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Utilization of satellite technology in communication systems, disaster monitoring, border surveillance, and military intelligence: a literature review

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ABSTRACT

Background: The utilization of satellite technology has become a critical aspect in many fields, including communications, disaster monitoring, border surveillance, and military intelligence. The ability of satellites to provide real-time, high-resolution data offers significant benefits in supporting these activities. This study aims to explore the contributions and benefits of satellites in this context through a literature review approach. **Methods**: This study used the literature review method, which involves collecting, analyzing, and synthesizing relevant scientific studies. The literature search was conducted through scientific databases with relevant keywords. The selected literature was categorized based on the main topics of communication systems, disaster monitoring, border surveillance, and military intelligence. Analysis was conducted to identify key findings and research gaps. **Results**: The review research shows that communication satellites enable fast and reliable transmission of information, both domestically and internationally, without significant time delay. In disaster monitoring, satellites such as ASTER and Sentinel-2 have proven effective in detecting environmental changes and supporting rescue operations. For border surveillance, ESA's Sentinel-2 satellite with high spatial resolution is able to effectively monitor borders. In the context of military intelligence, the use of global satellite navigation systems (GPS, GLONASS, BeiDou, Galileo) enables more accurate and real-time threat tracking and detection. **Conclusion**: This research confirms that satellites play a vital role in communications, disaster monitoring, surveillance, and military intelligence. The ability of satellites to provide high-resolution, real-time data is essential in supporting these critical applications. As satellite technology continues to evolve, these benefits are expected to increase, contributing even more to global security and prosperity.

KEYWORDS: communications; border surveillance; disaster monitoring; military intelligence; satellites.

1. Introduction

Remote sensing plays an important role in the defense and security of a country using satellites. The field emerged in the late 1950s during the Cold War and built on advances in rocketry after World War II. In less than 70 years, satellite observations have changed the way scientists observe and study the Earth (Ackerman et al., 2019). Satellite networks can fulfill various needs in the fields of communication, surveillance, intelligence, and of course for monitoring natural disasters that occur in an area. Due to its characteristics and

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broad coverage and the ability to provide a wide bandwidth with a consistent level of service, satellite connections are attractive to both developed and developing countries.

National defense is all forms of efforts to maintain the entire sovereignty, integrity, and safety of the entire nation from threats and disturbances. Indonesia's defense system is universal, involving all citizens, territories and other national resources. Therefore, it is prepared early and implemented in a total, integrated, directed, and sustainable manner by the government to uphold state sovereignty, territorial integrity, and the safety of the entire nation from all threats (Utomo et al., 2021).

There is no doubt that satellites, both GEO and LEO, will be an important part of the Next Generation Internet (NGI). There are several reasons why satellites will play an important role in NGI, namely, satellite services can be provided over a wide geographical area including cities, villages, remote and inaccessible areas. It is worth noting that two-thirds of the world still has no infrastructure for the Internet. Satellite communication systems have highly flexible bandwidth-on-demand capabilities. Alternative channels can be provided for connections that have unpredictable bandwidth demands and traffic characteristics, which can result in maximum resource usage. New users can be easily added to the system by simply installing an Internet interface at the customer's location. As a result, network expansion will be a simple task. Satellites can act as a security valve for NGI. New applications such as "Digital Earth", as well as teleducation, telemedicine, entertainment, etc., can be implemented via satellite. location is a very important feature of many wireless networks, border areas are very important locations to be monitored to avoid loss (Qu et al., 2017).

Seeing the great potential of satellite technology in various fields, this research aims to explore the role of satellites in remote sensing and its implications for national defense and security. The main focus of this research is to analyze the efficiency and effectiveness of satellites in providing communication and surveillance services and how this technology can be integrated into the national defense system to maintain the nation's sovereignty and safety.

2. Methods

The research method used is a literature review, which involves collecting, analyzing and synthesizing various scientific studies related to satellite usage. The literature review was conducted by determining the topic and searching for previous research journals and other documents that would be used as sources of analysis. The results of the collection of analysis sources were selected and chosen based on the latest research. Furthermore, the sources were grouped according to the main topic and subtopic categories. This research examines the contribution of satellites in communication systems, disaster monitoring and rescue, regional border surveillance, as well as intelligence and surveillance of military activity or threats. The following is the research brainstorming:

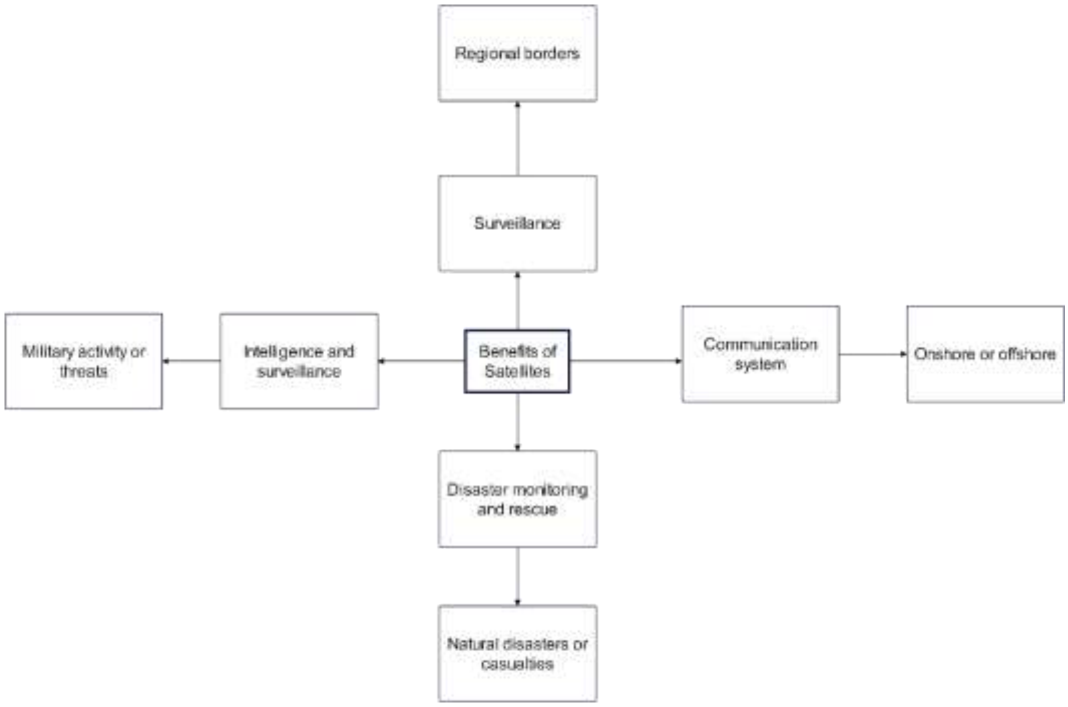

Fig. 1 Brainstroming

3. Results and Discussion

3.1 Communication system

The use of satellites in the Internet Of Things communication system, satellite communication, digital channelizer is one of the most important parts that support multiple transponders. Due to its wide range, satellite communication systems are more susceptible to interference than other types of wireless communication systems (Kim et al., 2020). is an evolving paradigm that shows the new direction of the internet in the future, where many heterogeneous networks containing different user data will be integrated transparently and seamlessly, which integration aims to allow anything with a receiver to access the internet anytime and anywhere. In addition, through this easy access to various types of internet of things devices such as environmental monitoring sensors, household electrical appliances, actuators, vehicles, etc., data with the internet network provides unprecedented services for private users, business users, government users, the military and anyone who uses the internet. Clear applications of the internet will be seen for individual needs such as peer-to-peer communication, e-health, and assistance for industrial and smarth grid needs (Qu et al., 2017).

Satellite-based systems, which are mainly LEO satellites have been adopted in machine to machine or M2M. These M2M satellite systems depending on small LEO constellations have been proposed, researchers propose for satellite-based M2M networks in terms of clustering, connectivity, and availability. The homepage of "ORBCOMM" is a leading global provider of M2M using the LEO satellite constellation (orbit altitude 815 km). The services provided by the satellite targeted sensor system (SRSS) focus on new bandwidth allocation methods.

Currently, satellite-based monitoring remains in the way of remote sensing including satellite imagery, shipboard satellite sensors, and on-board synthetic satellite thickness radar (SAR) systems. Those traditional techniques have limitations listed as follows: Weather influence: The above-mentioned sensing techniques, especially optical sensing by satellite images, are affected by weather conditions. Fog, clouds or haze will cause inaccuracies in satellite images. Meanwhile, when comparing selected data on a timeline, different weather conditions will eliminate the comparison (Qu et al., 2017). Indirect results: Results from sensing need to be analyzed by specialists to obtain the underlying information. Therefore, in order to collect different types of water information, the whole system needs to launch corresponding satellites, which will certainly increase the construction and operation costs. All these LEO and MEO systems are based on satellite constellations with multiple spherical common-period orbits with low (typically 700-1400 km) or medium (typically 10 000 km) altitudes (Ekici et al., 2001); all orbits in each constellation have the same inclination with respect to the equatorial plain. The same number of satellites circulate (usually with regular phasing, random phasing only in Teledesic) in each orbit, and so does the corresponding circular coverage area on earth, thus achieving continuous and global coverage (Werner, 1997).

The benefits obtained from telecommunications systems using satellites are in each orbit that has different coverage so that the closer the distance from the satellite to the earth's surface, the better so that communication is carried out both within a country and between countries can be done without any time delay resulting in delays in conveying data in the form of information either in text, images, sound, or images and sound with good quality.

3.2 Surveillance

One of the benefits of satellites also functions for surveillance where the intended supervision is to monitor the boundaries of the specified area so that there are no things that can cause harm to a country, so monitoring or surveillance using satellites is needed. Advances in satellite remote sensing technology have revolutionized the approach to monitoring the Earth's surface. The global soil layer is changing rapidly due to anthropogenic activities (e.g., agricultural expansion and urbanization) and natural processes (e.g., flooding) (Murthy et al., 2014). Passive detection of moving aerial targets is essential for smart surveillance. Its implementation can use signals emitted from satellites. Currently, different types of satellites coexist that can be used for passive detection. As a result, satellite signal receivers may receive signals from multiple heterogeneous satellites, making it difficult to detect echo signals. These changes affect human life, and therefore effective monitoring mechanisms are necessary for the sustainable management and use of natural resources (Kim et al., 2020).

The development of the Copernicus Program by the European Space Agency (ESA) and the European Union (EU) has contributed to surface monitoring. Earth by producing the Sentinel-2 multispectral product. The Sentinel-2 satellite is the second constellation of ESA's Sentinell mission and carries a multispectral scanner on board. The main objective of the Sentinel-2 mission is to provide high-resolution satellite data for self-surveillance, climate change and disaster monitoring, as well as complement other satellite missions such as Landsat. Since the launch of the Sentinel-2 multispectral instrument in 2015, there have been many studies on land cover/land use classification using Sentinell-2 images. However, there is no review study dedicated to the application of ESA Sentinel-2 land use coverage/surveillance (Segarra et al., 2020). Therefore, this review focuses on two aspects namely, evaluating the contribution of ESA Sentinel-2 to land cover/land use classification, and exploring the performance of Sentinell-2 data in different applications (e.g., forests, urban areas and natural hazard monitoring). This review shows that Sentinel-2 has a positive impact on land coverage/use monitoring, particularly in monitoring crops, forests, urban areas, and water resources. The current high adoption and applicability of Sentinel-2 can be attributed to its higher spatial resolution (10 m) than other medium space resolution images, high time resolution of 5 days, and availability of red end bands with multiple applications. The ability to integrate Sentinel-2 data with other remotely sensed data, as part of data analysis, improves overall accuracy (OA) when working with

Sentinell-2 images. The free access policy encourages increased use of Sentinel-2 data, especially in developing countries where financial resources for acquiring remotely sensitive data are limited. Literacy also shows that the use of Sentinel-2 data results in high accuracy (>80%) with machine learning classifiers such as support vector machines (SVM) and Random forest (RF). Sentinel-2 over sensors similar to Landsat-8 (Segarra et al., 2020).

Applications of Sentinel-2 data vary from region to region, especially the type of data integrated with Sentinel-2 However, other classifications such as maximum likelihood analysis are also common. Although Sentinel-2 offers many opportunities to classify land coverage/use, there are challenges that include drift with Landsat OLI-8 data, lack of heat bands, and differences in spatial resolution between Sentinell-2 bands. Sentinel-2 data show promise and have the potential to contribute significantly to land cover/use monitoring (Phiri et al., 2019). For surveillance of border areas using ESA's Sentinel-2 satellite where land coverage/use monitoring has a high spatial resolution than medium resolution images that can monitor a variety of land coverage/use monitoring, especially in monitoring crops, forests, urban areas, and water resources so that they can be monitored without being left behind.

3.3 Intelligence and surveillance

Surveillance in military activities also requires remote sensing in monitoring, one of which is satellite. Location is a very important feature of many commercial, public service, and military wireless networks. And the information collected or communicated by wireless nodes is often only meaningful in combination with the node's location knowledge. For example, sensor networks are used to detect spatial variations in environmental conditions (Wymeersch et al., 2009). The goal of self-localization is for each node to know its own state. A state typically includes a two- or three-dimensional position, and possibly other properties such as the velocity and orientation of the node. The terms state, position, and location are interchangeable, while in our example we will narrow the scope of state to two-dimensional geographic coordinates (Bevis et al., 1992).

A four-system positioning model that uses GPS, GLONASS, Galileo, and BeiDou significantly improves satellite visibility, spatial geometry, and positioning accuracy, especially in constrained environments (Kim et al., 2020). We will distinguish between two types of nodes that have a known state at all times. Both agents and anchors can move. In addition to the long-established global satellite navigation systems (GNSS) GPS and GLONASS, two additional systems have recently emerged, Galileo and BeiDou. GPS is currently operating at full capacity and GLONASS has been updated and is also fully operational. Location knowledge is a key feature of next-generation wireless networks, enabling many applications in the military (e.g., blue force tracking), public (e.g., search and rescue), and commercial (e.g., navigation) sectors. Cooperation between nodes has the potential to dramatically improve localization performance. The main approaches to cooperative localization are from the viewpoint of approximation theory and factor graphs. A network message passing algorithm can then be obtained with an appropriate message schedule, taking into account the time-varying network topology. The RMS value of clock difference between real-time and batch-processed solutions for GPS satellites is about 0.10 ns, while the RMS values for BeiDou, Galileo and GLONASS are 0.13, and 0.14 ns, respectively. Adding BeiDou, Galileo and GLONASS systems to standard GPS processing, reduces the convergence time by almost 70%, while the positioning accuracy is improved by about 25% (Li et al., 2015).

Some outliers in the GPS-only solution disappear when multi-GNSS observations are processed simultaneously. Due to the same ranging and positioning principles for different GNSSs, most of the observation error models and satellite power models for GPS can be used directly for other systems, i.e., GLONASS, Galileo and BeiDou (Li et al., 2015). However, some modifications in themulti-GNSS processing are required due to different frequencies, additional parameters (e.g., ISB) and especially due to different characteristics of the BeiDou orbit (e.g., satellite attitude control mechanics, constellation distribution, detection and manipulation maneuvers). Location knowledge has a large number of related research challenges, including efficient, robust, and accurate coverage algorithms. In military surveillance by using 4 systems at once namely GPS, GLONASS, BeiDou, Galileo to fully utilize the observations of all navigation systems for accurate orbit determination, clock estimation, and real time positioning. Rigorous multi GNSS analysis is performed to achieve the best consistency by processing observations from various GNSS together in one common parameter estimation procedure. Meanwhile, an efficient multi GNSS system and timely positioning service is designed and demonstrated by using GnSS experiment, Beidu experimental tracking network, and international GNSS service network including stations around the world.

3.4 Disaster monitoring and rescue

Disaster observation and rescue that will be carried out in the event of a disaster or accident can use a remote sensing system with the help of satellites. One of the following satellites with consideration of land changes Surface temperature is very important in global change studies, in estimating radiation budgets, in heat balance studies, and as a control for climate models (Gillespie et al., 1998). Satellite data and image analysis can effectively support rapid mapping tasks in disaster and crisis management support, assisting relief efforts and civil security efforts (Kim et al., 2020).

Emissivity is highly indicative, even diagnostic, of composition, especially for the silicate minerals that make up most of the land surface. Surface emissivity is important for the study of soil development and erosion and for estimating the amount of and changes in the fragile vegetative cover under which the substrate is exposed. important for bedrock maps and resource exploration (Van Der Werf et al., 2010). ASTER includes a five-band multispectral TIR scanner designed to recover land surface "kinetic" temperatures and emissions, not just temperatures above known emission-homogeneous surfaces, such as water. It is designed to obtain a global emissions map of the land surface, but will also recover surface temperatures and emissions for the requested location over the entire six-year lifetime of EOS-AM1 (Gillespie et al., 1998). With 90 m TIR spatial resolution and 15 m VNIR resolution, ASTER acts as a high-resolution addition to other EOS imaging experiments. Because of their high resolution, ASTER and data can be confirmed with field experiments and, at the same time, used to understand the average response of lower resolution scanners. Geological image rationalization and interpretation techniques date back to the early days of aerial photographic geology and early Landsat multispectral data sets (MSS) where the VNIR band was first used to generate imagery. The French Satellite Pour l'Observation de la Terre (SPOT) system is used in geology because of its unprecedented spatial resolution and stereo capabilities. Several studies have demonstrated the use of SPOT data for lithologic mapping for (semi-)automated flaw detection and delineation. It has also been shown that subpixel measurements of surface displacement along failures can be generated from SPOT data.

While other instruments such as the IRS-1A are also used by the geological remote sensing community, the application of remote sensors in geology was accelerated with the arrival of the Landsat Thematic Mapper (TM) instrument. Landsat TM has been used for many years by the geologic remote sensing community to map lithology and delineate lines specifically to match alteration mineralogy. Especially band ratio techniques, decorrelation stretching and saturation enhancement and principal component analysis (PC) (PCA) have been popular techniques. The last decade has seen a trend towards higher spectral resolution (hyperspectral remote sensing) and towards band positioning of key absorption features (ASTER) (Gillespie et al., 1998). Hyperspectral remote sensing is defined as "taking images in many, narrow and conjugate spectral bands to rebuild a full spectrum that can be compared directly with field or laboratory spectra. There are strengths and weaknesses to this technique. The strength of the availability of hundreds of spectral bands is that it allows for mimicking the reflection or radiation spectra obtained in the field, allows for cross-comparison with field data, and allows for catering to many different applications (van der Meer et al., 2012). Satellite utilization in disaster monitoring using the ASTER satellite with the advantage of including a five-band multispectral TIR scanner designed to recover land surface "kinetic" temperatures and emissions, not just temperatures above the homogeneous surface of known emissions, such as water.

4. Conclusions

The benefits obtained from telecommunications systems using satellites are in each orbit that has different coverage so that the closer the distance from the satellite to the earth's surface, the better so that communication is carried out both within a country and between countries can be done without any time delay resulting in delays in conveying data in the form of information both in text, images, sound, and images and sound with good quality. For surveillance of border areas using ESA's Sentinel-2 satellite where monitoring of coverage / land use has a high spatial resolution than medium resolution images that can monitor a variety of coverage / land use monitoring, especially in monitoring crops, forests, urban areas, and water resources so that they can be monitored without being left behind. In military surveillance using 4 systems at once, namely GPS, GLONASS, BeiDou, Galileo to fully utilize the observations of all navigation systems for accurate orbit determination, clock estimates, and real time positioning. Rigorous multi GNSS analysis is performed to achieve the best consistency by processing observations from various GNSS together in one common parameter estimation procedure. Meanwhile, a multi GNSS system that is efficient and timely placement service is designed and demonstrated using the GnSS experiment, Beidu experimental tracking network, and international GNSS service network including stations around the world. The use of satellites in disaster monitoring using the ASTER satellite with advantages including a five-band multispectral TIR scanner designed to recover the "kinetic" temperature of the land surface and emissions, not just the temperature on the homogeneous surface of known emissions, such as water. So that the various things described can help the state in the field of defense and security of a country.

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