Review of 5G and 6G applications for mobile wireless communication in the military environment

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Abstract:

Introduction/purpose: This paper seeks to provide a review of the applications of the fifth (5G) and the next, the sixth (6G), generation of mobile wireless communications in the military environment.

Methods: Analyzes and syntheses were used to consider various aspects, challenges, developments, and implementations of the fifth (5G) generation as well as the sixth (6G) generation mobile wireless communications for military purposes.

Results: The background and the state of the art of 5G and 6G mobile wireless communications are presented. Next, 5G military impact and initiatives are described. The paper also presents future prospectives of 6G for its usage in the military. Finally, possible 6G military applications are presented.

Conclusion: 5G had achieved the first deployment by 2020 and completed the first phase of its evolution in 2022. The 5G Advanced starts as a version towards the sixth generation in a way to find different solutions for implementation not only for commercial, but also for military purposes. With the platform approach to connectivity, 5G military networks contain different requirements, range of implementation options with spectral efficiency, latency, and reliability as primary performance metrics. Toward 6G, machine learning (ML) and artificial intelligence (AI) methods have proposed new approaches to modeling, design, optimization, and implementation in military systems.

Key words: the fifth generation (5G) technology, 5G military initiatives, the sixth generation (6G) technology, 6G military applications.

Introduction

Wireless communication systems belong to one of the most important mediums for information exchange and core communication for military relations, especially since 2020 when the fifth generation (5G) networks began with advancement changes worldwide. Today, it is a large evolving field with growing military applications in connection with the physical layer of radio links. The main idea is shifting towards system and application level optimization in order to obtain an improved performance for different, especially military, applications, taking into account that every object will have in built sensors to make decisions with the ability to communicate to every other object without human intervention. In this case, 5G networks represent a kind of infrastructure used to make all this a reality (Forbes, 2018) at ultra-low latency in an extremely dense environment (for example, 1000x more connected compared to a 4G network).

High reliability is also one important characteristic. To pave the way to superior capacity, spatial efficiency, and flexible operation to the next generation military operation wireless systems, new services are introduced. This is achieved by extending the next generation bandwidth and pushing up the transmission rate by coordinating resources across adjustment cells for reduced interference intense reuse of cellular networks and with mesh networking components as well as smart antennas technology for spatial multiple – based transmission (Rao et al, 2014). 5G will work on mm Wave band with directional antenna and beam forming techniques, shared spectrum access and provide super high speed full – duplex communications. These are some of the technologies common among commercial and military communications. It will become a key stone of future military technology. 5G communication will make the machine – to – machine (M2M) communication possible without requiring solutions or communication relay wire crafts. A significant research period in the academic community and industry contributed to the appearance of the next generation of wireless systems – 6G. Some parts of these 6G systems show that machine learning (MC) and artificial intelligence (AI) methods are significant for the protocols and the network architecture.

Background and state of the art

In every decade since 1980, there has been global standardization 3GPP for mobile communication, together with new generations of mobile standards. 1G was the first mobile generation, voice centric, with limited date capabilities in the 1980s. 2G was the first digital mobile communication voice-centric network with limited data capabilities in early

1990s. In 2003, 3G was the first wireless mobile data communication technology that enabled data streaming and mobile Internet access. The first all IP wireless data communication technology launched in 2008 was 4G. Packet switching and adaptation of IP protocols in 3G and 4G networks have led to the applications such as streaming, e-commerce, social networks games, etc. on mobile devices. Also, 5G enables massive Machine – Type communication (MTC) like D2D, Vehicle to Vehicle (V2V) or Vehicle to Infrastructure (V2I) Communications that will minimize the boundary between the digital and physical world (Rodrigez, 2015). Some advanced goals of 5G systems are presented in (Geller & Nair, 2018). They are ranging from 1 Gbps up to 20 Gbps, latency better than 1ms, massive connectivity at super high speed, 1000s of interconnected devices and 1000 x BW per limit are 100% coverage with 99.999% availability, high energy efficiency – 90% reduction in energy and up to 10-year battery life for machine type communications. Various applications can be classified into three domains such as: enhanced mobile broadband (eMBB), Massive Machine – Type Communications (MTC), and Ultra – Reliable Low Latency Connections (uRLLC). The target speed for eMBB platforms is with downloads better than 200 Mbps. Interconnected smart devices, vehicles, and IoT reduction in industrial equipment necessitate the development of metric MTC. The third application, uRLLC, serves for real-time data collection necessary for quick decision making.

To meet the above goals, there are some new technologies applied to 5G systems. For example, Heterogeneous Networks (Het Nets) serve by overlaying a cellular system with small cells of some technology, i.e. micro, pico or femto cells. Het Nets achieve a significantly better area spectral efficiency compared with previous networks. Massive Multi – Input Multi – Output (MIMO) technology is applied for multiple co-located antennas, up to a few hundred, to simultaneous serve/spatially multiple a number of users in the corresponding frequency resource. In the mm Wave, ultra-broadband wireless tapes can be provided due to the availability of spectrum. It should be noted that the smart antenna sizes ($\lambda/2$) and their small separations (around $\lambda/2$) will enable packing tens of antenna elements in one square centimeter. In twin, this will allow achieving very high beam forming gains in relatively small areas. Also, this can be implemented at the Base Stations (BS) and the User Equipment (UE) and improve the system capacity mm Wave, 1s being perceived as the most promising spectrum for further network due to support for massive MIMO and the availability of abundant spectrum in the corresponding frequency band (Bhardway, 2020).

Device – to – Device (D2D) communications enable efficient spectrum usage in 5G and efficiently upload traffic from BSs. The first challenge is in number of devices that need to be connected in large numbers (50 billion devices). The other challenge is for real time and remote control of mobile devices (such as vehicles) through the network and it requires extremely low latency of less than a millisecond. Tactile Internet that is targeting a 20 x latency improvement for 4G to 5G, could be a possible solution. Software – defined network (SDN) can provide logically centralized intelligence, programmability and abstraction so that scalability and flexibility of the network can be with a huge improvement, while cost can be significantly reduced (Agiwal et al, 2016).

Network Function Virtualization (NFV) allows the provisioning of virtual network functions in the network edge, sharing aspects of the Network as a service. These technologies in that way allow the implementation of network functions in software able to run independently of underlying server hardware (Fang el al, 2017).

Actual notation operation articles can be virtualized in a multi – version way, allowing services and functions to be reliably scaled as required. As a result, barriers associated with proprietary hardware are overcome, simplifying the deployment of novel network services. As for network slicing, it is the ability of the network to configure and run multiple logical networks as virtually independent business operations on a common physical infrastructure. Network slicing is a fundamental architecture component of the 5G network.

It is important to emphasize that 5G+ (advanced 5G) is expected to enter the market already during 2024.

Together with development, improvements and implementations of 5G technology, nowadays research community is developing 6G cutting edge technology which is expected to be even more revolutionary not only from the economic and commercial point of view, but also for military applications.

Many of the technologic and user case aspects of 5G are essential for building 6G and lead to applicable optimization and cost reduction.

The implemenatation of 6G has been originally planned to be ready by 2030, but the first applications for mobile telephony will be ready in 2026 (Telefonica, 2022).

6G smart architecture consist of autonomous networks that integrate networks from space through the air to the ground and underwater in order to provide continuous and unlimited wireless connectivity and services.

6G is expected to be able:

- to connect the world with virtual, augmented and mixed realities;

- to transmit holography applications in real time, in high definition and with virtually no latency;
- to have potential bitrate at 1 terabyte per second together with promising latency of only 0.1ms;
- to offer efficient and effective, but also secure communications between different type of devices;
- to work in conjunction with artificial intelligence (AI);
- to use higher frequencies and ranges than 5G networks, for example, to utilize the terahertz band of frequency and provide substantially higher capacity and much lower latency (to support one microsecond-latency communication);
- to connect digital, physical and human worlds;
- to provide greater security and privacy;
- to increase the number of simultaneous device connections;
- to substantially reduce energy consumption;
- to be used in the terahertz space communication segment; and
- to use innovative infrastructure and enhanced integration of "space-air-ground-sea communication technologies".

Important expectations from 6G will be a vastly superior bandwidth, extremely low latency, and high connectivity properties.

6G is expected to be suitable for a wide range of issues, such as advanced functions in portable devices compatible with XR (VR, AR, MR) devices, high definition images and holograms exceeding up to 8K and beyond, as well as sense communications involving tactile sense. Next, communications between human beings and between human and different things will be ultra-real and will introduce real-time holograms, as well as flying taxis and Internet-connected human's bodies and brains.

In order to provide services for many different types of equipment, 6G would be extending the coverage areas for drones, flying cars, ships, and space stations.

Technologies likely to be used in 6G are terahertz and space-air-ground integrated networks (SAGIN).

Finally, the terahertz (0.3 THz to 30 THz) radio frequency band has a real potential to be the next player in wireless communication in 6G as well.

5G military impact and initiatives

5G technologies will have a huge impact on military applications for autonomous vehicles, logistics, maintenance, training, AI (artificial

intelligence), augmented and virtual reality, and Intelligence, Surveillance, and Reconnaissance (ISR) systems capabilities for decision making in command and control (*C2*) as shown in Figure 1.

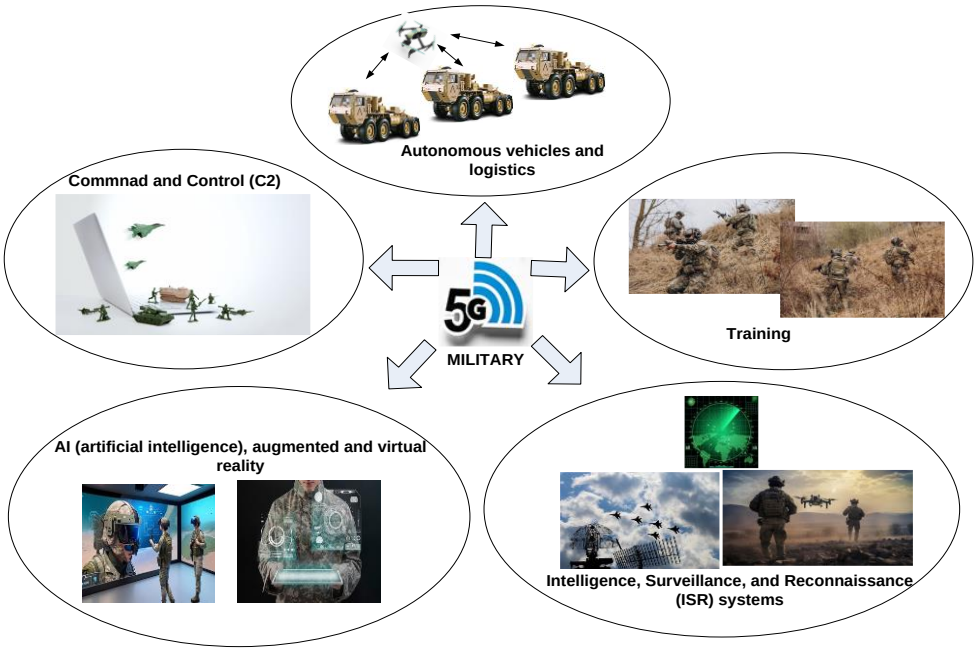

Figure 1 – 5G military applications

The key technology characteristics and improvements in 5G enable it to be more suitable for enhanced sharing of different services (data, video, locations, etc.) between and within military units or combat platforms, as well as command posts on battlefields without the threat of detection, jamming, eavesdropping, etc.

Secondly, interconnected with drone platforms, 5G will have a serious impact on military logistic schemes in order to provide precise delivery all necessary supplies for combat units in order to be sustainable on appropriate locations.

Next, close-range D2D communications supported by 5G will provide fast information sharing without necessity to use military relay stations.

Also, 5G supports interconnectivity of various platforms (sensors, drones, robots, vehicles, etc.) to reduce the response time in military operations, especially in emergency situations.

Next, the concept of smart bases will be possible because 5G will improve access control solutions and provide optimal deployment available resources in the base, as well as support sensors which provide perimeter security without the threat of enemies detecting its communications.

Finally, 5G will be an appropriate platform for telemedicine applications including remote surgery and healthcare in war operation zones (Bhardway, 2020).

In hypersonic weapons usage scenarios, 5G can be able to provide real-time connectivity to these weapons from ground stations as well as to detect them with air defense systems.

Standard 5G technologies are enhanced to connect many platforms and networks operated by various branches of armed services. This is the 5G military initiative (MIL). It has two complementary elements. The first element uses an open scenario: quick, ad hoc establishment of secure, local-based 5G technology. The final goal is to allow forces to take sensors data from any platform and to make it accessible to any shooter. There is no matter how the platform and the shooter are connected to the network (Walker et al, 2021).

Inside a hybrid base station, there is a series of systems, so-called tactical gateways. This will enable a base station to work using different communication protocols. Gateways consist of hardware and software based on military-presented open-architecture standards. These standards are characterised by the fact that they can enable a platform, e.g. a fighter jet, made by one contractor to communicate with a battery made by another supplier.

The second element of the 5G MIL involves connecting local mash networks to the global Internet. A connection between a local network and the wider Internet is known in practice as a backhaul. The connection might be on the ground or in space, i.e., between civilian and military counterparts. In that way, a software-defined virtual globe defense network is achieved.

It is of importance to note that software-defined treatment will allow networks to be reconfigured automatically while operating. It can be a huge challenge, since the network is formed virtually in order to provide the flexibility needed to deal with the exigency of the war. Automatically reconfigurable SDNs will make the need for an enormous video bandwidth in a certain area; different streams of data might need different levels of encryption as well as conveying targeting data in a great number of software programs running on the network.

A key element of 21st century strategy is to collaborate with innovative commercial companies to leverage their technologies for military applications. Technologies such as 5G AI, distributed cloud computing, and anatomy are highly applied. When the military goes to war, it brings its communications infrastructure with it.

One of the most important challenges in 5G is a key large number of interconnected devices with infrastructure with symmetric resources (size computational resources, power requirements, BW, etc.) to be used in a completely new paradigm of the IoT. To ascertain desired functionality, there are a lot of security challenges. For example, security of radio interfaces, security of networks, protecting against Denial of Service (DoS) attacks on the infrastructure, distributed control systems requiring coordination to prevent signaling storms, preventing DoS attacks on end-user devices, etc.

These challenges are highlighted by Next Generation Mobile Networks (NGMN) as well. Massive connectivity will increase the attack surface for the 5G network. Also, the impact of attacks will be seen more deeply. The main raisons are challenges in the containment of a successful attack, due to transit boundaries inter and intra-network arising out of logical separation using NFV as well as SDN of the underlying networking and processing infrastructure, rather than physical separation. Security has been always a major concern for wireless communications and with IP becoming the backbone of cellular communication all threats to an IP network become inherent to cellular networks.

A number of security threats and solutions have been presented by various authors, classified in terms of generic security requirements and applications of technology in perspective (Huawei, 2021; Abd-Elrahman et al, 2015).

Security threats and solutions have been classified broadly in categories such as: threats due to the wireless nature of the network, threats due to vast deployment of end-devices of diverse nature, and threats on information components such as base stations, servers, etc. 5G technology has the potential to make the concept of smart bases a reality. With the maturing of biometric technology, it can be deployed for automated and robust control.

6G military of the future

The terms 6G and 5G refer to the sixth and fifth-generation mobile wireless networks. It is well known that 5G networks have data transmission speeds greater than 4G invoked in 2009; 6G will have a

speed 10 times greater when compared to 5G. It means that 6G has a distinct technological and rich potential for military applications. The gradual application of military 6G might be one of the main focuses for the armed forces to adapt to future military changes. Thus, 6G has a rich potential for military applications (Center for Joint Warfare Studies, 2020).

Beyond data transmission speed, some other potential 6G benefits are better Internet access, high transmission rates, low delay and broad bandwidth delivering military advances: gathering intelligence, visualizing combat operations and precisely delivering logistical support. On the other hand, the commander could make right decisions quickly after the control-and-command network named, learned, and analyzed data from the battlefield.

Some countries published statements expressing their interest in using 6G networks to modernize their armed forces; however, 6G is still a theory. Many countries see 6G as an opportunity to transform their military operations at every level from equipment and war formations to battlefield communications.

6G is bringing the Internet of Military Things which refers to all the smart devices not frequently used in military areas. It should be noted that it ranges from sensing and actuating devices to devices that capture and can carry data. Of course, they are operational with 4G, while some of them need 5G. As for others, they will have to limit 6G to be developed and put into service. It is believed that the military will include smart city monitoring, logistics support, and other functions with the aim to make management as easy as possible.

6G can be the core technology for military strategic networks which consist of a large number of different platforms which could be floating in the space/near space, flying in the air, on the surface and in deep-diving-autonomous underwater vessels (Sakhuja, 2021), in order to conduct large scale surveillance, reconnaissance, and exploration.

6G can be a core architecture in a mix of manned and unmanned forces for better battle efficiency and efficient operational and logistics management.

Today, there is communications blackout at hypersonic speeds, so 6G can be a key technology to solve problems in hypersonic weapons programs.

Potential 6G military applications

In the open literature, there are the following most important fields for possible 6G military applications: battlefield communications, improved location services, and equipment development. The data speeds together

with coverage make a useful communication tool in high stakes environments. Higher communication rates lead to more effective operations, to shorter conflicts, and fewer lives lost.

One of 6G potential capabilities is to improve location detection to be accurate within centimeters, making at the same time technology such as autonomous vehicles practical. The other applications including drones or unmanned vehicles may be sent into dangerous environments. Also, some research notes that high-accuracy localization will improve radar technology as it relates to mobile devices.

The Internet of Things will allow the development of more intelligent autonomous military devices. Battlefields of the future will be populated by different things.

Keeping pace with rivals is one of the ways to ensure national security. Machines instead of humans, i.e. enabling more précise war operations, will affect the way wars are waged. In that way, it will be possible to reduce or eliminate accidents. Each of the noted applications has a potential to be used in waging wars as well as to be used in everyday life. People track research studies and developments even 5G is going to roll out (Bhardwaj, 2022). The 6G possible military use cases are shown in Figure 2.

6G will play a key role in the informatized environment for the military because:

- it would help develop state-of-the-art AI systems that can process vast amounts of data, which military devices receive from a multitude of sensors and sources necessary for their combat operations (Sakhuja, 2021),
- it will support real-time analytics in order to provide command personnel with solutions or courses of action based on the data receieved from military devices, cut latency, and extract the most appropriate data to enable an efficient response.

6G benefits would deliver military advances, such as gathering intelligence, visualizing combat operations, and delivering precise logistical support.

The military expects from 6G to provide fast, reliable and secure transfer of much larger amounts of data between rapidly moving military platforms, as well as high data transmission rates in the outer space for ballistic-missile early warning (Lee et al, 2022).

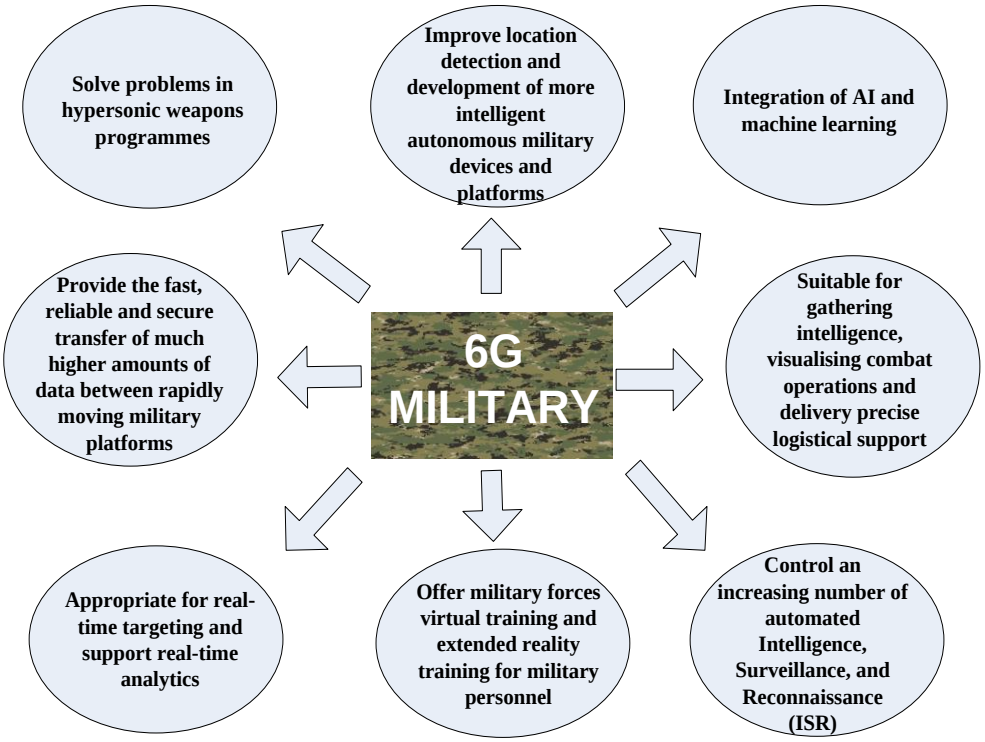

Figure 2 – 6G possible military use cases

On the other hand, at the tactical level, 6G would be appropriate for real-time targeting, AI-enabled decisions by the tactical level of command, and swift data exchange between sensors and combat shooters.

In addition to its possible use in weapons programs, the army is in a position to use big data to enhance command and control, defense mobilization, and finally decision making using integration of AI and machine learning across 6G applications.

In order to control an increasing number of automated Intelligence, Surveillance, and Reconnaissance (ISR) assets, 6G will be appropriate as technology for military's growing requirements to gather, analyse, and share information rapidly, as well as to effectively command geographically dispersed mobile forces (Uppal, 2023).

It should be added that 6G might offer military forces virtual training and extended reality training for military personnel; for example, it could significantly improve fighter pilot training, providing more realistic and

unpredictable scenarios that accurately reflect real combat situations (Hornada, 2022).

Conclusion

The fifth generation (5G) of mobile wireless networks had started with their first deployment by 2020 and completed their first phase of evolution in 2022. The platform in which there is a single standard that can adapt to the heterogeneous connectivity requirements of use cases is one of the most important characteristics of 5G networks. The following dimensions are characterized: faster and better mobile Internet access, low latency with high reliability, and a massive number of Internet of Things (IoT) devices. In validating its effectiveness in the military domain, the main difficulty is the fact that experiments and corresponding data are not completely available.

When applied to military communications, 5G is in a position to improve intelligence, surveillance and reconnaissance systems and processing, enabling new networks of command and control. Also, it is of great importance to provide security mechanisms at each layer in order to prevent attacks.

Today, there is a huge research interest in the academia and industry towards the next generation 6G (sixth generation) wireless systems. Some of the most important characteristics of 6G are machine learning (ML) and artificial intelligence (AI). A large number of connected devices and the network virtualization techniques will increase the potential attack surface. Machine learning forms part of AI. It enables a device to perform tasks without giving any special instructions.

ML and AI methods will play very important roles when analyzing the protocols and architecture of 6G. On the other hand, one of the most important characteristics of 5G is that it will support heterogeneous networks to serve voice, video and data, in addition to new intelligent services.

These services will be embedded by network device to Device (D2D) communications. 6G will give operators greater control over unmanned military machines that would play a leading role in future wars.

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Revisión de aplicaciones 5G y 6G para comunicaciones inalámbricas móviles en el entorno militar

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CAMPO: telecomunicaciones
TIPO DE ARTÍCULO: artículo de revisión

Resumen:

Introducción/objetivo: Este artículo busca proporcionar una revisión de las aplicaciones de la quinta (5G) y la próxima, sexta (6G), generación de comunicaciones inalámbricas móviles en el entorno militar.

Métodos: Se utilizaron análisis y síntesis para considerar diversos aspectos, desafíos, desarrollos e implementaciones de las comunicaciones inalámbricas móviles de quinta (5G) y sexta generación (6G) con fines militares.

Resultados: Se presentan los antecedentes y lom as avanzado de las comunicaciones inalámbricas móviles 5G y 6G. A continuación, se describen el impacto y las iniciativas militares del 5G. El documento también presenta las perspectivas futuras de 6G para su uso en el ejército. Finalmente, se presentan posibles aplicaciones militares del 6G.

Conclusión: 5G logó el primer despliegue en 2020 y completó la primera fase de su evolución en 2022. El 5G Advanced comienza como una versión hacia la sexta generación de manera de encontrar diferentes soluciones de implementación no solo para uso comercial, sino también para propósitos militares. Con el enfoque de plataforma para la conectividad, las redes militares 5G contienen diferentes requisitos, una variedad de opciones de implementación con eficiencia espectral, latencia y confiabilidad como principales métricas de rendimiento. Hacia el 6G, los métodos de aprendizaje automático (ML) y de inteligencia artificial (IA) han propuesto nuevos enfoques para el modelado, el diseño, la optimización y la implementación en sistemas militares.

Palabras claves: la tecnología de quinta generación (5G), iniciativas militares 5G, la tecnología de sexta generación (6G), aplicaciones militares 6G.

Обзор применения 5*G* и 6*G* в мобильной беспроводной связи в военной среде

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РУБРИКА ГРНТИ: 49.33.29 Сети связи
ВИД СТАТЬИ: обзорная статья

Резюме:

Введение/цель: В данной статье представлен обзор применения мобильной беспроводной связи пятого (5G) и следующего шестого (6G) поколений в военной среде.

Методы: Анализы и синтезы использовались при рассмотрении различных аспектов, проблем, разработок и внедрения пятого (5G), а также шестого (6G) поколения мобильной беспроводной связи для военных целей.

Результаты: Сначала были представлены история и современное состояние мобильной беспроводной связи поколений 5G и 6G. Затем описаны военное влияние и возможности 5G. Также в статье

представлены будущие перспективы использования 6G в армии. И, наконец, представлены возможности 6G в военном применении.

Выводы: Первое развертывание сети 5G произошло в 2020 году, а его первая фаза эволюции была завершена в 2022 году. Продвинутая система сети 5G стартовала как версия шестого поколения для нахождения различных решений внедрения не только в коммерческих, но и в военных целях. С учетом платформенного подхода к подключению военные сети 5G отличаются различными требованиями и рядом вариантов применения. Причем спектральная эффективность, задержка и надежность являются основными показателями производительности сети. Возможности 6G, машинного обучения (МО) и искусственного интеллекта (ИИ) предлагают новые подходы к моделированию, проектированию, оптимизации и внедрению в военные системы.

Ключевые слова: технология пятого поколения (5G), военное применение 5G, технология шестого поколения (6G), военные приложения 6G.

Преглед примене 5Г и 6Г за мобилну бежичну комуникацију у војном окружењу

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ОБЛАСТ: телекомуникације
ВРСТА ЧЛАНКА: прегледни рад

Сажетак:

Увод/циљ: У раду је приказна примена пете (5Г) и напредне шесте генерације (6Г) код мобилних бежичних комуникација у војном окружењу.

Методе: Анализе и синтезе су коришћене за разматрање различитих аспеката, изазова, развоја и примене пете генерације (5Г), као и шесте генерације (6Г) мобилних бежичних комуникација у војне сврхе.

Резултати: Представљена је позадина и стање мобилних бежичних комуникација 5Г и 6Г. Затим, описан је војни утицај и иницијативе код 5Г. Такође, у раду су представљене будуће перспективе 6Г за употребу у војсци, као и могућа примена 6Г.

Закључак: Пета генерација постигла је прву примену до 2020. године и завршила прву фазу еволуције 2022. године. Она покреће напредну верзију ка шестој генерацији на начин да пронађе

различита решења за примену не само у комерцијалне, већ и у војне сврхе. Са платформским приступом повезивању, 5Г војне мреже садрже различите захтеве, низ опција примене са спектралном ефикасношћу, кашњењем и поузданошћу као примарним показатељима перформанси. У правцу 6Г, методе машинског учења (МУ) и вештачке интелигенције (ВИ) предложиле су нове приступе моделовању, пројектовању, оптимизацији и примени у војним система.

Кључне речи: технологија пете генерације (5Г), војне иницијативе пете генерације (5Г), технологија шесте генерације (6Г), војне примене 6Г.

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