5G and Next-Generation Mobile Communications

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The age of fifth generation (5G) mobile communications, the next dominant critical telecommunications capability, will fully arrive in the 2020s if it follows the 10-year maturity cycle of the previous four generations. 5G offers a broad spectrum of applications boosted by massive connectivity, ultra-high reliability, and capacity enhancements (e.g., gigabytes in a second). This ubiquitous capability for handling huge amounts of data comes with the promise of enabling dramatic increases in numbers and types of connected devices, including new networks of varying requirements and capabilities. **Although 5G is commonly described as a major advance in mobile technology, it actually represents several separate but interrelated advances**, which are summarized in the table below.

Features	***Benefits (compared to 4G)***
Millimeter wave spectrum	Increased data transfer rates
Small cells	Higher number of connected devices; more spectrum reuse
MIMO output base station antennae	Tenfold increase in number of antennae per base station
Beamforming	Stronger signal strength; reduced opportunities for signal interference
Full duplex communications	Simultaneous send/receive from same antenna at same frequency
Network slicing	Multiple virtual networks created from slices of a shared physical infrastructure, each slice with its own purpose
Edge computing	Faster data transit times source- to-destination; minimal data transit via internet

***Millimeter Wave Spectrum*.** 5G will use frequencies at the top of the radio frequency (RF) spectrum (30–300 gigahertz). These high frequencies, the millimeter wave spectrum, have shorter wavelengths (1–10 millimeters), which are able to carry much more data, but attenuate rapidly. This implies that base stations leveraging the highest frequencies of 5G are likely to be in urban or specialized rural locations. Higher frequencies do not penetrate walls and degrade in rain, so these frequencies will alter how cellular services are deployed in urban environments.

Small Cells. Increasing the number of cellular base stations is one way of addressing both the significant attenuation of millimeter wave frequencies and the anticipated increase in connected devices. These new base stations are likely to take the form of small cell technology: low-powered radio access nodes that can work in either licensed or unlicensed spectrum and have a range between 10 meters and 2 kilometers. Small cells connect to the rest of the cellular network either through wireless or physical (e.g., fiber optic) connections. The ever-increasing number of cells allows for even more devices to connect in a given area and simultaneously allows for spectrum to be reused many times over within other cells.

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NS D-10827

Massive Multiple Input Multiple Output (MIMO) Base Station Antennae. To accommodate the increase in new devices, additional antennae must be installed on each base station. MIMO technology currently increases the number of antenna per base station from 12 to about 100—nearly a tenfold increase. Consequently, the opportunity for signal interference grows as the number of new devices and base stations increases.

Beamforming. Beamforming uses various technologies to transmit radio waves directionally rather than omni-directionally. This means that the signal strength is higher for the recipient to which it is directed but much lower for others not in the path (or paths) to the recipient by design. By limiting the spread of radio waves, beamforming further enables the reuse of limited spectrum.

Full Duplex Communications. Traditional radios can only transmit or receive at a given point in time, much like a walkie-talkie. Although now aspirational, it may be possible in the future for 5G radios to leverage multiple technological advances to achieve simultaneous send and receive capability from the same antenna using the same frequency. This would achieve more efficient use of spectrum for faster data transfer.

Network Slicing. Network slicing allows for virtualization of network functionality like routing and firewalls. This allows 5G to look like multiple separate networks, each with different capabilities.

Edge Computing. To meet the highest performance requirements, such as ultra-low latencies, 5G requires the use of edge computing with services collocated with, or very near to, the base stations. This enables faster transit times from data source to destination. It also minimizes the amount of data that must transit the internet—a consideration for data-intensive applications.

5G opens the door for additional applications, which is important to the Department of Defense (DoD) because it will either impact current DoD systems, affect future DoD operations, or introduce new complexities in the critical infrastructure. However, 5G will also introduce new vulnerabilities, particularly since U.S. adversary China has taken the lead in development and marketing of 5G components. These inherent vulnerabilities must be considered as DoD transitions to a set of unproven, complex, and emerging capabilities over which it has limited control or influence.

Within DoD, critical ultra-reliable and latency communications, vehicle-to-vehicle and air-to-ground communications, satellite communications, and the mobile internet of things are among the areas most likely to be affected by 5G. While encryption and authentication technologies can ensure data are not compromised during transmission, overhead for cryptography can be impractical, negating the advantages of using 5G in the first place. DoD will need to carefully evaluate which applications will benefit from 5G capabilities.

The addition of numerous small bases and beamforming technology may benefit DoD with more accurate relative location determination; enhanced positioning, navigation, and timing; and increased resilience to jamming. Although network splitting will allow separation of military from commercial communications and latency-tolerant from low-latency communications, current security practices favor using separate hardware for Federal Government data storage and processing, which may preclude network slicing. Ensuring a trusted supply chain for integrated circuits, base station equipment, core networking equipment, and handset equipment will also be important, particularly given that China and Korea are currently the primary source of 5G components.

As plans for 5G concerns evolve, DOD should work at the inter-agency level to create requirements and shape relevant policy. DoD should partner with the Department of Homeland Security, the Intelligence Community, the National Institute of Standards and Technology, and the General Services Administration to adopt standards that ensure 5G applications have security controls for the DoD.

Based on IDA NS P-10594, *Implications and Considerations of 5th Generation Mobile Networks (5G) for the US Department of Defense*, L. A. Odell, C. D. DiLorenzo, J. C. Fauntleroy, R. R. Wagner, T. C. Rabren and G. A. Thompson April 2019. Research sponsored by the DoD Chief Information Officer.