	Code Division Multiple Access
CR	Cognitive Radio
GSA	Global mobile Suppliers Association
LAN	Local Area Network
LTE	Long Term Evolution
MTC	Machine-Type Communication
PAN	Personal Area Network
RAN	Radio Access Network
SDR	Software Defined Radio
VFN	Virtualized Network Function
WAN	Wide Area Network
WLAN	Wireless Local Area Network
WWWW	WorldWide Wireless Web

REFERENCES

[1] Rupendra Nath Mitra, Dharma P. Agrawal: *„5G mobile technology: A survey”*, http://www.sciencedirect.com/science/article/pii/S2405959515300503

[2] ***: *„NGMN 5G WHITE PAPER”*, NGMN Alliance, February 2015, http://www.ngmn.org

[3] ***: *„The Road to 5G: drivers, Applications, Requirements and Technical Development”*, GSA, November 2015, http://www.gsacom.com

[4] Radu Dragomir, Cristina-Gabriela Gheorghe: *„Next Generation of Femtocells and 5G Systems”*, Telecomunicații, Nr. 1/2016

[5] Saurabh Patel, Malhar Chauhan, Kinjal Kapadiya: *„5G: Future Mobile Technology-Vision 2020”*, International Journal of Computer Applications (0975 – 8887), Volume 54 – No. 17, September 2012

[6] ***: *„5G Energy Performance”*, Ericsson White Paper, April 2015, http://www.ericsson.com

[7] Zoran Bojkovic, Miodrag Bakmaz, Bojan Bakmaz: *„On the Road to Energy Efficient 5G Mobile Networks”*, Recent Advances on Systems, Signals, Control, Communications and Computers, http://www.wseas.us/e-library/conferences/2015/Budapest/DNCOSE/DNCOSE-19.pdf