5G: the Network of the Future. Benefits and Perils

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Abstract

The fifth generation mobile network (5G) is a set of emerging global telecommunications standards, generally using high-frequency spectrum, to offer network connectivity with reduced latency and greater speed and capacity relative to its predecessors. One example is emerging autonomous cars and intelligent transportation, to which small latency is essential. It is argued that the current communications infrastructure is highly energy-inefficient and the 5G should be designed to solve this problem, by increasing energy efficiency by several orders of magnitude. To meet 5G requirements, we need dramatically new network architectures and technologies, such as heterogeneous ultra-dense networks, massive multiple-input-multiple-output (MIMO), and millimetre wave communications.

Keywords: Latency, coverage, heavy data traffic, influence on flora and fauna, health problems, higher transmission rates.

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Introduction

Discussions on fifth-generation (5G) mobile communication began around 2012. In many discussions, the term 5G is used to refer to specific new 5G radio-access technology. However, 5G is also often used in a much wider context, not just referring to a specific radio-access technology but rather to a wide range of new services envisioned to be enabled by future mobile communication [TER 19].

Fifth-generation (5G) wireless network technology is being touted as the true "next generation" of wireless communications, capable of performance levels far beyond the limits of fourth generation (4G) Long Term Evolution (LTE) wireless networks [TRU 19].

The evolution of LTE will be able to support a wide range of the use cases envisioned for 5G. Taking into account the more general view that 5G is not a specific radio-access technology but rather defined by the use cases to be supported, the evolution of LTE should thus be seen as an important part of the overall 5G radio-access solution, (Figure 1) [ABD 16], [ATT 16].

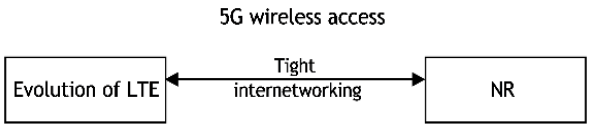

Figure 1 Evolution of LTE and NR jointly providing the overall 5G radio-access solution

Despite LTE being a very capable technology, there are requirements impossible to meet with LTE or its evolution. Furthermore, the technology development over the more than 10 years that have passed since the work on LTE was initiated allows for more advanced technical solutions.

To meet these requirements and to exploit the potential of new technologies, 3GPP initiated the development of a new radio-access technology known as NR (New Radio) (Figure 2), [AYA 18], [DAH 18].

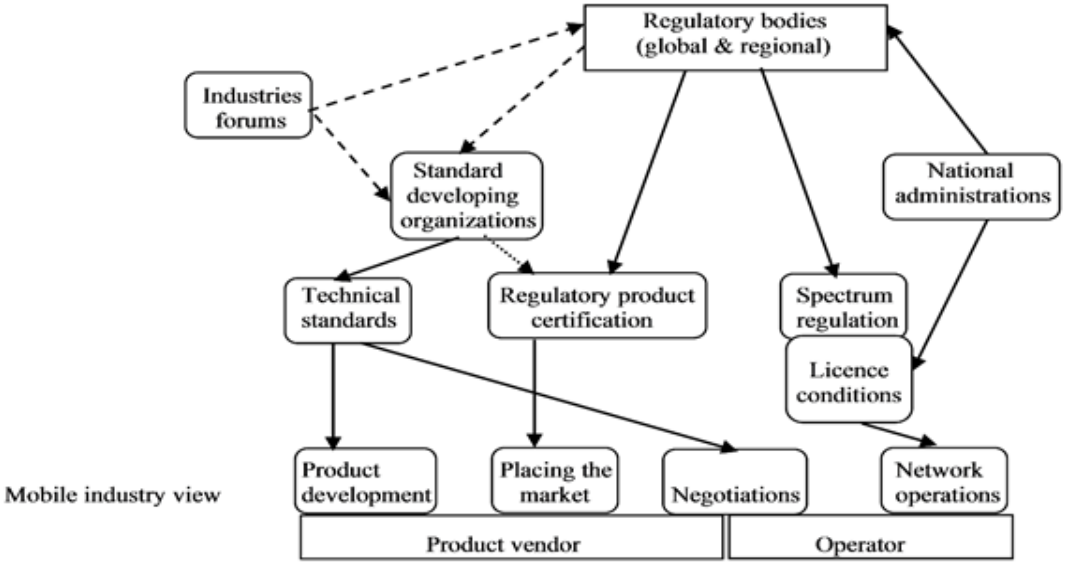

Figure 2. Simplified view of the relationship between regulatory bodies, standards developing organizations, industry forums, and the mobile industry [DAH 18]

The first version of the NR specifications was available by the end of 2017 to meet commercial requirements on early 5G deployments in 2018. The 5G ecosystem is building out to be substantially more versatile than LTE [ERI 15].

For 3rd Generation Partnership Project (3GPP) Release-17 work program, the physical layer work in RAN1 will start at the beginning of 2020 year, whilst radio protocol and architecture work in RAN2 and RAN3, respectively, will start in the 2nd quarter. Release 17 is perhaps the most versatile release in 3GPP history in terms of content.

From January 2020, RAN1 will start working on several features that continue to be important for overall efficiency and performance of 5G NR: MIMO, Spectrum Sharing enhancements, UE Power Saving and Coverage Enhancements. RAN1 will also undertake the necessary study and specification work to enhance the physical layer to support frequency bands beyond 52.6 GHz, all the way up until 71 GHz.

In addition, several features have been approved to address different needs of vertical industries: Sidelink enhancements to address automotive industry and critical communication needs, Positioning enhancements to address stringent accuracy and latency requirements for indoor industrial cases [HUA 16], [KRE 15].

5G may be the catalyst for explosion

With existing networks, there are several challenges that service providers need to face. Latency, coverage, heavy data traffic, and slow connection speeds are but a few of the obstacle operators face today. With 5G however, these challenges can be addressed so as to allow room for new developments within the IoT sphere.

Wearable technologies have become one of the many "new norms" since the initial beginnings of the IoT and there is now huge market for various different types of wearable technologies; their growth has been somewhat stunted in some industries and sectors.

5G networks will likely becoming essential to public and emergency services. With increased connection speeds, expanded area of cover and more niche applications being developed, the process of developing smart homes and cities could contribute to a second IoT explosion when coupled with the capabilities of 5G networks. With the introduction of more capable networks, the degree to which the IoT will be impacted is yet to be seen.

The 5G terminals will have software defined radios and modulation scheme as well as new error-control schemes can be downloaded from the Internet on the run. The development is seen towards the user terminals as a focus of the 5G mobile networks. The terminals will have access to different wireless technologies at the same time and the terminal should be able to combine different flows from different technologies (Figure 3), [MIJ 16].

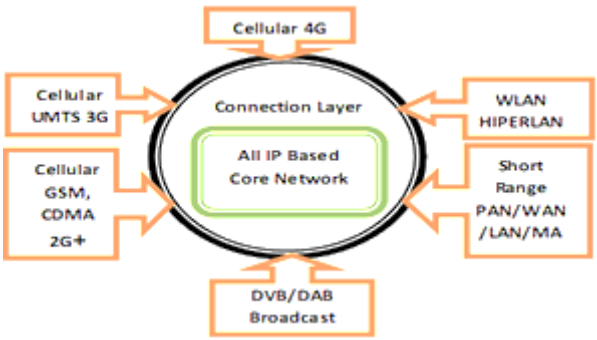

Figure 3. Seamless connections of networks

5G promises to improve both video-streaming support and low-bandwidth IoT deployment, but much of this is still in the future even as 5G deployment escalates. This leaves plenty of opportunity for Long Term Evolution machine-type communications (LTE-M)

and Narrowband IoT (NB-IoT), as well as much of its competition in the unlicensed spectrum like LoRaWAN and Sigfox" [BOJ 13].

5G and the influence on flora and fauna

According to a recent study by a nature conservation organization, 5G waves are harmful to insects. And its effects on humans are no more encouraging.

"If the bees disappear, man's days are numbered." It was Einstein who would have said that phrase [DEM 19].

This study, published in 2018 in the journal *Scientific Reports*, reminds us that 4G waves are not harmful to insects.

Indeed, they do not generate frequencies higher than 6 GHz. As far as 5G waves are concerned, the difference is enormous since they can go up to 120 GHz!

However, according to researchers, the waves absorbed by insects via their antennas can cause a sharp rise in their body temperature - and this from 10 GHz upwards.

Pro Natura wants governments to be able to resist pressure from lobbies. It is therefore incumbent on them to lower the radiation limit values. The organisation even believes that the next generation of telecommunications frequencies will operate at millimetre wavelengths between 30 GHz and 300 GHz [SEG 18], [WAN 20].

The promise of 5G

There are great expectations for 5G networks, even before the infrastructure has been built (Figure 4).

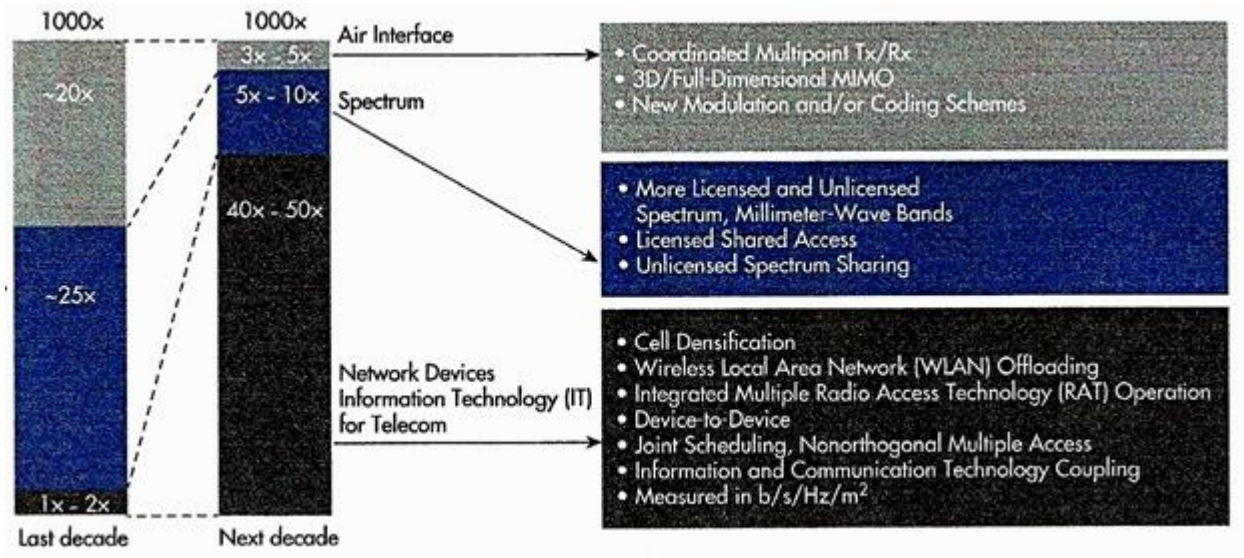

Figure 4 The need for bandwidth to transfer large amounts of data through wireless channels makes the use of millimetre-wave frequencies in 5G wireless networks inevitable (*Graphic courtesy of National Instruments*)

Earlier generation wireless /cellular networks were based on supporting voice communications, although that started to change with 2G and 3G systems.

The nature of modern communications has changed, largely due to the influence of the Internet, and has become very data-centric, with network performance. Building 5G networks that leverage millimetre-wave bandwidths, however, requires millimetre-wave signals at sufficient signal strength, and that will depend on the availability of practical millimetre-wave power amplifiers (PAs).

Given the physical connection between frequency, wavelength, and various circuit features needed to support operation at those high frequencies, such as resonators and transmission line structures, design challenges arise from the extreme miniaturization of millimetre-wave circuits and the need to conserve signal power as much as possible by minimizing forward and reflected signal losses [ROS 14].

In order to elucidate some important issues, we imagined a discussion with a Swiss specialist in the field. Our questions are written in italics and his answers into quotation marks.

— *This new technology in mobile telephony should make it possible to access the Internet ten to a hundred times faster. But also, to reduce latency time, favouring the emergence of autonomous cars or telemedicine. Does this mean that the population will be exposed to more intense radiation?*

— "Not necessarily. Similar measurements with dosimeters were taken in 2009 and 2016. And despite the boom in 3G, despite the launch of 4G, field measurements of the number of volts per metre had increased only by an extremely small amount. This will also be the case with 5G, there will be no exponential increase in radiation."

— So, how do you explain the difference between the 1.5 V/m measured and the 28 V/m to 61 V/m limit?

— "It has a lot to do with individual behaviour, the expert says. The 1.5 V/m measurements is made when a person is subjected only to the waves of an antenna, and not simultaneously to the waves emitted by nearby electronic devices.

It is estimated that 90 % of personal exposure to electromagnetic fields is attributable to end-user devices, not infrastructure.

If someone is concerned about their exposure, by far the most effective measure is to reduce the dose from mobile phones, laptops with Wi-Fi, cordless phones, etc.

More base stations do not necessarily mean more personal exposure.

On average in Switzerland, about 90 % of an individual's exposure to non-ionizing radiation is caused by his or her own mobile devices and only about 10 % by more distant sources such as mobile phone base stations. When a mobile phone has a good network connection (e.g. near a base station), it radiates up to 100,000 times less than a mobile phone with a weak network connection (e.g. in a cellar 2-3 km from a base station). As a result, a denser network of base stations in areas of high mobile phone use may even help to reduce a person's total exposure to radiation.

At the international level, it is considered that 5G will be used in frequency ranges from 24 GHz to 86 GHz, the so-called millimetre waves. From a scientific point of view, concerning these waves and in comparison with 3G and 4G, little is currently known about human exposure to these waves and potential health effects.

Few scientific studies have been conducted to date. However, it is known that the radiation emitted by millimetre waves penetrates less deeply into the body than the frequencies used so far for 3G and 4G, and that this energy is therefore absorbed by a smaller volume of tissue."

— The WHO (World Health Organization) has classified the electromagnetic fields produced by mobile phones as a possible human carcinogen. What can we make of this?

— "The category in which the WHO has classified electromagnetic fields is one in which the overall carcinogenic risk is low but is neither proven nor completely excluded. This category includes many other substances, including for example gherkins or aloe vera... This classification must therefore be put into perspective. We know that waves act on our bodies, but it has never been proven that they increase the number of cancers, for example.

Rats and mice, which had been exposed to high doses of waves, did not show an increase in cancer, but in the end lived longer than others who had been spared them.

Regarding studies on humans, it has been and always will be difficult, if not impossible, to conduct studies on subjects not subjected to waves. Even though the use of mobile phones has exploded in recent years, we have not seen a massive increase in cancer cases.

Generally speaking, if the number of cancers is increasing, it is mainly because humans are living longer. Age is a well-known risk."

— But it's been proven that a long phone call heats up the part of the brain close to the device.

— "While this has been proven, it has not yet been sufficient to demonstrate that it represents an adverse health effect. Don't forget that we are talking about the telephone here, which is recommended to be kept away from the head via a hands-free kit. We're not talking about waves generated by antennas; we're talking about waves generated by the phone. This brings us back to what was stated above: it is the use of electronic devices that is important. And much less mobile phone antennas. The most important and direct health risk of mobile telephony remains the inattention that mobile phones can generate, especially on the road and for pedestrians".

5G and health problems

For the opponents of 5G, it is urgent to wait. This precautionary principle provides a welcome moment of respite.

A group of scientists (*5G Appeal*) from 36 different countries are calling for a moratorium on the development of 5G within the European Union. For them, 5G would significantly increase exposure to electromagnetic radiation — they mentioned in their appeal.

> We, the undersigned scientists, recommend a moratorium on the deployment of 5G, the fifth generation of wireless media for mobile communications, until the potential dangers to human health and the environments have been fully assessed by independent industry scientists. 5G will significantly increase exposure to radio frequency electromagnetic fields (RF-EMF) compared to existing 2G, 3G, 4G, Wi-Fi, etc. networks. RF-EMF emissions have been proven to be harmful to humans and the environment.

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Biography

Titu I. BĂJENESCU was born in Câmpina (Romania) on April 2, 1933. He received his engineering training at the Polytechnic Institute Bucharest. He served for the first five years in the Romanian Army Research Institute including tours on radio and telecommunications maintenance, and in the reliability, safety and maintainability office of the Ministry of Defence (main base ground facilities).

R&D Experience: design and manufacture of experimental equipments for Romanian Army Research Institute and for air defence system.

He joined Brown Boveri (today: Asea Brown Boveri) Baden (Switzerland) in 1969, as research and development engineer.

R&D *Experience*: design and manufacture of new industrial equipment for telecommuni-cations. In 1974, he joined Hasler Limited (today: Ascom) Berne as Reliability Manager (recruitment by competitive examination).

Experience: Set up QRA and R&M teams. Developed policies, procedures and training. Managed QRA and R&M programmes. As QRA Manager monitoring and reporting on production quality and in-service reliability.

As Switzerland official, contributed to development of new ITU and IEC standards.

In 1981, he joined "Messtechnik und Optoelektronik" (Neuchâtel, Switzerland, and
Haar, West Germany), a subsidiary of Messerschmitt-Bölkow-Blohm (MBB) Munich, as Quality and Reliability Manager (recruitment by competitive examination). *Experience*: Product Assurance Manager of "intelligent cables". Managed applied research on reliability (electronic components, system analysis methods, test methods, etc.).

Since 1985, he has worked as an independent consultant and international expert on engineering management, telecommunications, reliability, quality and safety.

Mr. Băjenescu is the author of many technical books, published in English, French, German and Romanian.

He is an university professor and has written many papers and articles on modern telecommunications, and on quality and reliability engineering and management. He lectures as invited professor, visiting lecturer or speaker at European universities and other venues on these subjects.

Since 1991, he won many Awards and Distinctions, presented by the Romanian Academy, Romanian Society for Quality, Romanian Engineers Association, etc. for his contribution to reliability science and technology. Recently, he received the honorific titles of *Doctor Honoris Causa* from the *Romanian Military Academy* and from *Technical University of the Republic of Moldavia*. In 2013, he obtained, together with prof. Marius Bâzu (head of reliability laboratory of Romanian Research Institute for Micro and Nano-technologies – IMT) the *Romanian Academy "Tudor Tănăsescu" prize* for the book *Failure Analysis*, published by John Wiley & Sons.