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New Horizons in Tactical Communications: An Overview of Emerging Technologies Possibilities

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***Abstract*—The proliferation of new technologies with 5G and future 6G networks may also find application in the field of military communications. However, new challenges must be considered due to the level of security required in tactical environments. In this article, we have focused on analyzing these challenges in practical use cases for military communications. First, we select and present a set of emerging technologies associated with 5G and 6G, such as Artificial Intelligence, network virtualization and softwarisation, Neuromorphic Processors, Internet of Things (IoT), Network Slicing, Tactile Internet or Blockchain, focusing on their applicability in tactical environments. On the other hand, we present an overview of the primary tactical radios that can face the challenges imposed by these technologies. Then, we show the main benefits and possible scenarios to improve efficiency in the military environment, such as situational awareness to increase the safety of soldiers on the battlefield, thanks to emerging technologies selected as potential candidates.**

I. Introduction

Tactical communications are military communications in which information, especially orders and military intelligence, is transmitted from one command, person, or place on the battlefield to another, particularly during combat. It includes any type of information delivery, whether verbal, written, visual or auditory and can be sent in various forms. Many advances in wireless technologies have their origin in military communications. This is the case of frequency hopping in the second generation of mobile communication or direct sequence spread spectrum (DSSS) in the third generation. Instead, wireless communications have continued to evolve independently of military communications since the fourth generation without considering their needs. Today, the fifth generation (5G) [1] introduces new technologies and paradigms that were not present before, such as the virtualization of network elements, a 5G-enabled technology considered fundamental and most attractive to improve tactical communication. Virtualization can help network security. For this reason, the commercial and tactical security guidelines provided by 5G are analyzed for communications in public environments to validate if the security level of a public 5G network can be extrapolated to military scenarios [2]. 5G will dominate next-generation telecommunications networks and enable new applications, playing a pivotal role in future societies. For this reason, it is time to re-unify the advances in civil and military communications. That brings several challenges and security concerns to the broader community and new opportunities in many military areas, such as capability interoperability, development, resilience, and secure communications, empowering tactical communication networks with enhanced security and protection for all assets that are part of a tactical scenario. All defense systems (land, sea, air, and space) can be seen enhanced by the new technologies that 5G brings, mainly from a safety point of view. In this context, the North Atlantic Treaty Organization (NATO) and NATO Communications and Information Agency (NCIA) [3] conducted a preliminary assessment of 5G technologies and of their potential for military applications, identifying four areas where 5G could have a place:

- Communications and Information Systems (CIS) for expeditionary operations,
- tactical operations,
- maritime operations,
- static communications.

However, it does not associate which candidate emerging technologies could be related to these areas for different operative use cases. Recently, other independent works have been carried out to include the opportunities of 5G in the military field. Network Slicing, a key 5G technology, is first proposed for military use. Software-Defined Networking (SDN) [4] comes hand in hand with 5G to guarantee greater network scalability. A mechanism based on SDN to adaptively ensure Quality of Service (QoS) for user data flow is proposed by leveraging SDN in heterogeneous tactical networks. Sensor networks [5] are essential on the battlefield, and thanks to the Internet of Things (IoT), these networks can offer more advantages in the tactical world, as analyzed. The function of interoperability between systems is vital in defence, mainly between command and control (C2) systems [6].

Beyond 5G, the study performed by NCIA is also a key topic for the NATO 2030 agenda, where artificial intelligence (AI), data autonomy, quantum-enabled technologies, hypersonic technologies, and biotechnology should be strategically considered as technology roadmap in the evolution of military communications. All these technologies pave the path of development from 5G to the sixth generation (6G) [7], where AI is the key technology. Preliminary proposals are presented using Reinforcement Learning as an AI technique used by agents in tactical networks to learn autonomously, improving situational awareness [8].

Against this background, in this paper, we have selected emerging technologies promoted by 5G and 6G that can benefit tactical communications. First, a high-level system

description of these technologies has been carried out to identify opportunities for military applications. In addition, it can provide the reader with a context for understanding their application in the proposed tactical scenarios or use cases.

This work is an analysis of emerging technologies and their application to the military field, with special emphasis on tactical scenarios, on improving such scenarios and therefore serving as a starting point for new scientists to open up new lines of research. It is not merely a compilation, but an analytical basis for future work.

The rest of this paper is organized as follows: Section II presents a brief background of two main elements in tactical communications to be renewed. Section III proposes a group of emerging technologies as a potential candidate in tactical communications. In Section IV, the use cases are presented. Finally, the conclusions are summarized in Section V.

II. Tactical Communication Panorama

We begin the analysis by giving an overview of the two main components of tactical communications that are the object of evolution using 5G/6G-enabled emerging technologies: the tactical radios and the waveforms to transmit information on the battlefield. The waveform is the shape of a signal in the time domain that provides information about the signal beyond the spectrum.

A. Legacy Tactical Radios

Tactical radios are a fundamental necessity for soldiers during military operations as they allow them to communicate and share a common vision of the entire operating environment. Some examples of military radios currently used are collected below.

- **Land mobile radio** [11]: This is the primary tactical system used for garrison communications, ranging from single-channel analogue systems to digital trunk systems. It is used mainly for critical communications within a tactical scenario or with public networks. For this reason, the increase in the level of security provided by 5G networks would help renew this type of radio.
- **PNR500**[14]: This radio is a lightweight, personal network portable radio set used for squad and platoon-level communications over a very short range (over 800-1000 meters range) in the Ultra High Frequency (UHF) band.
- **RF-5800H-MP**[14]: This radio is a multiband system type. It is an advanced radio that provides reliable tactical communications on the Very High Frequency (VHF) band and uses Electronic Counter-Counter Measures (ECCM) waveforms.
- **RF-7800H-MP**[15]: It is the smallest, lightest and fastest portable High Frequency (HF) broadband radio available today. It has capabilities for long-range, Beyond-Line-Of-Sight (BLOS) environments, which provide continuous coverage on the power of a single battery, compatible with an SDN-compatible architecture.
- **AN/PRC-117G (V)1(C)**: It is a multiband multi-mission manpack radio for tactical combat-net radio (CNR) that offers integrated communications security and satellite communications.

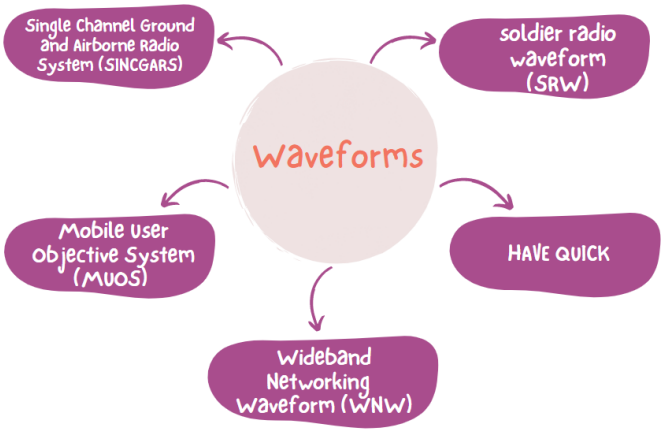

Figure 1: Waveforms used in tactical communications

- **PR4G** [16]: It is a tactical VHF radio belonging to the CNR family. It mainly provides military units with a command, control, communications, and intelligence system in VHF with a complete system for electronic counter countermeasures.
- **SPEARNET** [17]: It is a Mobile ad hoc network (MANET) type radio, which maximizes network coverage, especially in complex areas where good coverage cannot be maintained. Ad-hoc means networks with interconnected computers that communicate directly with each other without the need for a router. One of the main characteristics of this radio is the ability to transfer data at high speed.

The legacy frequency bands for military applications mentioned by these radios are primarily three bands: HF comprises the range of 3-300MHz; VHF, which refers to the range between 30-300MHz and finally, the band UHF, refers to the range 300MHz-3GHz. Satellite communications for military purposes are used in the frequency band L (1-2 GHz) and X (8-12 GHz) for accessing remote sites in military missions. The great inconvenience these frequency bands present to accommodate new technologies driven by 5G/6G is the limitation in bandwidth (amount of data that will be able to be transmitted).

B. Legacy Tactical Waveforms

With the increasing battlespace and sophisticated adversaries, the availability of effective military communications platforms is more crucial than ever. Tactical waveforms are critical elements, and their ability to reliably and securely transmit to and from the combatant on the battlefield. The most used waveforms in tactical environments are summarized in Fig. 1.

- **SINCGARS:** waveform uses a non-IP low bandwidth voice coding format that has been implemented in many legacy tactical radios.It also supports low-rate data communications. This waveform is used in vehicle-mount, backpack, airborne, and handheld.
- **SRW:** is an open-standard voice and data waveform designed as a mobile ad hoc. It is used to extend wideband battlefield networks to the tactical edge.
- **HAVE-QUICK:** is a waveform designed for an electromagnetic-resistant frequency-hopping system that

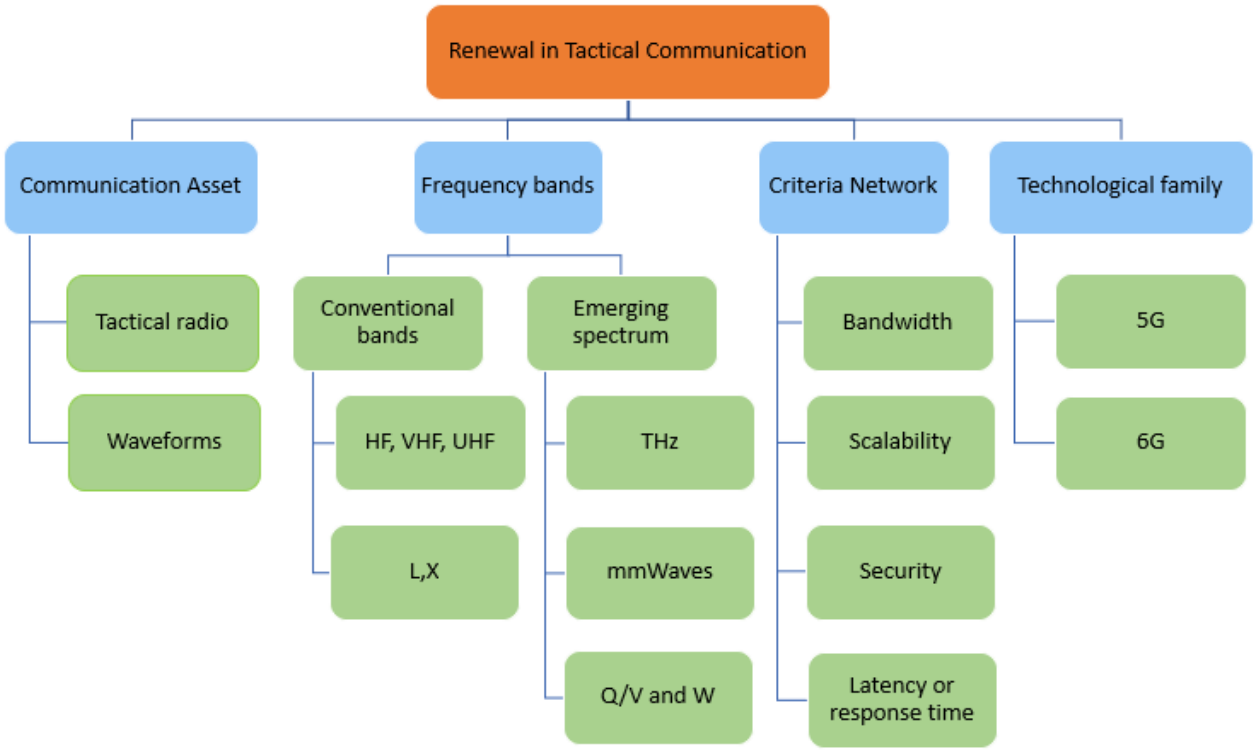

Figure 2: Renewal in Tactical Communication

protects the military. It is used in UHF band for aeronautical mobile traffic.

- **MUOS:** waveform is used by terminal and manpack radios in software-defined radios (SDR) to provide narrowband communication in UHF band.
- **WNW:** is a waveform designed to provide network connectivity between aircraft and ground vehicles BLOS. It is used also for SDR which provides connectivity to command posts at company, platoon and battalion level.

C. Lines of action for renewal

New military missions with more complex tactical scenarios require requirements that the conventional tactical radios and waveforms used so far cannot cope with. The lines of action for the renewal of tactical communications are reflected in Fig. 2. Fundamental assets such as radio and waveforms first need to be upgraded. The mentioned above classical waveforms are used with multiplexing and multiple access schemes (MAS) based on traditional resources such as frequency-division multiple access (FDMA), time-division multiple access (TDMA) or code-division multiple access (CDMA), which are limited for the high number of active elements in the current tactical scenarios. Therefore, novel Nonorthogonal multiple access (NOMA) is a promising technique which outperforms the traditional MAS and presents challenges for tactical networks. In addition, these radio and waveforms are provided for low communication bandwidths, which is entirely incompatible with the new technologies driven by 5G.

On the other hand, new scenarios, such as electronic warfare, call for new features in this type of security-focused radio. Everything points to the innate characteristics of 5G and its evolution. The refurbishment criteria are based on achieving higher bandwidths, as modern tactical scenarios exchange more data. New missions include new elements in the scenario that require interoperability between them, which requires the ability to offer scalable networks. More data brings with it the requirement for higher levels of security. Finally, in the face of new elements in modern scenarios, response times between all actors must be shortened to ensure security. The main one to be increased is the limited bandwidth problem, solved in civil communications using new spectrum bands such as THz and mmWaves. This also becomes a challenge for military equipment. New satellite communications also have emerging bands, such as Q/V and W, which require upgrading tactical radios.

III. 5G/6G TECHNOLOGIES AS POTENTIAL CANDIDATE

New wireless networks (5G/6G) bring a series of emerging technologies we can use to meet the needs identified above under the criteria network in Fig. 2. We have selected in this work a group of these technologies as shown in Fig. 3 to improve tactical communications, mainly based on providing higher bandwidth and more robust levels of security and encryption. In the following, a brief description of each is provided to contextualise their use in military environments. We emphasise that this is not an exhaustive list but only based on the criteria network established in Fig. 2. Any technical

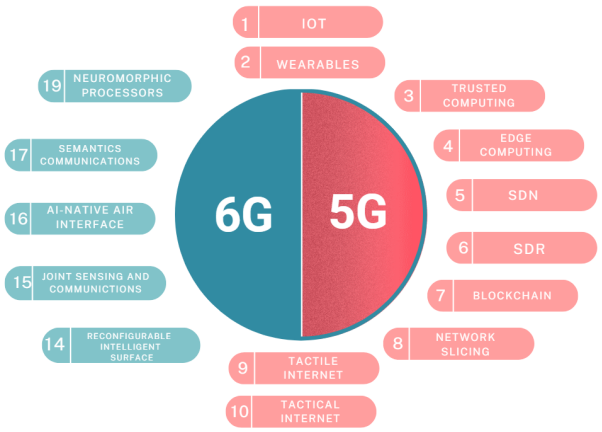

Figure 3: 5G and 6G Emerging technologies

detail can be found more in-depth in works with the direct object of said technologies in the literature. Other technologies may be included in future works.

- **Internet of Things (IoT)**: is a network of everyday physical objects connected to other device systems with IoT connectivity to collect, store and share data. The main characteristics are connectivity, scalability, power and security. There is a new term MIoT, which refers to the IoT for military applications such as weapons, robots or vehicles. Some Military Internet of Things (MIoT) applications are Military equipment logistics to facilitate efficiency, visibility and military equipment.
- **Wearables**: are devices can operate at higher speeds with fewer interruptions and cover larger areas.
- **Trusted computing:** is a technology to avoid exposing information to the enemy.
- **Edge computing**: This technology involves storing and processing data closer to the edge of a user's network and not through a centralized data centre. This is used mainly by IoT devices since they exchange large amounts of information.
- **SDN**: This technology splits the control and data plane. The primary purpose is to centrally control all network resources to optimize and automate their scheduling based on requirements.
- **SDR:** This system uses software to process various signals. It is an excellent solution that shapes more powerful tactical radios in the military field.
- **Blockchain (BC)**: This technology allows multiple users to post simultaneously through a secure algorithm in various locations without any risk of data manipulation, offering higher confidence.
- **Network slicing (NS)**: It is implemented as an end-to-end logical network. The main advantages are enhanced mobile broadband, ultrareliable high-speed data connections, low latency, and massive IoT.
- **Tactile Internet**: Adds a new dimension to human-machine interaction by enabling haptic and tactile sensations.
- **Tactical Internet**: This technology seeks to improve the efforts of the Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) with internet-based applications. Military organizations usually use this network to provide communications services that connect decision-makers with commanders.
- **Reconfigurable Intelligent Surface (RIS)**: is a new antenna of low-cost made of meta-surfaces that can reflect signals in the desired manner and has the immense ability to enhance the data transmission from the sender to the receiver. This is advantageous in a tactical scenario to avoid interference and signals coming from enemies and as an anti-jamming technique.
- **Joint Sensing and Communications (JSC)**: new waveforms can perform both simultaneous functions. This gives us new enhanced radars. Radar detects and identifies targets, while communication transmits information between assets.
- **AI-Native Air Interface (AINAI)**: describes a disruptive change to the classical way communication systems are designed, standardized, and developed. The objective is to offer an architecture with the data it needs most efficiently by considering the constraints of the available hardware and the radio environment.
- **Semantic Communications (SC)**: a new approach to only transmit necessary information relevant to the specific task at the receiver, which leads to an intelligent system significantly reducing data traffic. This offers a considerable advantage for tactical radios like the ones discussed in the previous section, as they typically have low bandwidth.
- **Neuromorphic Processors (NP)**: to computing functions that mimic the human brain with fine-grained parallel processing and real-time learning. The advantages of neuromorphic computing are supporting event-based low-energy consumption, scalable parallel processing, and combining memory and computation in a neuron unit. Tactical scenarios requiring a rapid response to threats, including a NP in the tactical radio help improve situational awareness.

In addition to the emerging technologies mentioned above, it should also be noted that advances in massive MIMO are making possible the incorporation of Non-Coherent communications [9], [10], [12], [13]. This type of communication is based on the ability to demodulate signals without the need for channel estimation. Non-coherent communications are not emerging as new technologies but have regained interest and prominence thanks to advances in new technologies. It can be very interesting for the tactical field since the ability to detect without channel information avoids interception problems or signal attacks.

A proposal of these key technologies applied to renew tactical radios is shown in Table I. The challenges for all tactical radio is the integration in IoT network and using AINAI. Regarding waveforms, SDR, JSC and NP are the candidates for new proposals.

IV. Use cases

A subset of operations and military scenarios that can be carried out on the battlefield has been selected in this work to

Table I: Association of tactical radio with emerging technologies

Tactical Radio	Technology
Land mobile radio	Trusted/Edge Computing, BC, SC, NP
PNR500	SDR, SDN, JSC, NP, RIS
RF-5800H-MP	SDN, SDR
RF-7800H-MP	SDN, SDR, RIS, JSC
AN/PRC-117G (V)1(C)	SDN, SDR, RIS, JSC
PR4G	SDN, SDR, RIS, JSC, NS
SPEARNET	NS, NP, SC, SDR, SDN Wearable

exemplify the application of some emerging technologies in tactical communications.

A. Use case 1: Combat Search and Rescue - CSAR

This scenario refers to the military rescue air operation conducted during war conditions within or near combat zones. The main operational task of the rescue is to locate, communicate and recover the aircrews shot down during combat and possible survivors. Medicalized helicopters equipped with tactical radios with limited capacity only for voice communication, low bandwidth, and GPS system. Any military tactical scenario needs reliable, secure, and fast communications. Speed up response times to locate casualties. Larger bandwidths allow more information to be sent to rescue teams.5G technology reduces latency and allows reliable connectivity and high efficiency. The IoT on the Battlefield (IoBT) allows significant technological development in military operations. IoBT uses sensors, wearables, and edge computing technology to reduce communication latency between IoT devices and manage network bandwidth.

B. Use case 2: Medical Evacuation - MEDEVAC

This scenario is based on a system of transporting wounded combatants from one location to a specialized hospital. Some of the 5G technologies that can be applied to this scenario are IoT or wearables. For example, smart clothing has sensors that can measure, for instance, heart rate or blood pressure. It is possible to monitor the health of the soldiers in real-time with so much precision and transmit this data directly to specialized doctors who can carry out a personalized follow-up so that they can be diagnosed early and evacuated as soon as possible.

C. Use case 3: Classic Voice Service Virtualization

Some services used by military troops are essential communication services (voice, data, messaging, and video). However, other value-added services require network-slicing mechanisms to provide ultra-reliable communications. Some of them are the following: Push-To-Talk (PTT), Fixed-mobile convergence (FMC), QoS, on-demand coverage, and satellite backhaul. By isolating and limiting the segments, it causes that, in the face of an enemy attack, not all the segments of the network are involved, so it provides much more protection, is much more secure, and offers less latency.

D. Use case 4: Electronic warfare

This scenario refers to using and exploiting an enemy's electromagnetic spectrum by blocking or interfering with the communications or the spectrum. They can also intercept, interrupt and decode communications to obtain information from the enemy. Currently, more and more threats are received by enemies, hence the need to cover the highest 5G frequencies (24-44GHz) due to the large capacities and faster speeds available. Blockchain technology should be highlighted in this use case as the main one since access and identity management is essential to avoid possible communication intrusion. In addition, trusted and edge computing help overcome any electronic attack. From the point of view of the application layer, the transmission of information can be enhanced by semantic communications that detect intruders and by RIS to prevent interference. The SDR technology has acquired a fundamental role in communication in any combat operation thanks to its performance and flexibility which helps Electronic warfare with multi-functional capabilities such as multiple waveforms that accept SDR, advanced cryptology and increased processing power produce better real-time communication and decision-making with just one radio.

E. Use case 5: Troop Training

Through augmented reality, the virtual world is intermingled with the real world. In the case of the military environment, for example, it is of great help to improve the ability of soldiers to detect the enemy or even obtain information from the battlefield in real-time. Significantly, the use of augmented reality for military training is essential. With the help of virtual reality glasses, it is possible to simulate a computer-recreated scenario entirely similar to the real one so that soldiers can train in an environment with real equipment they would use in their missions. Trusted and Edge Computing, Tactile and Tactical Internet are the technologies that contribute to virtual and augmented reality technology. It focuses mainly on the interactions between person-machine and machine-machine. Still, it incorporates tactile and haptic sensations to interact with the environment in real-time. It offers high availability, security, and very fast reaction time using virtual reality glasses. In addition, 6G may create a native interface based on AI to empower the bandwidth.

F. Use case 6: Situational Awareness

Situational awareness (SA) refers to having a general view of the entire environment in which a combatant or military platform is. Due to the rapidity with which battle scenarios are changing, real-time SA is necessary. JSC can help collect more information more effectively by using the same signal with radar and communication functions. This information is processed by Neuromorphic processors much faster than a conventional processor, allowing to obtain a greater amount of useful information for SA. AI may also help to reduce computing complexity.

Table II: Summary of Use Cases (UC) for tactical scenarios employing emerging technologies

# Use Cases	*5G Use cases in tactical environments*	Applied *Emerging technologies*
UC 1	Combat Search and Rescue (CSAR)	IoT, Edge Computing
UC 2	Medical Evacuation (MEDEVAC)	IoT, Wearables
UC 3	Classic Voice Service Virtualization	Network slicing
UC 4	Electronic warfare	Blockchain, Semantic Communications, AI-native interface, RIS, SDR
UC 5	Troop Training	Wearables, Tactile Internet, AI-native interface
UC 6	Situational Awareness	SDR, AI-native interface, Neuromorphic processors, JSC
UC 7	Military logistic report	IoT, Tactical Internet, AI-native interface, Neuromorphic processors
UC 8	Fire Control/Support	IoT
UC 9	Military Intelligence Operations	Trusted Computing, SDN, Blockchain, Network slicing
UC 10	Command and Control Post	Trusted Computing, Network slicing, Neuromorphic processors

G. Use case 7: Military logistic report

This UC is fundamental in army operations since it ensures the correct supply of the units' resources for their military operations. One of the technologies that have a significant impact on logistics is the IoT. These devices provide higher security in monitoring logistic processes, improve visibility in the supply chain and, above all, obtain information in real-time on the status of products and services. The tactical internet is another technology that can be of remark. These networks are used to provide communication services that connect strategic decision-makers with the commanders, which allows real-time information (provided by NP) on the status of the service.

H. Use case 8: Fire Control/Support

Fire control refers to the set of activities that use the organized use of resources by commanders during the execution of a combat task. For better combat control, fire control is an essential and fundamental element. This use case belongs to the Massive Machine-Type Communications (mMTC) communications scenario. The sensors transmit massively and real-time data at high speeds through IoT technology in complex environments, such as a combat environment.

I. Use case 9: Military Intelligence Operations

These are one of the fundamental pillars for the success of military operations. They are responsible for collecting and analyzing information about other countries' forces, plans, and military operations to discover the possible intentions of rivals and criminal organizations, thus exploiting their enemies' weaknesses and helping the commanders in orientation and decision-making. One of the technologies could be trusted computing. Since there is so much data exchange worldwide, information security must be critical; one advantage of trusted computing is to avoid exposing information to the adversary. Within this technology, SDN and blockchain are related. Thanks to the virtualization of the networks, it is possible to increase the network's security by being more robust thanks to the automation of the processes. Semantic Communication and AINAI contribute to identifying data within this type of operation.

J. Use case 10: Command and Control Post (CCP)

CCPs are facilities where military personnel plan, direct, coordinate, and control forces and operations to accomplish the mission. It is a point where large amounts of information are located. NP provide the ability to process all this amount of information, while Trusted Computing guarantees the reliability of the data. The post can also be introduced within IoT networks or in one of the Network Slicing slices.

V. Conclusions

The technology associated with 5G and future 6G networks is challenging for military communications in tactical scenarios. This work has selected and analyzed a group of leading technologies that allow tactical networks to evolve. The virtualization of networks with 5G helps to guarantee greater security. These developments are vital in improving the feasibility of truly network-centric operations for military applications. Software-defined networks, IoT, blockchain, Artificial Intelligence, semantic communications, or neuromorphic processors help increase communications performance. These technologies have improved ten classic use cases in the military field. This work is an analysis to serve as a starting point for new scientists to open up new lines of research. It is not merely a compilation but an analytical basis for future work.

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