Employing Fifth Generation (5G) Mobile Communication Networks for Sensor Management in Intelligence, Surveillance, and Reconnaissance (ISR)

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Cellular communications is entering its fifth generation (5G) of technological evolution. The progression of the technologies is shown in Figure 1. The first generation (1G), which employed analog communications, appeared in the 1980's. Digital transmissions were added to analog voice communications in the second generation (2G) during the 1990's. It was during this period that Code-Division Multiple Access (CDMA) and Global System for Mobile communication (GSM) were first employed. Digital pack transfer capabilities, allowing access to the Internet, was introduced in the third generation (3G) of cellular systems. The fourth generation (4G) was introduced around 2010. 4G, among other improvements, focused on increasing data rates, widening transmission bandwidths, and multiple antenna beam steering. Starting with the 3G, an international partnership of regional standardization organizations created the Third-Generation Partnership Project (3GPP). This partnership is now responsible for the development of world-wide technical specifications for mobile communications [1] [2].

The 3GPP started the process of developing 5G specifications in 2012 by defining several service based use cases to guide the development of new radio (NR) and core network (5GCN) cellular communications technologies. Figure 2 illustrates three main use cases and example applications. The three main use cases include Enhanced mobile broadband (eMBB), Massive Machine-type Communication (mMTC), and Ultra-reliable and Low Latency Communications (URLLC). eMBB use cases require the 5G NR to support high data rates and high traffic volumes. This use case supports wireless broadband, and smart phone usage. mMTC

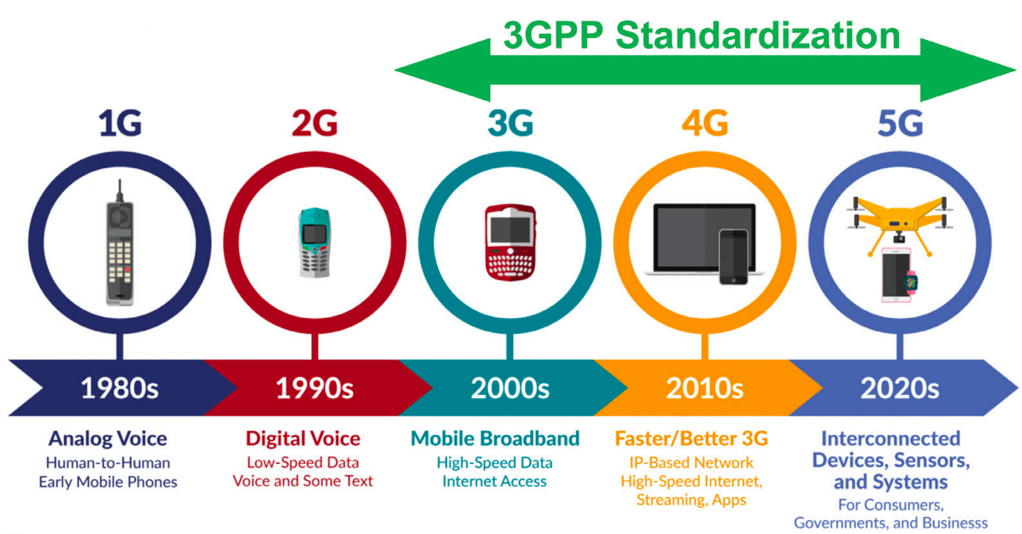

FIG. 1 Advancement of Cellular communications [2]

use cases requires the 5G NR to support massive numbers of low cost and/or low energy consumption devices. mMTC, for example, can support Internet of Things (IoT) devices and sensors. URLLC use cases require the 5G NR to support very low latency communications, and very high reliability and availability. This use case is important for real-time communications such as vehicle to vehicle (V2X) and Vehicle to Infrastructure (V2I).

With the massive proliferation of IoT devices, intelligence operations can use 5G technologies to quickly collect, decipher, and act on sensor information [3]. Many IoT sensors and actuators employ a sufficient security architecture [4]; therefore, it is possible to intercept and decode sensor communications from IoT devices such as security cameras, machine sensors (e.g. motion, proximity, temperature, vibration, bio, gas, and force sensors). Additionally, a lack of security among IoT actuators means that machines may be spoofed or otherwise controlled by adverse parties.

Surveillance operations can use 5G communications technologies to track devices including, vehicles, smart devices, phones, and IoT sensors. Some devices can self-report their locations using internal position sensors. (e.g. accelerometers and/or GPS). However, 5G NR advancements now open up the possibility of using 5G infrastructure as a radar, allowing devices to be tracked, even when they are not communicating with a 5G network. The new advancements include, higher frequency spectrum, wider bandwidths, massive Multiple Input Multiple Output (MIMO) antenna technologies, beam forming, beam steering, and cooperating base stations.

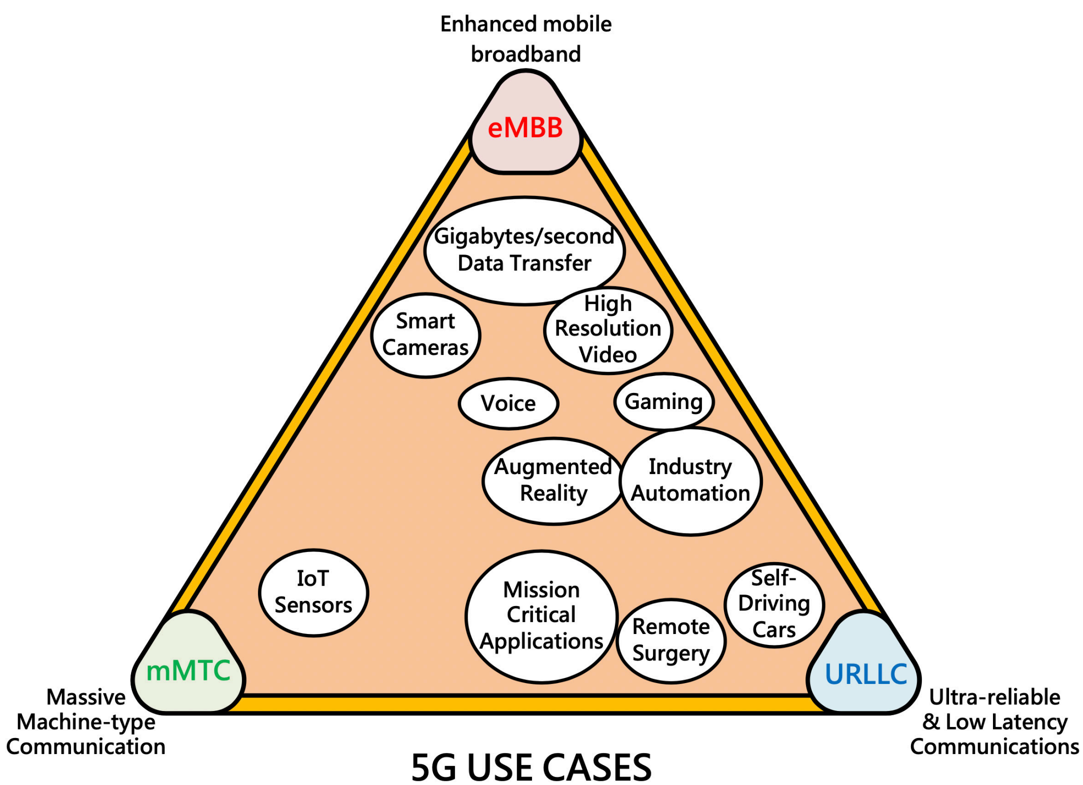

FIG. 2 5G use cases that have driven the development of new 5G technologies

5G has expanded its spectrum above 24.25 GHz (also called as millimeter-wave). The U.S. Federal Communications Commission (FCC) has been auctioning off multiple bands from 24 GHz to 48.2 GHz bands for licensed use and has made 64 GHz to 71 GHz spectrum available for unlicensed use [5]. The shorter wavelengths of the higher frequencies significantly increase the reflective resolution of a return signal from a small objects. This will allow better identification of objects such as drones and their payloads [6].

5G NR now supports adaptive bandwidths. Low bandwidths allow a device to operate in a low-power configuration for some applications (e.g. IoT communications). However, the same device may switch to a high bandwidth when necessary for applications that require more data throughput (e.g. updating firmware). These different configurations use bandwidth parts that can be used simultaneously on a channel. Using multiple bandwidth parts can also allow a wireless device to increase signal transmission power.

Massive MIMO groups together multiple antennas to provide better throughput and better spectrum efficiency [7]. Initial MIMO configurations were implemented to take advantage of the diversity of the multiple antennas (different antennas may have different propagation paths), to increase the probability of successful communications. Massive MIMO in 5G also enables a propagation signal to be shaped (beamforming) to create beams in space that focus power in a particular direction. This is done by adjusting the phase and amplitude of each antenna element. Beamforming was implemented to increase network coverage and spectral efficiency by sending signals with higher power effective radiated power (ERP) over a narrow beam. This is in contrast to legacy cellular systems that use spectrum to send a signal to a whole cell area. The narrow beams formed via beamforming also have the advantage of decreasing interference by limiting the signal to a restricted spatial zone [8].

Antenna beams in 5G may also be steered (beam steering) by adjusting the formed beam to move in space. Beam steering enables tracking an object such as a moving cell phone. However, beam steering may also be used to track other moving objects such as automobiles and drones.

These new capabilities to steer millimeter-wave signals give each base station the ability to act as a radar system. However, 5G also provides for coordination between base stations and antenna panels. This enables a 5G network to use groups of base stations and antenna panels as a powerful coordinated radar sensor capable of identifying and tracking moving vehicles, even when they are purposefully running silent under EMCON. (e.g. all electronic communications such as cell phones and transponders turned off) as shown in Figure 3.

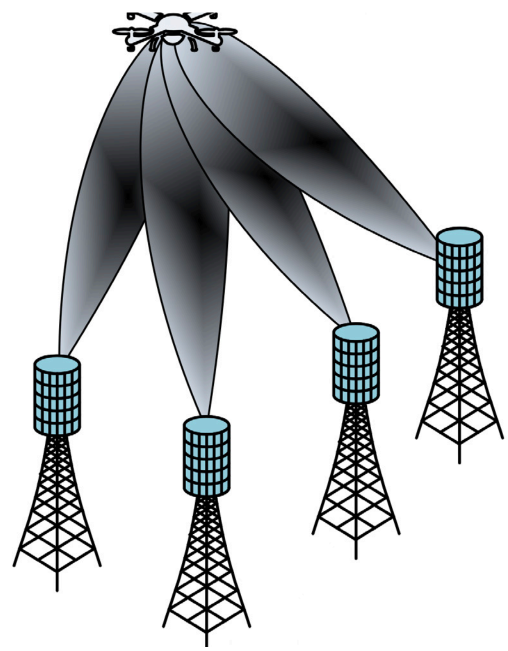

FIG. 3 Coordinated 5G Massive MIMO antennas using beamforming and beam steering to track an aerial drone.

This sensor tracking capability may be used to identify UAVs, enforce no-fly zones, and manage air traffic. The addition of new signal processing algorithms may be used to identify unique motion states of a target drone caused by the drone's rotor configuration [9]. These radar signatures can be used to quickly identity and track the target aerial vehicle. In many cases, the signatures can be used to match a target to a known device using a library of signatures. When the target is not in a library of known devices, millimeter-wave signals, because of their small wavelengths, may be used to image the target and its payload.

In summary, cellular communications have made major technological advancements to keep up with developments in other fields such as automation, multimedia, and sensor management. These technological developments can be repurposed to support ISR purposes. In particular, the 5G terrestrial infrastructure can provide a national radar tracking network.

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Ofinno, LLC, is a research and development lab based in Northern Virginia, that specializes in inventing and patenting future technologies. Ofinno's researchers create technologies that address some of the most important issues faced by wireless device users and the carriers that serve them. Ofinno's inventions have an impressive utilization rate. Ofinno's research involves technologies such as 5G Radio and Core networks, IoT, V2X, and ultra-reliable low latency communications. Our innovators not only create the technologies, they oversee the entire process from the design to the time the technology is sold. For more information about Ofinno, please visit www.ofinno.com.