The Study of the Influence of Internet of Things and Virtual Reality on 5 G Networks

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ABSTRACT: *Most people depend on mobile networks. The future autonomous networks largely depend on the virtual reality and Internet of Things with the support of modern technologies. We have studied the standards and features such as mobile cloud, cognitive radio, virtualization and software based networks of the fifth generation networks. We found that this new network can capable of transferring more volume of data with high speed. We have studied the technical features and requirements of the network and resources.*

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1. Introduction

The 4th generation networks already have been developed in Bulgaria and now the mobile industry points toward the next generation network - 5G. This year the 5G networks and the mobile wireless connections were the accent on the Mobile World Congress held in Barcelona, Spain. Seen on a broader scale every 10 years new generation cellular network has been developed [1]. Following this tendency it is expected that a new generation would show up in 2020 where in comparison with 4G the planned the max peak data rate will be 20 Gbit/s [2]. Technical characteristics comparison of mobile cellular generations related to data speed are shown in Table 1.

The fifth generation mobile system differs from the previous third and fourth generations in that it represents a heterogeneous network integrating 4G, WiFi and other wireless technologies. It combines cloud infrastructure [3], a virtualized network core, intelligent end-to-end services, and a high-performance distribution model designed to transfer data generated by milliard mobile devices, machines, and sensors. The fifth generation will be a prerequisite to transform the mobile network from a man-centric to a much broader network, which will include many machines, sensors and other interactive things that will lead to

Generation	Third generation 3G (IMT - 2000)	Fourth generation 4G (IMT - Advanced)	Fifth generation 5G (IMT - 2020)
Max data rate	2 Mbit/s	1Gbit/s	20Gbit/s
Technology	WCDMA	OFDMA IP -ядро	OFDMA IP-core, combination of LAN and WLAN
Multiplexing	CDMA	CDMA OFDM	CDMA OFDM
Handover	Horizontal plane	Horizontal and vertical plane	Horizontal and vertical plane

Table 1. Technical characteristics comparison of mobile cellular generations

milliard mobile devices. High data rate and intelligence will be the main features of the 5G network. The quality of service and service priority in the 5G networks will be on an extremely high level and the network itself will determine this automatically. The 5G networks will be implemented with applications for data analysis, traffic prediction and network monitoring to save time, high efficiency and network intelligence. The system will be able to optimize and customize the capabilities of each user application.

2. 5th Generation Network

2.1 Requirements

Enhanced Data Rates **-** The 5th generation of mobile cellular systems will achieve thousands of times higher data rates to current systems. These networks will support broadband channels of several tens of Gbit/s to ensure customers with Gbit service everywhere and any time.

Reduced Network Latency **-** Due to inclusion of variety of devices with remote access, such as robots, machines, automotive, and others, will require a highly reliable wireless communication channel with extremely low latency time.

Massive Number of Connections **-** With the emergence of the 5th generation, the number of connected devices is expected to increase at a very fast pace. Also, the amount of data transferred over the mobile network will be tremendously increased.

High Reliability **-** The 5th generation mobile systems will be designed to be highly reliable and available with 0% service outage. This is a prerequisite for maintaining a variety of critical services that are not yet available in current networks. The main mobile network goals are to ensure reliable end-toend service and zero service outages.

High Efficiency and Performance **-** One of the key factors for high network performance in 5th generation is the infrastructure of very small cells and high energy efficiency. By definition the small cells are low power wireless access points that operate in the licensed spectrum and are managed by the operator to provide improved cellular coverage, capacity and services for home and business users in urban and suburban areas. Small cells can differ on their coverage areas - the smallest size one is the Fempto-cell, followed by Pico-cell, Micro-cells, and the largest of which is Metro-cell for densely populated urban areas.

2.2 Network Architecture

Cloud Services and shared cloud-based resources in their development period include many different variations of resources that can be shared within a particular cloud or between interconnected clouds. In both cases, we can distinguish resources by the following features - hardware or software, limited or unlimited, case-specific or common. Number of other alternatives exist that can form a group of virtual resources shared in the cloud. Examples of cloud-types are - clouds for so-called computing resources (processor, memory and network), storage clouds, game clouds, etc.

User Resources **-** The user itself is not physically part of the cloud but the resources we look at are owned, managed and controlled by the user. Based on the level of integration in social aspects, the user resources can be delimited as follows:

• Individual, where a single user controls one or more devices and adjusts the operational parameters not only for the one device but for all devices also. This can be called a "personal" cloud. Every interaction here is user dependable, but it may not be a single user, but an organization. Knowing or predicting the individual user behavior is extremely useful as it can be applied to realization of common strategies for interoperability between the sets of devices that constitute this "personal" cloud.

• Group levels include multiple users or operators, and here the social aspect is included which requires additional considerations. Knowing the social or group behavior and along with the individual behavior allows to form cooperative strategies to maximize the utility for the whole group and individual members. Generally, individual members will join the cloud if there are benefits that can be realized.

• Universal resources include the common control capabilities of available resources that are in the cloud range. An axiomatic example of such infrastructure would be an emission measurement sensor led by community government, but still sending short messages to all devices in the cloud.

***Software Resources* -** It is necessary to distinguish the operating system from not-serviced software coming with a mobile device on the one hand and the user-supported software e.g. - mobile applications, from another:

• Operating systems determine the overall cloud node operation. Examples of operating systems - Android, Windows, iOS, etc.

• Usually the unsupported software is present on most mobile devices and works on the background for users. Such types of programs are pre-installed on mobile devices to monitor device usage and return data to the vendor.

• Mobile applications can be installed based on user needs. For individual operating systems, a large number of applications are available which can be downloaded and installed by the users on their devices. User-level apps can be shared in the cloud.

The *hardware resources* available to mobile cloud users represent physical devices or components that build the cloud itself. By definition the available resources can be categorized into different groups:

• Computer or computing – processors (CPU), graphic processors (GPU), or special processors for digital signal processing (DSP), etc.

• Storage - operational energy-dependent memory (RAM), non-volatile memory for long-term storage (FLASH), disk arrays (HDD RAID), etc.

• Detectors or sensors - for temperature, pressure and location. Also microphones, cameras, etc.

• Drive mechanisms - servo motors, display, flash, traffic lights and notification semaphore, etc.

• Power - batteries, mobile batteries, solar panels or uninterrupted power from the power grid.

***Network Resources* -** As we look at mobile devices as key players to the methodical research cloud models of the future, connectivity as an opportunity to share resources and connectivity as a resource is significant. The common technologies available on mobile devices are as follows:

• Cellular - from 2G to current 4G technologies.

• Wireless LANs - with the emergence of smartphones, the WLAN interface is additionally used to unload the cellular traffic and to transfer large-sized files in ad hoc mode between mobile devices.

• Bluetooth Interface - today's benefit of this technology is reduced power (Bluetooth Low Energy, BLE) needed to transfer small data files to an almost touch-based network approach.

• Infrared (IR) visible light communications - optical aerial interfaces based on radio frequencies. There are manufacturers of smart devices that incorporate IR transceivers into their devices to allow a remote control.

• Cable interfaces may be present on some mobile devices to allow dial-up communications, either directly or by using dongles.

Network Coding **-** with the introduction of mobile clouds the communication architecture will change radically. At present days, the cellular communications architectures design is still dominated by the centralized management links "point to point". Mobile clouds will interrupt this type of structural design, relying on distributed functionality. The mobile cloud is able to retrieve content from multiple sources at the same time and potentially through several air interfaces. Due to these radical changes, the basic communication technology as well as policies will also be changed. Some of the major challenges in using multiple sources and interfaces include:

• The need to coordinate which data packets to be transmitted from each source and / or air interface, which requires a high signal load and

• The fact that productivity will depend heavily on the changing conditions of these sources / interfaces.

To remove these problems the mobile clouds can use network encryption as a key that will enable this technology. The network encryption cuts off with "Save and Forward" conceptual scheme of current networks, where each node in a packet switched network accepts, stores, and transmits bundles without changing their content and replaces that model with a new "Calculation and forwarding". In this new scheme, the packages that enter a node on the network will be stored, but the packets that go out will be generated as combinations of packets that are already stored in the node buffer. This means that an intermediate network node can work on the content of incoming data. On the one hand, this allows destinations to focus on getting enough combinations to recover original data instead of focusing on individual packets. This means that coordination between multiple sources / interfaces is relieved so that each source / interface can transmit different line combinations to the end recipients. This also allows for more robust mechanisms to deal with system dynamics, where data recovery is no longer dependent on a specific packet that slows down or the interface is interrupted after it gets enough of it. On the other hand the network coding fundamentally changes the resource management across the network. While all packets entered a node will leave this node after a while, as they were stored and forwarded, with that the network coding stops and sends (linear) combinations of received packets, allowing the node to send less packets with the same or higher rate than the incoming rate depending on network conditions and topology. Unlike the existing coding strategies based on the principle for "Erase / error" and encoding of the source or channel, network coding is not limited to end-to-end communications. In this way, these features make network coding an extremely important mobile cloud solution.

Network Slicing is an important ability of 5G systems for network resource efficiency, flexible deployment and allows a new generation of mobile applications and services. The network slice purpose is to provide all necessary resources that various services require from a mobile network through different logical subnets determined by the service type. The basic services that 5G networks need to support are presented by the ITU in three main groups (use cases): Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC) and Massive Machine Type Communications (mMTC). Each of these groups has different service requirements such requirements are the bandwidth, the number of terminals in the system, the time-delay of the signal, the velocity, etc.

The 5G network must be adaptable and adjustable according the terminal applications. Network slices represent stand-alone, end-to-end logical subnetworks utilizing common physical infrastructure. They have direct access to the network resources, services, and functions, and autonomously allocate these resources. Terminal devices will be able to switch from one network slice to another and to stay connected to multiple network slices simultaneously.

2.3 Efficient Radio Resource Management

The cognitive radio is a new technology that has the potential to meet the stringent requirements for spectrum availability in the 5th generation of networks. Cognitive radio is defined as a radio that can adapt its transmission parameters according to the characteristics of the environment that operates. Cognitive radios are equipped with cognitive capabilities and could be reconfigured. In cognitive radio networks two types of users are presented - primary users who are licensed users and have priority over the frequency spectrum and secondary users who are opportunistic users. They have access to the radio spectrum on a non-interactive or leased basis, according to policies agreed with the main users or designated by the regulatory authorities. Frequency spectrum is one of the most important natural resources that is regulated and exhaustible. The rising number of new applications coupled with the demand for strict requirements and for channel capacity the huge demand to realize the 5G networks, because according to today's standards, bandwidth and power consumption would be a hindrance. That is why efforts are currently being concentrated on new communication and networking models that can intelligently and effectively address these issues. Based on the Shannon theory of information capacity it is obvious that the modern propagation models, the modulation techniques and error correction have improved the capacity of current mobile systems reaching the maximum possible. To increase the available bandwidth for data transmission seems to be the most promising approach to increasing the capacity of future mobile networks, including the fifth generation.

Cognitive radio technology can be presented as an opportunity for effective resource management and utilization due to its intelligent and adaptable nature. Cognitive radio networks will be different from traditional communication models it means that radio stations / devices are capable of adapting their operational parameters, such as frequency, transmission power and modulation types with the variations of their working radio environment. The cognitive radio first acquires knowledge of the state of its radio environment. In the first place, it is aware of spectrum, geographic information, transmitted waves, network protocols types, security policies, local available resources and user needs. Based on this contextual platform the cognitive radio distinguishes the most effective strategy to utilize and adapt the transmission parameters in order to use the available technologies on the best way. The typical cognitive cycle is shown in Figure 1.

The main cognitive radio functions in the cognitive cycle are:

• Radio Frequency Spectrum Observation and Analysis

• Distribute and manage the radio frequency spectrum

• Spectrum handoff and mobility.

Spectrum Monitoring and Analysis - This feature allows cognitive radio to detect a portion of frequency spectrum that is not used by mainstream users. These unused portions are called spectral white space. The function also monitors any white space used for secondary transmission to be released in case the primary user reappears. The characteristics of the observed radio channels are calculated on the basis of the collected information from the observed module. An efficient algorithm is then used to extract information on spectral conditions in terms of used time and frequency of the spectrum and provides information on the spatial and time availability of a licensed spectrum.

Radio Spectrum Allocation and Management - After the initial processes of spectrum observation and analysis, spectrum allocation, management and retransmission allows secondary users to have the best bandwidth for data transmission and to hop around multiple radio frequency bands depending on the characteristics of the channels changing in time to meet the quality of service (QoS) requirement. The nature of spectrum mobility in cognitive radio networks can be divided into the following categories:

• Spectrum mobility in a time domain where the cognitive radio adapts its working frequency bands to the new available free bands through different time slots.

• Spectral mobility in the spatial domain, where cognitive radio changes its transmitting frequency based on the current geographic area. This means that when it moves from one place to another the operating frequency changes accordingly.

Figure 1. Cognitive cycle

3. Fifth Generation Devices for Cognitive Radio

The terminals designed for 5G cognitive radio are intended to be software-defined devices that provide both multi-modes maintenance and effective radio frequency spectrum utilization. The devices will be ready for the fifth generation mobile networks challenges if they have the capabilities to offer the following features: excellent performance, reliability, affordability and ease of personalization and use, ability to deliver a variety of applications. The components of cognitive terminals for 5G are illustrated in Figure 2. Software- Defined Radio components:

• Geo-locator - the cognitive radio uses the transmitter location provided by a geo-locator (such as a GPS receiver) for making the appropriate decisions.

• Training system - learning capacity is the most important part of cognitive radio. Different justifications and training systems are used to build and apply knowledge about learning states and reactions. In another use of classical artificial intelligence a fuzzy logic system for wave adaptation is used.

• Policy database - The database can be defined and updated by local or global regulatory authorities. It may include the status of the local radio frequency bands and the available channels.

• Sensors measure and monitor radio communications in the environment and collected information is provided to the cognitive core.

• Optimization algorithms - cognitive devices work with different algorithms and technologies to build and adapt radio waves. The sensors collect information from the radio medium that feds to the cognitive radio that is responsible for optimizing and selecting the appropriate frequency, transmit power, routing, performance, and digital error rate.

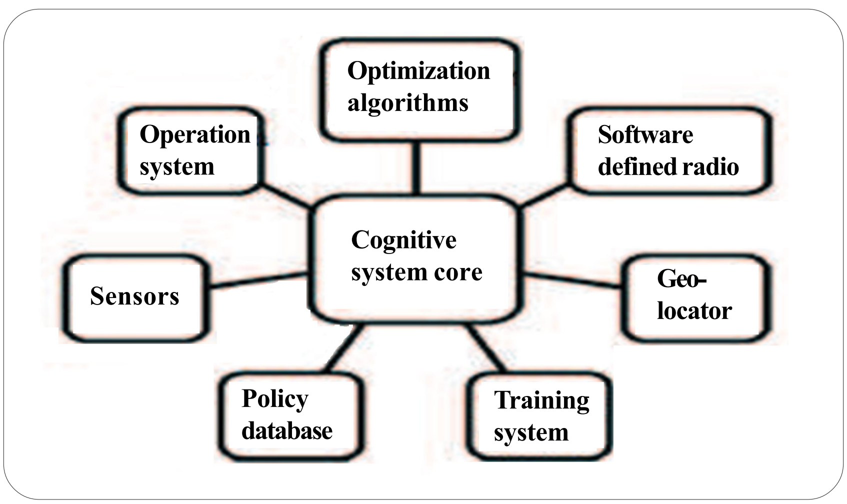

Figure 2. 5G components for cognitive terminals

• Cognitive system (core) - the cognitive core plays an essential role in coordinating and managing the internal parts of the device. This module supports different prediction algorithms and radio schemes for resource allocation.

• Software-defined radio is the main component of the cognitive terminal. This device is software-reconfigurable and designed with programmable components such as digital signal processors (DSPs), field programmable gate arrays (FPGAs), analogue-to-digital and digital-to-analog converters (ADC / DACs), reconfigurable amplifiers, smart antennas and broadband radio frequency (RF) circuits. Software-defined radio is defined as an object that provides software management of various modulation techniques, broadband or narrowband operability, communications security features, and wave requirements to current and emerging broadband standards.

Figure 3 presents a software-defined radio architecture. The main software-defined radio features are presented as follows:

• Unobstructed ubiquitous communication - As selecting the appropriate wireless network for user's location and requirements.

• Reconfiguration - changing all radio parameters based on internal and external policies.

• Interoperability - capable to explore and communicate with different mobile networks.

• Getting closer to the desired service quality - improving service economy, according to the data rate and cost.

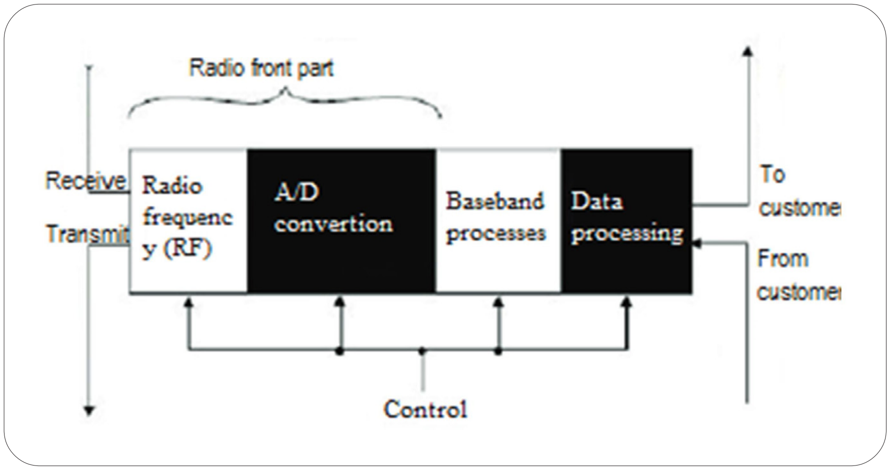

Figure 3. Software-defined radio architecture

4. Conclusion

The mobile cellular networks are immutable part of modern people's life, and will be tomorrow. Data rates are considered as basic technical feature of current systems. Consumers' demands are increasing and system requirements are increasing as well. The new networks need to be highly reliable, low latent, highly efficient and productive, energy - efficient, to provide massive connectivity and very high data rates. With the introduction of the fifth generation and future technologies as mobile cloud, cognitive radio, virtualization, software-defined networks, our idea of mobile cellular systems will change very significantly.

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