AN ASSESSMENT OF CLAIMS REGARDING HEALTH EFFECTS OF **5G MOBILE TELEPHONY NETWORKS**

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An Assessment of Claims regarding Health Effects of 5G Mobile Telephony Networks

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Contents

Preamble

This document was produced by a team of researchers from the Next Generation Enterprises and Institutions, and Next Generation Health clusters of the CSIR. It is a response to media claims of links between 5G mobile telephone networks and the worldwide COVID-19 outbreak that started in late 2019. It is based on our best understanding of the interactions between radio frequency signals and human tissue, as well as epidemiological evidence of the effects of current mobile phone networks.

1. Overview of 5G Networks

Speculation linking 5G mobile telephony and data networks to a range of health threats, has been rife. Some claims even go to the extent of attributing the current COVID-19 pandemic to the initial rollouts of 5G networks. Unfortunately, a lot of opinions aired do not come with a high degree of credibility and amount to no more than flights of fancy. Some of them even claim that there is no virus and that all the health effects are caused by 5G.

The “evidence” cited includes a preliminary 5G rollout during 2019. Propaganda networks show maps comparing 5G networks with COVID-19 infection rates. One would expect such correlation to exist, based purely on population density. Where there are a lot of people, there is high demand for mobile telephony. Those same high numbers and densities of people also increase the likelihood of large numbers of infections. These high-density population zones also have the highest number of soccer balls, yet no-one has (yet) implied that soccer balls cause COVID-19.

In a nutshell, as should be evident from the description that follows, 5G networks differ very little from their predecessors. In addition, no large-scale 5G rollouts have taken place, and most areas in which virus victims are found do not even have any 5G rollouts. Every previous introduction of mobile phone technology has been accompanied by similar sensational reactions. Nevertheless, no deterioration in public health associated with these technologies has been scientifically proven.

The best way to address these perceptions is to explain what 5G networks are and how they differ from existing networks. Given that current 5G networks are almost identical to existing networks, it should soon become evident that little has changed.

1.1 What are 5G networks?

Fifth-generation mobile networks (5G) are the next generation in an evolving series of mobile networks. The first generation came into being in the early 1980s. These analogue networks had low capacity and low coverage, and user equipment was very expensive. The explosive growth of mobile networks that continues today started with the second generation (2G) commonly referred to as GSM. South Africa introduced 2G networks around 1994. The third generation (3G) in 2002 introduced mobile broadband access. The current 4G networks appeared around 2010. Each previous generation lasted roughly a decade, and it is likely that 5G will in turn be superseded after a similar interval. Table 1 shows a summary of mobile networks’ evolution.

As of 2020, 5G is being introduced globally. The International Telecommunication Union (ITU) is the United Nations agency tasked with formulating the standard, which is officially known as IMT-2020[1]. The initial formulation required a theoretical peak download speed of 20 gigabits per second and an upload speed of 10 gigabits per second, as well as many other requirements.

[1] International mobile telephony (IMT) standard from ITU, ending the development phase by 2020 and starting with deployment from around 2020.

As with all previous mobile networks, 5G offers digital services. Text, speech, images, moving video and telemetry are all converted to a data stream, which is then sent to the destination device. Here, it is converted back into whatever format the user requires, typically much the same as the format in which it was initially sent. Mobile networks are cellular, meaning that the network consists of many adjoining cells. The mobile network manages the handover of the user device from one cell to another, and the user is generally not even aware of this process taking place in the background.

Table 1. Summary of five generations of mobile networks

Generation	Time period	Frequency Range	Requirements & Comments
1G	1980s	Up to 890 MHz	No ITU official requirements Analogue technology
2G	1990s	Up to 1,9 GHz	No ITU-specified official requirements Introduced digital technology
3G	2000s	Up to 2,1 GHz	ITU's IMT-2000 requirements: 144 kbps mobile, 384 kbps pedestrian and 2 Mbps indoors
4G	2010s	Up to 2,6 GHz	ITU's IMT-Advanced requirements: ability to operate on channels up to 40 MHz wide (through channel aggregation) and very high spectral efficiency. Audio by IP
5G	~2020s	FR1: Up to 7 GHz FR2: Up to 95 GHz	ITU's IMT2020 requirements: enhanced mobile broadband (eMBB at 1 Gbps), massive machine-type communications (mMTC) and ultra-reliable and low-latency communications (URLLC). Move towards software defined networking (SDN) based architecture.

Successive generations of mobile networks have offered increasingly sophisticated services. 5G continues this evolution by offering the user very wide bandwidth, high quality of service and capacity well beyond that of existing networks. This combination of improvements is made possible by more frequency spectrum being used and by innovative techniques such as carrier aggregation[2] and multiple-input and multiple-output (MIMO)[3].

5G systems promise to provide affordable ubiquitous wideband Internet access. It is especially attractive in countries that lack a developed broadband network, including almost all of the African continent. 5G will make use of a wide range of technologies, which will work together in the background to provide the user with unprecedented wideband Internet access, almost regardless of location and at an affordable price.

[2] Carrier aggregation means that several sub-bands can be used as a single wide-bandwidth channel.
[3] Multiple input multiple output (MIMO) uses multiple antennas to increase throughput and/or reliability.

Although operators are rolling out networks branded as 5G and handset manufacturers are selling equipment touted to have 5G capabilities, 5G is not ready for the big time just yet.

The IMT2020 standardisation process is scheduled for completion around the end of 2020[4]. One of the frontrunners vying for adoption is the 5G New Radio (5G NR), promoted by 3GPP[5], the same consortium that proposed universal mobile telecommunications services (UMTS) and long-term evolution (LTE) that formed the backbone of the existing 3G and 4G networks. Existing rollouts risk interoperability problems, as the final standards may not coincide exactly with the equipment and protocols now being implemented.

Radio technology started about 130 years ago in the long-wave spectrum. While this part of the spectrum required simple equipment and provided long range, it required huge antennas and suffered from limited capacity and high noise. Increasingly, users were clamouring for space and the quality of services demanded increased bandwidth. Improved sound quality, television, colour television and data services all required more and more space. Higher and higher frequencies were pressed into use. Even then, limited capacity was available and users had to be crammed into available spectrum ever more densely.

5G will continue this trend, expanding into ever-increasing frequencies and shorter wavelengths. However, for the moment the standards-writing and evaluation process is still in progress, and most of the systems now being built use existing frequency assignments. They are also subject to the same power level restrictions imposed on existing mobile networks. From a technical point of view, the signals are similar to those of existing networks.

To facilitate the large bandwidth requirements of 5G, and to provide for regional differences in spectrum assignments, 5G NR allows networks to operate on a wide variety of frequencies. The lower frequency range (FR1) covers 450 to 7125 MHz, which covers all of the existing mobile networks and television broadcasting allocations. FR2 includes much higher frequencies in the extremely high frequency (EHF) range, approximately 24 to 95 GHz[6]. The EHF spectrum is also known as the millimetre-wave band, as the associated free space wavelength varies from about 6 to 12 mm.

South African institutions, including the CSIR, are participating in the ITU process for assessing the proposed IMT2020 or 5G technologies. In the meantime, tentative rollouts of 5G-branded networks mostly involve incremental additions to the existing 4G network (called non-standalone 5G) rather than full 5G implementations (standalone 5G). Most early 5G deployments in South Africa have been in the FR1 bands, especially around the 3,5 GHz band.

In 5G, there is no distinction between telephony networks and the Internet. Users will have access to virtually any service or information found on the Internet.

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[4] https://www.itu.int/md/R15-IMT.2020/new/en

[5] 3GPP stands for the 3rd Generation Partnership Project, an umbrella body for a number of standards organisations that develop protocols for mobile telecommunications. The project covers cellular telecommunications technologies, including radio access, core network and service capabilities, which provide a complete system description for mobile telecommunications. 5G started with 3GPP Release 15, finalised in June 2018. More info at https://www.3gpp.org/.

[6] WRC-19 assignments range up to 71 GHz.

Clearly, with so many users vying for so much data, required capacity is going to be hundreds of times more than what is currently available. To accommodate this demand, more radio frequency spectrum is required.

Any radio-based service is regulated by national governments according to international treaties. The Independent Communications Authority of South Africa (ICASA) assigns spectrum to various users on as equitable a basis as it can, and also governs the maximum transmit power levels allowed to minimise interference[7] between users.

1.2 What are the health effects of mobile networks?

The power levels are regulated not only to minimise interference between users but also to ensure that humans are not exposed to unsafe levels of exposure. International guidelines published by bodies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Institute of Electrical and Electronics Engineers (IEEE) are formulated to prevent excessive signal strength that could result in noticeable heating of human tissue and other harmful health effects. The ICNIRP's *Guidelines on Limiting Exposure to Electromagnetic Fields*[8] "for the protection of humans exposed to radiofrequency electromagnetic fields (RF) in the range 100 kHz to 300 GHz" and the IEEE's C95[9] standard are technology neutral and include 5G, Wi-Fi, Bluetooth, mobile phones and mobile base stations.

With the introduction of each generation of communications system, naysayers raise protests about the perceived dangers of the technologies. Inappropriate analogies often form the basis for these conspiracy theories.

To provide a sound basis for assessing 5G signals, we need to examine the electromagnetic spectrum. All radio signals, including mobile network signals, form part of the electromagnetic spectrum. Table 2 shows a simplified version.

Table 2: Electromagnetic spectrum

	Non-Ionising Radiation				**Ionising Radiation**		
	Radio signals		Light				
	AM, FM and TV	Mobile and other wireless networks	Infra-red	Visible	Ultra-violet	X-rays	Gamma rays
Frequency (approximate)	Up to 700 MHz	0,7 to 100 GHz	10^{11} to 10^{14} Hz	Around 10^{15} Hz	10^{16} to 10^{17} Hz	10^{16} to 10^{20} Hz	>10^{18} Hz
Wavelength (approximate)	Over 400 mm	400 to 3 mm	3 mm to 300 nm	Around 500 nm	Around 100 nm	Around 1 nm	Around 1 pm

7 ICASA is responsible for protection against interference in South Africa. Not all bands and technologies are protected. For example, Wi-Fi uses unlicensed bands where no interference can be guaranteed.
8 https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html
9 https://standards.ieee.org/standard/C95_1-2019.html

As one can gather from looking at this electromagnetic spectrum, the short wavelength radio signals behave somewhat like radio signals and somewhat like light. They travel in straight lines and are not good at penetrating objects. In general, the higher the frequency, the shorter the range. Accordingly, in low-density areas like the South African countryside, it is unlikely that frequencies much higher than existing frequencies will be used. Those very short waves, branded millimetre waves for obvious reasons, are more likely to be found in very local applications, such as to provide Wi-Fi-like service indoors or in a sports arena.

There is consensus that ionising radiation, which falls in the upper portion of the electromagnetic spectrum, can cause biological damage. However, radio signals such as those used by mobile telephony networks do not have enough power to cause instantaneous atomic or molecular level changes in the human body. Moreover, 5G millimetre-wave signals do not penetrate deeply enough to cause any noticeable effect internally.

The existing limits on signal power have served us well. With half a century of operation of mobile phone networks behind us, there is no evidence of a related significant decline in public health. If 5G networks are so similar to existing networks, we should not expect a sudden decline in public health with the introduction of 5G networks either.

1.3 What can we expect from 5G networks?

As already stated, 5G networks will provide Internet-like services, anywhere. You can expect high-quality video and audio, access to a wide range of information on demand and sophisticated communications services. In fact, it is hard to imagine what could evolve, as the availability of nearly unlimited bandwidth will undoubtedly lead to the invention of new services and applications that we have not imagined yet. Imagine yourself back in the twentieth century. Could you have imagined a world with WhatsApp, Facebook, Twitter, real-time selfies and YouTube? It is almost as hard as imagining a life without them now!

There are also other services that may be less pertinent to the consumer, but which may have a huge impact on how we do things. The spectacular Internet services mentioned above go by the name of enhanced mobile broadband (eMBB) in IMT2020 literature. Typical measured throughput is between a quarter and several gigabits per second[10] (Gbps), with a latency of perhaps tens of milliseconds.

Ultra-Reliable Low-Latency Communications (URLLC) will provide services with guaranteed reliability and low delay. It will facilitate the introduction of safety-critical real-time applications such as remote surgery and interconnected self-driving cars. Very low latency of 1 ms and block error rates approaching 10^{-9} can be expected.

Massive machine-type communications (mMTC) will allow a practically unlimited number of devices to intercommunicate. Think of the Internet of Things, in which huge numbers of low-cost devices consuming very little power will pass information to servers or other small devices, making it possible to understand and control our world in a way that we can hardly

[10] Average speeds can be expected to measure in tens to hundreds of megabits per second (Mbps), depending distance and environment between the base station and the user's handset and demand from other users.

anticipate. While 4G can accommodate around 100 000 devices per km^2, the corresponding figure for 5G is around 1 000 000 devices per km^2.[11]

5G uplink and downlink decoupling[12] will allow the communication range of base stations to be increased without increasing power levels. The increased communication range means that fewer base stations are needed. These techniques can also help to make communications more affordable in rural areas, connecting more people.

There have been many initial 5G trials and demonstrations. The first high-profile 5G rollout was at the 2018 Winter Olympic Games in Pyeongchang, South Korea. One hundred cameras were positioned inside the Olympic Ice Arena, allowing viewers to see time-sliced views of the athletes in motion. Ericsson and Intel have deployed a 5G connection to connect Tallink cruise ships to the Port of Tallinn in Estonia. Huawei and Intel have demonstrated 5G interoperability tests at the Mobile World Congress 2018. ZTE conducted tests in China, where speeds over 19 Gbps were achieved in the 3,5 GHz band. Its URLLC test showed a latency of well under a millisecond.

As of May 2020, there are around 7500 5G deployments by 121 operators across the world[13]. Despite the effects of COVID-19, the first quarter of 2020 saw 98 new 5G deployments. South Africa has seen deployments by Rain[14] in Johannesburg, Tshwane and Cape Town. Vodacom and MTN are planning to roll out 5G networks in 2020. Vodacom has also conducted a limited rollout in Lesotho in August 2018.

Until the "Emergency Release Of Spectrum To Meet The Spike In Broadband Services Demand Due To Covid-19"[15] announced by ICASA on 6 April 2020, all the African rollouts and the majority of those worldwide have been in the existing 3,5 GHz band. The emergency spectrum release temporarily opens up a few additional bands. Their emissions are subject to the same health safety and other regulations and will be similar to the emissions from the existing mobile networks. The new emergency mobile networks should therefore be as safe as the previous networks.

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[11] An average of one device per square metre!
[12] https://www.huawei.com/en/press-events/news/2019/2/huawei-5g-ul-dl-decoupling-awarded
[13] https://www.speedtest.net/ookla-5g-map
[14] https://www.rain.co.za/. The article about the rollout: https://www.forbes.com/sites/tobyshapshak/2019/02/26/data-only-operator-rain-launches-africas-5g-live-network/#323b6b9856f5
[15] https://www.icasa.org.za/news/2020/emergency-release-of-spectrum-to-meet-the-spike-in-broadband-services-demand-due-to-covid-19 and https://www.icasa.org.za/news/2020/temporary-radio-frequency-spectrum-issued-to-qualifying-applicants-in-an-effort-to-deal-with-covid-19-communication-challenges

2. Summary Technical Data on 5G

This section is based on 5G NR specifications published by 3GPP. These specifications are a frontrunner in the race to be adopted under the IMT2020 programme, but other choices may be selected instead of or in addition to the 3GPP proposal.

2.1 Which frequencies will be used for 5G in South Africa?

In South Africa, 5G can be deployed only in the officially recognised IMT bands. Most countries closely follow the guidance of ITU to ensure coordination of spectrum use with adjacent countries. The National Radio Frequency Plan[16] lists bands and services available for use in IMT. Table 3 depicts the 2018 ICASA frequency plan with IMT allocations. It includes emergency allocations announced in 2020 for the COVID-19 outbreak[17].

Table 3: ICASA frequency plan including the IMT allocations

IMT Band	Frequencies	Samples of current allocation
IMT450	450 – 470 MHz	
IMT700	694 – 790 MHz	FDD mode: • IMT700: 703 - 733 MHz and 758 - 788 MHz • IMT800: 791 - 821 MHz and 832 - 862 MHz 1. *Telkom, MTN and Vodacom have been temporarily assigned 40 MHz each.*
IMT800 BTX	791 – 821 MHz	
IMT800 MTX	832 – 862 MHz	
IMT900 MTX	880 – 915 MHz	
IMT900 BTX	925 – 960 MHz	
IMT1800 MTX	1710 – 1785 MHz	
IMT1900 TDD	1900 – 1920 MHz	
IMT2100 MTX	1920 – 1980 MHz	
IMT2100 BTX	2110 – 2170 MHz	
IMT2300 TDD	2300 – 2400 MHz	TDD mode: *1. Telkom has been temporarily assigned 20 MHz in addition to the 60 MHz it already has in this band.* *2. Vodacom has been temporarily assigned 20 MHz.*
IMT2600 MTX	2500 – 2570 MHz	• FDD portion: 2500 - 2570 MHz and 2620 - 2690 MHz
IMT2600 TDD	2570 – 2620 MHz	

[16] The latest plan for South Africa is dated 2018 https://www.ellipsis.co.za/frequency-licensing/national-radio-frequency-plan/.

[17] Government Gazette 43207 dated 6 April 2020 and the subsequent press release https://www.icasa.org.za/news/2020/temporary-radio-frequency-spectrum-issued-to-qualifying-applicants-in-an-effort-to-deal-with-covid-19-communication-challenges.

IMT2600 BTX	2620 – 2690 MHz	• TDD portion: 2575 - 2615 MHz RAIN is assigned 20 MHz in the TDD portion. 1. *Telkom has been temporarily assigned 40 MHz.* 2. *Vodacom has been temporarily assigned 50 MHz.* 3. *MTN has been temporarily assigned 50 MHz.* 4. *RAIN has been temporarily assigned 30 MHz in addition to the 20 MHz it already has.*
IMT3500 TDD	3400 – 3600 MHz	TDD mode: Telkom is assigned 28 MHz from 3400 -3428 MHz in the band and Liquid Telecoms is assigned 56 MHz from 3544 MHz to 3600 MHz. 1. *Telkom has been temporarily assigned 12 MHz.* 2. *Vodacom has been temporarily assigned 50 MHz.* 3. *MTN has been temporarily assigned 50 MHz.* 4. *Liquid Telecoms has been temporarily assigned another 4 MHz.*

Some of these bands have been constrained in notices throughout the IMT Radio Frequency Spectrum Assignment Plans (Final) published by ICASA in Government Gazettes:

- No. 38640 (Notice 270 of 2015): 450 – 470 MHz,
- No. 38640 (Notice 271 of 2015): 703 – 733 MHz and 758 – 788 MHz,
- No. 38640 (Notice 272 of 2015): 733 – 758 MHz
- No. 38640 (Notice 273 of 2015): 791 – 821 MHz and 732 – 762 MHz
- No. 42337 (Notice 165 0f 2019): 825 – 830 MHz and 870 – 875 MHz
- No. 38640 (Notice 275 of 2015): 880 – 915 MHz and 925 – 960 MHz,
- No. 38640 (Notice 276 of 2015): 2300 – 2400 MHz,
- No. 38640 (Notice 277 of 2015): 2500 – 2570 MHz and 2620 – 2690 MHz,
- No. 38640 (Notice 278 of 2015): 3400 – 3600 MHz).

From the list it is clear that, for the time being, no provision has been made for millimetre-wave allocations in South Africa.

The Final International Telecommunications Roadmap 2019[18] of South Africa listed these bands in preparation for the final decision made at the ITU World Radiocommunications (WRC) conference. WRC-19 was held in Egypt during 2019, and identified the following millimetre-wave bands for 5G deployment: 24,25 - 27,5 GHz; 37 - 43,5 GHz; 45,5 - 47 GHz; 47,2 - 48,2 GHz and 66 - 71 GHz. The millimetre-wave bands are yet to be considered for IMT in South Africa in its local regulations.

[18] https://www.ellipsis.co.za/roadmap-for-international-mobile-telecommunications-imt-in-south-africa/

Millimetre-wave bands allow more spectrum and thus faster data speeds. The last band listed in Table 2 above alone offers 5 GHz of spectrum, more than eight times as all the existing bands combined.

Millimetre-waves come with disadvantages, though. The technology is more expensive for the time being. It is also more sensitive to distance, rain, vegetation and other obstacles. These properties make millimetre-waves most suitable in extremely densely occupied areas such as sports stadiums or shopping malls.

2.2 A Brief Comparison of 4G and 5G

This comparison is based on the IMT2020 proposal by 3GPP, pending finalisation of the 5G standards.

- **Frequency bands:**
  - 5G NR uses existing 4G bands and potentially adds more EHF frequency bands. These EHF bands have not been authorised in South Africa and have not been used widely anywhere in the world.
- **Bandwidth and channel aggregation:**
  - ***4G: LTE-Advanced[19]: up to 100 MHz***
    - LTE-Advanced allows aggregation of multiple component carriers on the physical layer, with allocations of 1,4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz, and 20 MHz each. Up to five carriers can be aggregated, allowing a maximum frequency band allocation of 100 MHz.
  - ***4G: LTE-Advanced Pro[20]: up to 640 MHz***
    - Advanced carrier aggregation of up to 32 carriers. Maximum theoretical bandwidth is 32 x 20 MHz = 640 MHz, with a maximum bitrate of 1 Gbps.
  - ***5G: Up to 1 GHz***
    - 5G allows for up to 1 GHz bandwidth using single or multiple carriers, with a maximum bitrate of 20 Gbps.
    - Below 6 GHz, channel bandwidth of 5 to 100 MHz is supported.
    - Above 6 GHz, channel bandwidth of 50 to 400 MHz is supported.
- **Maximum radiated power in South Africa (as defined by ICASA regulations[21]):**
  - Base Stations: Not to exceed 61 dBm/5 MHz EIRP[22]. If this formulation is retained for 5G, it implies that 5G base stations could produce higher radiated power than 4G due to the greater bandwidth, by up to 10 dB over LTE-Advanced and up to 2 dB over LTE-Advanced-Pro.
  - Mobile Station transmissions should not exceed 23 dBm EIRP. This limitation is bandwidth-independent, meaning that 5G handsets may not exceed the signal strength limits of existing mobile networks.
  - Typically, millimetre-wave signals employing MIMO will feature significant antenna gain, which will necessitate a substantial decrease in transmitter power.

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[19] The LTE-Advanced is sometimes abbreviated as LTE-A. LTE-Advanced was introduced with ITU's IMT-Advanced and implemented in 3GPP Releases 10 to 12.

[20] LTE Advanced Pro (LTE-A Pro, also known as 4.5G, 4.5G Pro, 4.9G, Pre-5G, 5G Project) is a name for 3GPP Release 13 and 14.

[21] See "Radio Frequency Spectrum Assignment Plan Rules for Services operating in the Frequency Band 3400 to 3600 MHz (IMT3500)", Government Gazette No. 38640 (Notice 278 of 2015) for 3,5 GHz band and similar regulations for other bands.

[22] EIRP = equivalent isotropic radiated power.

- **Other features:**
  - 5G increases the number of antennas supported for MIMO and introduces beam forming in the vertical plane to serve tall buildings.
  - 5G NR supports up to two downlink/uplink switching points in a slot.

3. Summary notes

The continued development and implementation of 5G is not even close to its peak. The potential of this technology to significantly build on the opportunities offered by its predecessors as well as to birth new services and applications is immeasurable. As with all responsible and sustainable technological advancement, the growth of mobile networks and the technology that supports this growth is closely regulated to ensure that users can safely enjoy the benefits.

Scientifically sound information is easily accessible and consumers are encouraged to question conspiracy theories rather than accepting these and their inherent outcome of promoting fear and uncertainty.