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BSc THESIS

Applications of 5G Communications in Civil Protection

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ABSTRACT

5G networks are widely considered as one of the most fundamental technology developments of our century, providing ultra-high-speed, low-latency and scalability. Over the coming years, 5G is expected to create the wireless network capacity, performance and flexibility to support an explosive increase in connected devices, along with exciting new use cases. This innovative technology can improve the whole spectrum of everyday life from health to entertainment and from agriculture to civil protection. Mission critical Communications, the cornerstone of civil protection, are to be greatly impacted by 5G. This thesis studies how new 5G components and technologies such as augmented reality, e-health and optimized routing of ambulances are able to support the role of civil protection while enhancing the protection of the environment and the economy.

SUBJECT AREA: Fifth-Generation Network

KEYWORDS: Fifth-Generation Network, Civil Protection, Augmented Reality, Virtual Reality, Sensors, Remote Health

ΠΕΡΙΛΗΨΗ

Τα δίκτυα πέμπτης γενιάς θεωρούνται ευρέως ως μία από τις πιο θεμελιώδεις τεχνολογικές εξελίξεις του τρέχοντος αιώνα, προσφέροντας υψηλή ταχύτητα, χαμηλή καθυστέρηση και κλιμάκωση. Τα επόμενα χρόνια, τα δίκτυα πέμπτης γενιάς αναμένεται να δημιουργήσουν τη χωρητικότητα, την απόδοση και την ευελιξία του ασύρματου δικτύου για να υποστηρίξουν μια εκρηκτική αύξηση στις συνδεδεμένες συσκευές, μαζί με πρωτοποριακές εφαρμογές. Αυτή η καινοτόμος νέα τεχνολογία μπορεί να βελτιώσει όλο το φάσμα της καθημερινής ζωής από την υγεία στην ψυχαγωγία και από τη γεωργία στην πολιτική προστασία. Οι κρίσιμες επικοινωνίες, ο ακρογωνιαίος λίθος της Πολιτικής Προστασίας, θα επωφεληθούν σε μεγάλο βαθμό από το 5G. Η παρούσα εργασία μελετά πώς νέα στοιχεία και τεχνολογίες του 5G όπως η επαυξημένη πραγματικότητα, η ηλεκτρονική υγεία και η βελτιστοποιημένη δρομολόγηση ασθενοφόρων μπορούν να υποστηρίξουν την Πολιτική Προστασία ενισχύοντας παράλληλα το περιβάλλον και την οικονομία.

ΘΕΜΑΤΙΚΗ ΠΕΡΙΟΧΗ: Δίκτυα πέμπτης γενιάς

ΛΕΞΕΙΣ ΚΛΕΙΔΙΑ: Δίκτυα πέμπτης γενιάς, Πολιτική Προστασία, Επαυξημένη πραγματικότητα, Εικονική πραγματικότητα, Αισθητήρες, Απομακρυσμένη Υγεία

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ALGORITHMS

1. INTRODUCTION

Civil protection is a comprehensive emergency communications service, including an incoming and an outgoing part. As for the incoming part, the citizen can call an emergency phone number (112 in Greece) in any case of emergency, anywhere in Greece or the European Union (EU). As for the outgoing part, every citizen can be notified through various means and communication channels of a threatening or ongoing catastrophic event or dangerous situation that poses an immediate threat to his/her life, health, or safety and receive instructions to take self-protection measures [1].
The state of emergency in civil protection occurs in the event of a physical accident and large-scale technological disaster in the population and infrastructure. Sometimes the available services are not sufficiently available locally, regionally, or in a national level. In these cases, emergency remedial measures are required for a while, as defined in the institutional framework, by the administration's guidelines instructions, circulars, and regulatory acts regarding the designation of areas in an emergency. Any specific issues not included in the above are regulated by the minister of citizen protection and the respective co-competent minister's joint decision [2].
Emergencies generally include earthquakes, landslides, forest fires, floods, severe weather, volcanic eruptions, industrial accidents, and Chemical, Biological, Radiological and Nuclear (CBRN) incidents. The disaster management community demands greater efficiency and adequate communication and coordination throughout the disaster management life cycle, including emergencies.
The concept of communication during an emergency includes all those actions needed to make an informed and organized group of people aware of the seriousness and the danger of the situation. The procedure aims to notify the involved and general public to remain calm and aware of the impending threat or disaster. Proper communication must be fast, reliable, up-to-date, and aimed to avoid making a situation worse due to not making the appropriate decisions. In such complex cases, immediate, high-speed, and essential communications are deemed necessary, in order not to repeat the mistakes of the past, where there were serious communication problems between e.g. police and fire brigades, as they had no access to video or audio during the critical hours of the fire.
Public Protection and Disaster Relief (PPDR) wireless communications refer to wireless applications designed for public safety and civil protection. The national authorities or stakeholders will be able to use these technologies to respond to emergencies. At the same time, commercial mobile broadband networks will help conduct critical communications once they are made to comply to the appropriate legal and regulatory frameworks.

1.1 Purpose of study

The purpose of this study is to assess the feasibility of using 5G technology for Civil Protection. The emergency services provided today are outdated and in need of constant improvement. In addition to enabling a two-way communication between the authorities

and citizens, these services will evolve to such an extent that they will include new applications such as the intercommunication among first responders, forecast emergencies and more effective disaster response. Moreover, it is envisioned that the mobile network will act as a communication line for vital issues in cases of general emergency [1].
Such an example is the case of natural disasters, in which 5G should be able to provide robust communications. Many types of communications (e.g., voice, text messages) are required from people in the disaster area. Survivors should also be able to report their whereabouts/presence so that rescue teams can locate them as soon as possible. Low energy consumption both at the grid and the end user side are critical in emergencies, while at the same time the network should be able to support such situations for extended periods.
The application of 5G technology in civil protection is underway in many of the EU Member States. The overall project will include the field of public safety, security, and technology rescue (5G PPDR). The goal is to improve incident management. 5G will provide in most cases, extremely high bandwidth, heavy connectivity, and therefore the future infrastructure will serve a wide range of applications and areas, including emergency situations. This will improve efficiency, making the reaction time faster and as a result save more lives [3].

1.2 Structure of study

The rest of the document is structured as follows:
Chapter 2 presents the 5G networks, their historical evolution, which targets they will help accomplish as well as the innovative applications that will be used to support civil protection.
In chapter 3, some applications of 5G networks are presented, namely Augmented Reality (AR), sensors and remote health monitoring.
Regarding AR, an extensive presentation of this technology is being conducted, as well as an analysis of possible scenarios to help the coordination between first responders. Regarding the sensors applications, after a brief description of the innovations that can be used, an algorithm found in the recent literature [4], that can optimize routes of UAVs in critical missions, is presented and analyzed extensively. Finally, after a description of remote health monitoring and assistance, an optimized route for ambulance transfer via 5G is studied.
Chapter 4 concludes the thesis by summarizing the technologies and applications that will support civil protection in the near future.

2. 5G NETWORKS: KEY COMPONENTS AND RELEVANCE TO CIVIL PROTECTION

This chapter explores the background and context of 5G, highlighting its historical development to date, presenting a description, and providing an overview of its digital developmental map.

2.1 Historical evolution of wireless networks up to 5G

The current transition to a new generation of mobile telecommunications came from creating new needs such as lower latency and higher speeds [5].

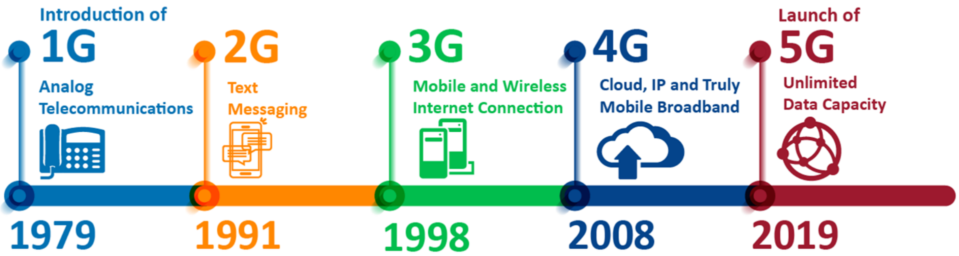

Figure 2.1: The evolution of 5G [6]

- **First Generation (1G) 1981 – Nordic Mobile Telephone (NMT) launch.** The first mobile systems were based on analog transmission. They had a low traffic density of one call per radio channel, poor voice quality, and they used insecure and unencrypted transmission, which led to the spoofing of identities.

- **Second Generation (2G) 1991 – Global System for Mobile (GSM) launch.** The second generation of mobile systems was based on digital transmission with several standards (GSM, ERMES, CT2, CT3, DCS 1800, DECT). Today, GSM communications is the most popular standard, using the 900MHz and 1800MHz frequency bands. GSM mobile systems developed digital transmission using Subscriber Identity Module (SIM) technology to authenticate a user for identification and billing purposes and to encrypt the data in order to prevent eavesdropping. The transmission uses Time Division Multiple Access (TDMA) and Code Division Multiple Access One (CDMAOne) techniques to increase the amount of information transported on the network. Each operator must cover the whole area or have agreements to permit roaming [7].

- **Second to Third Generation Bridge (2.5G) 2000 – General Packet Radio Service (GPRS) launch.** The introduction of GPRS is seen as an extra period of mobile networking development, between 2G and 3G. GPRS is a data service that enables mobile devices to send and receive e-mails and picture messages. It allows very high operating speeds of up to 115kbit/s, which have been increased to a maximum of 384kbit/s by using Enhanced Data rates for Global Evolution (EDGE). Typical GSM data transmission rates reached 9.6kbit/s.

- **Third Generation (3G) 2003 – First UK 3G launch.** The third generation of mobile systems unifies different mobile technology standards. It uses higher frequency bands for transmission and Code Division Multiple Access to deliver data rates of up to 2Mbit/s to support multimedia services voice, video, and data (MMS). The European standard is Universal Mobile Telecommunication Systems (UMTS). Mobile systems continue to use a digital transmission with SIM authentication for billing systems and data encryption.
  Data transmission uses (Wideband Code Division Multiple Access (WCDMA), one technique to achieve data rates between 384kbit/s and 2048kbit/s. Some 3G providers use Asynchronous Transfer Mode (ATM) for their 'over the air' network with Multiprotocol Label Switching (MPLS) or IP for their backbone network.
  Mobility, like in 2G, prohibits seamless roaming across heterogeneous access networks and routing domains. The transmission band frequencies are between 1900 and 2200 MHz.

- **Fourth Generation (4G) 2007.** It is based on an ad hoc networking model with no need for a fixed infrastructure operation. Ad hoc networking requires global mobility features (e.g., Mobile IP) and connectivity to a global IPv6 network to support an IP address for every mobile device. Seamless roaming in heterogeneous IP networks.

2.2 Transition from 4G to 5G

The transition from 4G / LTE networks to 5G was an evolutionary process and not a process that aims to implement 5G. Initially, providers need to start by upgrading their network management tools. The investment is repaid immediately in the existing 4G / 3GPP Long Term Evolution (LTE) networks, making them more flexible, facilitating the development of services, and preparing the fixed-mobile convergence in the future at a later stage of the network. Management and Orchestration (MANO) is a Network Function Virtualization (NFV) framework for managing and orchestrating network operations and other software components. The MANO architecture facilitates the development and interconnection of services, as they are independent of the exclusivity of physical devices and move to virtual machines. Because network components can be deployed quickly in virtual environments, the MANO architecture can reduce operating costs, Operating Expenses (OpEx), by managing and orchestrating computing resources, storage, networking, and virtual network functions such as routing, firewall, and load balancing.
Today's standard Gi-LAN is a complex combination of physical devices, each of which implements a single network function, for example, the Carrier Grade Network Address

Translation (CGNAT) or the Application Delivery Controller (ADC). Network providers can add value to current 4G / LTE networks and prepare for the transition to 5G by integrating some of these features into a single firewall. The development of a converging firewall dramatically reduces latency and simplifies the management of Gi-LAN in order to reduce Capital Expenditure (CapEx) and Total Cost of Ownership (TCO). When considering Gi-LAN integration, it is crucial to choose a solution that has the flexibility to be deployed in many versions. An optimal strategy is to use Gi-LAN on a physical device and then transfer the bodily functions to the hardware or virtual agents.

2.3 Overview of 5G

The 5G networks are the future backbone of society and the economy, as they will connect many different systems. According to the latest research [8], the 5G network will be able to offer connections faster than the current ones. 5G is designed for millions of devices constantly connected. 5G connections will be high-speed, very stable, as they will support even more concurrent users and devices, serving them at speeds much higher than those of 4G.
The important thing that 5G will bring is the minimization of the delay with which the devices communicate with each other, dramatically increasing the response time and improving the network user experience. The use of high-frequency communication bands range can offer maximum speeds up to 10Gbps and will drastically change everyday life. One of the advantages of 5G is that the rate will not be reduced when multiple users are connected to one cell simultaneously, whereas this is not the case with 4G.
5G is also able to support multiple and separate parts of the network at the same time, instead of keeping only one extensive network. In other words, it will support multiple virtual networks simultaneously, giving users the best possible quality of experience. The 5G network can adapt immediately to manage each need that arises individually, whether it is a car's automated reaction that requires close to zero response time in order to avoid an accident or a remote surgery that requires absolute precision.
A key factor for successful emergency operations is reliable communication and access to critical information in real-time. A new perspective on 5G broadband networks, the new radio access technology New Radio (NR), will be used to support communication, aiming at public safety and saving lives in emergencies.
The civil protection community will use specialized Land Mobile Radio (LMR) systems for Push-to-talk (PTT) as the primary mobile communications system. TETRA and P25 are the predominant PTT systems in use. These narrowband communication systems can only provide voice-over services with limited data capabilities. As it is known that different institutions typically use various networks (frequencies and technologies), communication between organizations can be challenging to coordinate.
The old public telecommunications networks require modernization to improve security, awareness of a problematic situation, and operational efficiency for first responders. A global trend today is for LMR systems to be replaced by 3GPP (3rd Generation Partnership Project) LTE / NR broadband networks to support more advanced use cases and

critical deployment services such as real-time video, AR, and head-up displays. Fast and reliable voice communications must be guaranteed between social actors and across national borders. Life monitoring data from security sensors must be communicated directly to command centers show as to enable better, more immediate, crucial, and more effective decisions to save lives. Robots and drones with augmented reality and tactile technology will be able to be controlled remotely from the network for real-time video streaming, serving for complex rescue operations.
Enhanced Mobile Broadband (eMBB) services are supported by existing 2G to 4G networks, but with improved performance and a seamless user experience for coverage and mobility. The eMBB will initially be an extension of existing 4G services and be among the first 5G services. Regarding eMBB, 5G is expected to offer three features: a) Higher capacity: Broadband access should be available in densely populated areas, both indoors and outdoors, such as city centers, office buildings, or public spaces, such as stadiums or conference centers. b) Improved connectivity: Broadband access must be available everywhere to provide a consistent user experience. c) User mobility is not what enables broadband services to vehicles, it is the need. It provides service for connected devices with sensitive latency, such as factory automation, autonomous driving, industrial internet, smart grid, or robotic surgeries. Ultra-Reliable Low Latency Communications (URLLC) services meet specific latency, availability, and reliability requirements. URLLC technology is supported by the 5G New Radio (NR) standard defined by the latest release (Rel-17), 3GPP as shown in Figure 2.2.
Massive Machine Type Communications (mMTC) provide connections to many devices that periodically transmit small amounts of data. It is a new category of 5G services that can support a high connection density of electronic devices [9]. Table 2.1 presents the use of these technologies in the automotive industry, health, energy, public safety, and especially in critical civil protection domains [10].

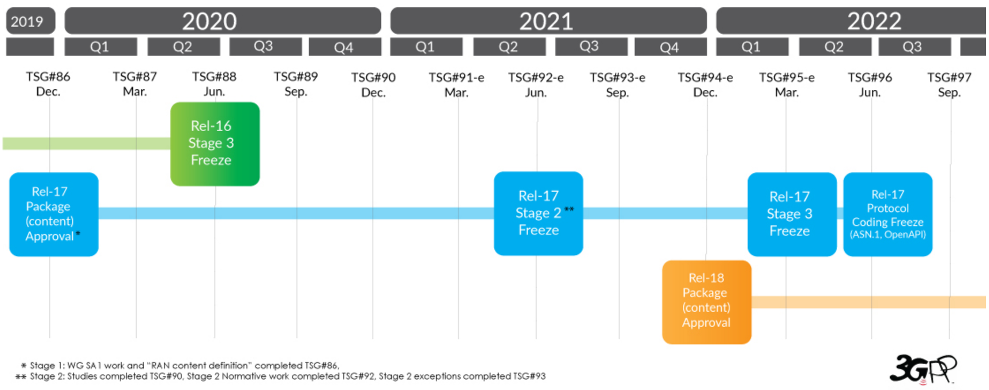

Figure 2.2: The timeline of 3GPP Release 17 [8]

Table 2.1: The uses of eMBB, URLLC, mMTC technologies in various industries [11]

Industry	eMBB	Massive MTC	URLLC
Automotive	Telematics (Entertainment)	Telematics (nonrelated to entrainment)	Self-driving and safety use cases
Health		Remote monitoring of health and wellness. Asset management and intervention management in hospitals. Smart Medication	Robotics and emergency care management.
Energy	Infrastructure and asset management (drones and video)	Advance Metering Use cases. Infrastructure and asset management (remote monitoring)	Grid Management and Automation
Transport	Broadband connectivity through WIFI access in transportation.	High-resolution video/mobile TV-based applications.	Asset tracking and fleet management Self-driving truck/bus
Public Safety			Rapid Disasters response. Public event Management. Critical Asset Protection. Remote Area Coverage.
Manufacturing	VR/AR mobile equipment	Asset monitoring and fleet management, Predictive Maintenance, and Data collection.	Automation, remote operation, and control.

Two examples of technological innovation that will make possible the aforementioned services are Network Slicing and Network Function Virtualization (NFV).
5G network slicing is a network architecture that enables the multiplexing of virtualized and independent logical networks on the same physical network infrastructure. Each network slice is an isolated end-to-end network tailored to fulfill diverse requirements requested by

a particular application.
NFV is the ability to instantiate network functions in real time at any desired location within the operator's cloud platform. Network functions that used to run on dedicated hardware for example firewalls and encryption at business premises can now operate on software on a virtual machine. NFV is crucial to enable the speed, efficiency and agility to support new business applications and is an important technology for a 5G ready core.

2.4 5G Advanced to act as stepping stone for future 6G networks

5G Advanced is expected to enhance 5G to its full capabilities and is an important stepping stone for some of the use case capabilities that the industry wants to enable at a larger scale in the 6G era.
With 5G-Advanced, AI/ Machine Learning (ML) will be introduced to many network parts at many layers and in many functions. From optimizing beamforming in the radio layer to scheduling at the cell site with self-optimizing networks, AI/ML is envisioned to achieve better performance at lower complexity. As far as 6G Networks are concerned, it is expected that AI/ML techniques will be solidified as core properties of the system, rather than mere enhancements. This clean slate approach will allow AI/ML algorithms to optimize the communication between two endpoints of the network.
5G-New Radio will expand cellular telecommunications beyond just data communication and substantially improve range and speed, while decreasing latency and error rate, especially for indoors and underground facilities where satellite signals are unavailable. 6G will take localization to the next level by taking advantage of broad spectrum and new spectral ranges up to terahertz.
According to the potential features of future 6G networks, the digital, physical and human world will seamlessly fuse to trigger extrasensory experiences. One of the most notable aspects of 6G will be its ability to sense the environment. The network will become a source of situational information, gathering signals bouncing off objects and determining type and shape, relative location, velocity, and perhaps even material properties. This sensing network would open the door for many new services. In outdoor environments, the network could detect all vehicles and pedestrians' location, speed, and trajectory in an area, issuing warnings if any of their paths are about to intersect. The network could detect if a vulnerable person has fallen on the floor at work or home, alerting emergency responders about possible trauma. These will be done with higher levels of network security and cyber-resilience and with Communication Service Providers (CSPs) continuing to act as a trusted party.

2.5 5G in Civil Protection

Threats can evolve rapidly, and first responders face increasingly dangerous conditions when called upon to keep citizens safe. Both first responders and their communities deserve modern services with all capabilities and applications of current technology. When firefighters, law enforcement officers, and emergency physicians have improved protection and accurate awareness of the situation, they can better protect citizens and themselves and provide more effective services, as shown in Figure 2.3 [12].

With the development of 5G Information and Communication Technologies (ICT) systems, it is vital to look at how broadband networks and network-enabled technologies can maximize public safety and synchronize critical information on time, which is crucial to saving human lives. At the same time, it must be borne in mind that correspondents need not only ”smarter” but also more user-friendly devices and technologies to increase their concentration and accelerate their action [13].

The key innovations that 5G introduces derive from the ultra-high speeds, low latency and massive connectivity option it offers. The changes that 5G will bring to the utilization of smart devices and the widespread use of new applications lead to its characterization as an independent and dominant component of the next technological revolution. Things that until now seemed utopic will soon be part of everyday life. Autonomous driving and the widespread use of telemedicine (even with robotic applications) are just two examples of the future of applications on these networks. This will mark a new era for rescue operations, services and the improvement of people’s daily lives.

5G will provide civil protection with multi-agency cooperation and interoperability mechanisms (such as police, fire brigade, medical units, etc.), a supportive regulatory environment where first responder priority is given, advanced services (such as UAV, mobile nodes, robots, etc.) and interoperability with other technologies (such as TETRA, 4G / LTE).

5G’s role in civil protection is about continuous connectivity under any circumstances. Typically, stakeholders develop a well-thought-out and optimized network development plan based on the population density in an area. However, in disasters and emergencies, the cellular coverage and capacity provided by the network in a particular geographical location may not be sufficient. In such a case, additional means are needed to support a credible and effective aid mission [12].

To ensure coverage and capacity of first responders beyond residential areas, where services are generally not available for simple equipment, many network coverage extension solutions have already been implemented in the current version of 5G NR (Rel-17). They can be applied to critical mission services. These coverage and capacity solutions will continue to evolve to include improvements and new features in future NR versions (Rel-17 and beyond).

In areas with limited coverage, telecommunications operators can apply advanced antenna systems and NR-supported beam modulation techniques to increase signal strength in a specific direction to serve better communication needs in an area. The built-in wireless access feature introduced in the NR Rel-17 is also a good candidate for flexible network coverage to ensure the protection of citizens. In the future, network operators will be able to build flexible, temporary networks by placing nodes on land-based emergency vehicles, referred to as mobile nodes, and communicating with Unmanned Aerial Vehicles (UAV) to cover isolated areas [15].

When not covered by the network, the secondary communication, defined in NR Rel17, is crucial for first responders in facilitating direct communication between devices.

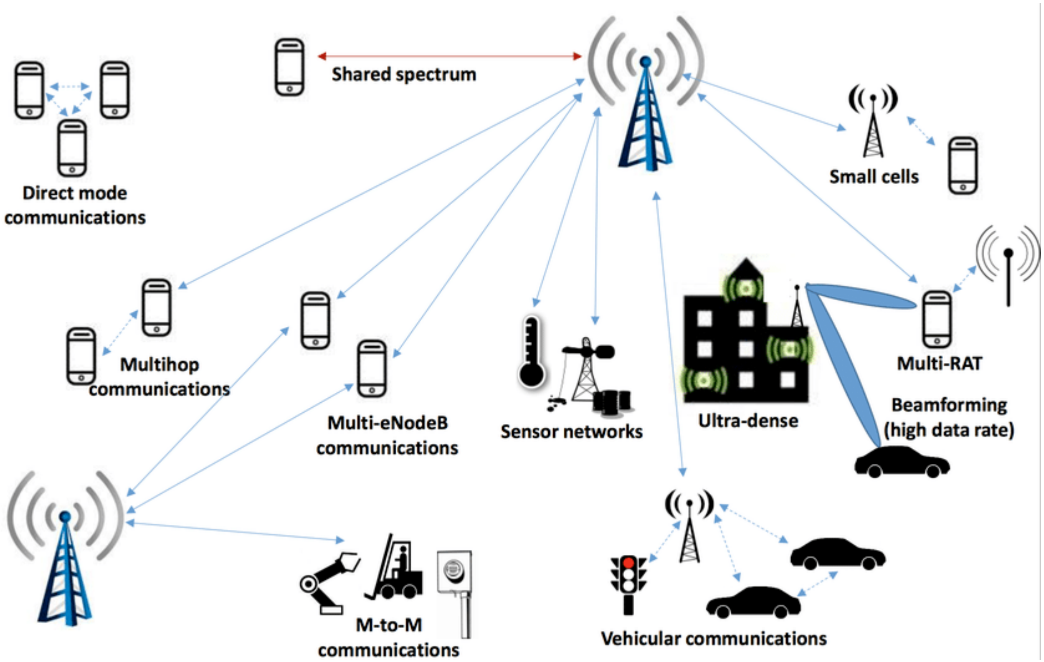

Figure 2.3: 5G network architecture in public safety [14]

Another useful function of 5G concerns the automated traffic control system and driving in case of emergency. Advanced safety applications will be able to reduce road accidents, improve car traffic, and support mobility for emergency vehicles (e.g., ambulances, fire trucks). These applications will provide numerous possibilities for communication between cars or cars with headquarters and between road users, such as pedestrians and cyclists. An application such as controlled vehicle group driving will require extremely low end-to-end delays for specific warning signals and higher data rates for video-to-car information exchange between cars and centers. 5G should provide the required high reliability, low latency, and high scalability features [16].

5G will offer another significant innovation in emergencies. As far as autonomous vehicles are concerned, the advent of 5G is expected to take their role to the next level. A vital parameter of the operation of driverless cars is the ability to send and receive commands and process data in a short time. While these cars moving between people and other vehicles, should be able to communicate directly with all systems, something that can not be done en masse with today's methods. With 5G, these obstacles are eliminated.
A first responder in an ambulance moving in the streets of Athens should be equipped with a virtual reality helmet (headset), which transmits real-time video images to a doctor waiting at the hospital. The response time between what the responder and the doctor see is almost zero, allowing them to offer crucial and effective care to the patient or the injured, thanks to the 5G network service explicitly dedicated to their needs. The doctor will be able to remotely guide the nurse to perform ultrasound examinations. Also, in the ambulance, a camera transmits to the physician a high-definition video stream of the procedure. Combined with the live stream of information obtained from the patient's scans,

the physician can recognize the patient's acute symptoms and read his/her medical history in real-time, offering a vital service [17].
Finally, another notable feature of 5G will be the warning of cities in case of an earthquake. With the 5G network, an alarm signal can be sent faster than the arrival of the seismic wave, ahead of the seismic vibration. Thanks to the 5G technology, the seismic activity is closely monitored. The residents of the earthquake-affected area are notified in time and immediately take care of their safety (e.g., timely evacuation).
Some features of 5G technology are shown in table 2.2.

Table 2.2: 5G network features [18]

Specification	Targeted values	Measurement unit
The maximum possible transmission rate in the DL direction	20	Gbps
Average transmission rate perceived by users	100	Mbps
Spectral performance	4 times that of 4G	Bps/Hz
Network delay	1	ms
Device density	106	Devices/km2
Energy efficiency	100 times that of 4G	Bit/Joule
Motion density	10	Mbps/m2
Speed of communication in moving UEs	Up to 500	km/h

Critical communications are currently covered by the commercial networks of cellular providers, which are not designed for this purpose. This results in the unreliability of the existing media of the emergency teams. Therefore, the need to modernize Critical communications with the help of the New Generation 5G broadband networks becomes urgent.
These new generation networks provide a continuous connection to the Internet for all staff members' devices and additional surveillance enhancement devices in the areas where a disaster/emergency occurs (UAVs, drones, robots). Augmented reality helmets/headphones, etc.), network coverage in isolated areas (using mobile nodes and beam configuration), high bandwidth available at high frequencies targeted by the 5G network ($>$ 20GHz), and almost zero latency.
Consequently, the 5G networks allow direct and reliable communication between the

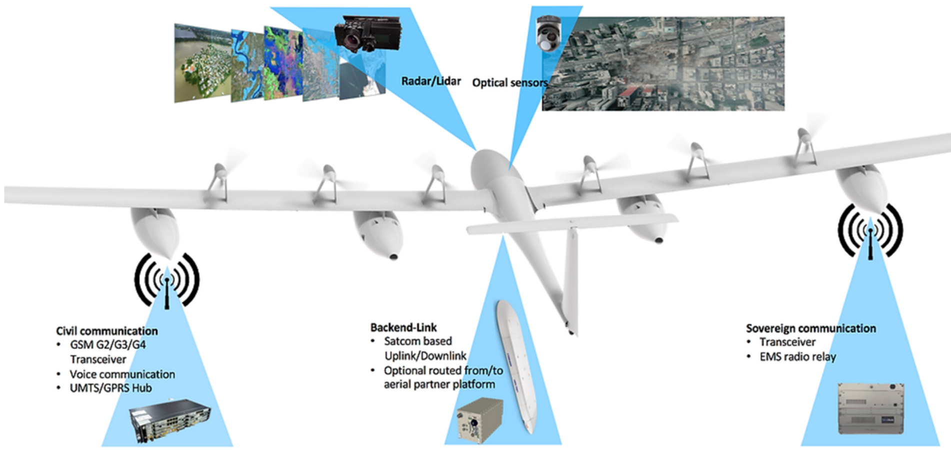

Figure 2.4: Common Rules for UAV Operation in civil protection [19]

members of the civil protection staff, whether they are at the site of the disaster (First Responders) or the headquarters of the civil protection command center, collecting information, analyzing it and coordinating the disaster management process. This communication is crucial for the successful management of the emergency (e.g., rescuing people trapped in a burning building) at the lowest possible cost (casualties, property damage) and enhancing the victims' safety.
The security of first responders is ensured by clearer monitoring of the situation, by extracting valuable results from the analysis of the collected data, as well as by combining real-time data with historical data (i.e., data derived from the experience of previous corresponding emergencies), but also with data from the Electronic Medical Record of the first Responders. All of the above aim at designing the optimal crisis and hazard management strategy by the first Responders, with the least possible risk to their safety.

2.6 Comparing the differences between Wi-Fi 6 vs 5G

5G and Wi-Fi 6 are the latest wireless connectivity technologies. They're both remarkable advances that will greatly enhance connectivity for consumers, but 5G is better suited technology for civil protection.
Many differences between Wi-Fi 6 and 5G come from the contrast between their innovation types, which is the most eminent differentiation between Wi-Fi 6 and 5G. While 5G is a cell innovation, Wi-Fi 6 is Wi-Fi, an adaptation of WLAN innovation.
For Wi-Fi, associations use equipment from specialist organizations for web network. Regarding cellular networks, cell pinnacles and small cell coverage provide connectivity to associated end users.
Cellular technology is carrier-based, which is also true for 5G technology. This means operators exclusively operate cellular networks on licensed spectrum bands, which are

meant to prevent interference between connected devices. On the other hand, Wi-Fi operates in unlicensed bands that don't require permission to use.
Cell innovation is transporter based, which is likewise valid for 5G innovation. This implies administrators only work cell networks on authorized range groups, which are intended to forestall obstruction between associated gadgets. Then again, Wi-Fi works in unlicensed groups that don't expect authorization to utilize.
Concerning cell access, this is straightforward and simple for associated gadgets to acquire, in light of the fact that cell networks don't have similar verification necessities as Wi-Fi organizations. Be that as it may, 5G likewise utilizes a few confirmation types, which incorporate 5G validation and key arrangement, Extensible Authentication Protocol (EAP)- AKA and EAP-Transport Layer Security to reinforce 5G organization security.

Table 2.3: WIFI vs LTE/5G

Wifi	Private LTE/5G
Low coverage per Access Point (typical 80m/max 250m)	High coverage per Access Point (typical 500m/max 15km)
Small number of active connections per AP	High number of active connections per AP
Spectral performance	High number of AP required
Best effort	Reliable QoS
Possible interference	Dedicated spectrum
Medium security	High security
Unreliable latency	Predictable latency
Limited mobility	High-speed mobility

	4G	5G	WIFI 4/5	WIFI 6
Latency	3	4	2	3
Data throughput per area	3	4	3	4
Connection density	3	4	1	3
Reliability (Mobility & Load)	3	4	2	2
Penetration	2	1	3	1
Range (coverage)	4	3	2	2
User experience data rate	3	4	2	4
Security (incl. Anti Interference)	3	4	1	2

1 – low 2 – medium 3 – high 4 – very high

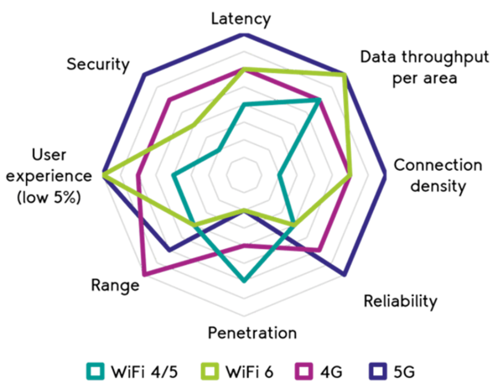

Figure 2.5: WiFi vs LTE/5G - Qualitative rating [20]

LTE/5G are future-proof technologies supporting civil protection.

2.7 Effective communication of first respond teams

First responders usually work in teams, and communication within their teams is essential for effective coordination during an emergency. Services such as group messaging and emergency messaging Mission-Critical Push-to-Talk (MCPTT) allow individuals to communicate within their teams and coordinate their actions in the best possible way for a meaningful and immediate result. A feature of these services is that they reduce the communication coverage in order to serve more groups of first responders. In this way, a standard data set can be transmitted to all users within a group.

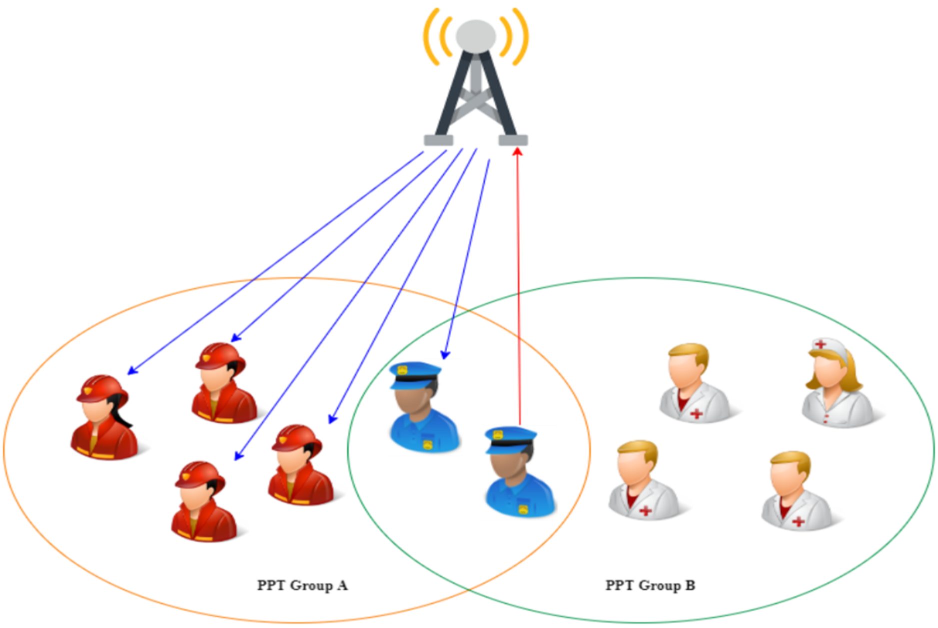

Figure 2.6: Group communications for first responders services [21]

Considering these services and benefits, an enhanced Multimedia Broadcast Multicast Services (eMBMS) framework has been created to provide efficient group communications over LTE networks, and a multi-distribution and transmission framework for activating similar functions is being developed in 5G NR Rel-17.

2.8 Priority and quality assurance

In a major emergency in a small area, user-generated data traffic can increase significantly, for example, by making emergency calls to friends or relatives. If rescuers and

users share the same network, first responders should be prioritized ensuring a fast connection to the network and ensuring mission critical traffic during network congestion. In some cases, different priorities are even required between first responders and mission critical services. These requirements can be met by using different NR features and functions to restrict regular users from accessing the network and different traffic management solutions for users already connected to the network.
NR has introduced a unified access control framework (UAC), which the user equipment (UE) requires in order to properly secure the core network from malicious access. Before the UE sends a specific connection request to a network, the UE will determine whether it is allowed to send the request or not. This is done by checking the transmission system information received from the network and the user or service priority information stored in the UE. In a high traffic load, the network may configure the transmitted system information to allow connection requests from first responders but exclude requests from regular users.
If a connection request is made by a user, then an access process begins, in order to establish connection with the network. The network can identify the type of service or UE access ID that triggers the connection request during this process. Using such information, the network can check the access request from each user individually and reject requests from regular users when necessary [15].

2.9 Condition awareness and operational efficiency

Awareness of the situation is critical for first responders arriving at a rescue site. This information is used to help first responders better evaluate and plan a continuous operation, achieving the certainty that they can do their job safely and efficiently.
Locating first responders or equipment used in a rescue operation is also essential. The current NR specification includes device-centric positioning solutions and network positioning solutions. First responders can share their location, signal measurements, or related sensor information with the network or other first responders. Additionally, the 5G network can provide instant placement support, for example, by transmitting link Placement Reference Signals (PRS) or counting by audible Coupling Reference Signals (SRS). Utilizing some of its key features and specifications, the 5G NR can enhance network deployment capabilities. More accurate localization can be achieved by utilizing the wide bandwidth available in high-frequency bands and the beam modulation detection instruction. In addition, the use of the mobile node allows for the flexible deployment of additional temporary base stations near a rescue area. By adding additional communication links to a first responder, these additional base stations can help further increase the accuracy of the positioning services provided by the network, enhancing state awareness and thus their more efficient operation.

2.10 Impact of 5G Key Features on UAVs

In conjunction with remote systems, UAVs contribute to setting up mobile bandwidth hubs quipped with GPS, to backup First Responders (e.g., Firefighters) in real-time. To that end, UAVs could use a smarter Radio Access Network (RAN) architecture, no longer limited by the proximity of the base station or complex infrastructure. Some of the technology enablers that support 5G networks and impact the use of UAVs are:

- **5G Spectrum and Frequency**
  UAV connectivity for 4G LTE has been already widely studied and 5G NR has substantially higher capabilities. Several frequency ranges are devoted to the current 5G radio (NR). Millimeter wave frequencies are defined between 30 GHz and 300 GHz, and can provide high throughput and low latency communication between the UAV and a remote command center. Communication within the mmWave groups and other transmissions over 6 GHz have risen as a central component of the 3GPP Fifth Era (5G) NR standard due to their colossal potential but can be ineffective for long-distance communication. In this way, in densely populated zones, sub-6 GHz frequencies are repurposed for 5G, which can be utilized for empowering long-distance independent Beyond Visual Line-of-Sight (BVLOS) UAV missions. UAV network for 4G LTE has as of now been broadly examined, and 5G NR has significantly higher capabilities.

- **Beamforming**
  Modern deterrents for 5G broadcasting communications are the particular characteristics of UAV frameworks, such as three-dimensional space nimbleness and the significant scale, weight, and control imperatives. To enhance the capability of signal reception in UAVs, a beamforming technology is required and 5G offers this advantage. 5G Multiple Input Multiple Output (MIMO) clusters with thousands of small receiving wires combined in a single arrangement can be utilized to assess the foremost compelling transmission way to each end-user unit (e.g., UAV).

- **Multi Access Edge Computing**
  5G NR employs advanced physical layer topologies that essentially diminishe the inactivity of the Radio Access Network (RAN), which, when combined with Multi-access edge computing (MEC) capabilities, enables the interface to attain exceptionally low latency. As an advancement of cloud computing, MEC is a crucial element of the infrastructure that takes apps from centralized data centres to the Edge network, which means closer to the end user, offering advantages such as low latency, high bandwidth, and real-time access to Radio Access Network (RAN) information. Besides using 5G for communicating with drones, the Drone Pilot will be hosted at the MEC; hence guaranteeing very low-latency communication. Moreover, the softwarisation of the pilot and the offloading of it at the edge of the network, alleviates the UAV from additional energy consumption, providing an energy-efficient UAV variant.

- **Network Function Virtualisation (NFV) and Software Defined Networks (SDN)**

Another enabler for 5G is NFV which separates the functions that typically run in hardware and implements them as software such as switches and firewalls, and sends them as virtualized occurrences within the 5G architecture, usually at its edge, utilizing the MEC infrastructure. In the UAV industry, the virtualisation process affects various components that are offloaded from the UAV, such as the pilot and the C2 components. NFV usually couples with SDN, which introduces support for dynamic programmability of network nodes enabling the separation of control and data planes.

- **Network Slicing**
  The concept of network slicing allows for multiple virtual networks to simultaneously run on-top of a shared physical network infrastructure. In order to meet the performance of different networks and devices, such as sporting activities, festival parties, etc., 5G embraces three types of new scenarios, URLLC, eMBB, and mMTC. Therefore, network slicing is one function that is particularly interesting for the UAV. It makes a secure slice of aerial vehicle control independent of contact with payloads, such as video streaming to the ground.

As specified by 3GPP, the new 5G Network Core uses a cloud-aligned Service Based Architecture (SBA), as Figure 2.7 depicts, that covers all 5G functions and interactions, including authentication, protection, session management and end-user traffic aggregation. It also emphasizes NFV, with virtualized functions deployed using the MEC infrastructure, as an integral design principle. The 5G core network's main objective is to isolate the control plane from the data plane by building it as a network feature.

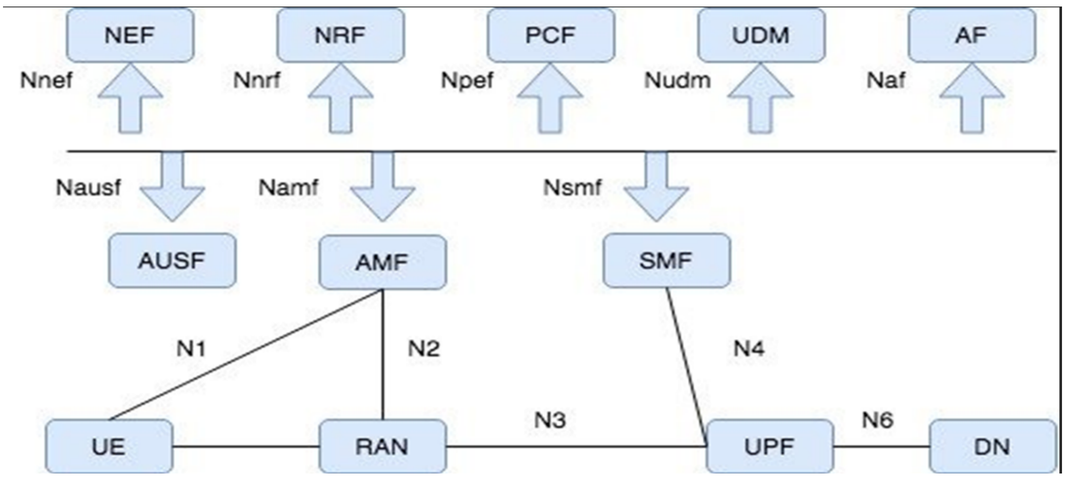

Figure 2.7: 5G Reference architecture [22]

In order to achieve effective and more scalable network slicing, another important principle is to eliminate dependencies between the Access Network (AN) and the Core Network

(CN) and modularize the function architecture. The following key Network Functions (NFs) are part of the 5G core network architecture:

- Access and Mobility Management Function (AMF) is responsible for access control and mobility.
- Session Management Function (SMF) configures sessions according to policy.
- User Plane Function (UPF) manages and forwards users' data traffic.
- Authentication Server Function (AUSF) handles the authentication.
- Policy Control Function (PCF) handles policy and charging rules.
- Unified Data Management Function (UDMF) integrates subscriber information for both fixed and mobile access in the NG core.
- Network Slice Selection Function (NSSF) supports the selection of a Network Slice instance.
- Network Repository Function (NRF) provides NF service registration and discovery.
- Network Exposure Function (NEF) handles the exposure of capabilities and events.

3GPP has implemented a reference model for UAS in 3GPP TR 22.825 based on 5G Core SBA, as shown in Figure 2.8, where a UAV (treated as an end-user device) can be controlled remotely either directly or through the network, i.e., allowing Beyond BVLOS control by a UAV controller. In terms of coverage, authorization, monitoring and Quality of Service (QoS) support, UAVs can then leverage the benefits of the 3GPP scheme. In addition, the 3GPP framework allows UAS Traffic Management (UTM) to communicate with the UAS and allow approved tenants to query UAV identity and UAS meta-data, e.g., public safety agencies.

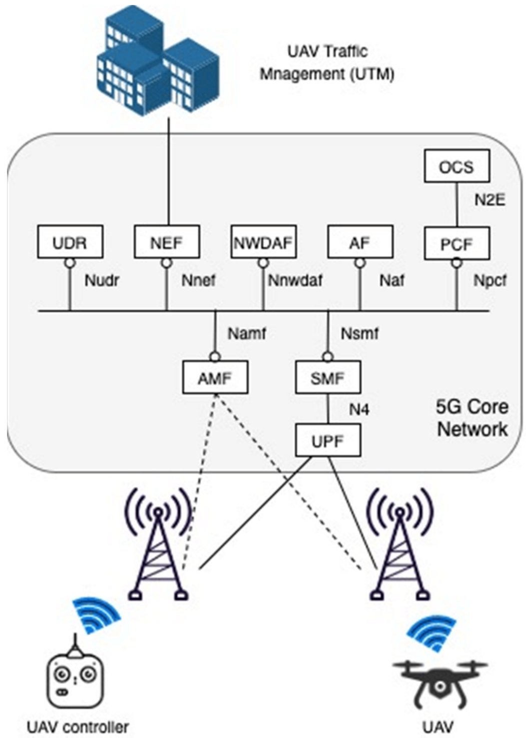

Figure 2.8: The UAV reference model in 5G [22]

The Service-Based Architecture (SBA) is expected to further boost support for UAV facilities, including UAV navigation and air traffic control, weather forecasting and UAV connectivity management.

3. 5G APPLICATIONS

3.1 Augmented Reality Applications

Augmented reality is the direct and indirect viewing of a physical environment in real-time, augmented by elements reproduced by computer devices, such as audio, video, graphics, or location data. Augmented reality can support many different application areas, such as education, entertainment, and medicine, with more recent applications optimizing critical awareness. As the prevention and proper management of natural and artificial disasters plays a crucial role in saving human lives, the availability of embedded and ”smart” portable computer systems opens new routes in managing land and infrastructure by civil protection bodies. A powerful processor, camera, motion sensor, Global Positioning System (GPS), and solid compass enables civil protection to perceive critical and dangerous situations faster and act immediately and effectively. AR permanently changes industrial development, production, and business processes: from automotive design development to aircraft engine virtual representations and conflict investigation. AR systems could also be helpful in training and preparing first responders to engage in search and rescue operations in areas critical to Public Safety, such as medicine, air traffic control, firefighting, etc. These complex operations include dealing with emergencies, such as evacuating buildings, fire or landslides, etc. [23].

3.1.1 The evolution of augmented reality

The term augmented reality refers to the addition of virtual information to the environment that humans perceive through their sensory organs using appropriate devices. In this process, the real world is not degraded. On the contrary, it is a combination of the world as humans perceive it and information produced by a computer; therefore it is amplified or ”augmented”. AR enables the user to see virtual objects and real time information, mixed with natural elements [24].

In general, any system that combines the virtual element with the real one can interact in real-time and is placed in three dimensions, can be considered AR. Thus, with AR technology, the experience of the physical world is enhanced. It does not create a different and fragmented environment that replaces the real but adds information to it, which we can process [25].

The early 2000s saw the increasing adoption of advanced technologies for consumer entertainment. Technologies that directly contact the user in its natural environment were adopted, such as interactive screens, visualization, and adaptation of online products, digital signage, etc. Among these technologies, augmented and virtual reality applications, increasingly used in glasses, projectors, and fixed interactive screens, are evolving faster.

In the struggle for economic prosperity and sustainable development worldwide, digitization is fast becoming a new engine of economic growth. A successful 5G network deployment across Europe is a prerequisite for this European digital transformation. 5G provides the essential infrastructure for creating "smart" cities, which will push their demands to the limit. Low latency and extremely high reliability are critical for Internet of Things (IoT) applications, such as intelligent sensors, which produce large volumes of data.

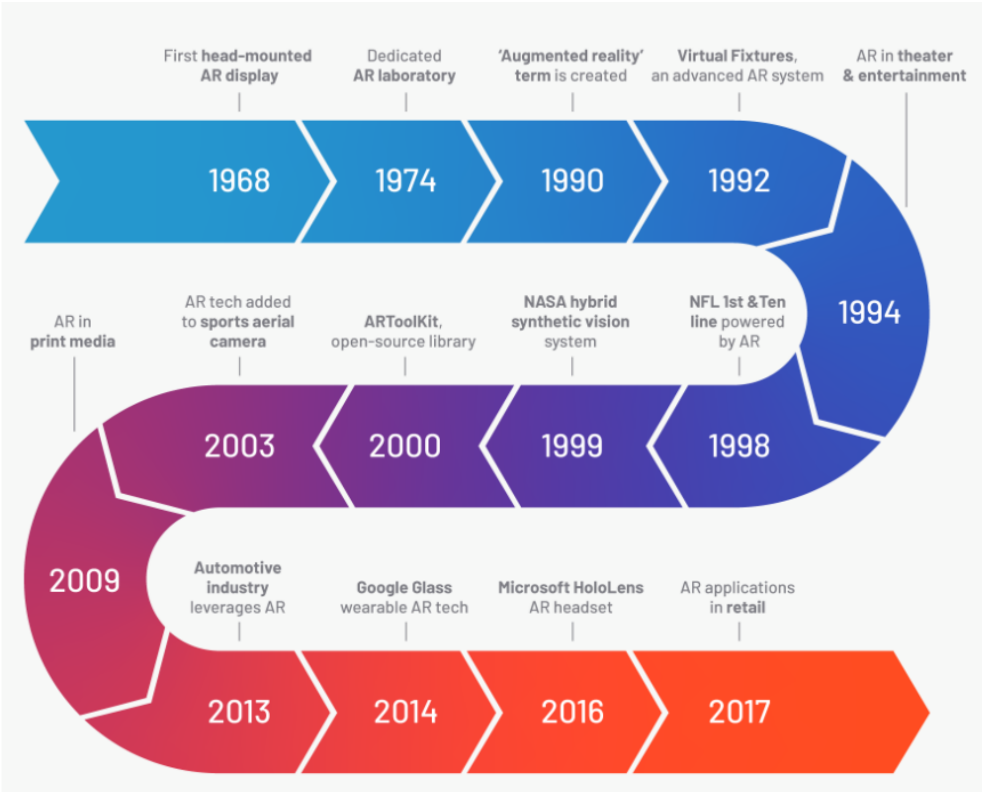

Figure 3.1: Augmented Reality Timeline [26]

Imaging devices are essential for augmented reality as they are the ones that will present to the user the individual results and the information that will be requested [27]. There are three main categories: Head-Mounted Displays (HMD), Handheld displays, and Spatial Augmented Reality (SAR devices).

- **Head-Mounted Displays**
  A head-mounted display is worn on the head or as part of a helmet with a small display optic in front of one (monocular HMD) or both eyes (binocular HMD). An HMD has many uses, including gaming, aviation, engineering, and medicine. An optical head-mounted display (OHMD) is also a wearable display that can reflect projected images and allow users to see through it.
  The video devices are based on cameras, videotaping the natural world and combining video with additional graphic information. The result is displayed in real-time in front of the user's eyes through the screens.

Figure 3.2: Google glasses with eyeglass frame [28]

- **Handheld displays**
  The Handheld displays are small size devices which help the user enhance the surrounding environment by holding them in his/her hands. The main feature of these devices is the built-in camera through which the natural environment is captured in video. All the information can be added to the current video before being presented to the user. To accomplish this process, portable imaging devices use a variety of sensors, such as digital compasses and GPS for detection sensors. There are three categories of commercially available portable imaging devices: the widely used smartphones, the rarely used Personal Digital Assistants (PDAs), and Tablet PCs.

- **Spatial Augmented Reality**
  Spatial Augmented Reality is named as such because it creates images by using extensive optical data aligned in space. Such components are mirror beam combiners, transparent holograms, radio frequency tags, and video projectors. The spatial representations can be applied to more than one user and enable the collaboration between them. This is because spatial indications distract most of the technology from the user and integrate it into the environment. Virtual information is displayed directly on the actual objects, and the user is free from wearing or carrying devices [31].
  There are three categories of AR spatial imaging, depending on how they enhance the environment:

  – the use of video-optics (video see-through)

  – the use of optics (optical see-through)

  – and the direct augmentation.

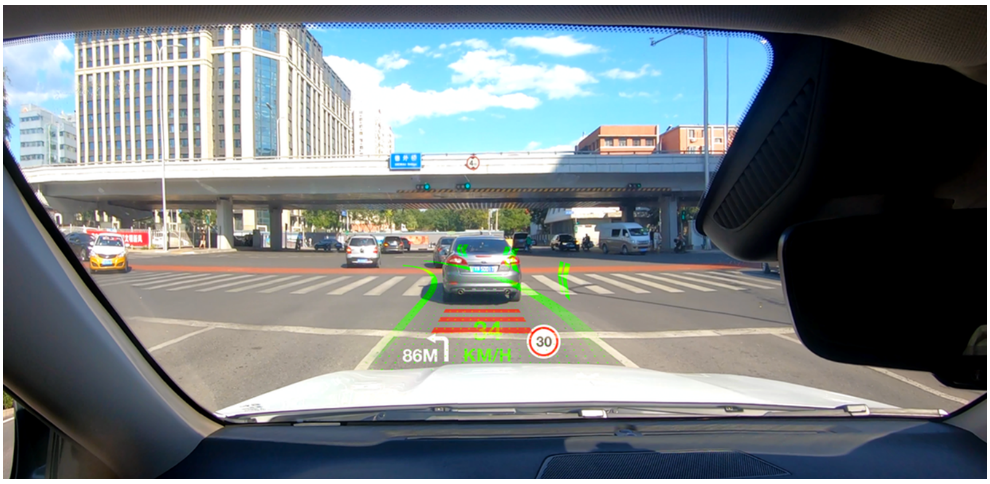

Figure 3.3: Car with head-up display [29]

Screen-based video see-through uses video blends, and the merged images are displayed on a regular screen.

This type of augmentation is common in cases where mobile application support or visual boost is not required. Also, it is a very cost-efficient approach to AR since the necessary equipment for its implementation is limited to premade hardware and an ordinary computer. On the other hand, in screen augmentation, the user's visual field is proportional to the screen size and, therefore, limited. Another disadvantage of video-optical technology is the limited resolution of the image, both of the virtual objects and the natural environment.
Unlike wearable and portable optical imaging devices, spatial-visual see-through displays produce images aligned within the natural environment using spatial optical combiners, such as mirror or beam combiners, transparent screens, or optical holograms. This augmentation facilitates the adjustment and convergence of the eyes, enables higher and scalable resolution, more accessible and more stable calibration, resulting in a better-controlled environment for tracking, tracking lighting, etc. As for the disadvantages of the method, the spatial visual representations do not support mobile applications, or the occlusion between real and virtual environments. In addition, the interactive manipulation with virtual and real objects behind the optical combiners is prevented. Finally, the limited size of screens and visual combinations causes "window violation," meaning virtual things outside the display area show an abnormal cut.
Projection-based spatial displays use front-facing projection to project images directly into the surfaces of natural objects smoothly. This is achieved by using a variety of projectors such as single, static, or directional, and multiple projectors, the diversity of which increases the possible imaging range and enhances the image quality. Projective spatial representations show improved ergonomics, the theoretically unlimited field of view, scalable resolution, and more effortless adjustment of the eyes - because virtual objects are presented close to their actual position in the

Figure 3.4: Smartphones and Augmented Reality [30]

environment - in contrast to wearable imaging devices.
Augmented reality systems will revolutionize how rescuers have access to more and better information during their training and operations to know their environment better, analyze the data they receive more accurately, and make fast and vital decisions.
Augmented reality devices are still at a relatively early stage. As technology and social ethics evolve, augmented reality will likely face new challenges in complying with current regulations (legal and ethical) and maintaining a seamless user experience.
For example, there is a possibility that the expectation of privacy may be an obstacle to the adoption of specific applications of AR technology, such as the placement of AR cameras on glasses, the AR helmet, etc.
While the AR helmet was created, it was not widely used by early responders. However, 5G can provide significant support for AR tools that first responders can use.

Once 5G technology is established, emergency responders will be able to provide more effectively services and work more efficient in case of a disaster. Existing 4G LTE and Wi-Fi networks are slower and less reliable. A significant problem is the congestion of the network due to the vast amount of data that these technologies produce and exchange, especially during emergencies when everyone is using their phones. Once 5G is established in all systems, it will be feasible to connect a variety of devices and allow the various tools to use the direct information to make quick and correct decisions.
Regarding future goals of augmented reality, the U.S.A. National Institute of Standards and Technology (NIST) is looking for ways to create augmented reality user interfaces that will receive information from smart buildings, city sensors, and staff screens to provide first responders with real-time awareness of a critical situation. The challenge combines two

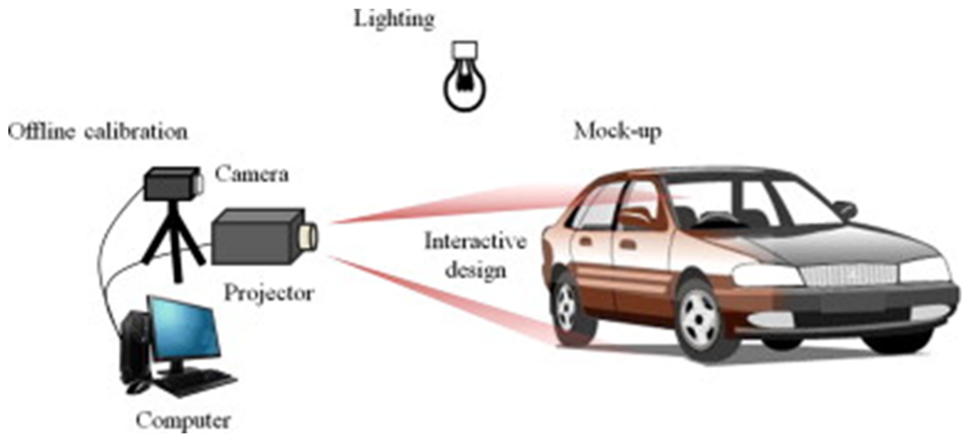

Figure 3.5: Spatial augmented reality for product appearance design evaluation [32]

related technologies, IoT and AR, and seeks data flow to provide information for decision making and resource development in fires, floods, active shooting situations, and tunnel collapses. Systems must provide support to both commanders and field correspondents. Stream simulations will receive information from intelligent city networks necessary for emergency scenarios, such as the threat's exact location, air quality, temperature, etc. The best streams will be the primary input of the system for the creation of AR interfaces, as they will contribute to the improvement of the original augmented reality interfaces - head-up screens and holograms - in collaboration with the Civil Protection service.

3.1.2 AR technology in Status Awareness

The effectiveness of emergency response depends on proper communication and administration of different types of agencies, because only one of them is not able to successfully manage critical situations. This escalation, complexity, and heterogeneity prevent central management from achieving Common Operational Picture(COP) among many cooperating correspondents, hindering the optimization of crisis management [34].
Control centers need to coordinate actions between correspondents with different perceptions of the same incident, such as a firefighter and a police officer, but without always being aware of the timeliness and accuracy of the information collected by each correspondent. Thus, the above control centers are limited to covering critical situations due to a lack of rules and means of cooperation, which jeopardizes the possibilities of early assessment, security, risk mitigation, and crisis management and, instead, the difficulty of effectively dealing with large and complex disasters.
More specifically, powerful and portable 4G / 5G critical communications networks and applications can be made available to facilitate continuous voice communication and data exchange between commanders and first responders. In addition, first responders will have access, in real-time, to essential data sources, such as video from self-driving vehicles, drones, medical records, biosensor data from wearable sensors, contamination level

Figure 3.6: Firefighter helmet with AR technology [33]

data, and victim identification information, and the detection of objects to improve their mode of action and achieve the best possible result. As more data becomes available, combined with AR / Mixed reality (MR) intelligence and accurate indoor/outdoor tracking technologies, AI algorithms will analyze this data to extract meaningful information, easily assimilated during a threatening and challenging situation. In addition, an effective COP will help first responders prepare and further raise awareness of their problem without detaching their focus from the project.
The main goal of civil protection is to optimize efficiency and security for first responders, introducing a common technological and conceptual framework for maximizing situational awareness in terms of enhancing capabilities for early detection, safety assessment, and mitigation of risk, together with straightforward COP and optimal management of businesses in any scale and complexity of disasters.
The shared awareness of the situation from different bodies and services will be promoted by integrating other technologies (sensors, monitoring subsystems, manned and unmanned systems, early warning systems, communication systems, satellite systems, and integrated systems) with different organizational cultures the groups involved.
The convergence of the next-generation ICT systems will allow a rapidly evolving network of wirelessly connected devices to coexist and communicate. In addition to the rapid development of the network itself, the various applications for Civil Protection and status awareness, such as critical communications, intelligent vests, AR / MR services, UAV coordination, and remote operations, will also increase. These applications are expected to enrich the operating environment with an evolving intelligence that can help rescuers, ultimately transforming the way they interact with their environment. In this regard, the capabilities of 5G next generation networks will contribute to more effective protection of the public and rescuers.

The benefit that is expected to arise, in addition to the significant networking with bod-

Figure 3.7: Example of how AR technology could be applied for an improved situation [35]

ies that manage natural and technological disasters and the exchange of knowledge and experiences, will be the knowledge of new innovative tools of awareness of the situation in case of disaster or crisis, the utilization of digital 3D measuring models, the use of an uncrewed vehicle with fixed wings ”fixed-wing drone,” with the possibility of adopting a camera for aerial photos that form the basis for the export of orthophoto maps and measuring 3D models, as well as the use of portable level measurement systems, river speed, etc.

Emergency preparedness is an essential element of emergency management and involves designing appropriate responses to dangerous events. Dealing with such conditions, such as the evacuation of interiors of buildings, is critical to the effective management of the search and rescue operation. Early correspondents often cannot accurately perceive the situation, which will allow them to understand the layout of a building as they enter it. Emergency plans must be communicated to both the occupant of the building and the first responders in a timely and accurate manner to protect public safety. The technology of modern smartphones offers a platform through which first responders can provide 3D representations that maintain the topology of built-in multilevel spaces by adding the environment that allows the individual to understand better the evacuation plan of buildings and the available exits.

3.1.3 Augmented reality in equipment

The future lifeguard will be staffed by COP augmented reality equipment that will be integrated into the uniform, boots, and helmet, enhancing operational skills and allowing the immediate assessment of the level of risk and severity of the emergency. Rescuers today are faced with high-risk challenges that complicate their work. Communicating automatically and quickly with the administrative centers can provide critical minutes of an effective and coordinated response to the crisis. The ultimate goal is to save more people with less risk for first responders.

Each country could develop a civil protection strategy in response to the need for international community assistance to deal with disasters. It aims to protect people, their environment, property, and cultural heritage in a significant natural or artificial disaster. A prerequisite for achieving this goal is the continuous awareness of a threatening situation so that there is a timely response. Then, the main goal is to utilize state-of-the-art technologies to provide humanitarian assistance, improve the experiences of fundamental problems and offer in the advance perception of the situation and timely warnings to the first responders. The AR tools of the control center operators will allow them to access and interact with an augmented world in real-time, as shown in the image below [36].

Figure 3.8: Use information from the control center [37]

For example, the Commander will be able to add, remove, and move real/virtual objects and manipulate them multiple times using speech commands or enhanced gesture control. Augmented reality tools will go beyond existing technology to optimize the AR experience and provide a more reliable connection between the real and virtual environments. To further enhance the quality of the experience, the augmented reality framework will support a program to measure the user's physical performance and vital signals, which is expected to lead to the highly realistic and well-integrated audiovisual performance of synthetic objects. Particular emphasis will be placed on practices that will reduce the cognitive burden of first responders to ensure that the volume of information provided regarding the physical world does not exceed the user's ability to handle it.

In terms of user interface (UI) and user experience (UX), a dynamic approach should be considered that allows the visualization elements to be adapted to both the needs of first responders (e.g., control center, first respondents), as well as the available devices (e.g., AR headphones, AR glasses, mobile phones, etc.). By using augmented reality solutions, the information will be displayed in 3D, allowing rescuers to:

- observe the whole area with an elevation camera
- use first-person visualization.

Visualization, among other things, will provide 3D navigation instructions and information. Augmented reality glasses will be a great help to rescuers because they will enable them to identify more clearly and more directly people and objects under the rubble in case of earthquakes or trapped in case of fire or flood. In addition, the correspondents will be equipped with a portable device that will allow video recording, with a navigation system for providing location information, a head-up screen, and a wireless network connection. The glasses currently in use is the most economical platform with these features.

Figure 3.9: Use AR technology from the first correspondents [38]

The visualization of the information from the AR glasses will provide the correspondents with training scenario information through an open screen of open listening. This will allow correspondents to visualize the route they have taken and insert virtual ”beacons,” which will indicate important locations or objects in the environment. In addition, it will enable coordinators to offer real-time guidance as needed, guiding the first responder based on the suggested search pattern. Coordinators will also be able to streamline the training scenario at any time to introduce the appropriate challenges.

Another important aspect of first responders state awareness (SA), based on AR, is related to Wearable, Augmented Reality Displays (WARD). These devices provide instant access to real-time information to support decision-making. The effects of using WARD on operator performance, SA, and communication in a critical security system such as maritime transport. Closed-loop communication and information exchange have improved threat avoidance, suggesting that operators can avoid accidents or failures through WARD uptake that promotes information sharing and verification.

Figure 3.10: Augmented reality use by the fire brigade [39]

Augmented reality capabilities will provide new solutions for training first responders, building evacuation, navigation, and full WARD integration into critical security systems. Unlike traditional perspective rendering systems, they will significantly improve the realism and quality of the experience, allowing for a personalized and customizable second virtual screen (or projection) for each operator. Finally, perhaps the most essential possibility that augmented reality will offer in critical situations is that, in optimizing the experience, it will allow rescuers (e.g., firefighters) to access and interact in an augmented world in real-time.
The enhanced world will include scene metadata on a state-of-the-art status map, layered, and allow the user to be guided and interact in various ways with sensors and colleagues. For example, the rescuer will be able to add, remove and move virtual objects and manipulate them using speech commands or enhanced gesture control with natural tactile feedback. This exciting augmented reality space will allow security professionals to optimize their time observing network activity and potential mitigating threats, providing a more precise framework to compare different objects in the real world.

3.2 Sensors Applications

Civil Protection personnel is active in preventing and responding to natural, technological and other disasters or emergencies, based on the relevant planning by risk management. The contribution of this personnel has two main tasks; to minimize the negative impact of the catastrophe and to repair the damage caused.
It is therefore understandable that civil protection personnel is often confronted with dangerous situations, the management of which requires particularly delicate handling, but also specialized tools, which contribute to the more effective management of emergencies, as well as to ensure its safety.

These tools relate to direct and reliable communication technologies between the various members of a civil protection group and text, voice, image, or video data from multiple sources (drones, mobile nodes, sensors, GPS, etc.).

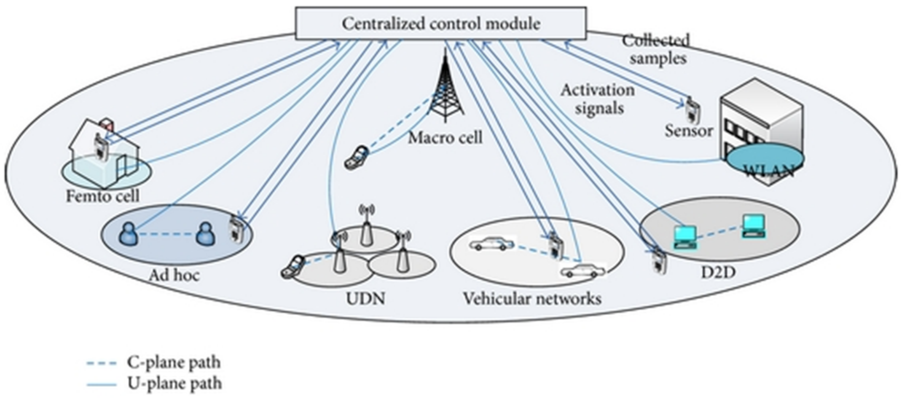

Figure 3.11: Sensors deployment and signaling in 5G heterogeneous wireless networks [40]

Communication between Civil Protection staff and the collection and transmission of data requires very low delays, continuous flow, high reliability, and constant availability. These requirements can not be covered by the existing 4G networks of the Mobile Telephony Providers, which will show more and more delays with time and the exponential growth of Internet users. In addition, new challenges are emerging, such as extending network coverage to isolated areas and the need to split the network into specialized, virtual networks to provide the best possible management of increased Internet traffic (connection requests) [41]. It is becoming clear that the requirements of critical civil protection communications go beyond the limits of the fourth generation network, paving the way for the integration of the unlimited possibilities offered by the new fifth-generation web (5G New Radio).

3.2.1 Overview of Sensors

Sensors convert physical information into an electrical signal. Some physical quantities usually measured with sensors are temperature, position, and displacement of an object, fluid level (essential for floods), speed and acceleration of an object, force, fluid flow, voltage, current, humidity, radiation, etc. Sensors collect information (data) from systems and control systems. They are used both in everyday objects, such as the buttons of an elevator (touch sensors), and in very specialized things, such as robots that perform remote surgeries.

They measure data that people and services need to deal with daily practical problems. The need to deal with complex issues, such as natural disasters and the evolution of technology has given a significant impetus to developing sensors. Future advanced sensors are expected to emerge from nanotechnology and biotechnology research. The main

features of the sensors are accuracy, fidelity, and calibration. The operator's digital representation of measurement is objectively provided, indicating much greater accuracy than the analog one. Also, digital recording enables the operator to analyze better and edit the information data.
The use of sensors is necessary for cases where excellent monitoring of the space/situation is required, such as in the case of automatic operations (telesurgery, remote driving, etc.), because they offer the possibility of an exhaustive analysis of the environment, collecting many and various data at any time.
Therefore, combining the information obtained from appropriate, each time, sensors, with the ability to collect, transfer and analyze real-time data offered by 5G networks, can ensure the enhancement of critical PP communications and, of course, the security of its staff [42].

3.2.2 Use of sensors in Civil Protection

The extraction and sorting of diverse and multidimensional data in a dangerous situation or emergency, such as those often encountered by IP personnel, plays a crucial role in understanding the situation. Optimal response strategy is the one that minimizes, as much as possible, the negative impact of this situation (victims, injury of First Correspondents, material costs).
Data that help enhance the security of first responders are collected from both sensors and other devices. These devices must be portable or can be easily carried by the first responders, and also small and light so as not to impede their movement. Specifically, flexible sensors or ”smart” devices (watches,helmets, glasses etc.) are integrated into first responders uniforms or vests or attached to their skin.
The wearable sensors used are biometric sensors that can analyze blood or sweat, measure heart rate, blood oxygen saturation rate, and identify the potential physical inability to complete the work in progress [43].
Wearable systems can monitor groups in difficult situations that are particularly dangerous to their health, such as first responder groups. For such a system to be worn successfully, many specifications must be met both by itself and by those directly involved. More specifically:

- Be light and comfortable.
- The energy consumption should be low, and the energy sources that supply the system should be contained.
- The cost should be small and manageable.
- Be simple to use.
- Be safe for the user's health.

- Have a built-in alarm processing and activation capability and maintain a seamless connection with a medical reception center 24 hours a day.
- Ensure total connectivity (telemonitoring, tele-activation, tele-off, remote operation control) [31].

Figure 3.12: Sensors in the suit of the firefighters [44]

In addition to the wearables, temperature, location sensors, Chemical, Biological, Radioactive, Nuclear, and Explosive detection sensors (CBRNE) are installed on UAVs and drones. The drones can conduct research in inaccessible areas and in dangerous weather conditions, without affecting the safety of first responders and without risking the loss of life. In addition, sensors that perform various measurements, such as measuring the amount of residual oxygen in an oxygen device, can be used as equipment to protect rescuers.
Also, there is the possibility of autonomous mobile robots, equipped with real-time sensors, to be included in the critical missions, undertaking the transport of valuable equipment, so as not to burden the first responders, exploring the environment to identify potential dangers, preserving the safety of first respondents, and assist survivors trapped in inaccessible places. Also, 360° thermal cameras mounted either on helmets or UAVs, drones, and robots can collect useful data.
The augmented reality components of the first responders' equipment help clarify the vision of the FP personnel located in the critical area, offering them, for example, visibility through dense smoke using high-speed thermal cameras and filtering the environment. They remove the non - helpful and annoying elements (sirens, fire, water, screams), keeping only the useful information for the first responders [45].
One of the bigger challenges faced by the first responders in natural or manufactured disasters is the immediate and effective response rate they must show to locate survivors

within the critical 72-hour time frame. These conditions carry a high risk due to unbalanced factors and as a result many people put their lives in danger.
A protective suit, which rescuers will use in dangerous and challenging conditions, such as fires, floods, earthquakes, and landslides. This garment will combine microtechnologies, telecommunications, and textiles, resulting in:

- Constantly monitoring the vital functions of the first responders (respiration, blood circulation).
- Monitor bio-sensors for sweat, stress, and body temperature.
- To monitor the posture of the body and its activity.
- To detect chemical and toxic gases outside.

With this outfit, the rescuers, whose missions are characterized by difficult conditions with significant physical and psychological strain and increased stress levels, can simplify and reduce the difficulty of their work and return safely to their base. Figure 3.13 shows a first responder of the future, who will be equipped with AR glasses, ”smart” environmental sensors, and health sensors, connected to a 5G/6G network.

Figure 3.13: The next generation first responder [46]

”Smart” sensors are a combination of microprocessors using operating systems to connect to other sensors and perform measurements continuously. Intelligent sensors, using unique algorithms, can be organized on their own within smart grids, with the lowest power consumption, performing various functions. They are cheap, but also quite sensitive. They can be used by the tens or even the hundreds, creating a new scientific instrument for measuring and recording. At the same time, they are smart enough to automatically find the ”shortcut” to communicate with other sensors.

3.2.3 Use of 5G network for transfer, data analysis, and communication

All of the above would not be possible without the assistance of Artificial Intelligence (AI) and the capabilities offered by the 5G network. The amount of data collected by the various sensors, ”smart” devices, and augmented reality equipment requires capacity (bandwidth) and speeds much higher than those offered by the existing 4G network to be transferred and processed in real-time. The Real-time data analysis is very important in critical situations, so the on the spot decision-making must be done promptly and reliably.
Wearable systems are essential in fires, earthquakes, and floods. A wearable system should collect vital data (respiratory, cardiac) in real-time, before, during, and after an activity. Teams, such as first responders that perform dangerous and challenging activities, will be served by this system as it can help department managers determine if and to what extent their development staff is at risk. While the coordinator monitors the collected data from first responders by the wearable system, he/she can raise an alarm if any data exceed the safety limits.
Therefore, in critical situations, the transfer and analysis of the collected data require a 5G network. Connectivity is ensured through a fifth-generation portable telecommunications system with coverage of dynamically adaptable UAVs and drones, which offers extensive range even in isolated areas. Drones and UAVs are part of a heterogeneous communications system consisting of the aforementioned portable telecommunications system and the existing / fixed 5G network, with an additional connection to a back-end satellite network.
In addition to data transfer and analysis, the 5G network supports direct, continuous, and reliable communication between the various teams of Civil Protection personnel, which not only ensures the smoothness of the actions of the First Correspondents but helps to strengthen their security.

3.2.4 Awareness of the situation and support for decision making

Artificial Intelligence contributes to the analysis and synthesis of data collected by various sensors, intelligent devices, and augmented reality components to extract information important for complete situational awareness and assist in decision-making with the actions of the first respondents. The use of Machine Learning (ML) algorithms contributes to the comprehension of data and the extraction of important information through their investigation, extraction, and synthesis, which allows the modeling of the critical situation and, consequently, the assistance in keeping the first responders safe. In addition, a visual analysis of the geographical representations (Geovisual Analytics) can be take from the camera, which is present in drones and UAVs, is performed. The visual analysis provides a clearer picture of the area, risks, and challenges, facilitating decision-making.

Continuous knowledge of the exact location of First Responders can enhance their security and improve crisis management by enhancing situational awareness and decision-making. In conjunction with wireless bandwidth networks, UAVs contribute to implementing mobile bandwidth nodes equipped with GPS (”anchor nodes”) to support the First Correspondents’ positioning in real-time. The results of the data analysis are displayed on visualization interfaces with the ability to interact. They show complex and dynamic data on the various devices of civil protection personnel (mobile phones, tablets, helmets / AR glasses).

3.2.5 UAV-Based Intelligent Transportation System for Emergency Reporting

With the rapid advancement in communications, UAVs have emerged as promising enablers for the next generations of wireless networks, which open the door for the innovator and the entrepreneurs to come up with disruptive solutions and a massive number of beneficial applications. The applications of the UAV communications include[47]:

- coverage extension for communication networks after disasters,
- message relaying between IoT devices, and
- dispatching distress messages from a device located within a coverage hole to the emergency center.

Based on the outcomes of the study by “UAV-based intelligent transportation system for emergency reporting in coverage holes of wireless networks” [4], an optimization algorithm can reduce the time it takes for the UAV to send messages and the time it takes to be active in emergency situations. The contributions of [4] can be summarized as follows:

- A path loss map to model the uplink transmission of the UAV and the trajectory design and an algorithm which provides a fast solution and the best path for the UAV.
- A simulation of the algorithm and study of the performance under two different scenarios.

3.2.5.1 System Model

It is not unusual nowadays that people can find themselves in harmful and even life-threatening situations because they face a problem with their vehicles outside the urban area. They may not be able to ask for help due to unavailability of the communication services. The problems that the traveler’s vehicle may face include mechanical malfunction, battery discharging, running out of fuel, being stuck in sand dunes, failure of the GPS and many other problems.
During critical moments, victims involved in the accident may not request help from the

emergency response center. These situations can happen, for example, when the victim's vehicle is located within a coverage hole in a wireless network. These situations gave birth to the idea of an UAV to work as an automatic emergency dispatcher for a user in a vehicle facing a critical condition.
Firstly, A UAV that is stationed on a vehicle or on the ground, takes off when an event occurs. Once an accident is confirmed, the UAV checks to see whether it is located within a coverage hole or not. If it is located within a communication network, it sends a distress message directly to the emergency response center. Otherwise, it flies to a location where a communication network is accessible and sends the distress message accordingly.
Figure 3.14 , shows an application of the proposed solution [4]. First, two vehicles enter a coverage hole area where the communication service is not available. Second, an excessive change in the vehicle acceleration is detected by the UAV. Third, the UAV detaches itself from the vehicle right after the accident. Fourth, the UAV searches for the closest location with an access to a communication service once the collision is confirmed. Finally, the UAV sends the distress messages to the emergency center.

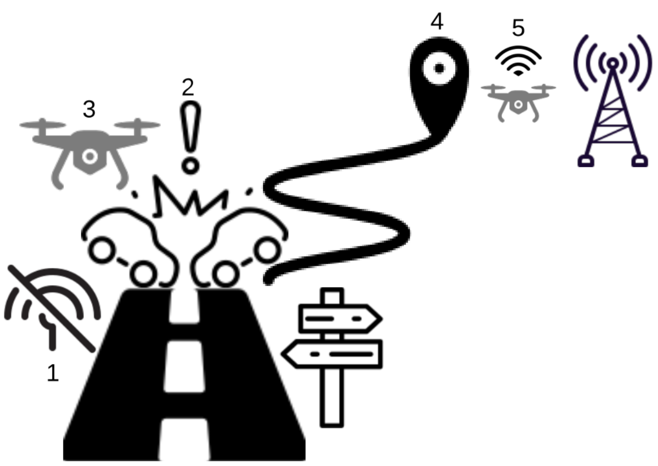

Figure 3.14: The UAV conveys emergency messages and sends them to the closest available network access point [4]

One way to support this idea is to use a path loss map for UAV trajectory design, mathematically formulated as an Integral Linear Program (ILP). This idea aims to minimize the delivery time of critical messages and the completion time of UAV missions.
As is well known, every UAV moves in 3D space to transmit distress messages and information. Therefore, there are infinite points in the 3D space that can represent all possible UAV positions during each time slot. Consequently, it discretizes the three-dimensional space, as shown in Figure 3.15.

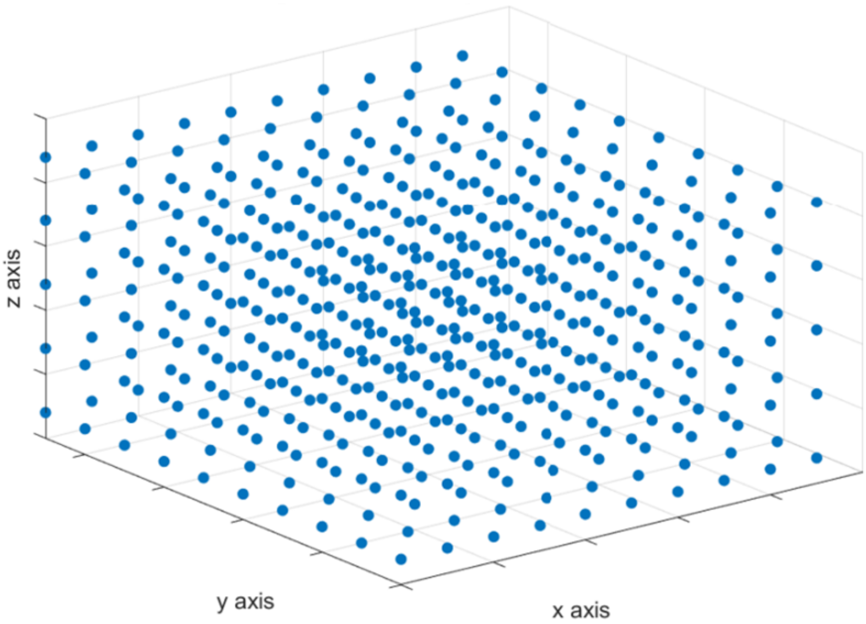

Figure 3.15: Three-dimensional path loss map [4]

A ”Road Loss Map” can be therefore defined, which is a 3D map with a set of points in a 3D space and each point is associated with a path loss value, as shown in the Figure 3.16. The path loss map consists of N points, and each point i is associated with a location on the three-dimensional space, (x_i,y_i,z_i), in addition to the path loss value.Assume, the number of access points is B, and the path loss value at any location is associated with one access point that results in the minimum path loss value.
The color of each point on the road loss map indicates the path loss value in dB, as shown in Figure 3.16 by means of a color scale.

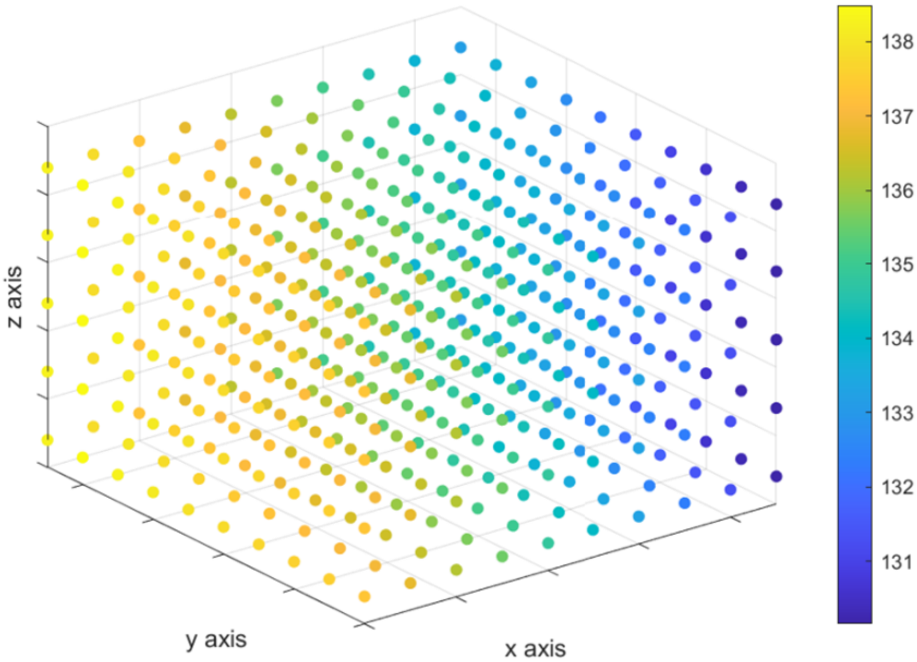

Figure 3.16: Colored path loss map indicating the path loss values (in dB) associated with each point [4]

A UAV can use the loss map to send the distress message from one or more locations with a loss value less than or equal to a limit λ. The UAV is considered to be equipped with a GPS device for navigation and flies at a maximum speed of S m/s. Flight time is set to T slots, where the duration of each slot is δ seconds. The duration of the slot includes the movement of the UAV and the data transmission time. The UAV receives a confirmation from the access point when the message is successfully received. Otherwise, the UAV adjusts its position and sends the message again. The access point receives the message sent by the UAV successfully if the message is sent from a location where the path loss value is less than or equal to λ. The optimization of the model can be done in the form of Integral Linear Program (ILP), which is known to be NP-Complete. To solve this in a polynomial time, it can be implemented with a multi-priority UAV orbit optimization algorithm, as described in algorithm 1 [4].

The first and second priority of the UAV is the delivery of distress messages and the completion of the mission, respectively, as soon as possible. The third priority is to go to its final position via the shortest route to save on UAV battery. After the completion of these three goals, the UAV can return to base.

As shown in Algorithm 1 the input is a weighted graph, G, generated from the path loss map. The graph consists of all nodes in the path loss map, and there is an edge between any pair of adjacent nodes if the distance between them can be traveled by the UAV within one time slot. The weight of each edge is the UAV flying time between the pair of nodes associated with this edge. It utilizes Dijkstra's algorithm to calculate the shortest path between any pair of source and destination nodes.

Algorithm 1 Prioritized Multi-objective UAV Trajectory Optimization [4]

1: Set $N^{current}$ to the node ID associated with accident.
2: Set N^{next} to the node ID associated with the closest location that has an access to a communication service.
3: Find the shortest path, P_1, from $N^{current}$ to N^{next}.
4: Set $N^{current} = N^{next}$.
5: $P_2 = \phi$.
6: **for** `z = 2` $\cdot \cdot \cdot$ γ `do` **do**
7: **if** $\exists n \in Neighbor(N^{next})$ s.t. $\overline{PL_n}\lambda$ and n is the closest to the final location among all neighboring nodes and $N^{current}$ **then**
8: Add n to P_2.
9: N^{next} = n.
10: **else**
11: P_2 = $N^{current}$
12: Exit the loop.
13: **end if**
14: **end for**
15: $N^{current}$ = N^{next}
16: Find the shortest path, P_3, from $N^{current}$to the final location.
17: Set the UAV trajectory path, P, to (P_1 $\cup P_2$ $\cup P_3$).

Step 1 of Algorithm 1, is to denote the location of the UAV after the occurrence of the accident by $N^{current}$.
Then, the UAV searches for the closest node in the graph associated with a path loss value less than or equals to λ.
It denotes this node by N^{next} , as shown in step 2. The UAV calculates the shortest path, P1, from $N^{current}$ to N^{next} and flies to location N^{next}. Next, the UAV starts sending its distress message to the emergency center. The UAV sets $N^{current}$=N^{next} as shown in step 4.
Once the UAV reaches to a communication network access point, it can stay there until it sends all distress messages then go to its final location. However, the UAV can reduce its mission time by jointly sending the distress messages while going to its final location. In other words, the UAV can send its first distress message at N^{next} node and send the remaining messages in the beginning of the return path to its final location. Accordingly, the UAV flies to a neighboring node to N^{next} if the following conditions are met:

- the neighboring node, n, satisfies the condition $\overline{PL_n}\lambda$ and,
- the location of the neighboring node, n, is closer to the final location.

The UAV repeats the same process to send the subsequent distress messages until all messages are sent. If the two conditions are not met, the UAV stays at N^{next} until sending all distress messages as described in steps 5–14. Finally, the UAV flies to its final location and finishes its mission. The union of the three derived paths forms the UAV trajectory, as described in steps 16–17.

3.2.5.2 Time complexity

In some steps the Algorithm finds the shortest path between a pair of points using Dijkstra's algorithm. The time complexity of finding the shortest path between two points using Dijkstra's algorithm is $O(|E| + |V| \log_2 |V|)$, where $|E|$ and $|V|$ are the number of edges and nodes in the graph, respectively. Let K be the maximum number of neighboring nodes connected to each node in the graph G. It is shown in step 7 of Algorithm 1 that the algorithm goes over K neighboring nodes to node N^{next}, in worst case, to search for the next candidate destination. This process is repeated for (γ-1) times in the worst case. Accordingly, the time complexity of Algorithm 1 is $O((|E| + |V| \log_2 |V|)K(\gamma - 1))$.

3.2.5.3 Simulation Results

Consider a UAV used as an automatic emergency dispatcher for a vehicle located at a coverage hole. Two base stations are located far away from the UAV, where their locations in the three-dimensional spaces are $(8000, 0, 20)$ and $(8000, 8000, 20)$. Based on the location of the base stations, the path loss map is derived. A three-dimensional space is used, 5000 m × 5000 m × 250 m, to model the path loss map. To study the effect of the number of points in the path loss map on the computational time, two different grid sizes are considered (1) dense grid and (2) sparse grid. The dense grid, shown in Figure 3.17, consists of 500 path loss points (10×10×5 points, with a vertical/horizontal spacing of $50/1000$ m). On the other hand, the sparse grid, shown in Figure 3.18, consists of 125 path loss points (5×5×5 points, with a vertical/horizontal spacing of $50/500$ m).

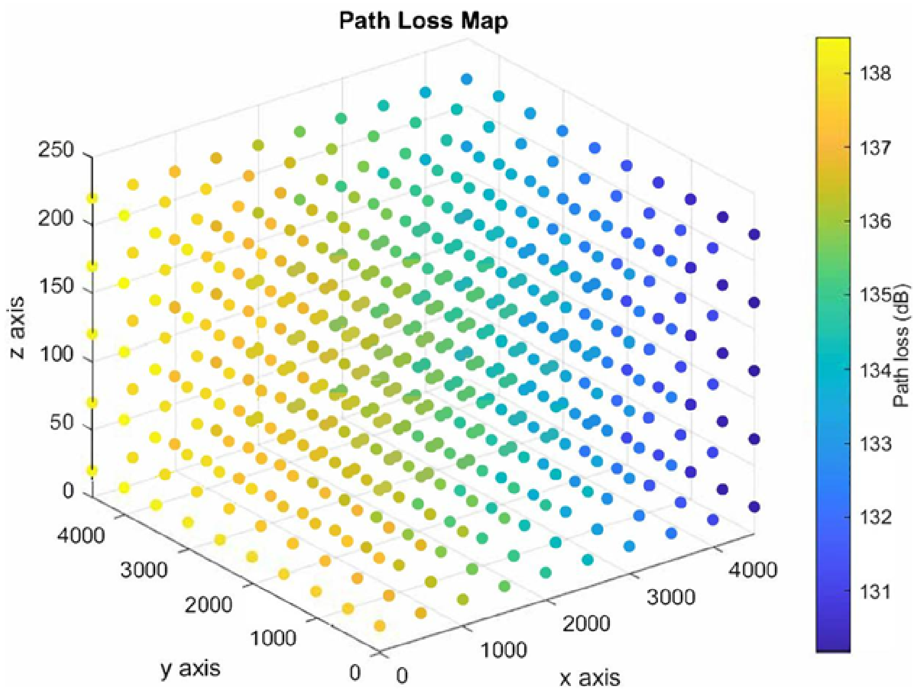

Figure 3.17: Dense path loss map [4]

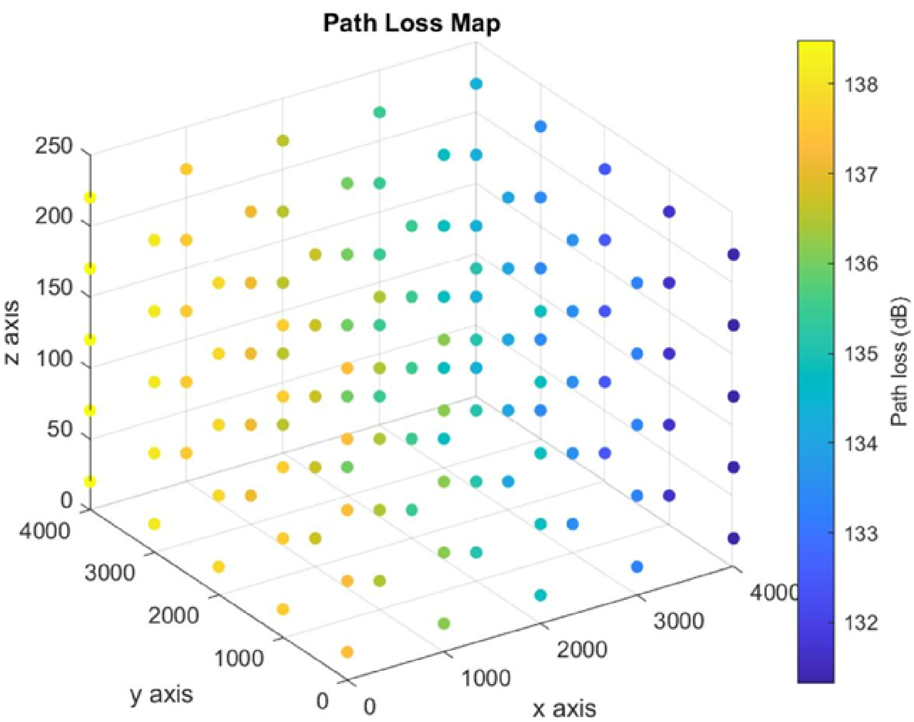

Figure 3.18: Sparse path loss map [4]

As shown in Table 3.1, a better solution can be derived when the dense grid model is adopted. The dense grid has a larger number of nodes distributed over the 3D space, which allows the UAV to have shorter path options. Therefore, the dense grid provides more flexibility for the UAV to reach to a location with low path loss value and to reach to the final location in a shorter distance and time. On the other hand, it is shown in Table 2.2 that adopting the sparse grid can reduce the computational time significantly although it leads to degrading the obtained solution. Therefore, there is a trade-off between getting a more accurate solution and reducing the computational time. Hence, the decision to use a particular path loss map density should be based on the UAV computational power and flexibility of getting a less accurate result.

Table 3.1: Computational vs. delivery time

	Dense Grid	Sparse Grid
Slot duration (s)	30	60
Computational time (s)	1505	13
Slots to deliver the message	11	9
Slots to return to final location	16	12
Time to deliver the message (s)	330	540
Time to return to final location	480	720

Assuming the threshold λ=133 dB, the UAV flies to one or more locations associated with path loss values less than or equal to 133 dB and sends the distress message from them. In our scenario, the UAV goes to locations 21 and 123, respectively, after delivering the distress messages.
Figure 3.19 shows the UAV trajectory generated using Algorithm 1. The UAV flies to point 101 and sends the first distress message, then flies to point 106 and 111 to send the rest of the distress messages. Finally, it goes back to its final location. In both solutions, the UAV finishes delivering the distress message and goes back to its final location.

The UAV's trajectory of scenario 2 has been derived after solving the original optimization model and the resulting trajectory is shown in Figure 3.20. Scenario 2 is similar to scenario 1 except that the final location is at location 123. The UAV delivers the distress messages and goes back to the final location.

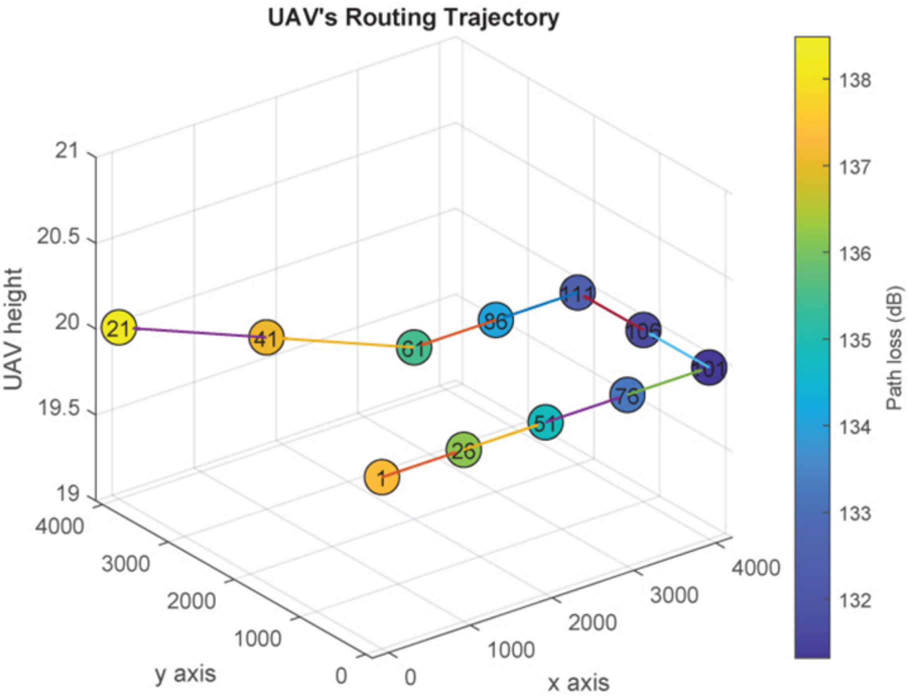

Figure 3.19: UAV's trajectory design over the path loss map using Algorithm 1 (Scenario 1) [4]

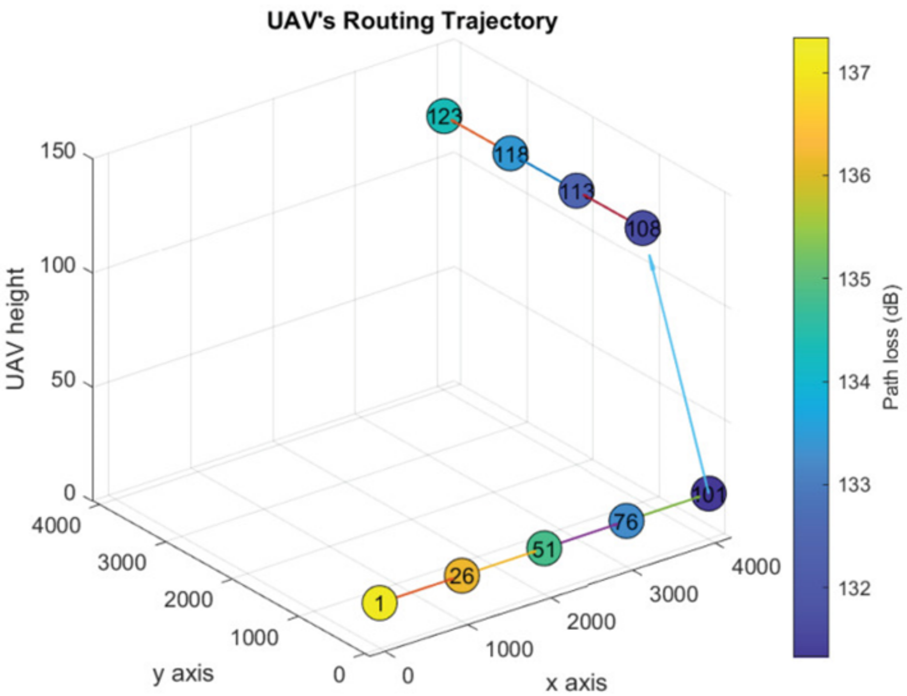

Figure 3.20: UAV's trajectory design over the path loss map using Algorithm 1 (Scenario 2) [4]

Observing Table 2.3, the computing time of Algorithm 1 in both scenarios, is significantly fast.

Table 3.2: Computational time

	Scenario 1	Scenario 2
Time to get Algorithm 1 solution	0.023 s	0.023 s

3.3 Remote health monitoring and optimal ambulance routing via 5G

First-line health care services are always facing the challenge of limited resources and an increasing number of patients. Because real-time data access (with delays at the msec level) and the ability to perform successful decisions for human life are critical to healthcare environments, this area will benefit significantly from 5G technology [48].

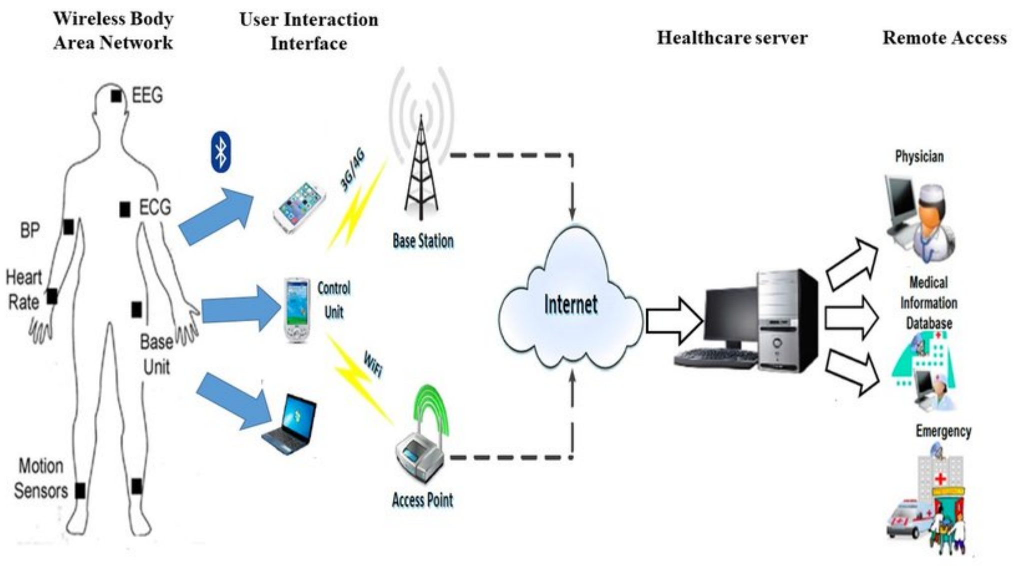

Figure 3.21: General overview of the remote health monitoring system. [49]

5G technology will offer particularly significant benefits to the automated driving and traffic control system in cases of critical need. Advanced safety applications will be able to reduce road accidents, improve vehicle traffic and support the mobility of emergency vehicles, in this case, ambulances. The ambulances and human resources (nurses, drivers) will be equipped with many sensors, high-speed thermal, high-definition, and robotic mechanisms. As shown in Figure 3.21 The state-of-the-art healthcare equipment at the forefront, with the support of the speed, availability, and responsiveness of the 5G network, will be a real revolution in the field of Health and Critical Care Management.

3.3.1 Remote monitoring of health through 5G

5G technology will create an Internet of Medical Things (IoMT). It will help advance medical innovations, supporting technologies such as AR, VR, AI, remote medical learning, and remote Patient tracking. Together, these technologies can enhance the effectiveness of prevention and treatment of pandemics or other emergencies and lead to the digital transformation of healthcare systems. The communication and τηε data exchange is essential for patient control but also for monitoring the evolution of critical situations. In addition to emergency management, 5G technology in the health sector will lead to a more general improvement in health services. Giving ground to remote health monitoring will allow timely and valid diagnosis of diseases, preventing excessive and incorrect administration of treatment [50].

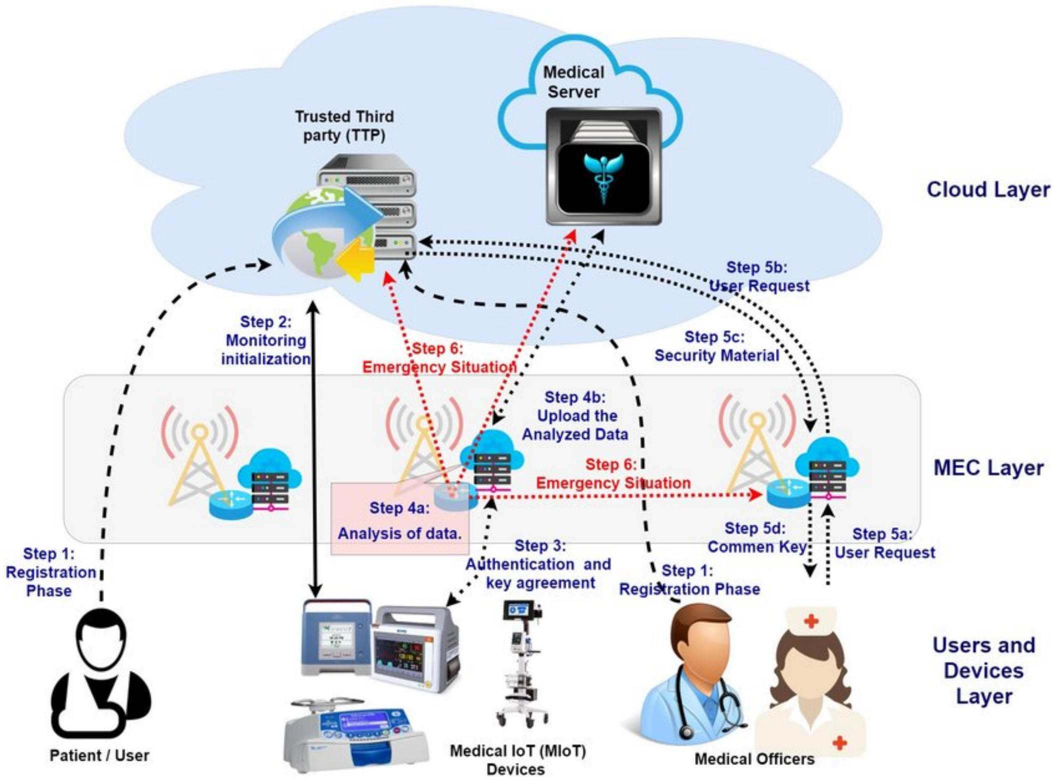

Figure 3.22: remote patient monitoring scheme in 5G [51]

The new capabilities of 5G networks will make possible the adoption of smart health.

Smart health services will be able to improve significantly the healthcare of citizens by collecting and processing the appropriate data, keeping a digital medical record(which is instantly accessible by doctors), distant monitoring of elderly, disabled people or people living in not easily accessible areas.
Moreover, an important service is the electronic exchange of documents between hospitals or doctors, in order to speed up the process of recovery of patients. Finally, an important innovation is the platform for monitoring elderly people, where sensors can alarm relatives or doctors in case of vital sign anomaly.5G will allow better mobile connections, increased transmission capacity data through larger bandwidth, and help healthcare workers provide improved, remote care in real-time.
In addition, the creation of a 5G consultation platform will allow rapid, reliable, and uninterrupted communication between health professionals, offering lasting support, improving the effectiveness of diagnosis and treatment, reducing the excessive workload of medical staff (e.g., in pandemic cases) and the risk of expert exposure to diseases (e.g., in the case of a pandemic, health professionals are not constantly exposed to infected patients, while they offer their lasting support, with great precision and immediacy).
Moreover, patient monitoring is going to improve the life for people with chronic diseases, facilitating access to health services, without the need for physical presence of medical personnel (transport costs, air pollution from moving vehicles).

3.3.2 Optimal routing of ambulances through 5G

Regarding the optimization of ambulance routing, 5G technology will contribute by adjusting traffic with travel control mechanisms, intelligent parking,monitor the waste collection, and motion priorities in Ambulances and other emergency vehicles [52].

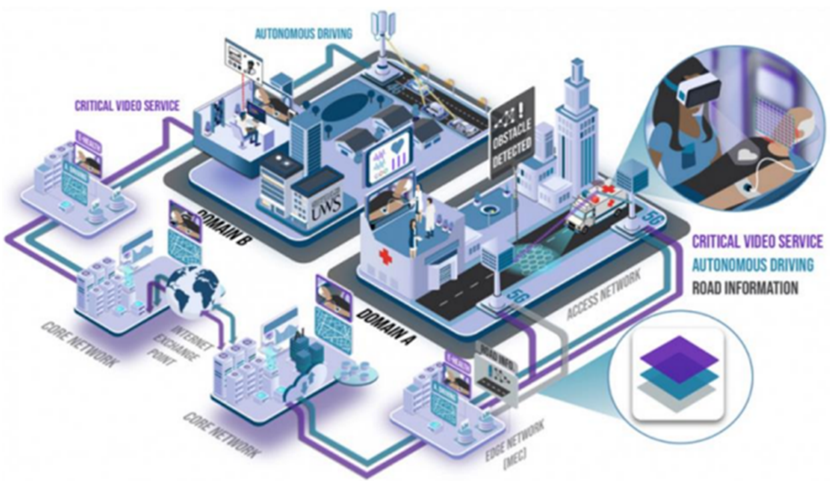

Figure 3.23: "Smart" Ambulance Equipment Equipped With "Pieces" Network 5G and Farm Recognition Obstacles and Videos Flow Optimization in real-time [53]

As 5G network is to the fore, the realization of a 5G-enabled service will have the potential to bring innovative benefits to individuals, organizations and societies. In particular, the 5G network enables ambulances to connect a patient, who may be wearing emergency medical equipment and wearable devices, to the emergency department. Patient data starts to be collected and is continuously sent back to the destination emergency department while a patient is in the ambulance. This allows the emergency department team to provide emergency treatment in a remote and immediate manner and offers ambulance paramedics more correct and faster decisions in order to stabilize a patient [54].

4. CONCLUSIONS

Based on all of the above, 5G offers tools to strengthen the central role that civil protection plays in managing critical situations. It provides speed and reliability in communications, connectivity without interruptions, the extension of network coverage even in isolated areas, and access to multiple users simultaneously. In this way, it allows communication between the various groups of personal civil protection, irrespective of their location and the transfer data needed to obtain full awareness of the situation. The analysis of these data using artificial intelligence is intended to extract important information on understanding and modeling the case, as well as visualizing the results in a manner that is understood for users. This whole process strengthens the work of civil protection bodies and the safety of the operating personnel.

AR is a promising technology, with a lot of potential in the assistance of civil protection and first responders. Natural disasters that can be a threat to civilian lives, like large wildfires, floods, earthquakes etc., are happening in large scale. Therefore, it is essential that first responders are equiped with the necessary tools (like AR) in order to be able to face these critical situations efficiently. The extra information and capabilities that AR systems provide could make it easier for rescuers and civil protection agents to assess every situation, as well as minimizing the required time of the mission, thus reducing the total risk.

Based on the study [4], a UAV-based method for conveying the distress messages from coverage holes to the emergency center was presented. First, it modeled the problem using a three-dimensional path loss map.Then, proposed a heuristic algorithm to minimize the time required to deliver the distress message and complete the UAV’s mission time. Additionally, it investigated the scheme and simulated the proposed algorithm under two different scenarios. The effect of the path loss map density was studied, where the dense map allows finding more accurate results. On the other hand, sparse path loss map simplifies the routing problem and allows solving the problem in a shorter time. Moreover, it verifies the advantage of the proposed heuristic algorithm where it arrives at the solution with a significantly short the computational time.

We are at the dawn of the 4th industrial revolution and the digital economy, a catalyst of which is the digital transformation of all sectors of the economy and human activity through the growing use of IT and communication technologies. Seamless broadband high-speed access through sophisticated 5G mobile communications networks, the use of cloud computing and the interconnection of all kinds of objects that surround us, combined with the blooming of new technologies, such as artificial intelligence, Big Data Analytics, and blockchain. These profound changes can have an effect of great importance to safeguard life, health, and critical management sectors. The explosive appearance of fifth-generation networks combined with artificial intelligence opens new and particularly promising horizons in remote health monitoring (E-Health) and optimal routing of ambulances. Continuous and distinctive monitoring of patients, direct and reliable exchange of real-time data, rapid response and reliable communication between different health professionals, timely and valid diagnosis and treatment, and avoidance of physical are only some of the advantages of remote health monitoring. In addition, ”smart” ambulances, equipped with 5G and AI systems, provide elevated first-line care to the patient, as well as uninterrupted communication with health professionals located in both the destination hospital and elsewhere, improving the validity and immediacy of diagnosis And treatment, as well as recognizing potential obstacles, optimizing the choice of route to the destination hospital.

ABBREVIATIONS - ACRONYMS

1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
5G	Fifth Generation
5G+	Fifth Generation and beyond
6G	Sixth generation
EU	European Union
CBRN	Chemical, Biological, Radiological, and Nuclear
PPDR	Public Protection and Disaster Relief
NMT	Nordic Mobile Telephone
GSM	Global System for Mobile Communications
SIM	Subscriber Identity Module
TDMA	Time Division Multiple Access
CDMAOne	Code Division Multiple Access One
GPRS	General Packet Radio Service
EDGE	Enhanced Data rates for Global Evolution
UMTS	Universal Mobile Telecommunication Systems
WCDMA	Wideband Code Division Multiple Access
ATM	Asynchronous Transfer Mode
MPLS	Multiprotocol Label Switching
LTE	3GPP Long Term Evolution
MANO	Management and orchestration
NFV	Network Function Virtualization
OpEx	Operating Expenses
CGNAT	the Carrier Grade Network Address Translation

ADC	Application Delivery Controller
CapEx	Capital Expenditure
TCO	Total Cost of Ownership
NR	New Radio
LMR	Land Mobile Radio
PTT	Push-To-Talk
AR	augmented reality
eMBB	Enhanced Mobile Broadband
URLLC	Ultra-Reliable Low Latency Communications
mMTC	Massive Machine Type Communications
VR	Virtual reality
UAV	Unmanned aerial vehicle
LAN	Local Area Network
WLAN	Wireless Local Area Network
EAP	Extensible Authentication Protocol
MCPTT	Mission-Critical Push-to-Talk
eMBMS	enhanced Multimedia Broadcast Multicast Services
PRS	placement reference signals
HMD	Head-Mounted Displays
SAR	Spatial Augmented Reality
OHMD	Optical Head-Mounted Display
PDAs	Personal Digital Assistants
NIST	National Institute of Standards and Technology
COP	Common Operational Picture
ICT	Information and Communication Technologies
UI	User Interface
UX	User Experience
WARD	Wearable, Augmented Reality Displays
CBRNE	Chemical, Biological, Radioactive, Nuclear, and Explosive

AI	Artificial Intelligence
ILP	Integral Linear Program
IOMT	Internet of Medical Things
ML	Machine Learning
MR	Mixed Reality
BVLOS	Beyond Visual Line-of-Sight
RAN	Radio Access Network
SBA	Service Based Architecture
MEC	Multi-access edge computing
NFV	Network Function Virtualization
AMF	Access and Mobility Management Function
SMF	Session Management Function
UPF	User Plane Function
AUSF	Authentication Server Function
PCF	Policy Control Function
UDMF	Unified Data Management Function
NSSF	Network Slice Selection Function
NRF	Network Repository Function
NEF	Network Exposure Function
SBA	Service-Based Architecture

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