Factors influencing the choice of satellite communication system in crisis management in Poland

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***Abstract*— The aim of the article is to check the accuracy of using the mobile satellite communication system in crisis management process in Poland. The study presented in this article uses an approach that directs to the identification of key parameters supporting the selection of a mobile satellite communication subsystem as part of communication system for crisis management purposes. Crisis management is an important element of the process of returning to a stable state damaged by the impact of uncontrolled external factors. The parameters of mobile systems based on LTE communication in relation to the telecommunications infrastructure in Poland were compared with the possibility of using mobile satellite communication taking into account non-urbanized areas. In Poland, in accordance with the Crisis Management Act, there is a need to have a reliable crisis communication system that enables communication between the central command point, regional crisis management centers and poviat and municipal crisis management centers. Local centers operate based on digital services obtained from telecommunications operators and delivered to work stations at the permanent headquarters of officers involved in the crisis management process, as well as outside permanent locations to mobile control points in the area of the incident.**

Keywords— incident management, communication system, satellite communication

I. INTRODUCTION

Crisis management is an important element of the process of returning to a stable state disturbed by the impact of uncontrollable external factors. They can include local or local events, as well as escalate and spread or move to different areas from the initial one.

Effective communication is an important element in the management process.

Thanks to the exchange of information about the current status of activities, it is possible to effectively plan and manage the allocated resources. The infrastructure deployed in space and the innovative services based on it are one of the most innovative and technologically advanced areas of the global economy. Space technologies are increasingly used, m.in. in GPS navigation, airport surroundings, seaports, energy support, international transport. They are also used in crisis management in the event of disasters, potential acts of terrorism and the effects and extent of natural disasters. Hence the interest in assessing the possibilities and indicating the variants of using satellite communication systems as a tool supporting crisis management.

This article focuses on the use of mobile communication networks in crisis management. Effective communication is an important element in the management process.

Thanks to the exchange of information about the current status of activities, it is possible to effectively plan and manage the allocated resources. The infrastructure deployed in space and the innovative services based on it are one of the most innovative and technologically advanced areas of the global economy. Space technologies are increasingly used, m.in. in GPS navigation, airport surroundings, seaports, energy support, international transport. They are also used in crisis management in the event of disasters, potential acts of terrorism and the effects and extent of natural disasters. Hence the interest in assessing the possibilities and indicating the variants of using satellite communication systems as a tool supporting crisis management.

The layout of the rest of the article is as follows. The next section describes the state of terrestrial mobile networks. Then, the basic characteristics satellite solutions. Finally, the results

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will be presented the key factors. The final section contains conclusions.

II. DATA DESCRIPTION

The study used analytical data collected by entities measuring LTE signal strength in Polish as well as periodic reports of the Office of Electronic Communications (Report on the state of the telecommunications market in Poland.) based on data provided by operators.

Additional information was collected from the portals of companies offering solutions used in ICT systems, dealing with the analysis of offers on the telecommunications market, and the government portal containing a description of legal acts and describing the program implemented within the European Union.

III. RESEARCH

The first element of the study was the role of communication systems in crisis management. Crisis management is an activity of public administration bodies that is an element of managing national security, which consists in preventing crisis situations, preparing to take control over them through planned actions, responding to crisis situations, removing their effects and restoring resources and critical infrastructure. A crisis situation should be understood as having a negative impact on the level of safety of people, property of significant size or the environment, causing significant limitations in the operation of competent public administration bodies due to the inadequacy of the forces and resources at their disposal; (Act of 26 April 2007 on crisis management, Journal of Laws of 2007 No. 89, item 590).

Communication systems play an important role in the crisis management system, necessary to ensure situational awareness. The technical and functional solutions used in the control systems allow users to use modern digital communication services. They secure the need to obtain a significant amount of data used in the management process. They enable the operation of integrated information systems. They aggregate data from various sources (e.g. meteorology, hydrology, emergency services) and perform risk analysis and hazard forecasting. They allow the use of software for data analysis, a database of threats and resources, and interfaces for crisis management. They allow for integration and cooperation with other communication and alarm systems. They include radio, mobile telephony, and Internet telephony systems that enable fast and reliable exchange of information between different levels of crisis management, alerting the public, and transmitting orders and guidelines. They work on the basis of digital services obtained from telecommunications operators and are delivered both to workstations in the permanent headquarters of officers involved in the crisis management process, and outside fixed places to mobile command points in the area of the incident. This affects the effectiveness of the authorities responsible for public safety and order and rescue. Digital services are compliant with the standard of electronic communication services provided by modern ICT networks using the IP protocol.

The second element of the study are Actors involved in crisis management. Various entities are involved in crisis management in Poland, in accordance with legal regulations. Here are some key actors:

Voivode: It is the competent authority for crisis management in the province. The tasks of the voivode include managing the monitoring, planning, reacting and removing the effects of threats in the voivodship, performing tasks in the field of civil planning, managing, organizing and conducting training in crisis management and applying for the use of the armed forces or other services to perform specific tasks[Ibidem 1].

Municipal crisis management centres: The head of the commune or the mayor of the city may establish such centres which perform specific tasks related to crisis management, including the tasks specified in the Act on Assemblies[Ibidem 2].

Crisis Centre: Responsible, m.in, for assessing the state of flood protection, developing operational plans for flood protection, and coordinating tasks in the field of defence, national security and crisis management

(Logistics of multi-entity rescue operations, COLLECTIVE WORK, Editors: Jacek Roguski, PhD, Eng., CNBOP-PIB Publishing House, Józefów 2015).

Government organisations: Ministers in charge of government administration departments and heads of central offices are responsible for crisis management, including the development of crisis management plans and the implementation of tasks related to the protection of critical infrastructure. These entities cooperate and act in accordance with legal regulations to effectively manage crisis situations and protect the country's citizens and infrastructure.

It is important that decisions are made based on the largest possible set of information so that the crisis management process is burdened with minimal risk.

FIGURE 1: CRISIS MANAGEMENT CENTRE IN WROCŁAW, FOT. WROCLAW CITY HALL

Source: HTTPS://POLSKA-ORG.PL/8027013,FOTO.HTML

As a tool supporting the operation of crisis management bodies, the National Crisis Management Plan is created, as well as at lower levels provincial, district and municipal crisis management plans, hereinafter referred to as

"crisis management plans". The plan contains, among others, functional annexes to the master plan specifying the organization of communication. (Act of 26 April 2007 on crisis management, Journal of Laws of 2007 No. 89, item 590).

Communication systems play a key role in crisis management, enabling a fast and reliable exchange of information between different levels of crisis management. They support the process of alerting citizens and providing orders and guidelines. In Poland, according to the Crisis Management Act, there is a need to have a reliable crisis communication system that enables communication between the central command point, regional crisis management centers and district and municipal crisis management centers.

Communication between entities performing management tasks at the level of the County Office, in accordance with the possibilities and concluded supply or lease agreements between the supplier and the office, can be carried out by means of infrastructure made available by telecommunications operators, such as:

- fixed public telecommunications networks,
- mobile public telecommunications networks,
- the Internet.

The system should ensure the safety of citizens by being able to manage them on a permanent and effective basis. Other, also important features of an efficient communication system include:

- independence from terrestrial telecommunications infrastructure,
- dedicated character, guaranteeing continuous access to communication network resources in conditions of simultaneous demand by system users,
- efficiency of operation in the territory under management, without interruption in the absence of basic power supply, for a period of not less than 12 hours,
- guarantees of data transmission in sub-channels with a bit rate of up to 64kb/s, in parallel with the transmission of voice communication channels,
- ensuring the possibility of contact (from the central point – the base), conducting a conversation with each participant
- belonging to the communication network,
- the ability to transmit data between the portable computer used by the brigade in the field and the IT system of the facilities within the network.
- full coverage of the area with one satellite beam,
- the ability to change network parameters in terms of its throughput, number of users in the network, application needs, etc.,
- equipping the system with an internal device reporting data flows and monitoring the correct functioning of the network (Tomasz Wałek, Communication system as an important element of crisis management, Edition: KB 2013; 14 (14): 225-236).

For this purpose, GSM communication devices are used, such as telephones and modems used for data transmission, radiotelephones operating in the VHF range, in accordance with the National Frequency Allocation Table (https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20220001988/O/D20221988.pdf), and PTSN fixed networks and computers and tablets using Internet connections. In addition, satellite data transmission systems are used, thanks to which it is possible to effectively carry out tasks in the area where there is no GSM network coverage, or the coverage is poor despite the use of external directional antennas and link aggregation systems using multiple GSM cards of different operators in order to increase the bandwidth of the links (https://eshop.sectron.pl/pl/robustel-5g-router-r5020-b/p-15200/?utm_source=google&utm_medium=cpc&utm_campaign=21374994946&utm_content=CjwKCAjw7NmzBhBLEiwAxrHQ-bCvgsBe5W642QrMJTKBBJLYjaBkqFxqF4InNYi3LSUPxpOyby8E5xoC_u8QAvD_BwE&gclid=CjwKCAjw7NmzBhBLEiwAxrHQ-bCvgsBe5W642QrMJTKBBJLYjaBkqFxqF4InNYi3LSUPxpOyby8E5xoC_u8QAvD_BwE&gad_source=1).

The third element of the study is Mobile connectivity in the LTE system based on public operators in Poland. In mobile applications, the main means of communication is a digital telephony system based on the LTE standard.

It uses the following frequencies in Poland:

- 2600 MHz (2500-2690 MHz band),
- 2100 MHz (1900-2290 MHz band),
- 1800 MHz (band 1710-1785 MHz and 1805-1880 MHz),
- 900 MHz (band 876-915 MHz and 921-960 MHz),
- 800 MHz (791-821 MHz and 832-862 MHz bands).

The speed and stability of the Internet connection depend to a large extent on the LTE band used. Higher frequencies are called capacitive. They provide a high-quality network connection in densely populated areas, such as large cities. It is then possible to comfortably use the Internet at the same time by many users who connect using different devices. High frequencies work well in open spaces, provided the terrain is favorable. They generally allow you to achieve high internet speeds, but only in a small area. Waves of lower frequencies, called coverage, are characterized by a large range in villages and poorly urbanized towns – with a small population and low density of buildings. They provide a strong signal in buildings and also work relatively well in the mountains.

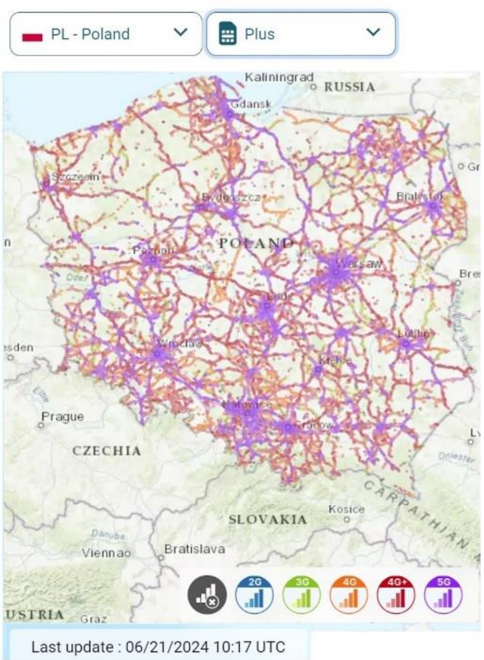
Therefore, it is worth using a device to receive the Internet that supports as many bands as possible, which will reduce problems with poor coverage and low transmission speed. Mobile operators can use a technology known as LTE band aggregation. It consists in combining up to five frequencies with a width of up to 20 MHz into one collective channel. Its total width can therefore be 100 MHz. This option allows users to be provided with a higher bandwidth connection, also in conditions of high network congestion.(https://www.netia.pl/pl/blog/4g-%E2%80%93-jaka-jest-czestotliwosc-lte-w-polsce)

Despite the significant development of fixed and mobile telecommunications networks, there are places where mobile network coverage is limited. This results from the economic calculation of operators providing access services and meeting the requirements of the telecommunications market regulator in Poland - the Office of Electronic Communications (UKE). (https://www.uke.gov.pl/o-nas/)

The range and stability of the link is of particular importance for emergency response groups performing their tasks in non-urbanized areas. In such cases, the main communication system is the one based on the mobile network.

The coverage of mobile networks is shown in the graphics below.

FIGURE 2: MAP REPRESENTS THE COVERAGE OF PLUS 2G, 3G, 4G AND 5G - PLUS MOBILE NETWORK

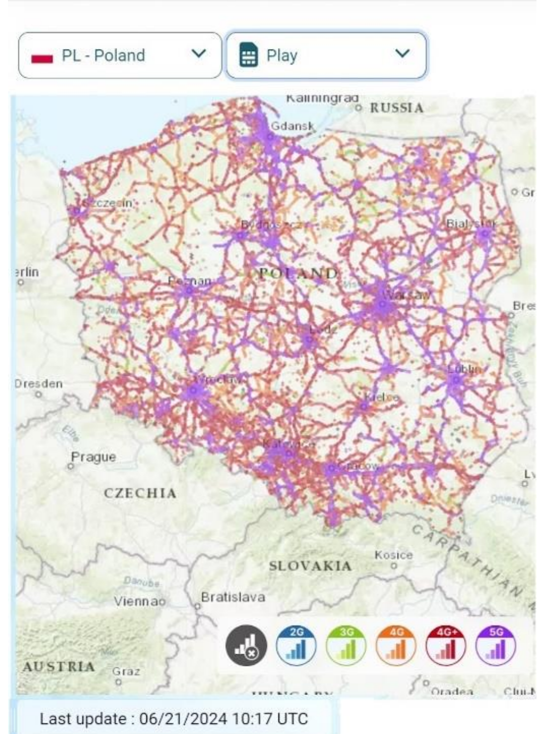


Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/2760.PLUS/SIGNAL?LL=51.80861490078537&LG=7.832229785694343&ZOOM=6

FIGURE 3: THIS MAP REPRESENTS BITRATES OF PLUS 2G, 3G, 4G AND 5G MOBILE NETWORK.

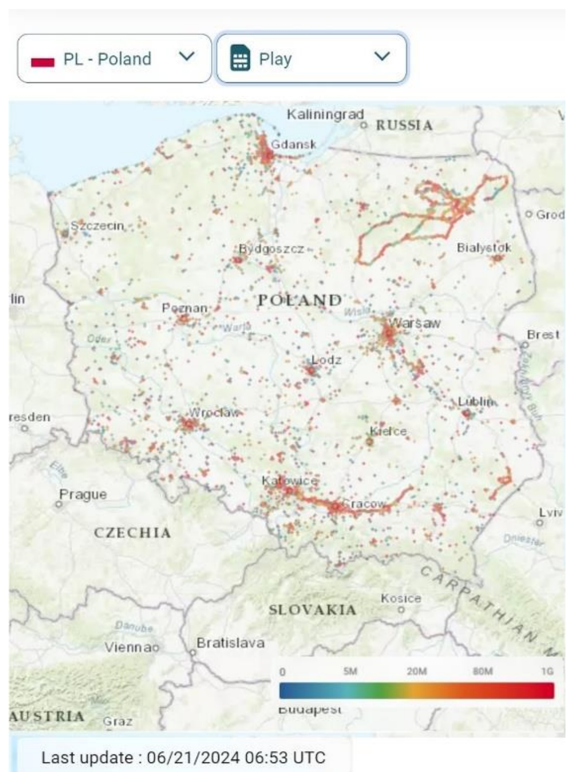
Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/2760.PLUS/DOWNLOAD?LL=51.80861490078537&LG=7.832229785694343&ZOOM=6

FIGURE 4: MAP REPRESENTS BITRATES OF PLUS 2G, 3G, 4G AND 5G -PLAY MOBILE NETWORK COVERAGE .



Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/5505.PLAY/SIGNAL?LL=51.81540712827211&LG=7.832229785694343&ZOOM=6

FIGURE 5: MAP REPRESENTS BITRATES OF PLAY 2G, 3G, 4G AND 5G MOBILE NETWORK.

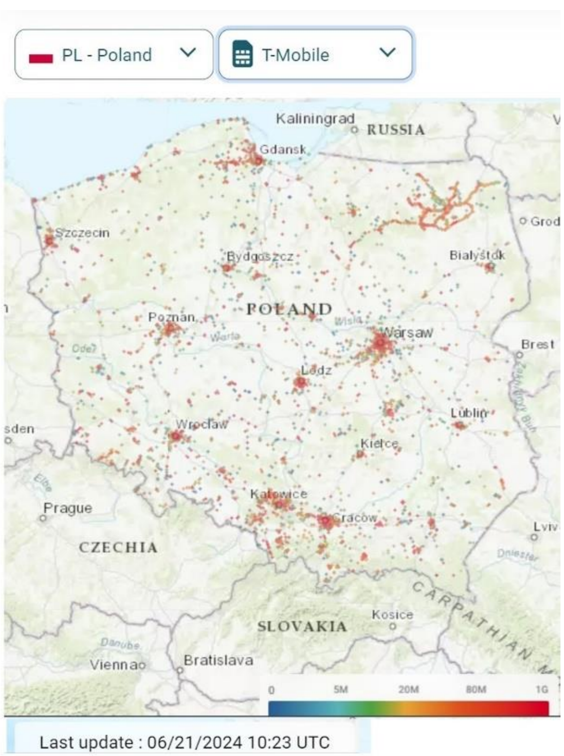


Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/5505.PLAY/DOWNLOAD?LL=51.81540712827211&LG=7.832229785694343&ZOOM=6

FIGURE 6: MAP REPRESENTS BITRATES OF T-MOBILE 2G, 3G, 4G AND 5G - PLAY MOBILE NETWORK COVERAGE .

Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/6090.T-MOBILE/SIGNAL?LL=51.81540712827211&LG=7.832229785694343&ZOOM=6

FIGURE 7: MAP REPRESENTS BITRATES OF T-MOBILE 2G, 3G, 4G AND 5G MOBILE NETWORK.

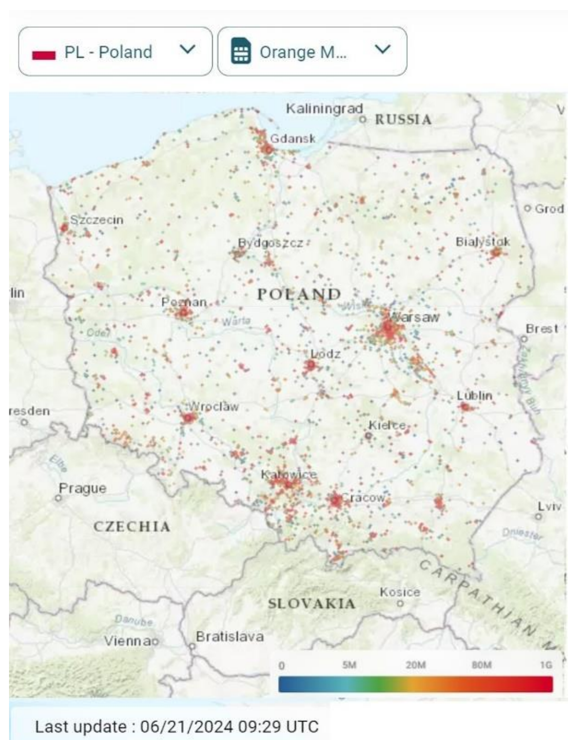


Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/6090.T-MOBILE/DOWNLOAD?LL=51.81540712827211&LG=7.832229785694343&ZOOM=6

FIGURE 8: MAP REPRESENTS BITRATES OF ORANGE 2G, 3G, 4G AND 5G - PLAY MOBILE NETWORK COVERAGE .

Source:HTTPS://WWW.NPERF.COM/EN/MAP/PL/-/59743.ORANGE-MOBILE/SIGNAL?LL=51.81540712827211&LG=7.832229785694343&ZOOM=6

FIGURE 9: THIS MAP REPRESENTS BITRATES OF ORANGE 2G, 3G, 4G AND 5G MOBILE NETWORK.



Source:https://www.nperf.com/en/map/PL/-/6090.T-Mobile/download?ll=51.81540712827211&lg=7.832229785694343&zoom=6

The presented drawings show that in a crisis situation we cannot fully count on data transmission in mobile networks and stable voice connections. Such a state significantly affects the ability to manage the operation.

The use of mobile Internet access is economically justified, due to the relatively low cost of data transmission subscriptions and the fact that it largely meets the needs of teams performing tasks as part of crisis management. The cost of an active SIM card with an unlimited data package is at the level of PLN 115 - 150 per month. Even if several cards are used to increase the bandwidth, this is not a high amount (https://panwybierak.pl/oferty/internet-mobilny/24).

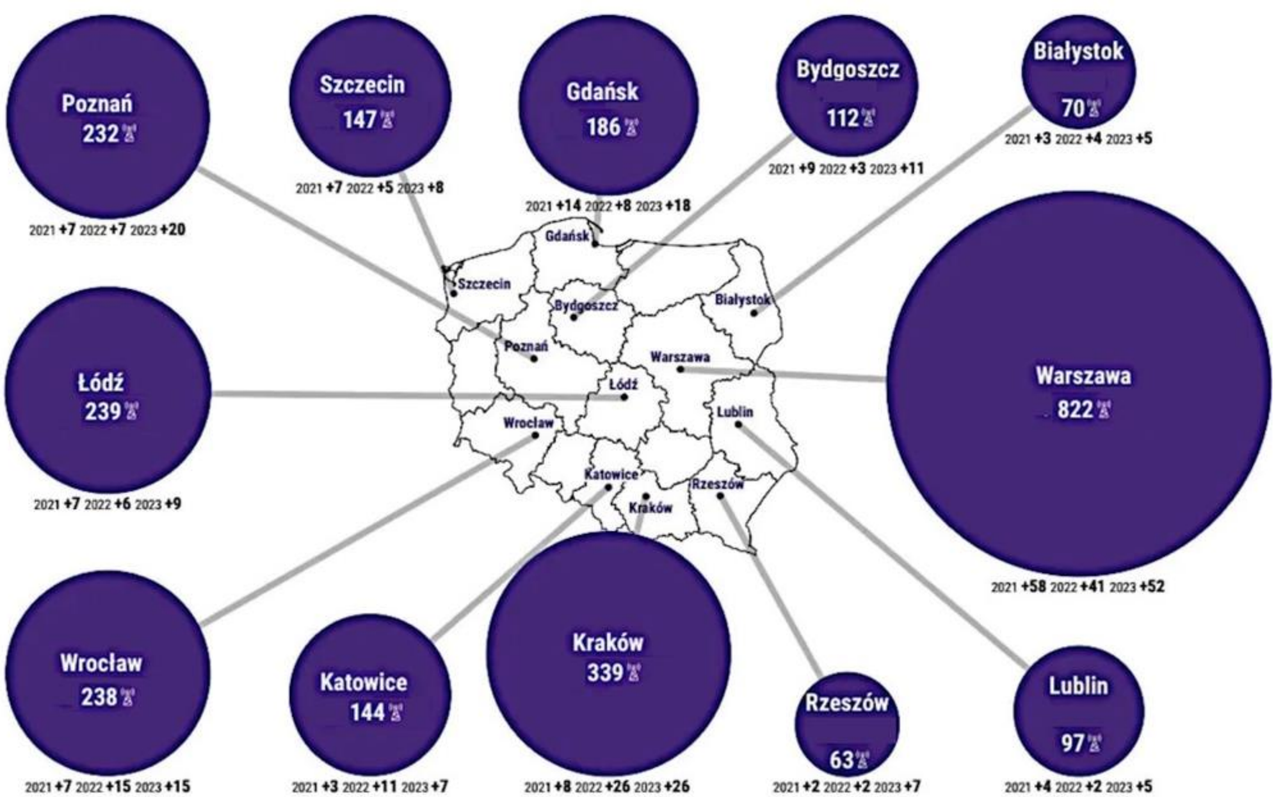
With the increase in the number of subscriber devices using the LTE signal, the availability of the connection per user decreases. It should be taken into account that in adverse weather conditions, the presented transmission parameters may deteriorate. The main parameter that allows for evaluation in digital transmission is BER (Bit Error Rate). BER can be affected by a number of factors (Roslan Umar, "Radio frequency interference: The study of rain effect on radio signal attenuation," Research Gate, vol. 19, no. 5, p. 6, 2015). During the rainy season, rain drops absorb and scatter transmitted signals which degrades the reliability and performance of communication links. Effects of rainfall are dependent on

frequency, rain rate, drop size distribution and drop shape, which are determined by the type of rain. By manipulating the variables that can be controlled, it is possible to optimize a system to provide the performance levels that are required. This is normally undertaken in the design stages of a data transmission system so that the performance parameters can be adjusted at the initial design concept stages.

Interference: The interference levels present in a system are often set by rain droplets and cannot be changed by the system design. However, it is possible to vary the power of the transmitted signal (Daksh Paul, 2Gaurav, 3Ishita Jindal, 4Ashish Sharma Performance Enhancement of 4G LTE Network During Rainy Weather by Bit Error Rate Reduction, JETIR December 2020, Volume 7, Issue 12).

The use of mobile connectivity during the crisis in the urban agglomeration offers significant opportunities to use the mobile network. On the example of the infrastructure of the PLAY operator, we can see that in large agglomerations the operator's network is developed, and even new base stations are being built.

FIGURE 10: PLAY NETWORK IN THE LARGEST CITIES IN POLAND

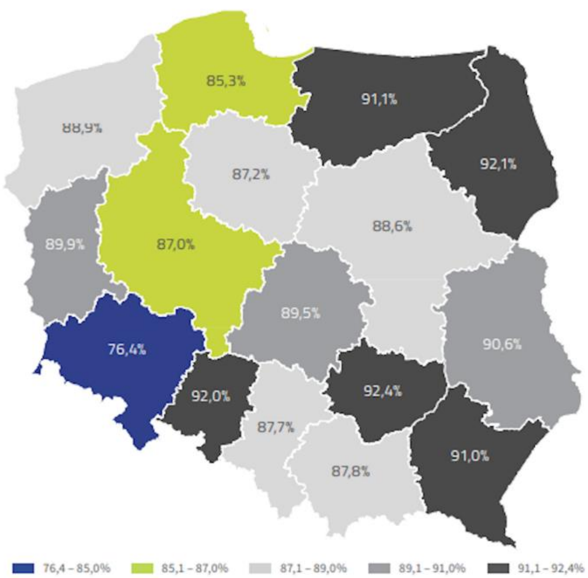


Source: HTTPS://PANWYBIERAK.PL/BLOG/TAK-ZUZYWAMY-CODZIENNIE-INTERNET-MOBILNY-RANO-TEAMS-WIECZOREM-SERIALE/

The graphic below presents the total coverage of the Polish area with the LTE data transmission network. Mobile Internet coverage is reported by spatial indication of address points located within the technological range of base stations. The coverage reported by operators for 2019 shows that LTE technology continues to have the highest share among mobile technologies (over 82.3%). The data reported during the inventory shows that about 10% of buildings in Poland do not have access to LTE Internet, and about 12% of buildings in Poland do not have access to LTE Internet. 10 voivodeships have higher than the national average. The highest percentage coverage of buildings with LTE technology coverage is in the

Świętokrzyskie (92.4%), Opolskie (92%) and Podlaskie (92.1%) voivodeships. On the other hand, the lowest in 2019 was recorded in the Lower Silesian Voivodeship (76.4%). (Telecommunications network coverage https://eregion.wzp.pl/obszary/zasiegi-sieci-telekomunikacyjnych).

FIGURE 11: PERCENTAGE COVERAGE OF LTE TELECOMMUNICATIONS NETWORKS



Source:HTTPS://EREGION.WZP.PL/OBSZARY/ZASIEGI-SIECI-TELEKOMUNIKACYJNYCH

The fourth is satellite communication Internet access systems. In Poland, satellite Internet is available via fixed and mobile connections. This type of Internet works using an in-orbit connection system and receivers installed on the system's subscribers.

Advantages of satellite communication in relation to systems operating on the basis of terrestrial telecommunications infrastructure or radio links of the LOS type. In crisis situations, the advantage is:

- Independence from terrestrial infrastructure,
- speed of network establishment even in the most damaged areas,
- mobility in the field of terrestrial devices,
- are key advantages of satellite communication in crisis situations.

In addition, satellite systems offer scalability, network control and greater immunity to interference compared to other communication systems.

Internet access services via satellite are offered in packages for individual and institutional customers. Individual customers often use stationary sets. In such solutions, modems integrated with the router through a wired connection to a local satellite dish allow you to receive and transmit the signal.

Satellite Internet is most often dedicated to people who have problems with connecting to e.g. fiber optic or LTE in their places of residence (suburban areas or villages).

Access to the links is obtained by means of a satellite dish and is characterized by lower transmission parameters than in fixed or mobile systems based on LTE networks. This is because the radio signal from the subscriber must travel to the satellite and then return to an access point on Earth that has the access link of the global Internet. Satellite links aimed at non-commercial customers cost from PLN 80 to PLN 450, depending on the parameters and additional options such as changing the location.

https://www.rachuneo.pl/artykuly/internet-satelitarny-sprawdzamy-oferty

The popular "Starlink" service in a commercial land-based mobile version costs from about PLN 1,400 to PLN 27,000.

Starlink is an online service based on a system of a large number of small satellites orbiting the Earth. Their number is gradually increased by placing more devices around the Earth, which are used to transmit wireless signals between each other and to terrestrial receivers.

Dedicated equipment is required to use the service. The biggest advantages of Starlink internet are the high speed of operation and the range, covering almost the entire globe. (https://gra.pl/internet-starlink-cena-limity-dostepnosc-w-polsce-i-nie-tylko-czy-warto-skorzystac-z-internetu-satelitarnego-elona-muska/ar/c12-16551721)

The previously described systems are based on public ICT systems. In order to maintain a high level of security, they require a connection via VPN (Virtual Private Network).

The other type of satellite communication is SATCOM. In the organization of emergency communication systems, satellite communication (SATCOM) can be an important element that increases availability and reliability. It allows the construction of private communication subsystems based on commercial or co-financed telecommunications satellites.

The system allows for:

- securing key connections between crisis management centers and command points,
- provides redundancy for critical connections, ensuring continuity of communication in emergency situations,
- mobility - thanks to the mobile SATCOM component, it is possible to quickly dislocate to places where communication is lost.

Satellite communication has a number of advantages in crisis situations, such as:

- independence from ground infrastructure,
- speed of network establishment even in the most damaged areas,
- Immediate reactivity and greater resistance to interference compared to other communication systems.

Satellite communication is based on the:

- Low Earth orbit - LEO,
- Medium Earth orbit - MEO and
- Geostationary orbit satellites, also referred to as a geosynchronous equatorial orbit - GEO.
- Low Earth orbit (LEO) encompasses Earth-centered orbits with an altitude of 1,200 miles (2,000 km) or less.
- Medium Earth orbit (MEO) between 2,000 and 35,786 km (1,243 and 22,236 mi) above sea level
- Geostationary orbit, also referred to as a geosynchronous

equatorial orbit (GEO), is a circular geosynchronous orbit 35,786 km (22,236 mi) in altitude above Earth's equator, 42,164 km (26,199 mi) in radius from Earth's center, and following the direction of Earth's rotation.

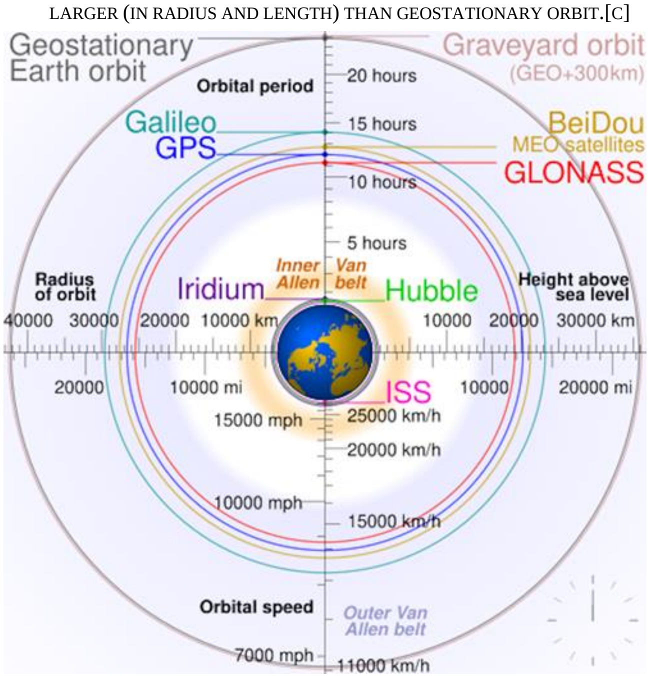
- Scope of operation of satellite communication devices.
- Satellite communication uses different frequency bands depending on the needs and applications. The frequency bands used in satellite communications and examples of their use are presented below:
- Ultra High Frequency (UHF) band:
- Frequency range: 300 MHz to 3 GHz.

Application: UHF channels are used for television, mobile telephony, satellite communications including mobile devices, GPS systems, Wi-Fi and Bluetooth technologies.

X-Band:

- Frequency range: 8 to 12.5 GHz depending on the application and orbit type.
- Application: X-band is used in government systems, satellite communications, radar Earth observation, atmospheric research, and scientific experiments.
- Ku-band:
- Frequency range: 117 GHz to 127 GHz (satellite reception) and 14 GHz to 145 GHz (signal sending).
- Application: The Ku-band is used to transmit data from satellites to Earth.

FIGURE 12: COMPARISON OF GEOSTATIONARY EARTH ORBIT WITH GPS, GLONASS, GALILEO AND COMPASS (MEDIUM EARTH ORBIT) SATELLITE NAVIGATION SYSTEM ORBITS WITH THE INTERNATIONAL SPACE STATION, HUBBLE SPACE TELESCOPE AND IRIDIUM CONSTELLATION ORBITS, AND THE NOMINAL SIZE OF THE EARTH.[B] THE MOON'S ORBIT IS AROUND 9 TIMES LARGER (IN RADIUS AND LENGTH) THAN GEOSTATIONARY ORBIT.[C]



Source: HTTPS://EN.WIKIPEDIA.ORG/WIKI/GEOSTATIONARY_ORBIT

With the many advantages of satellite communications, there are also challenges related to the cost of system launch, the cost of satellite bandwidth and the need for technology development and cooperation between different institutions.

The integration of satellite communications into emergency management systems is crucial to ensure the reliability and continuity of guidance and communication in the most critical situations, especially when traditional means of communication fail.

In Poland, the Polish Armed Forces have a developed satellite communication system in SATCOM system. It is not used to support the activities of other entities. In such cases, it is important to ensure compatibility and interoperability with military systems for the efficient use of resources in crisis situations. In order to increase the national potential in the field of satellite communication, it is necessary to take advantage of the opportunities arising from the implementation of the EU GOVSATCOM programme. Programme, will ensure the long-term availability of reliable, secure and cost-effective governmental satellite communications services for EU and national public authorities managing security critical missions and infrastructures. The program will reduce the cost of shared satellite links that can be allocated in the event of a crisis. (https://www.euspa.europa.eu/eu-space-programme/secure-satcom/govsatcom).

GOVSATCOM is a user-centric programme with a strong security dimension, is one of the elements of the Global Strategy for the European Union's Foreign and Security Policy of June 2016. The Programme will contribute to the EU's response to specific threats and will provide support to the EU Maritime Strategy and the EU Arctic Policy The EU GOVSATCOM initiative, which has been launched by the European Commission as part of the EU Space.

Three main use cases:

Crisis management, which may include civilian and military by common security and defense missions and operations, natural and man-made disasters, humanitarian crises and maritime emergencies.

Surveillance, such as border and maritime surveillance or surveillance of illegal trafficking.

Key infrastructures, e.g. Institutional Communications, various types of Critical Infrastructure, including Transport as well as EU space infrastructures such as Galileo and EGNOS. (Ibidem)

The implementation of the GOVSATCOM component of the EU Space Programme started in 2021, under the new EU Space Programme Regulation (https://eur-lex.europa.eu/legal-content/EN/AUTO/?uri=celex:32021R0696).

The Program Partner in Polish is the Polish Space Agency (POLSA). It is an executive agency, established in 2014. Its task is to support the Polish space industry by implementing the priorities of the Polish Space Strategy. POLSA cooperates with international agencies and state administration in the field of space exploration and use. He is responsible for the promotion of the Polish space sector in Poland and abroad. POLSA also conducts activities related to information and education on the use of satellite technologies (m.in. navigation, observation and communication) in the economy, administration and in everyday life.

https://polsa.gov.pl/o-polsa/

The fifth is SATCOM satellite communication systems in crisis management. Various types of satellite communication systems are used in crisis management, from telephony to digital data transmission systems, including SATCOM satellite communication systems. They may use links provided under the GOVSATCOM programme.

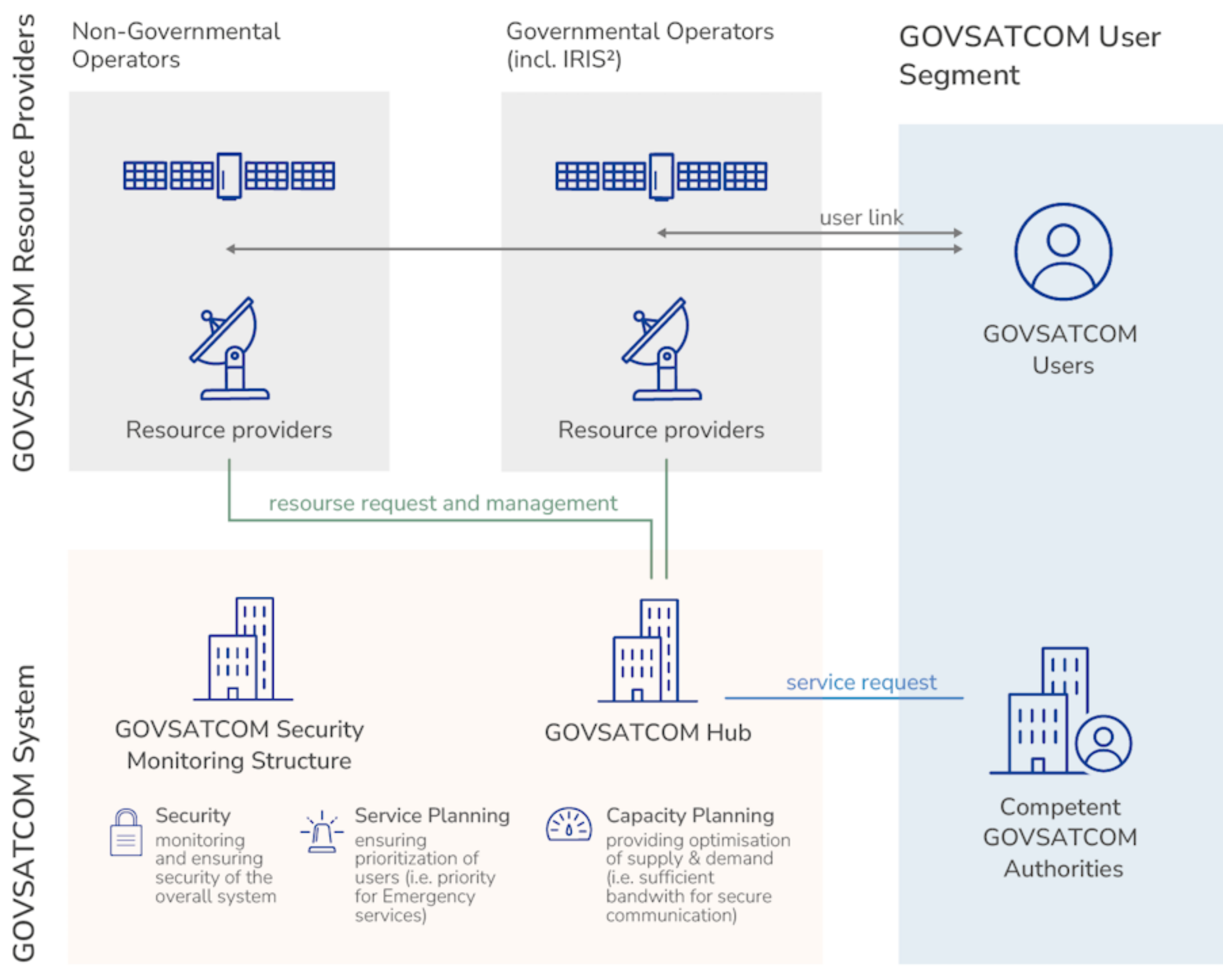
Terminals operating in the SATCOM system provide support for key connections between crisis management centers and command points.

They provide an element of redundancy for key connections, ensuring continuity of communication in emergency situations.

They can use a mobile component that allows for quick deployment to places where communication is lost.

Depending on the nature of the crisis and needs, they can use mobile terminals at the Manpack, FlyAway, DriveAway - On the move checkout. The system can operate on the basis of master stations.

FIGURE 13: GOVSATCOM HUB



Source: HTTPS://WWW.EUSPA.EUROPA.EU/EU-SPACE-PROGRAMME/SECURE-SATCOM/GOVSATCOM

The SATCOM system provides independence from terrestrial infrastructure, speed of network establishment in damaged areas, immediate reactivity and greater resistance to interference compared to communication systems based on terrestrial transmission infrastructure. The solutions are used for satellite communication, they are prepared for use in crisis situations and natural disasters. They are characterized by high redundancy, fault tolerance and encrypted communication. The use of the SATCOM system and many means and communication systems in crisis management allows for effective communication between different levels of crisis management, alerting the public and coordinating rescue operations in crisis situations.

The sixth is the factors influencing the choice of a mobile satellite communication system used in crisis management in the field. The following factors can be considered when selecting a field emergency management communication system to ensure reliability, efficiency, and rapid response in emergency situations.

Figure 14: Manpack terminals - compact Cobalt terminals with a modular design, adapted to be carried in a backpack by a single operator and providing communication in the Ku, X and Ka bands.

Source:HTTPS://WWW.GISS.PL/OFERTA/SYSTEMY-LACZNOSCI-SATELITARNEJ

Figure 15: Flyaway class terminal - extended satellite communication systems adapted to road, air and sea transport with antenna sizes of 1.2 to 2.4 m. FlyAway satellite terminals are equipped with an antenna controller and provide Ku, X, C and Ka-band connectivity.

Source:HTTPS://WWW.GISS.PL/OFERTA/SYSTEMY-LACZNOSCI-SATELITARNEJ

Figure 16: Drive Away / On the move class terminal - integration of satellite communication systems in vehicle bodies enabling the organization of mobile command centers and ensuring effective data transmission in all conditions.

Source:HTTPS://WWW.GISS.PL/OFERTA/SYSTEMY-LACZNOSCI-SATELITARNEJ

Figure 17: Master / HUB stations- central stations performing a management function in extensive satellite networks, equipped with antenna systems in size from 2.4 to 4.6 m

Source:HTTPS://WWW.GISS.PL/OFERTA/SYSTEMY-LACZNOSCI-SATELITARNEJ

The main factors include:

- availability and quality of terrestrial and satellite communication signals,
- independence from ground infrastructure,
- reliability,
- interoperability,
- scalability,
- simple to set up,
- power supply method,
- throughput,
- download-to-upload speed ratio,
- interference immunity,
- speed of network establishment,
- device / set size,
- mobility,
- purchase cost
- the cost of maintenance after warranty period ends,
- the cost of the service necessary to use the system.

Based on the above list, a recommended set of factors influencing the choice of a communication system used in crisis management in the field was selected.

TABLE 1: FACTORS INFLUENCING THE CHOICE OF A MOBILE SATELLITE COMMUNICATION SYSTEM USED IN FIELD EMERGENCY MANAGEMENT

Id	Name	Description
1	Independence from ground infrastructure:	In crisis situations, where the ground infrastructure can be damaged, independence from it becomes crucial. Satellite communication offers the possibility of continuing communication even in the event of destruction of the terrestrial infrastructure
2	Speed of network establishment:	In the event of an emergency, it is important to establish communication quickly. Satellite systems enable rapid network establishment even in the most damaged areas thanks to network pre-configuration
3	Download-to-upload speed ratio	The parameter shows whether it is a symmetric link - the same speed of receiving and transmitting data, or asymmetrical. In the case of an asymmetric link, the transmission speed is usually slower. The optimal value should be greater than 50%.
4	Mobility:	Ability to move quickly and establish connectivity in places where traditional means of communication may fail
5	Scalability:	Flexibility and the ability to expand as needed and adapt to user and capacity increases in emergency situations
6	Immunity to interference:	Satellite systems are more resistant to interference than those based on terrestrial infrastructure, including those deliberately introduced by third parties, which contributes to ensuring the reliability of communication in critical situations
7	Costs:	The cost of launching the system and satellite band are important factors. Cooperation between different institutions and the allocation of tasks to the local space industry can help to reduce these costs
8	Interoperability:	Ensuring the compatibility and interoperability of the communication system with existing systems, including military systems, is crucial for the effective use of resources in crisis situations

Source: OWN ELABORATION

Summary of assigned weights:

- Ground Infrastructure Independence: 5
- Network Establishment Rate: 5
- Mobility: 4
- Scalability: 3
- Interference immunity: 4
- Cost: 3
- Interoperability: 4

Such assessments help to prioritize factors and indicate which aspects should be paid special attention to when choosing a communication system in crisis management.

TABLE 2: ASSESSMENT OF FACTORS INFLUENCING THE CHOICE OF SATELLITE COMMUNICATION SYSTEM IN CRISIS MANAGEMENT.

Id	Name	Scales
1	Independence from ground infrastructure	5
2	Speed of network establishment	5
3	Download-to-upload speed ratio	5
4	Mobility	4
5	Scalability	3
6	Interference immunity	4
7	Costs	3
8	Interoperability	4

Source: Own elaboration

A scale from 1 to 5 was used to give weight to the factors influencing the choice of communication system in crisis management, where 1 is the least important and 5 is the most important.

IV. DISCUSSION

The results of conducted research confirm that the effectiveness the use of mobile connectivity in the LTE standard is an economically justified solution, but in the special conditions of the crisis, it may not meet all the needs of teams minimizing the effects of the crisis and people managing the operation. The use of satellite communication allows for the launch of information exchange, situational awareness and voice communication systems in locations not equipped with terrestrial infrastructure, without GSM network coverage or in the event of problems with the functioning of the infrastructure provided by public telecommunications operators.

The satellite communication system can complement the solutions used to secure the operation of communication tools used to support operations. Due to high construction and operating costs, it requires more work in the analysis and design phase as well as planning of use.

In order to build an integrated telecommunications environment using satellite links, the use of SATCOM solutions based on the national terrestrial infrastructure allows to increase the capabilities in the interoperability layer of services and ensure a higher level of system security.

The transmission resources of the European Union developed under the GOVSATCOM program, which are administered in Polish by POLSA, can be used in crisis conditions. This requires an analysis of the needs and cooperation of stakeholders, so that the system used maximally and at the same time optimally uses the resources of the entities involved.

Therefore, it is necessary to point out not only one communication standard for better results w securing communication during the crisis, but also will develop the ease of implementation in practice.

V. CONCLUSIONS

The motivation for the study was the competent risk of a crisis related to climate change and the possible destruction or damage of telecommunications infrastructure and electricity supply networks, resulting in the unavailability of mobile communication systems. The aim of the approach was to present a model of emergency communication using SATCOM technology, which, thanks to rapid technical development, is becoming more and more accessible, at the same time has such advantages as availability and quality of terrestrial and satellite communication signals, independence from ground infrastructure, availability and quality of terrestrial and satellite communication signals, mobility, speed of network establishment, reliability, interoperability, scalability, simple to set up. As a result of empirical research, the strengths of satellite communication were indicated and a set of main factors influencing the choice of a mobile satellite communication system was proposed, along with weights of significance for each of them.

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