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TOWARDS 5G — CLOUD-BASED RADIO ACCESS NETWORKS

ABSTRACT

In the paper a general concept of the 5G network architecture is presented as well as system requirements having impact on innovative solutions in the 5G network are highlighted. A major part of the paper is both presentation and discussion of the problem of Cloud Radio Access Network introduction for public networks in which the cell and resource virtualisation will be implemented. On the other hand, the problem of resource virtualization in the STRUGA system is discussed in which the C-RAN implementation is proposed for performance improvement.

Key words:
5G, phantom-cells, LTE-A, Cloud-RAN, virtual cells.

INTRODUCTION

The evolution of mobile communication systems with regard to growth of traffic demand is coming towards 5G systems implementation. A major aspect of network evolution is logical and topological conversion of the radio access network architecture. In a new concept the architecture proposal is based on heterogeneous Ultra Dense Network concept [4, 8]. In this case, for network implementation it can be used extensive, hierarchical cellular structure in which a number of radio access technologies can be used.

In a heterogeneous network the structure of cells consists of two basic types of cells, macro-cells and small-cells (micro-cells, pico-cells or femto-cells) in

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which more than one radio access technology is implemented. It means that there is possible the use of different radio access technology in macro-cells and small-cells. Additionally, if the same radio access technology is used in large and small-cells then physical resources used in small-cells can be virtualized by their coordination in a network cloud. Typically, in this case, the resources are defined for macro-cell but they can be multiplied by their use in a number of small-cells of very low range. It means that the resources are multiplied and simultaneously allocated in small cells because of low power of inter-cell interference. This concept is known as phantom--cells concept and it is firstly dedicated to LTE — Advanced evolution [7]. In phantom-cells there is used the same radio access technology for all cells, both macro-cells and micro-cells but, in general, the communication in macro-cells is realized in control-plane only while the useful data transmission in user-plane is made in small--cells. It guarantees low ranges of access points, low powers of signals transmitted, and, as a result, low power of inter-cell interference what guarantees very good connection performance and much better spectral efficiency compared to homogeneous networks as well as an efficient reuse of physical resources in small-cells due to their virtualisation.

The new concept of radio access network architecture is very important to machine-type communication networks (Machine-to-Machine — M2M) [4]. Especially, it can be used to sensor networks communication for companies and Intelligent Transportation Networks as well as for all devices in global Internet of Things. It's well known that in the coming years the radio communication traffic generated by machines, vehicles and devices, without a man contribution, will become dominant in mobile networks. In telematics it foreruns a revolution in their expansion and availability of new services.

MAJOR REQUIREMENTS AND THE 5G ARCHITECTURE

Major requirements for the 5G are defined by ITU (International Telecommunication Union) and they are the following [4]:

1. Global network throughput and cells throughput as well as achievable transmission rates for wireless connections should be so large and stable that it no longer be any problems that must be taken into account during services implementation process.
2. Very low latency, large reliability and high Quality of Service (QoS) as well as Quality of Experience (QoE) for implemented services, optimized for connections between humans and M2M-type (Machine-to-Machine) connections, especially, excellent quality subjective perceived by users.

3. Good conditions for realization of real-time services as well as high quality of connections between terminals and machines of large mobility and speed of motion (high-speed trains and cars), regarding to development of global V2X (Vehicle-to-Everything) applications between cars, trains and a road infrastructure.
4. Simultaneous service of very large number of users and machines in global M2M network, network optimisation for V2X-based communication and safety systems as well as revolutionary development of smart-city systems and Intelligent Transportation Systems [2] in a global scale.
5. Enhanced multimedia services, virtual reality services, mobile TV etc. of a large quality.
6. Modern applications related to medical assistance, safety and security, which also forms part of the WBAN (Wireless Body Area Networks) dedicated just for such purposes, especially in transport applications [2].
7. Internet of Things in wireless networks in which large and growing number of devices will be used. They will often continuously send information to other devices and people with different and varying requirements for energy consumption, power of signals transmitted and introduced delays.
8. Highly accurate location-based services for precise localization and navigation of: drones, cars and other vehicles, autonomous cars, etc.
9. Efficient methods of resource management, distributed scheduling, efficient frequency reuse [3, 5], and coordinated multipoint transmission [4] including virtual small-cells implementation within large cells.

The fulfilment of presented requirements will not be possible without total changes in a cellular network concept and an adopting of global network architecture, including different subsystems dedicated to various functions [1]. An example of the 5G architecture is shown in figure 1. The architecture consists of two basic elements i.e. a fixed core network and a radio access network. There is no doubt that some parts of the core will be implemented in Internet cloud what is very important from the point of view of low services latency compared to 3G and 4G networks.

In presented figure there are highlighted some important subnets for 5G:

1. Public Land Mobile Networks and other public, and in this: mobile small-cell networks, small-cell home networks for local Internet access and phone services as well as smart-house M2M communications and some local cognitive networks.
2. Global M2M networks for smart-cities, smart-buildings and corporations.
3. Intelligent transportation networks including ITS for road traffic management safety (cars, trucks, trains etc.) and rescue operations as well as for global V2X

communications and integrated WBAN networks. Additionally, mobile-cell networks in trains, busses etc., which can be implemented to global Internet access for passengers.

4. Dispatch solutions and special systems for public safety and rescue operations including trunking LTE-solutions and dedicated systems, e.g. for border guard, as the STRUGA system when connected to global Internet.

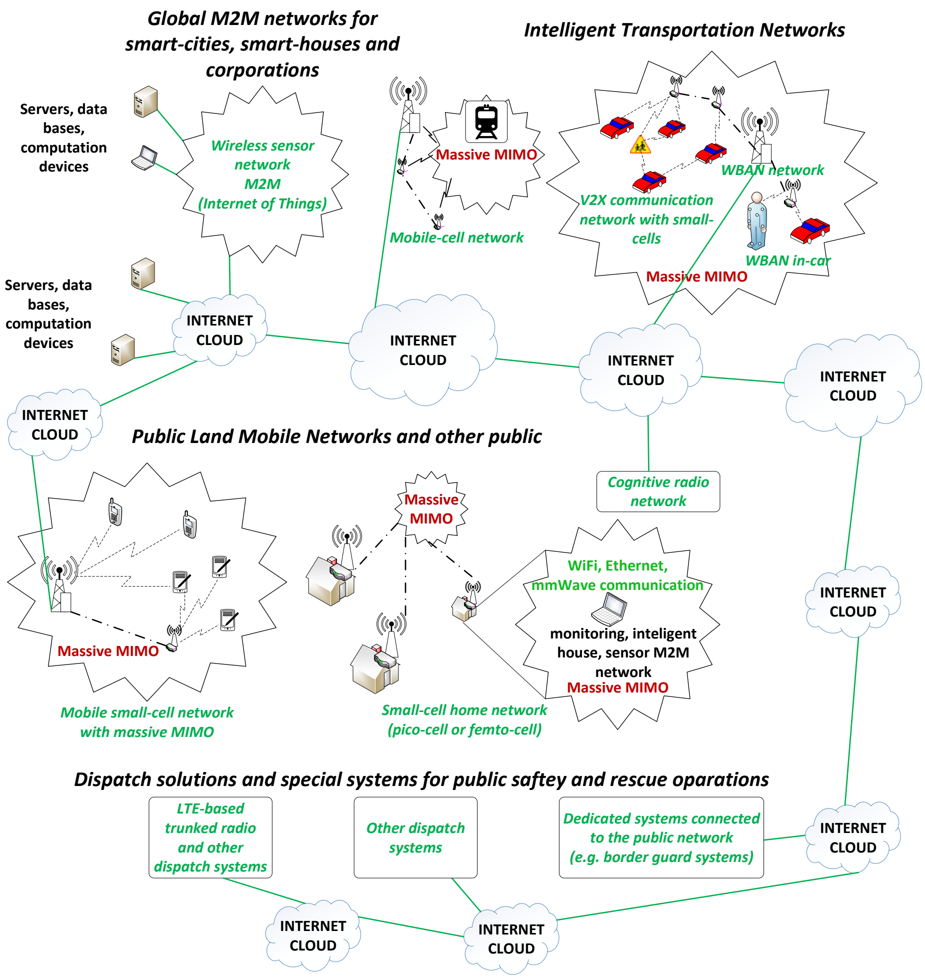

Fig. 1. General architecture of the 5G network [own study]

Interesting group of systems possible for integration with the 5G network are special systems for public safety as LTE trunking system or the STRUGA system, designed in Department of Radio Communications Systems and Networks at Gdansk

University of Technology, which is developed for a coast guard necessity. This is a system dedicated to multimedia data transmission from cameras and Voice over IP transmission between the coast radio stations and flying planes and drones, and marine ships or other watercrafts. This system is dedicated to large distance communication and it is, in general, based on the OFDMA (Orthogonal Frequency Division Multiple Access) technique. The coast part of STRUGA consists of a number of radio stations which are connected to the fixed infrastructure of coast guard networks and can be connected to public networks (in some parts). Now, a major challenge for this system is to find efficient methods for resource management, frequency reuse and cell virtualization at sea and under the sea, especially for planes, helicopters and unmanned drones.

Realization of the challenges of the 5G network makes a necessity for the Massive MIMO (Multiple Input Multiple Output) technique implementation [4], modern signal processing techniques and multiple access methods, maybe based on Non--Orthogonal Multiple Access — NOMA. Moreover, the evolution and development of the 4G LTE-Advanced can be a major part for 5G implementation. There is no doubt that the structure of a cellular network will be changed what, nowadays, takes place in an evolution of 4G LTE-Advanced system in which virtual cells are standardised (so-called 'phantom-cells'). In modern 5G network dominant will be small cells supported by Massive MIMO technology. While data processing for a core network can be allocated in an Internet cloud. Probably, some signal processing functions will be realized in a network cloud. Thus eNodeBs, access points and other radio elements can realize the frond-end functions only. It can simplify the process of interference coordination and resource management in a network.

THE CLOUD — RADIO ACCESS NETWORK

The architecture of 5G network includes both the radio access network (RAN) and the core network where the functions of the core are implemented at some nodes in a fixed network [6, 8]. These nodes can be centralized or distributed in a network dependent on their functions and capabilities. In principle, the fixed network is equipped to a number of different nodes and encompasses capabilities for an efficient and flexible operation of the RAN what is characteristic for the 5G. In particular, computing and storage functions can be realized in distributed form in the network cloud for very fast real-time connections and low latency of signals transmitted in an air interface. In typical 5G RAN a number of small — cells will be placed within large cells. Additionally, these small cells can be virtual just like physical resources can be virtual. It means that some resources can be the same for whole-macro-cell and they can be dynamically located to small cells using efficient algorithms of resource management and interference coordination as well as frequency reuse methods [4, 8].

In general, there are two concepts for efficient radio access operations with regard to the model of centralized and distributed network functions. A major challenge for 5G is the deployment of some layer of small-cells into macro-cells, using different concepts [6]. The first concept bases on the use of classic distributed RAN (D-RAN) both in macro-cells and also in small cells. In this case, classic methods of radio resource management can be implemented, as e.g. frequency reuse and scheduling etc. Secondly, centralized RANs, sometimes called the Cloud-RANs (C-RAN) can be implemented. In C-RAN a central eNodeB controls the transmission in whole macro-cell and in small-cells located at the area of the macro-cell. While useful signals of user-data are transmitted only in short range small-cells. Small cells are supported by local access points to eliminate the effect of low cell edge capacity due to inter-cell interference. In this case small-cells are the part of macro-cells and look like virtual cells using virtual resources.

The cell virtualization extends the idea of a virtualization into air interfaces beyond hardware. It provides the optimisation of a cell capacity by multiplication of the same spectrum to different users depending on their location and distance among them. The cell capacity can be efficiently delivered for various users in a dynamic form what we can see in figure 2. In general, in the C-RAN it is possible by virtualisation the reuse of frequency bands many times within the area of a single macro-cell. If the location of different users is known then there is possible the 'full' isolation for interference and the same physical resources can be allocated to many users at the same time without the effect of cell edge interference.

For the achieving of large 5G network requirements rather a combination and integration of existing radio access technologies with some new concepts is anticipated. The result of this is development of LTE-A standard which is very promising from the point of view of the 5G implementation. Additionally, 2G and 3G technologies are developed to C-RAN communications and others. For 5G systems some new frequency bands are expected to be used as both millimetre-waves and micrometre-waves what causes very small sizes of cells and the UDN networks. The UDN implementation is very convenient for the Massive MIMO implementation, thus, probably this technique will be very popular in 5G, as well as advanced interference management schemes e.g. coordinated multi-point (CoMP).

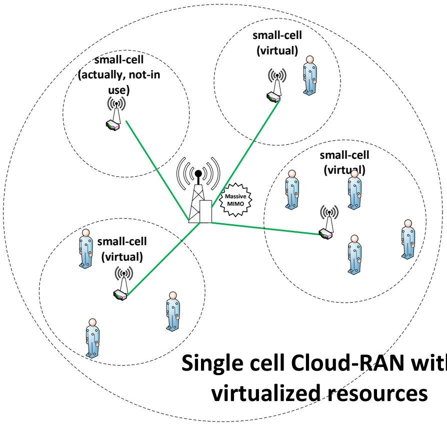

Fig. 2. Example of Cloud-RAN with virtual cells [own study]

Development of innovative functions of the 5G network requires research for different characteristic innovations in network architecture like follows:

- the Core Network functions are moved to aggregation nodes in the transport networks and can be virtualized;
- RAN functions are moved to aggregation nodes, in order to apply centralized joint processing of signals from many small-cells located within a macro-cell;
- multiple superimposed clusters with central processing can be implemented, serving multiple base stations and access points;
- access points, radio resource units, etc. can be connected via wireless backhaul links to other access points or base stations which have a fixed connection to the core network;
- access points, radio resource units, etc. can be connected to other access points or base stations via fixed links (e.g. optical);
- requirements for fronthaul interfaces (from access points to mobile terminals) can be defined in the same network infrastructure as backhaul interfaces [6].

From the point of view of the coastal and maritime systems like STRUGA, the problem of network and resource virtualization takes on a new meaning. First, the problem is a definition of small-cells which can be located at e.g. ships or planes. Secondly, not whole area can be covered by small cells and all types of these cells are the mobile-cells. Additional problem is that of very large coverage of each macro-cell defined by the coverage of coastal radio stations. It means that further work will be a great challenge but with a very big scientific potential. It's obvious that problem of C-RAN implementation can be very attractive from the point of view of maritime radio communication systems.

CONCLUSIONS

As one can see in presented considerations, the evolution of radio communication networks towards 5G is a huge scientific and technical challenge. It should be taken into account different requirements what guarantees very large network performance compared to both 3G and 4G networks. But the new concept of the 5G network architecture as well as cellular structure including virtual cells, introduces the need for extensive research into the use and management of radio resources. Therefore, the importance of virtualization techniques, frequency reuse methods and interference coordination techniques is now one of the main research trends in the world. Additionally, the use of C-RAN concept in maritime networks implementation is completely not known and has never been researched before.

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REFERENCES

[1] Fiorani M., Skubic B., Martensson J., Valcarenghi L., Castoldi P., Wosinska L., Monti P., *On the design of 5G transport networks*, 'Photon Network Communications', December 2015, Vol. 30, Issue 3.

[2] Gajewska M., *Design of M2M Communications Interfaces in Transport Systems*, [in:] *Challenge of Transport Telematics. Communications in Computer and Information Science*, ed. J. Mikulski, 2016, Vol. 640, Springer, Cham, Switzerland, pp. 149–162.

[3] Gajewski S., *Soft-Partial Frequency Reuse for LTE-A*, 'Radioengineering', April 2017, Vol. 26, No. 1, pp. 359–368.

[4] Gupta A., Kumar Rakesh J., *A Survey of 5G Network: Architecture and Emerging Technologies*, 'Special Section in IEEE Access: Recent Advances in Software Defined Networking for 5G Networks', 2015, Vol. 3, pp. 1206–1232.

[5] Hindia M. N., Khanam S., Reza A. W., Ghaleb A. M., Latef T. A., *Frequency Reuse for 4G Technologies: A survey*, 2-nd International Conference on Mathematical Sciences & Computer Engineering, ICMSCE 2015, Langkawi, Malaysia 2015.

[6] Karthikeyan S., Mustafa Y. A., Shailendra S., Sampath R., Srikanth V. K., *FluidNet: A Flexible Cloud-Based Radio Access Network for Small Cells*, IEEE/ACM Transactions on Networking, April 2016, Vol. 24, No. 2, pp. 915–928.

[7] Lokhandwala H., Sathya V., Tamma B. R., *Phantom Cell Realization in LTE and its performance analysis*, IEEE International Conference on Advanced Networks and Telecommunications Systems (ANTS), 2014.

[8] 5G PPP Architecture Working Group, *View on 5G Architecture*, July 2016, ver. 1.0.

W KIERUNKU 5G — SIECI DOSTĘPU RADIOWEGO W CHMURZE

STRESZCZENIE

W artykule omówiono ogólną architekturę sieci 5G oraz wymagania systemowe mające wpływ na stosowane w niej innowacyjne rozwiązania. Główną część stanowi prezentacja problematyki wdrażania sieci C-RAN w publicznych sieciach komórkowych, w których zostaną zaimplementowane metody wirtualizacji komórek oraz zasobów fizycznych. Przeanalizowano także problem wirtualizacji zasobów w systemie STRUGA, dla którego zaproponowano implementację sieci C-RAN w celu zwiększenia wydajności systemu.

Słowa kluczowe:
5G, LTE-A, komórki wirtualne, sieć dostępowa w chmurze.