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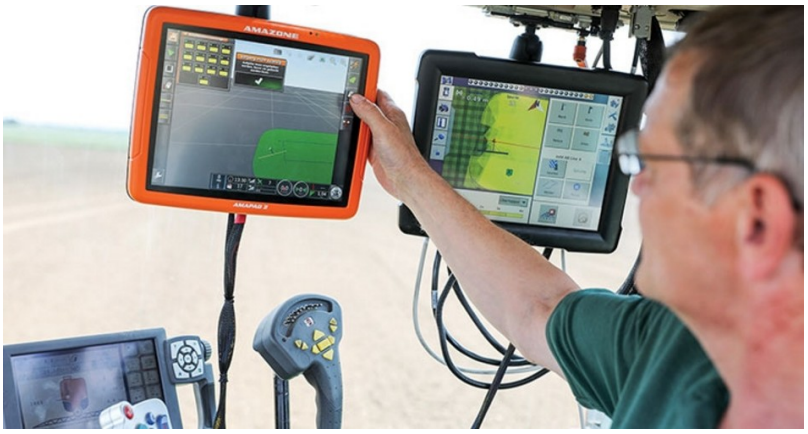
5G: The Potential and the Risks



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It was one of those perfect spring days. The sun was out, at long last, following the cold cloudiness that marked the first several weeks of the new season. Birdsong filled the air, and chipmunks, squirrels, and rabbits scurried here and there, animated by warmth of the sun. Standing in the door of his machine shed, a farmer looked out on his vast acreage. Greeting his gaze was a vast vista of newly sprouted corn, all growing in perfectly manicured rows. But there was something new, too, in the scene. Above, joining the birds newly exuberant with the arrival of spring, was a small fleet of autonomous drones, each equipped with optical and infrared cameras and wirelessly connected to the Internet, their collected imagery and sensor data transmitted in real time to a data center a thousand miles away. There, the data and imagery was overlaid with more real-time imagery and data captured by cubesats (miniature satellites) in low-Earth orbit, along with meteorological data collected locally at the farm itself and regionally.

All of this was immediately available to the farmer, who was alerted to changing conditions in his fields, also in real time, as the Artificial Intelligence (AI) that constantly monitored the data collected reacted to trigger conditions. With a bleep and pip, the farmer's mobile phone popped an alert: Soil moisture in field 7 was too low. This was followed by another pop-up alert: invasive weeds detected growing across fields 3-6. The farmer tapped his phone in response and to his left and right large, automated tractors stirred to life. Equipped with their own sensors tied to the same network and guided by advanced GPS tracking accurate to within 1.2 inches or less, the behemoth machines lumbered out to the fields where they began to apply just the right amount of herbicide to the emergent weeds they encountered. Meanwhile, in field 7, irrigation equipment sprang to life applying only the amount of water needed.

The farmer looked up from his phone and smiled. It was going to be a good day.

Fantastic Reality

The foregoing may sound like a fantasy. But, surprisingly, it is increasingly close to reality. Today, tractors are GPS guided, drones are widely employed in agricultural applications, and companies are exploring cubesats for agricultural use. Further advances will require additional sensors, but these will necessitate more bandwidth to be effective. And that's coming too, and not just to agricultural

applications. Today's 4G mobile networks, which have been instrumental in advancing mobile data communications, are about to be replaced with next-generation 5G technologies.

In fact, the rollout of 5G is beginning to happen, and it will occur faster than many may expect, for the technology not only has been developed by the largest and most scientifically advanced corporations in the West, but has received massive investment by dominant technology players in China such as Huawei, the huge but secretive electronics giant with what many believe are deep ties to the communist government. Moreover, that communist government has made the 5G rollout a key component of its current and future geopolitical and economic strategy. There's urgency both in China and around the world to be first with the 5G rollout, in significant part owing to security concerns over Huawei's very strong position in the technology, and also because of the competitive advantage that may be gained by the first player to bring 5G online broadly. Currently, the winner in that race appears to be China, with the country's 5G network having gone live in early November with 5G plans now offered by China Telecom, China Unicom, and China Mobile starting, according to CNBC, "at around 128 yuan or $18 per month." CNN Business reports that the service is now available in 50 Chinese cities including Beijing and Shanghai.

Apart from the security concerns, the technology offers immense promise for all sectors of the economy, and as such, major technology companies outside of China and throughout the West are investing heavily in 5G development and deployment. These include not just carriers such as Verizon and AT&T, but hardware and software manufacturers, including leading electronics firms Qualcomm in the United States, Samsung in Korea, and Ericsson and Nokia in Europe.

Supporters of the technology are prominent leaders in government service, in politics, and in industry, and they have been vocal in support of the promise of 5G, calling it nothing less than the key technology of the next Industrial Revolution. "Studying this, I'm amazed at how many facets of our life will be changed as a result of 5G. How we live, where and how we work, how we consume entertainment, how we're educated — all of life will be transformed," enthused former Speaker of the House Newt Gingrich.

Of course, when such sentiments are uttered by a globalist of Gingrich's stature, it suggests that not all elements of the impending transformation are likely to be good. And, in fact, for every 5G supporter such as Gingrich, there is a 5G skeptic who believes the technology represents not just a danger, but an existential threat to the health of millions of people. Some theorists with certain exotic views have gone so far as to call 5G a "kill grid" that will devastate humanity. In fact, a search for "5G kill grid" on Google returns over 1.5 million results.

Thus the question of 5G: Will it bring a new golden age of prosperity, advancement, and entertainment, as its proponents argue? Or, more darkly, will it lead to the sinister future of sickness, death, and dystopia as feared by its detractors?

As with most technological advancements, used improperly 5G technologies could cause problems. But used correctly, there is little doubt that the much faster capabilities of 5G will lead to both an acceleration of further innovation and a strong boost to economic growth.

What Is 5G Anyway?

As a name, 5G is not terribly high-tech: Spelled out, it simply refers to the fifth generation of mobile telecommunications technology. The first generation, or 1G, came into operation in the 1980s and

consisted of analog voice mobile communication. Roughly every decade since, mobile technology has made a generational leap. 2G technologies were introduced in the 1990s, bringing digital voice mobile communications online. 3G was introduced in the 2000s, and was boosted by synergies created with the introduction of the first 3G-capable iPhone by Apple late in that decade. For the last several years, 4G mobile broadband has allowed for the burgeoning of the mobile app ecosystem and the rapid growth of streaming media, among other things.

In the simplest sense, 5G represents simply the further development in speed and capability of an existing network, but while that may seem true to the end user, the very nature of the 5G network is itself revolutionary in the speed, bandwidth, and latency characteristics that it will offer. Shifting frequencies higher into the electromagnetic spectrum with 5G will offer much greater bandwidth, and sophisticated advances in all aspects of the technology mean that data transmitted using that bandwidth will move considerably faster, and will do so with almost no perceptible latency, meaning that actions taken over the network will occur without any apparent delay. The end result will be the ability of the network to carry vastly more data than is presently possible, and to transmit that data at much faster speeds.

In a section containing frequently asked questions about 5G, Qualcomm, one of the leading developers of the technology underlying 5G, underscored the change that the new technology represents. The new generation of mobile communications technology, the company says, is "a platform for innovations that will not only enhance today's mobile broadband services, but will also expand mobile networks to support a vast diversity of devices and services and connect new industries with improved performance, efficiency and cost."

Former Department of Defense chief information officer (CIO) Terry Halvorsen, now CIO at Samsung, echoed Qualcomm's position in recent comments to Newt Gingrich during an interview on Gingrich's podcast. Discussing developments in storage capacity and artificial intelligence and how these are linked and amplified by 5G, Halvorsen noted, "You've got the data speeds and latency being developed and delivered by a 5G network. You've got the ability to store data at the edge, which limits the amount of data you have to pass back to a central processing point. And you have AI, augmented intelligence, assisting the human in getting through and sorting all of that data. That's the revolution of the 5G ecosystem, that's what's really going to be powerful and is beginning to be fielded today."

How powerful? "We see 5G as technology as transformative as the automobile and electricity," says Qualcomm.

Economic Promise

"In the 5G vision, access to information and sharing of data are possible anywhere and anytime to anyone and anything," write 5G experts Hugo Tullberg, Mikael Fallgren, Katsutoshi Kusume, and Andreas Höglund in leading industry textbook 5G Mobile and Wireless Communications Technology. Employed by Swedish telecommunications giant Ericsson, and by Japanese telecommunications firm NTT Docomo in Kusume's case, they conclude: "5G expands the usage [of] human-centric communications to include both human-centric and machine-centric communications."

In other words, not only will consumers benefit from easy and fast access to streaming media, augmented reality, and even virtual reality anywhere at any time, but new fleets of machines with a new

proliferation of sensors will be able to be connected, sharing data for performance analysis and allowing new, AI-enabled control regimes for greater automation and throughput. This will be made possible by the increased capacity of the 5G network to carry more information, breaking through an existing bottleneck.

The most immediate impact most people will experience will be enhanced mobile entertainment experiences, with higher resolution graphics, fast frame rates, and response times that are indistinguishable from real-time. But while this will be the "flash" that is intended to help sell the technology to the average consumer hungering for the latest Apple or Android handset, it is in industry, agriculture, and infrastructure that 5G will, arguably, have the greatest impact.

"This will lead to socio-economic changes not yet imaginable," Tullberg, Fallgren, Kusume, and Höglund write. The changes 5G will bring, they predict, will include "improvements in productivity, sustainability, entertainment and well-being."

In 2017, the international information, research, and analysis firm IHS Markit conducted a study on the potential impact of 5G on the global economy. Like most other commentary on the promise of 5G, the IHS Markit author team compared the new mobile communications approach to older watershed technologies, including the printing press, the Internet, electricity, and the steam engine. "Each of these technologies is part of an elite class of socio-economic mainsprings known as General Purpose Technologies (GPTs)," write the report's authors. These, they note, have had "profound effects" that have resulted in "positive impacts for human and machine productivity to ultimately elevating the living standards for people around the world." 5G, they argue, is "a catalyst that will thrust mobile technology into the exclusive realm of GPTs." After surveying the potential impact of 5G in several sectors of the economy, the IHS authors reported that the technology would "fuel long-term growth to global real GDP" with over $200 billion invested annually in the technology's value chain while supporting up to 22 million jobs and $3.5 trillion in output in 2035.

Consider the potential impact in just one sector: agriculture. Already, advanced systems use GPS to position tractors and other equipment on vast fields for more efficient planting and harvesting. John Deere, for example, offers a wide array of guidance and automation capabilities for farmers that improve tractor positioning and increase performance while diminishing crop damage from operations.

"It's one of the most difficult and exciting programs that Deere's ever done," Terry Pickett, an advanced engineering manager at the company, told Network World in 2017. The system offered by John Deere is one of the most advanced of its kind and is certainly a market leader, allowing farmers to grow more crops more efficiently. Now imagine in a 5G world the ability to install an array of sensors that detect soil moisture and chemical makeup in real-time, allowing future machinery to adjust hydration and fertilizer and pesticide mix live as conditions are measured and encountered. Now extend this capability to all other market sectors, including manufacturing, logistics, and healthcare, to name a few, and the supercharged efficiency gains that may be possible are staggering in their implications. Doctors will be able to conduct exams, and potentially even perform surgery, from remote locations, something that will only be possible as a result of 5G's high bandwidth and low latency characteristics. Manufacturing industries will be able to install more sensors and do so wirelessly, eliminating wired complexities as they currently exist, freeing capital expenditures for other necessary innovation efforts. Transport companies will be able to track goods and equipment with ever greater fidelity, ensuring increasing rapidity of delivery, not just to consumers, but in business-to-business situations as well, improving

already existing efficiencies in just-in-time-delivery models that are already of central importance to many business. The range of applications is vast.

Short-term Reality

While all the corporate and government exuberance for 5G makes the technology seem promising, as 2019 comes to a close and the actual rollout of the technology is getting under way, there have been hiccups.

In the United States, Verizon has been a leader in bringing 5G to early markets.

In a press release on October 18, the company highlighted the fact that it had brought 5G capabilities online in several sports arenas, including Talking Stick Resort Arena in Phoenix, Chase Center in San Francisco, and Pepsi Center in Denver, with other arenas such as Madison Square Garden "coming soon."

According to the company, "for those connected to it on a 5G device, Verizon's Ultra Wideband 5G mobility service can provide the bandwidth for fans to access the content they want during events." Moreover, enthused Verizon VP for Technology Heidi Hemmer, "having that next generation technology in large venues like arenas should not only enhance the game-day experience for sports fans, but provide greater bandwidth for concert-goers, visitors or businesses working inside the venue."

Large, concentrated crowds of people attempting to access existing 4G networks can quickly consume the available bandwidth and slow access to a crawl, so Verizon's attempt to manage that problem for large venues, as described by Hemmer, makes sense. But the reality is that the frequencies used by 5G networks have a downside equal to their benefits. While they enable much greater bandwidth, the shorter wavelengths are easily blocked by walls, glass, water, and people.

As it turns out, that's a challenge. Covering the Verizon announcement, technology news site Arstechnica noted that Verizon had admitted that its 5G network "doesn't cover the whole arena for any of these NBA facilities."

"This isn't surprising, given that Verizon's early 5G rollout relies heavily on millimeter-wave signals that don't travel far and are easily blocked by walls and other obstacles," noted Arstechnica's Jon Brodkin.

A month earlier, Brodkin had pointed out that Verizon's 5G rollout in the first cities to get the service ran into similar issues. "You had to be near a 5G antenna to get a signal" he reported.

These are hints that the reality of 5G capability doesn't quite match all of the hype — at least not yet. In a post on his company's blog, Neville Ray, the chief technology officer for T-Mobile, admitted that the technology wasn't ready to deliver on the promises being made for it:

Verizon's launch gave everyone a look at the 5G experience they'll be charging an extra $10 a month for — and, no surprise — coverage is very spotty and unreliable. Verizon won't publish a coverage map or acknowledge how limited their strategy really is, but people quickly found that Verizon's 5G was awfully hard to find, barely available at the places it was promised to be available, dropping repeatedly to 4G and disappeared if they stepped into a building. Their rollout was called a "rush job" and "confusing. Frustrating. Absolutely insane."

As a direct competitor to Verizon, criticism like this from T-Mobile isn't terribly surprising. Still, the science behind the criticism illustrates that Ray has a point.

"Some of this is physics," he explains. "Millimeter wave (mmWave) spectrum has great potential in terms of speed and capacity, but it doesn't travel far from the cell site and doesn't penetrate materials at all. It will never materially scale beyond small pockets of 5G hotspots in dense urban environments."

However, there are solutions for this, including using lower-band spectrum along with the higher bands, and installing a vast new infrastructure of 5G equipment on buildings, lampposts, and every other bit of stationary infrastructure, among other things. But this will take time.

Public Peril?

Regardless of whether or not 5G will ultimately deliver on its promise of a new age in speedy telecommunications and data delivery, one thing it has been very good at is driving a new firestorm of fear through an American public that has grown increasingly skeptical of technical innovation.

Of course, there is good reason for that skepticism, with a daily parade of propaganda on nearly every topic pouring like Niagara Falls from all manner of pundits, politicians, and the mainstream media. Under such conditions, the rational response is to be increasingly skeptical.

Currently, the companies behind 5G and most mainstream commentators say that 5G is safe. Others argue that not only is it unsafe, but it represents an existential threat. As mentioned earlier, the more extreme critics of the technology call it a "kill grid" and point out that just as 5G uses parts of the millimeter wave spectrum, so too does the U.S. military's Active Denial System crowd-control weaponry, which uses millimeter waves to heat a target's skin to cause him to flee.

Hyperbolically calling 5G a kill grid masks a credible concern: In 2011, the International Agency for Research on Cancer (IARC) classified "radiofrequency electromagnetic fields as possibly carcinogenic to humans." This scary classification continues to lead to a great deal of concern, but the IARC danger classification assigned to radio frequencies also was given to things such as aloe vera, alcoholic beverages, and chlorinated drinking water. So while the concern is credible, the scale of the concern also should be kept in mind.

Though biological systems are exposed to a wide range of non-ionizing electromagnetic (EM) radiation at all times, from naturally occurring and from man-made sources, studies of the higher frequency ranges to be used by 5G are relatively rare when compared to the entirety of the otherwise vast body of literature that makes up scientific peer-review. Still, there is some literature to review.

What does existing research show with regard to the biological impacts of these frequencies?

First, the EM radiation in question is non-ionizing, meaning that it does not have enough energy to remove electrons from an atom, but just has enough to cause them to vibrate. Ionizing radiation includes X-rays (used regularly in medical imagery) and gamma rays and extremely short wavelengths of ultraviolet light. These types of radiation have enough energy to damage DNA and can cause cancer. Radio frequency radiation, by contrast, such as light in the visible spectrum, does not cause this damage.

In the United States, 5G is expected to use frequencies as high as 71 GHz, according to specifications for what is called 5G New Radio (5G NR). What does existing research show for frequencies in this part of the spectrum? In the higher frequency ranges, 5G NR specs envision using frequency ranges from 24.25 to 27.5GHz, 27.5 to 29.5GHz, 37 GHz, 39 GHz, and the 57 to 71 GHz range. What does existing

research show with regard to some of these frequencies?

Sixty GHz frequencies are in the upper range of 5G new radio specifications, so arguably may make a decent proxy for understanding biological impacts of the majority of the spectrum envisioned for 5G use. Reviewing millimeter-wave impacts on the human body, Maxim Zhadobov, together with coauthors Nacer Chahat, Ronan Sauleau, Catherine Le Qeument, and Yves Le Drean, noted in a 2011 paper published in the *International Journal of Microwave and Wireless Technologies* that "the primary biological targets of 60-GHz radiations are the skin and eyes," and that lesions have been found in eyes "after high-intensity exposure" at three watts per square centimeter for six minutes. But, they point out, "studies performed at 60 GHz (10mW/cm2, 8 h) [10 milliwatts per square centimeter for eight hours] demonstrated no detectable physiological modifications," indicating that millimeter waves act on the cornea in a dose-dependent manner. In other words, take too much in too short a period and it may be harmful under some circumstances, something which is true also of a good many other things, including aspirin, coffee, sugary soda, and much else besides.

As for the actual impact that 60-GHz exposure has on the skin, the researchers noted that it results in "significant heating, even for low-power exposures." They pointed out, however, that "it is important to underline that temperature increments induced by the PD [power density] below current international exposure limits are much lower than environmental thermal fluctuations." In other words, at power levels used by current technologies, any potential heating effect is much, much less than what one experiences from exposure to natural sources.

But does radio frequency radiation even at low power interact at all with biological systems? The answer remains somewhat unclear, but there are intriguing possibilities.

The reason they are intriguing, at least in part, is because some of the possibilities stem from the use of these frequencies for their purported therapeutic effects. "Application of millimeter waves for the pain therapy showed some positive results," notes the paper by Zhadobov and his coauthors. "Studies on animals demonstrated that the optimal effect was obtained at 61.22 GHz and 13.3 mW/cm2. Various scientific publications reported positive data using blind tests with animal or volunteer studies."

What should be made of this? According to the Zhadobov paper, after what the authors described as an "exhaustive analysis" they conclude: "Whereas some effects have been observed for the medium-power exposures (5-15 mW/cm2) leading to the local heating of the order of 1-20° C, most of the reproducible results for the lower PD demonstrated that *direct biological effects at 60-GHz are not likely*."

In less technical terms, one way to think about this is to consider the old phrase, "the dose makes the poison." This bit of wisdom, attributed to 16th century pioneering Swiss physician and chemist Paracelsus, is a clumsy way of pointing out the largely accurate truism that in sufficiently large doses even otherwise helpful and healthful substances can cause injury or death. Water, for example, is absolutely necessary for life. But, drink too much, and injury or death can occur.

In one such case, Jennifer Strange died in 2007 after trying to win a prize during a radio contest during which she drank nearly two gallons of water, leading, tragically, to fatal hyperhydration.

In the case of non-ionizing radiation, natural sources far outweigh those produced by human radio technologies. Anyone who spends any time in the sun, or who visits a tanning bed, or wields an arc welder for their career is exposed to far more non-ionizing radiation than is produced by radio communication sources. Moreover, modern civilization is electrically powered, and everything powered

by electricity, having an electric motor, or just transmitting electricity is generating electromagnetic field (EMF) radiation. This has been going on since Edison and Tesla and Westinghouse led the electrification of the world. To get rid of man-made EMF would mean shutting down the entire infrastructure of the modern world.

This doesn't mean there aren't safety matters to consider with non-ionizing radiation. But these are neither extraordinary or uncommon when compared with other types of dangers. Anyone who works in industry — manufacturing, timber, chemicals, etc. — is familiar with the concept of personal protective equipment (PPE). Many of the tools, processes, machines, and ingredients that are used to build or produce most, if not all, the products that we take for granted are dangerous and working with them requires the use of PPE to prevent injury. It has been this way since the first Neanderthal scraped his thumb while flintknapping an arrowhead or burned himself while making birch tar adhesive. No one seriously recommends we stop using the tools, ingredients, and products we depend on in the modern world just because using them unwisely or incorrectly can be unsafe in certain circumstances. The cult of safety over all, when it demands this, is demanding something that is entirely ludicrous.

Moreover, the same tools and technologies that some people fear because of their inherent dangers are themselves indispensable to health and well-being. Chemicals, for instance, often get bad press because of their dangers. But the chemical industry and its long history of innovation have been responsible for a vast number of the innovations that have made life less dangerous and more comfortable for billions over many decades. Just consider, for example, that if you enjoyed last night's evening meal, it was only because the chemical industry invented the process of manufacturing fertilizer (see the Haber-Bosch process). Billions have not starved to death because of this one innovation. The same could be said for radio-based communication technologies up to and including modern cellular. How many lives are saved every day because this technology exists? Far more than would ever be affected by the hypothetical dangers of the technology.

As many have noted with regard to 5G and other RF-based technologies, more research is needed to fully understand microwave and millimeter wave RF's effects on biology. Research, as cited here and in many other studies as well, indicates that there are biological effects from radio frequency exposure, and many questions remain inadequately answered. In the meantime, we've been using these wavelengths for several decades safely and successfully. This is a trend likely to continue.

As it will, in fact, continue with the introduction and eventual spread of 5G, human civilization will enjoy greater convenience, will be able to grow more food, will be able to share information more effectively, and will generate more wealth and well-being for more people, worldwide. There will be lives saved by 5G through medical advances, through more rapid access to emergency services, and through more access to the products and services that lead to healthier lives. Whether 5G will be as fundamental to the next technological revolution as the steam engine was to the Industrial Revolution is yet to be revealed. But it is, without question, one of the core technologies that will form the foundation of the next step in our civilization's further technological advancement.

Photo Credit: AP Images

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