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5G: FUTURE OPPORTUNITIES AND CHALLENGES

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Abstract. 5G is the new mobile communications technology which uses the latest techniques to provide a step change in performance, but it also provides some unique challenges. 5G provides the increased speed, bandwidth, low latency as well as the ability to support the low data rate communications required for many narrow band IoT applications. 5G signals - particularly those at millimeter-wave frequencies - struggle to penetrate walls and circumvent physical structures. Since the vision and the marketing for 5G is for to have its towers within several feet of one another, and to have 5G technology, inside of homes, within phones, games, appliances, et al., it is likely that nowhere may be safe from these waves. While the air outside will still contain ample amounts of oxygen in a 5G world, our bodies ironically could still suffocate. Nobody can avoid to be exposed. According to estimate, ”10 to 20 billion connections” (to refrigerators, washing machines, surveillance cameras, self-driving cars and buses, etc.) will be parts of the Internet of Things (IoT). All these together can cause a substantial increase in the total, long-term RF-EMF exposure to all planet citizens. More efficient 5G equipment will transmit more data and ultimately consume more energy. We must be realistic and show respect for humans and the planet. Will 5G be good for the environment? When 5G isn't enough, it will be time for 6G.

Key words: *Challenges, network densification, IoT, safety, health perils, long-term RF exposure, influence on environment, CO_2 emissions, climate change.*

Introduction

Mobile traffic has significantly increased over the last decade, mainly due to the stunning expansion of smart wireless devices and bandwidth-demanding applications. This trend is forecast to be maintained, especially with the deployment of fifth generation (5G) and beyond networks and machine-type communications [1 - 3]. A major part of the mobile throughput growth during the past few years has been enabled by the so-called *network densification*, i.e. adding more base stations (BSs) and access points and exploiting spatial reuse of the spectrum. Emerging 5G cellular network deployments are envisaged to be heterogeneous and dense, primarily through the provisioning of small cells such as picocells and femtocells. Ultra-dense networks (UDNs) will remain among the most promising solutions to boost capacity and to enhance coverage with low-cost and power-efficient infrastructure in 5G networks. Adaptive antennas have an increased efficiency of

the radio signal; this leads to a reduction of exposure per bit and higher energy efficiency. Total power of the antenna is distributed among the active users; therefore, adaptive antennas cannot always transmit the maximum power in all directions. All current approvals are based on the worst-case principle: This means that it is assumed that at any given time the entire power is sent out in all directions.

We're rushing into 5G without thinking about the consequences. Or, worse yet, we thought about it and decided to go anyway, without regard for people or the environment. On the one hand, we're making efforts to reduce our carbon footprint, and we're even counting on 5G for that [4, 5]. On the other hand, we are going to induce frightening pollution with a hundred billion objects connected to build and then recycle, we don't know how yet.

What the future brings

The future 5G networks are expected to provide a new level of efficiency and performance that will enhance a user's experience. The 5G networks are visioned to support and provide services that meet the communication requirements of ultra-reliable low-latency communications (uRLLC), enhanced mobile broadband (eMBB), and massive machine-type communication (mMTC) [6, 7]. The 5G consists of nodes and cells with heterogeneous characteristics and capacities including device-to-device (D2D) user equipment, femtocells, picocells, macrocells, and cloudlets, which form a multi-tier network architecture [8]. Figure 1 presents a multi-tier architecture scenario of the 5G mobile network with different enablers [9]. The network is comprised of D2D networks, macro and small cells, cloud-enabled networks and different enabling technologies.

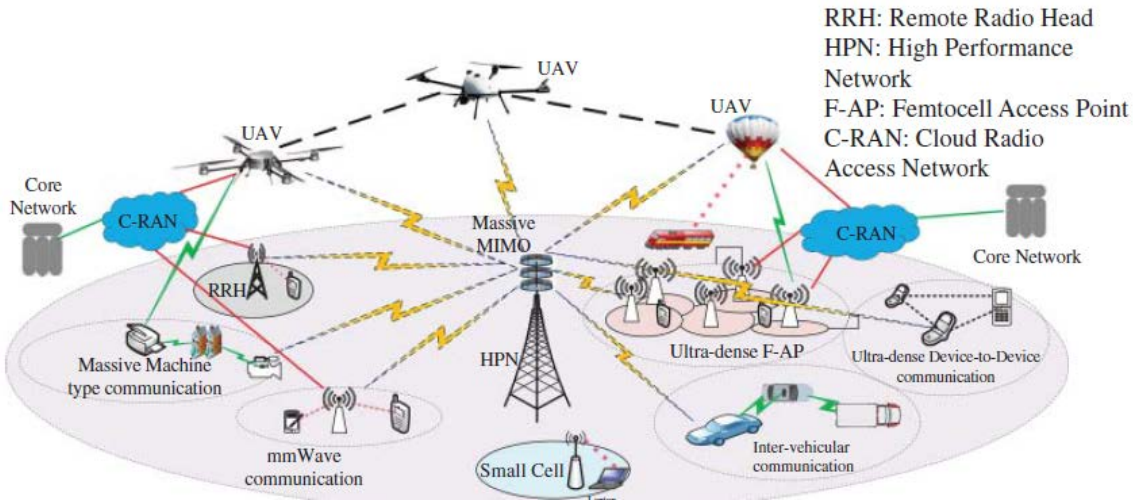

Figure 1. 5G ultra-dense network architecture (after [9] and [14]). UAV: unmanned aerial vehicle.

The future 5G networks are expected to provide a new level of efficiency and performance that will enhance a user's experience [10, 11].The 5G networks are visioned to support and provide services that meet the communication requirements of ultra-reliable low-latency communications (uRLLC), enhanced mobile broadband (eMBB), and massive machine-type communication (mMTC). The 5G will consist of nodes and cells with heterogeneous characteristics and capacities including D2D user equipment, femtocells, picocells, macrocells, and cloudlets, which form a multi-tier network architecture. Figure 1 presents a multi-tier architecture scenario of the 5G mobile network with different enablers.

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We are observing an ever-increasing number of connected devices and the rapid growth of bandwidth-intensive wireless applications. The number of wirelessly connected devices was anticipated to exceed 11.5 billion by 2019, i.e. nearly 1.5 mobile devices per capita. In addition, it is expected that we will witness a 10 000-fold growth in wireless data traffic by the year 2030. Such unprecedented increases in mobile data traffic and network loads are pushing contemporary wireless network infrastructures to a breaking point. These predictions have raised alarm to the wireless industry and mobile network operators who are faced with the challenges of provisioning high-rate, low-delay, and highly reliable connectivity anytime and anywhere without significantly increasing energy consumption at the infrastructure, such as base stations, fronthaul and backhaul networks, and core networks. 5G is the 5th generation of mobile network technology (Figure 2) designed to meet the huge data growth and connectivity demands of modern society [12].

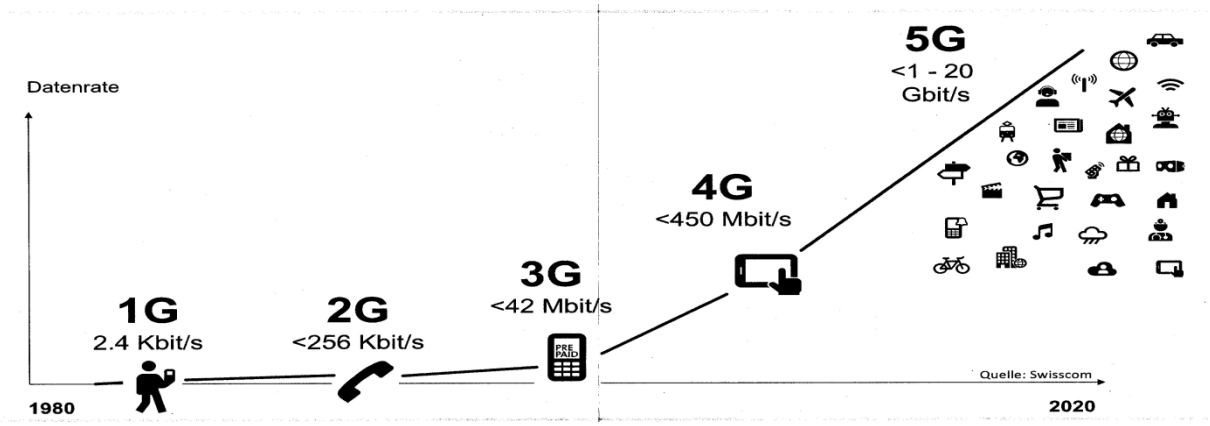

Figure 2 Increased performance in mobile communications.

In addition to their potential in provisioning ubiquitous high-capacity wireless connectivity, ultra-dense networks also offer numerous opportunities and flexibility to be incorporated with other 5G candidate technologies, such as mm-Wave communications, massive multiple-input multiple-output (MIMO), non-orthogonal multiple access, in-band full-duplex operation, simultaneous wireless information and power transfer (SWIPT), device-to-device (D2D) communications, and distributed caching, to enable the realization of 5G technologies and systems' full potential.

The performance of wireless networks relies critically on their spatial configuration upon which inter-node distances, fading characteristics, received signal power, and interference are dependent. Cellular networks have been traditionally modelled by placing the base stations on a regular grid (usually on a hexagonal lattice), with mobile users either randomly scattered or placed deterministically. Tractable analysis can sometimes be achieved for a fixed user location with a small number of interfering BSs and Monte Carlo simulations are usually performed for accurate performance evaluation. As cellular networks have become denser, they have also become increasingly irregular [13, 14]. This is particularly true for small cells, which are deployed opportunistically and in hotspots and dense heterogeneous networks (HetNets).

An example of dense small cells systems, with a region covered by a macrocell BS and a set of B small cell BSs is done in Figure 3.

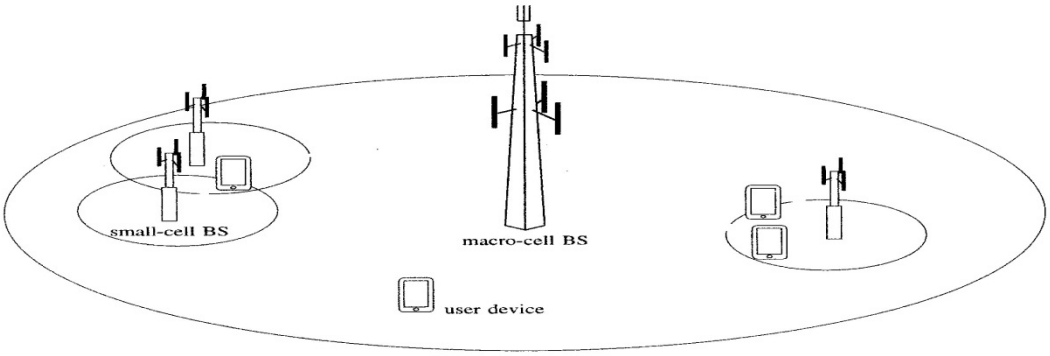

Figure 3. An example of dense small cells systems (after [10]).

There has been noticeable divergence on the conclusions of various network studies using spatial models, according to which densification is not always beneficial to the network performance. Recent and often conflicting findings based on various modelling assumptions have identified that densification may eventually stop delivering significant throughput gains at a certain point.

The energy problem and the environment

More efficient 5G equipment will transmit more data and ultimately consume more energy. The debate rages on 5G. However, there is another question on the minds of people: Will 5G be good for the environment? A research group in France has launched the charge: "There is now a consensus that 5G equipment consumes three times as much energy as 4G equipment." This is the starting point for the pessimistic scenario.

However, other specialists are convinced that 5G will reduce CO_2 emissions. They even speak of an opportunity for the planet.

In fact, it all depends on how we behave and, more importantly, on how we fill the gap; in other words, how we use the time, energy and/or money gained from this new technology. Will we consume even more data? It's called the rebound effect. It may increase CO_2 emissions. That is the danger.

Health consequences and climate change problem

When we discuss 5G, the question of its health consequences come first. However, there is another question that hardly anyone has paid attention to so far: Will 5G be good for the environment? For some, the answer is obvious: 5G should be the star of the Greens. It will make it possible to manage much better everything that is being done today in terms of sustainability: Water management, waste management, even the spread of pesticides in agriculture [15].

After health issues, 5G is concerned about climate change. The new mobile phone technology is spreading rapidly everywhere. However, what does it promise us in terms of climate change?

Moratorium or not, 5G equipment is proliferating in all countries because this new technology promises us, in the long-term, access to the Internet ten to one hundred times faster than 4G.

You will have sensors on glaciers, in forests or on the plumage of endangered birds. Thanks to the new applications that 5G will allow, you will be able to analyze everything in real-time.

Convinced, the Greens? They are persuaded that technology can be an opportunity. However, with 5G, we've put the cart before the horse. This debate is not at all mature, even in terms of scientific knowledge. And we get the impression that it's the operators who have the upper hand and not the state.

It will go faster, it will consume more energy.

In France, for example, the debate on the ecological usefulness of 5G is more lively than that of health. In a recent article published in the newspaper "Le Monde", the research group "Shift Project" - which advocates a decarbonised economy - launches the charge: "There is a consensus today that a 5G device consumes three times more energy than a 4G device." It must be recognized that more electricity will be required to power the new technology, but the mechanism needs to be explained; the deployment of 5G will significantly improve energy efficiency per transmitted data. However, as more data is transmitted, energy consumption will increase accordingly.

That said, the mobile ringing traffic is already doubling every 12 to 18 months today, 5G or not. However, critics of the technology don't stop there. They point to the hidden face of the iceberg: We will have to produce the autonomous cars, connected fridges and other intelligent tractors that 5G promises to replace other objects.

It will take a lot of modern components to make it all work. The tractor will have to be replaced by another machine [16]. All this will have to be produced. However, this will not speed up the ordinary replacement cycle. On the other hand, in some less developed countries, the 5G will be able to take off with new-generation objects - which is an opportunity for the planet. The 5G will be able to support a multitude of objects connected simultaneously, but also home automation, drone camera, all these objects and many others will be able to connect to the 5G network at the same time, without risk of saturation. With 5G, multiple connected objects will be able to operate simultaneously with unprecedented performance. Performance that will give rise to innovations that will revolutionize our daily lives [17].

There is also a study on the socio-economic impact of 5G which says that by 2030 - thanks to the "Smart Workplace Solution" - it bring gains in millions of Euros, but what is the gain in terms of CO_2? Studies are lacking. The energy savings and CO_2 emission reductions made possible by 5G will far exceed the CO_2 emission of the technology itself.

It all will depend on the guidance structure

The whole question is there: Will we use 5G first for better heating and to optimize our trips? Or soon to watch a tennis match in high definition on our new phone? A study by the University of Zurich published in 2017 provides the answers. According to the most optimistic scenario, the use of digital technology in Switzerland will be clearly beneficial to the environment by 2025. It will save - in other sectors - a little more than three times the greenhouse gas emissions that it will generate itself.

In the pessimistic scenario, on the other hand, digital technology will weigh even more heavily on the planet than it does today and will emit four times more greenhouse gases than it will save. In reality - say the researchers - everything will depend on the way in which the technologies are applied and supervised and, above all, on the way in which the objects linked to they are consumed.

When we telework, we do not systematically reduce our CO_2 emissions. That is the rebound effect.

Why is digital technology helping to reduce CO_2 emissions? Researchers at the University of Zurich explain it with simple examples: Teleworking means you don't have to use your car. "Intelligent" logistics means that lorries do not have to travel empty. *e-health* avoids the need to physically go to the doctor, etc.

However, if the gain to remain positive for the environment, the rebound effect still needs to be combated [18]. This is the whole question of how we are going to fill the vacuum - the time, energy, money - gained. For example, in the freight sector, researchers identify a major risk: Reducing costs through "intelligent" logistics could stimulate demand, ultimately leading to more CO_2 emissions. If the telecommuting day makes free up time used to drive to a game of tennis, it's missed again.

Beneficial applications

With 5G there will be even more potentially beneficial applications. There is great potential in the field of buildings and workplaces. 5G is an excellent example of the rebound effect. It is a standard with energy efficiency aspects at its core. However, it is not done in the spirit of reducing our greenhouse gas emissions. It is designed to absorb additional consumption! One could imagine that the time saved thanks to the technology would be used to exchange, to cook rather than to order ready-made meals via an application [19]. However, as these positive aspects bring little money to the market, they are not promoted by industry or even by the state.

Can 5G reduce CO_2 emissions?

The 5G was not designed to reduce CO_2 emissions. Can 5G ultimately reduce CO_2 emissions? The answer is probably no, although the future can never be predicted. The 5G technology itself was not designed to do this, but to increase the amount of data transmitted and to enable a whole host of applications such as autonomous vehicles or even touch internet.

It is precisely because it will encourage teleworking, *e-banking* and connected agriculture that some telephone operators claim that 5G is good for the environment; this is *a priori*. In reality, we do not know. However, we do know that so far there has been no reduction in greenhouse gas emissions linked to the use of digital technology. However, 4G already makes it possible to do teleworking and a lot of things compared to 3G. However, it has not substantially reduced pollution in other sectors, although we have been very much in favour of it. This can be explained by a number of phenomena such as indirect and rebound effects, and above all by the fact that our economic model has remained unchanged. Reasonably, it is not conceivable that 5G by itself will lead to a significant reduction in greenhouse gas emissions without further action.

Conclusions

Guilty for this are both 5G and the way we could use it. While the economy wants to develop 5G because it will bring new applications, new objects and concepts to the market and it will promote growth. However, it is not immaterial growth. Then, there will be marketing and lobbying to push the use of these objects. However, the citizen today, with a few exceptions, is not in strong demand for 5G. There is resistance to its implementation

among the populations because people are not fooled. There have been no 5G safety studies into short or long-term 5G health effects; the health effects of 5G are untested.

The deployment of 5G UDN in the practical cases will be faced with many challenges. In the UDNs, typical problems include interference, limited energy, backhaul, cost, and handover, spectrum reuse, and limited infrastructure resources. The essential reasons for almost all the problems are the scarcity and uneven distribution of the resource with respect to the traffic. Different alternatives have been proposed to solve these challenges, for example network slicing is introduced as a method for optimizing resources in 5G networks. However, due to the increasing network coordination and and management complexity among multiple network tiers, the nodes of the network will have to be capable of self-organization, for example autonomous interference minimization, load balancing, power adaptation, and spectrum allocation. Therefore, there is still a need for a better mechanism for addressing challenges to be designed.

When we discuss global warming, we point the finger at airplanes, at consumption, but never at digital - because it is less visible and more complex. However, recent estimates say that the digital generates more greenhouse gases than civil aviation. Some say that more people are using digital - which is true. However, it is also a sector that is growing faster than aviation: 8...9% a year! And even though renewable energies are developing, metals are not being extracted using solar panels.

A significant advantage is "Network Slicing", while applications compete in the 4G network, virtual networks with different requirements can be implemented on the same infrastructure with 5G. The deployment of 5G clearly opens the door to an even more connected future, a domotized environment with artificial intelligence, and 100% autonomous cars. With performances far superior to those of today's networks, 5G will change our daily lives thanks to the development of new uses and new functionalities. 5G creates huge business opportunities.

With 5G, the field of possibilities of augmented reality (AR) will take on a whole new dimension: After entertainment with video games, it is culture, education, industry, but also medicine that will see its use unfold. The 5G is seen as a new industrial revolution, ready to revolutionize our daily lives.

One cannot typically hear about 5G without hearing about some of the grave concerns about the safety and lack of testing of this technology. 5G may influence our body's form and function. 5G is about building ten-lane highways and making local residents believe that they will cause no more inconvenience than a cantonal road. It is necessary to put safeguards in place.

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