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Title: Review on Wireless Networks of the Sixth Generation (6G)

volume 08, Issue 05, Pages: 310-317

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Review on Wireless Networks of the Sixth Generation (6G)

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***Abstract*-** Wireless data traffic has risen dramatically as a result of the rapid development of smart terminals and the emergence of new applications (e.g., real-time and interactive services), and current cellular networks (even the upcoming 5G) are unable to keep up with the rapidly rising technical requirements. The sixth generation (6G) mobile network is projected to set a high technical standard for new spectrum and energy-efficient transmission solutions to handle the approaching challenges. In this article, we outline the prospective needs and provide a summary of the most recent research on the promising 6G approaches that have recently gotten a lot of attention. Furthermore, we discuss physical-layer transmission techniques, network designs, security measures, and testbed advancements, as well as a number of significant technological difficulties and potential solutions related with 6G.

***Index Terms*-** wireless networks; beyond 5G; 6G; 6G mobile communication;

I. Introduction

With the maturity and forthcoming commercialization of the fifth generation (5G), the expectation and development of 6G mobile network have attracted a great deal of attention. In the past two years, some countries have released relevant research plans concerning the development of 6G. For example, in September 2017, the European Union launched a threeyear research project on the basic 6G technologies. The main task is to study the next generation forward error correction coding, advanced channel coding, and channel modulation technologies for wireless terabit networks (https://futurecomresearch.eu). At the end of 2017, China began to study the 6G mobile communication system to meet the inconstant and rich demands of the Internet of Things (IoT) in the future, such as medical imaging, augmented reality, and sensing (www.china.org.cn). In April 2018, the Academy of Finland announced an eight-year research program, "6Genesis," to conceptualize 6G through a joint effort of the University of Oulu and Nokia. More recently, the U.K. government has invested in some potential techniques (e.g., €15 million in quantum technology studies) for 6G and beyond (https://www.standard.co.uk/ tech/quantum-technologies), some universities in the United States have lunched research on terahertz-based 6G wireless networks, and South Korea Telecom (SKT) has started 6G research based on the cell-free and non-terrestrial network techniques. In [1], based on the regularity of market entry of past commercial wireless communication systems and the expectation for 6G, the authors forecasted that 6G will start its commercialization in 10 years.

In general, the 6G mobile network is expected to provide
ultrafast speed, greater capacity, and ultra-low latency for supporting the possibility of new applications, such as fine medicine, intelligence disaster prediction, and surreal virtual reality (VR). Based on the former evolution rule of mobile networks, early 6G networks will be mainly based on the existing 5G architecture, inheriting the benefits achieved in 5G (e.g., the increased authorized frequency bands and the optimized de-centralized network architecture) and prodigiously changing the way we work and play.

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Around 2030, our society will likely become data-driven, enabled by nearly instantaneous, unlimited wireless connectivity [1]. As a result, 6G is expected to advance the wireless technologies we are familiar with today and achieve considerably enhanced system performance. As a vision for the future, in terms of speed, 6G will probably utilize higher frequency spectrum than previous generations in order to improvethe data rate expected to be 100 to 1000 times faster than that of 5G [2].

II. LITERATURE SURVEY

5G (from "5th Generation") is the latest generation of cellular mobile communications. Itsucceeds the 4G (LTE-A, WiMax), 3G (UMTS, LTE) and 2G (GSM) systems. 5Gperformance targets high data rate, reduced latency, energy saving, cost reduction, highersystem capacity, and massive device connectivity. The first phase of 5G specifications inRelease-15 will be completed by April 2019 to accommodate the early commercialdeployment. The second phase in Release-16 is due to be completed by April 2020 forsubmission to the International Telecommunication Union (ITU) as a candidate of IMT-2020technology.

The ITU IMT-2020 specification demands speeds up to 20 Gbit/s, achievable with widechannel bandwidths and massive MIMO. 3rd Generation Partnership Project (3GPP) is goingto submit 5G NR (New Radio) as its 5G communication standard proposal. 5G NR can includelower frequencies (FR1), below 6 GHz, and higher frequencies (FR2), above 24 GHz and intothe millimeter waves range. However, the speed and latency in early deployments, using 5GNR software on 4G hardware (non-standalone), are only slightly better than new 4G systems,estimated at 15% to 50% better. Simulation of standalone eMBB deployments showedimproved throughput between 2.5×, in the FR1 range, and nearly 20×, in the FR2 range.

Like the earlier generation 2G, 3G, and 4G mobile networks, 5G networks are digital cellularnetworks, in which the service area covered by providers is divided into a mosaic of smallgeographical areas called cells. Analog signals representing sounds and images are digitized inthe phone, converted by an analog to digital converter and transmitted as a stream of bits. Allthe 5G wireless devices in a cell communicate by radio waves with a local antenna array andlow power automated transceiver (transmitter and receiver) in the cell, over frequencychannels assigned by the transceiver from a common pool of frequencies, which are reused in geographically separated cells. The local antennas are connected with the telephonenetwork and the Internet by a high bandwidth optical fiber or wireless backhaul connection.Like existing cellphones, when a user crosses from one cell to another, their mobile device isautomatically "handed off" seamlessly to the antenna in the new cell.

Their major advantage is that 5G networks achieve much higher data rates than previouscellular networks, up to 10 Gbit/s; which is faster than current cable internet, and 100 timesfaster than the previous cellular technology, 4G LTE. Another advantage is lower networklatency (faster response time), below 1 ms (millisecond), compared with 30 - 70 ms for 4G.Because of the higher data rates, 5G networks will serve not just cellphones but are alsoenvisioned as a general home and office networking provider, competing with wired internetproviders like cable. Previous cellular networks provided low data rate internet access suitablefor cellphones, but a cell tower could not economically provide enough bandwidth to serve asa general internet provider for home computers.

The new 5G wireless devices also have 4G LTE capability, as the new networks use 4G forinitially establishing the connection with the cell, as well as in locations where 5G access is notavailable.

The high data rate and low latency of 5G are envisioned as opening up new applications in thenear future. One is practical virtual reality and augmented reality. Another is fast machine-tomachine interaction in the Internet of Things. For example, computers in vehicles on a roadcould continuously communicate with each other, and with the road, by 5G

III. Vision and Key Features for Future 6G Networks

Is there any concrete reason for 6G networks, given the vast capabilities of 5G cellular mobile wireless communications networks and their likely evolution? If that's the case, what are the missing LTE and 5G units that 6G must incorporate? Academics, industry, and research groups have established research modes for the formulation, definition, design, and identification of key core-enabling technologies that will drive the transition to a "beyond 5G" or 6G system [15,16].This section will cover a wide range of issues related to the vision and essential aspects of 6G communications that have recently been released. This section begins with a brief overview of the predicted applications that 6G communications will serve, which will lead to the identification of essential features that are required.

The following are five expected scenarios of applications that will be supported by 6G communications:

- eMBB-Plus

eMBB-Plus [17,18] in 6G will replace its 5G counterpart of eMBB and provide a high-quality experience (QoE) in data utilization and standards. Notably, other integral components of the wireless communication of network optimization, handover, and interference should be able to exploit the concepts of big data to facilitate these operations. Providing other add-ons such as accurate indoor positioning and a globally compatible connection among diverse mobile operating networks is expected, at an affordable rate for network subscribers. A strategy should be designed for eMBB-Plus communication services without compromising the security, secrecy, and privacy of network subscribers;

- Big communications (BigCom)

BigCom [19] in 6G aims to provide a large coverage of urban and remote areas by maintaining resource balance, thereby allowing subscribers to communicate with one another everywhere with a high data rate speed due to the unconventional technologies adopted by 6G communication systems, such as an extremely large bandwidth (THz waves) and a high AI that will include operational and environmental aspects as well as the services of the networks;

- Secure ultra-reliable low-latency communications (SURLLC)

Vehicular communications in 6G could also largely benefit from SURLLC [19,20]. SURLLC in 6G is an advancement of the URLLC and the mMTC in 5G and has more stringent demands on reliability (higher than 99.9999999%) and latency (less than 0.1 ms) coupled in a security framework;

- Three-dimensional integrated communications (3D-InteCom)

Before the evolution of 6G networks, device communication heights were inconsequential, as could be seen from the established propagation empirical models. This situation anticipates change in the 6G 3D-InteCom model [19–22], which highlights the need for a radical change from two to three dimensions, through which the heights of communications nodes must be considered. Some of the notable technologies that have already incorporated this dimension are satellite, unmanned aerial vehicle (UAV), and underwater communications. Thus, the analytical framework designed for 2D wireless communications that stemmed from stochastic geometry and graph theory needs re-adjustment in the 6G environment. Considering the device height leads to the actualization of elevation beamforming with full dimensional MIMO architectures, thereby preventing the need for a different approach for attaining network optimization

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- Unconventional data communications (UCDC)

Currently, the actual meaning and composition of UCDC [19] lack proper definition. Nevertheless, some of the following facets should be addressed: holographic, tactile, and human-bond communications.

Holographic communications: Holographic communications are one aspect that will add glamor to the 6G era. A hologram is a 3D technology that manipulates light rays beamed to an object and subsequently captures the resulting interference pattern using a recording device. In fact, transmitting 3D images without a stereo voice is insufficient to depict the in-person presence characteristics. In the 6G era, reconfigurable stereo audio will motivate the development of a platform for use in capturing several physical presences in each configuration. In other words, ample freedom for entities exists to interact with and modify received holographic data and video if the need arises. Holographic data are expected to consume a high bandwidth and must be delivered over reliable network links [23];

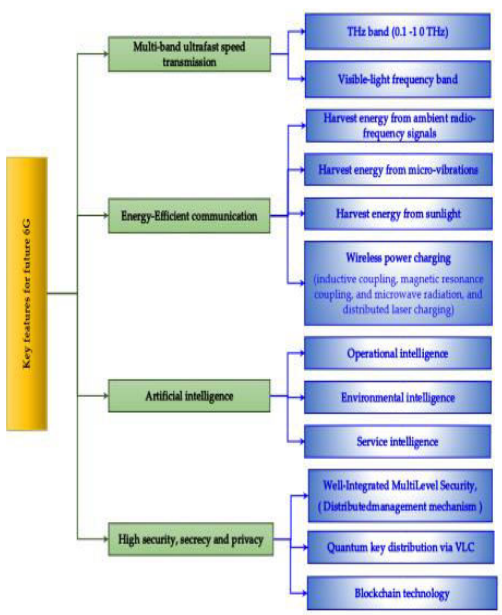

FIG.1.1.KEY FEATURES FOR FUTURE 6G

IV. RESEARCH ACTIVITIES

This section provides a brief overview of 6G research activities. Several 6G activities have been commenced globally by industrial organizations and governments whose objectives include formulating and defining 6G technology and then re-adjusting the outline in addition to the business model of wireless systems. The United States FCC has proposed allocating the 95 GHz to 3 THz spectrum to be used for 6G research, thereby setting the US as the pacesetter in the 6G research race. Other entities have begun concrete research efforts in 6G networks. Some of the notable names include the Finnish consortium through their 6Genesis Flagship Program and the Terabit Bidirectional Multi-user Optical Wireless System (MU-OWS) for 6G LiFi which commenced in early 2019. The 6G research race from academia can be said to have started in March 2019, when the first 6G Wireless Summit was held in Levi, Finland [13]. Apart from the aforementioned efforts, other mini workshops and conferences have been conducted globally to examine the prospect of 6G, including the Huawei 6G Workshop, the Wi-UAV Workshop of Globecom 2018, and the Carleton 6G Workshop. A research group based on the EU's Terranova project is now working toward a reliable 6G connection with 400 Gbit per second transmission capability in the THz spectrum [19]. LG Electronics also announced the foundation of a 6G research center at the Korea Advanced Institute of Science and Technology, Daejeon, South Korea. Samsung launched its 6G research in June 2019. SK Telecom announced a collaboration with Nokia and Ericsson for 6G research in 2019. In late 2018, China's Ministry of Industry and Information Technology declared its goal of leading the wireless communication market in the 2030s by expanding research investment in 6G. In addition, an EU–Japan project under Horizon2020 ICT-09-2017 funding called "Networking Research beyond 5G" also investigated the possibility of using the THz

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spectrum from 100 to 450 GHz. Table 2 summarizes the research initiatives into 6G communications. Moreover, IEEE launched the IEEE Future Network with the tagline “Enabling 5G and beyond” in August 2018. The ITU-T Study Group 13 also established the ITU-T Focus Group Technologies for Network 2030 in its aim to understand the service requirements for future networks by 2030 [19].

V. CONCLUSION

During the global deployment of 5G networks, a collaborative effort between industry and academia has begun to design the next generation of wireless communication systems (6G) to address the challenges that have arisen.

the issues that will arise when wireless data traffic grows dramatically. The 6G technology provides for higher bitrates.Apart from delivering a range of new services, the network will have a capacity of up to Tbps with a latency of less than 1 ms.This research began by presenting a vision and essential characteristics aimed at encouraging future 6G in the United States.energy efficiency, intelligence, spectral efficiency, security, secrecy, and privacy are the dimensions to consider.customizability and affordability Then we spoke about the various issues that could arise as a result of this.6G technologies and potential solutions for future 6G deployment. Finally, this project comes to a close withtransnational research activities aimed at forming a vision for the future

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