

REVIEW ON SATELLITE COMMUNICATION

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ABSTRACT

Satellite communication, an unprecedented invention, has completely altered global connectivity, serving as a backbone various sectors, such as like telecommunication, broadcasting, navigation, and remote sensing. The abstract will delineate the intriguing history of satellite communications and satellite orbits. Additionally, the abstract provides, when using artificial intelligence, it can potentially offer opportunities for enhanced performances, efficiency, and adaptability. In this review paper, we have discussing the numerous challenges facing satellite communication. The complexities surrounding satellite communication continue to present significant hurdles in terms, to both technical and operational aspects, thus impacting the overall efficacy, and reliability of satellite-based systems. Moreover, the integration of advanced technologies like artificial intelligence, machine learning, and blockchain may offer potential solutions to mitigate these challenges, paving the way for enhanced performances and increased efficiency. This review aims is to shed light on the current landscape of satellite communication by identifying critical issues and proposing innovative strategies for overcoming them.

Keywords: Satellite communication, Artificial intelligence, Satellite orbits, Advancement, Satellite history.

1. INTRODUCTION

In the international telecommunications networks, satellite communication is essential. Communication is commonly defined as the transmission of information. In general a communication satellite is an artificial satellite that establishes a communication channel between a source transmitter and a receiver at different locations on earth by relaying and amplifying radio telecommunication signals via a transponder. There are three types of satellites around the earth: Geostationary (GEO), Medium earth orbit (MEO), and Low earth orbit (LEO). A geostationary satellite orbits at an altitude of approximately 35,786 km (22,236 miles), allowing it to remain stationary over a specific longitude at the equator. Low earth orbit (LEO) satellites are situated at an elevation ranging from 160 km to 1,600 km above the earth's surface. Meanwhile, Medium earth orbit (MEO) satellites function at distance between 10,000 and 20,000 km from earth. Satellite communications involve transmitting or up linking signals from a ground station to a satellite. The satellite then receives the signals, amplifies it, and sends it back to earth. There are many advancements in satellite communications systems. In the present era, artificial intelligence have led to a growing demand for satellite communications systems. Satellite communications are being revolutionized by artificial intelligence (AI) in a number of ways, making the systems more sophisticated and effective. Artificial intelligence makes tasks more accurate using satellite communication systems. Although satellite communication offers improved

global coverage and increased communication quality, it has several challenges. In addition, achieving high energy efficiency for satellite communication is more challenging than for terrestrial networks. In this review paper we have discuss about challenges towards satellite communication systems. Furthermore, the growing use of satellites for new purposes and growing global demand for satellite communications services have captured the attention of the investment community. This has led to the formation of new satellite service providers and promoted mergers and acquisitions, the formation of new companies, the formation of global partnerships, and the privatization of previously government-owned satellite service providers. The satellite communications industry has grown significantly, with significant growth in the number of professionals and the scope of their activities. Although in this review paper describes the element of satellite communication, explains advances, issues and challenges in satellite communication and also explains the applications of satellite communication system.

2. NEED OF SATELLITE COMMUNICATION

Satellite communication serves several critical needs and plays an indispensable role in modern society. Here are some of the key reasons why satellite communication is essential:

- **Global Coverage:** Satellite communication specifies inclusion to regions place earthly infrastructure is deficient or economically not feasible to redistribute. It ensures connectedness to detached and isolated districts, containing rural domains, cliffs, oceans, and polar domains, place other forms of ideas can be impractical or non-existent.
- **Disaster Response and Emergency Communication:** During organic disasters, in the way that shocks, hurricanes, or tsunamis, earthly communication foundation grant permission be severely broken or ruined. Satellite communication offers a help by providing bouncy and reliable ideas links for danger responders, relief instrumentalities, and touched communities, permissive arrangement, help delivery, and ideas accompanying the outside world.
- **Remote Sensing and Earth Observation:** Satellites outfitted accompanying sensors and cameras provide priceless dossier for monitoring the earth's surface, air, and surroundings. Remote sensing satellites aid in weather science, preservation of natural resource, agriculture, city preparation, disaster administration, and experimental research, donating to better understanding and management of raw materials and referring to practices or policies that do not negatively affect the environment processes.
- **Telecommunications and Broadcasting:** Satellite communication eases long-distance voice, dossier, and video broadcast for science services, containing phone calls, broadband internet approach, station broadcasting, and combined use of several media content childbirth. Satellites authorize global connectedness, extending communication break 'tween people, trades, and societies worldwide.
- **Navigation and Positioning:** Satellite-located traveling systems, to a degree GPS (Global Positioning System), support precise standing, organize, and navigation aids for miscellaneous requests, including navigation, nautical, transportation, scrutinizing, plan, and location-located aids. These systems embellish security, efficiency, and veracity in guiding along route, often over water and logistics movements.
- **National Security and Defence:** Satellite ideas is lively for military and defence uses, containing command and control, intelligence accumulation, following, reconnaissance, and secure means. Military satellites allow strategic ideas links, authentic-time circumstantial knowledge, and coordinated armed conflict across far-flung distances and diverse atmospheres.
- **Business and Commerce:** Satellite ideas supports differing commercial endeavours and businesses, including nautical ships, aviation, lubricate and vapour exploration, excavating, farming, and tourism.

Satellites promote worldwide trade, management, supply chain administration, and detached operations, reinforcing output, efficiency, and connectedness in the worldwide economy.

- Connectivity in Aviation and Maritime Industries: Satellites play a critical function in providing communication and traveling duties to aircraft, ships, and seaward planks, enabling cautious and adept movements in remote or maritime airspace and nautical regions place earthly communication inclusion is restricted or non-existent.

3. HISTORY OF SATELLITE COMMUNICATION

The history of satellite communication is a fascinating journey marked by technological breakthroughs and innovations that have revolutionized global communication. Here's a brief overview:

Table 0.1: History of satellite communication

1945	Arthur C. Clarke's Remarkable Prescience.
1957	USSR Launches Sputnik 1.
1962	Skynet/ NASA Launch Telstar 1.
1964	Summer Olympics is Televised Live via a Satellite.
2003	Eutelsat Launches e-BIRD, Designed for the Internet Broadband.
2010-2011	Eutelsat and ViaSat Launch High- Throughput Satellites.
2014-2021	Satellite Constellations Dramatically Increase the Number of In-Orbit Spacecraft.

Overall, satellite communications have played a key role in shrinking the world and connecting people across previously inaccessible continents, oceans, and even remote regions. Its history is a testament to human ingenuity and the constant pursuit of innovation in the field of communication.

a. Geostationary Satellite (GEO)

These satellites orbit the Earth at the same speed as the Earth's rotation, allowing them to remain stationary relative to a fixed point on the Earth. Typically located at high altitudes (approximately 35,786 km or 22,236 miles above the equator), they are commonly used for broadcasting, communications, and weather monitoring. Additional examples of use-cases for GEO satellites include:

- Crew connectivity at sea
- Inflight Wi-Fi
- Disaster Response

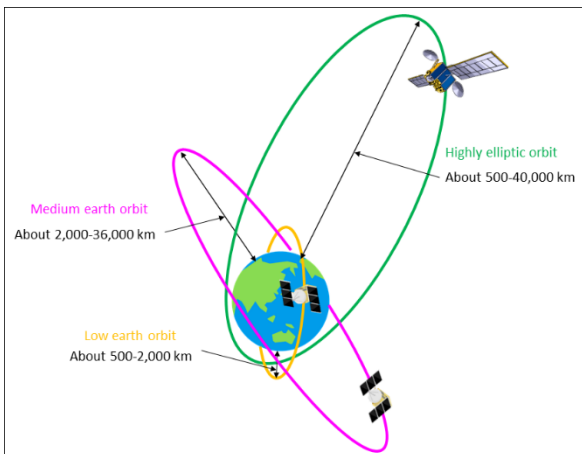
3.2 Low Earth Orbit Satellite (LEO)

LEO satellites orbit much closer to Earth, typically at altitudes of 160 to 2,000 km (100 to 1,200 miles). It is used for a variety of purposes, including communications, remote sensing, and scientific research. LEO satellites have low latency and can provide global coverage through satellite constellations. They can be used for several applications such as:

- Industrial IOT (Internet of Things)
- Maritime and tourism
- Government and tactical networks
- Emergency response and aid
- Telecommunications and mobile 5G broadband

3.3 Medium Earth Orbit Satellite (MEO)

MEO satellites orbit at an altitude intermediate between LEO and GEO satellites, typically 8,000 to 20,000 km (5,000 to 12,500 miles) above Earth. It is often used in navigation systems such as the Global Positioning System (GPS).



4.

4. WORKING PRINCIPLE OF SATELLITE COMMUNICATION

Satellite communications use a combination of orbital satellites and ground stations above the Earth to transmit and relay information using microwaves from one point on the Earth to another.

There are three steps in this process:

- uplink
- transponder
- downlink

For example, let's look at live TV. Broadcasters transmit (or transmit) signals to designated satellites via user terminals. This is called an “uplink.” Once received by an orbiting satellite, on board amplifiers boost the signal's power and change its frequency before it is relayed back to a designated ground station on the ground. This is also called the “transponder” stage. Finally, these transmitters send one or more signals back to Earth to ground stations around the world. This is called a “downlink.”

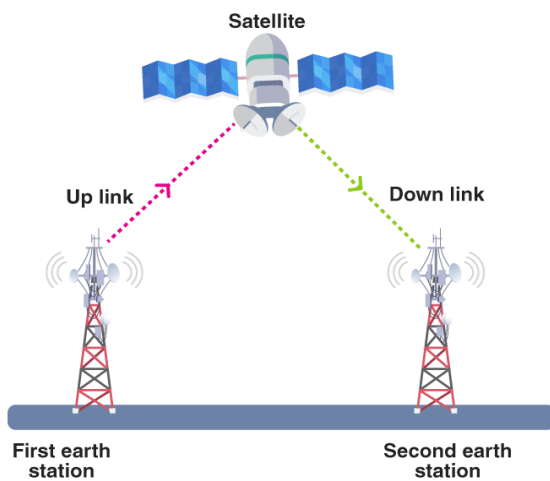


Figure 1.1: working of satellite communication

Two-Way Communication:

Satellite can facilitate do two-way communication naturally, allowing both the transmission and of signals between ground stations and satellite terminals. This enables several various, like telephony, internet access, broadcasting, remote sensing, and navigation Throughout this process, satellites orbiting the Earth play a tremendously crucial role inlaying signals across long distances, overcoming geographical barriers, and providing global connectivity. types of satellites, like geostationary low Earth orbit, and medium Earth orbit satellites, are used depending on the application and coverage requirements.

4.1 (AI) IN SATELLITE COMMUNICATION

Artificial intelligence (AI) can be integrated with satellite communications systems to improve various aspects of satellite operations, data analytics, and applications. Here are some ways to use AI in combination with satellite communications:

1. **Satellite operation optimization.** Artificial intelligence algorithms can analyse satellite telemetry data to optimize satellite operations, including orbit maintenance, power management, and payload configuration. AI can help automate routine tasks, improve efficiency, and reduce human error in satellite operations.
2. **Signal processing and data compression.** Satellite data can be efficiently processed and compressed using artificial intelligence technologies such as machine learning and deep learning. This is particularly useful for optimizing satellite communications links by reducing the bandwidth required to transmit large amounts of data from the satellite to the ground station.
3. **Predictable Maintenance.** AI-based predictive maintenance systems can monitor the health of satellite components and predict potential failures before they occur. AI algorithms can analyse telemetry data and historical performance indicators to identify patterns that indicate impending problems, allowing operators to take proactive maintenance actions and minimize downtime.
4. **Image and data analysis.** Satellites collect vast amounts of images and other sensor data that can be analysed using artificial intelligence algorithms for a variety of applications, including environmental monitoring, agriculture, urban planning, disaster response, and defence. AI can automate the analysis of satellite imagery to extract useful information, identify patterns, and detect anomalies.
5. **Autonomous Satellite System.** AI can be used to develop autonomous satellite systems that can make decisions in real time without human intervention. These systems can adapt to changing conditions, optimize resource utilization, and respond to dynamic mission challenges. For example, AI allows multiple autonomous satellites to collaborate on tasks such as swarming or distributed sensing.
6. **Natural Language Processing (NLP):** NLP technology can be integrated with satellite communication interfaces to enable natural language interaction between users and satellite systems. This will facilitate access to satellite services and enable applications such as voice-activated satellite terminals or Chatbot interfaces for satellite command and control.
8. **Disaster response and humanitarian assistance.** AI-based satellite communications systems can play a critical role in disaster response and humanitarian assistance by providing real-time situational awareness, coordinating emergency response efforts, and delivering critical information to affected areas.

By integrating artificial intelligence and satellite communications systems, organizations can leverage new capabilities, improve operational efficiency, and leverage the full potential of satellite technology for a variety of applications across a variety of industries.

4.2 ADVANCEMENTS IN SATELLITE COMMUNICATION

Advancements in satellite communication have been extremely significant, enhancing the capabilities, efficiency, and reliability of satellite-based systems. Some notable advancements include:

1. **High Throughput Satellites (HTS):** HTS utilize multiple spot beams and frequency reuse techniques to provide much higher data throughput compared to traditional satellites. This allows for increased capacity and improved performance, particularly for broadband internet services.
2. **Software-Defined Satellites:** These satellites feature reconfigurable payloads and flexible on board processing capabilities, allowing operators to adapt to changing communication needs, optimize resource allocation, and even provide on-demand services.
3. **Inter-Satellite Link (ISL) Technology:** ISL enables direct communication between satellites in space, bypassing the need for signals to be relayed through ground stations. This enhances network resilience, reduces latency, and enables more efficient data routing.
4. **Small Satellites and Constellations:** Advances in miniaturization and launch technology have led to the development of small satellites (e.g., Cube Sets) and constellations of satellites. These systems offer improved coverage, lower latency, and increased redundancy compared to traditional large satellites.
5. **Optical Communication:** Optical communication technology uses lasers to transmit data between satellites or between satellites and ground stations. It offers higher data rates, lower latency, and greater security compared to traditional radio-frequency communication.
6. **Reusable Launch Vehicles:** Reusable rockets, such as Space X's Falcon 9, have reduced the cost of launching satellites into orbit. This has made satellite deployment more affordable and accessible, enabling more frequent launches and faster deployment of satellite communication networks!
7. **Advancements in Antenna Technology:** Phased array antennas and electronically steerable antennas allow satellites to dynamically adjust their beam patterns, improve signal quality, and provide better coverage, particularly for mobile and maritime applications;
8. **Satellite-Based Navigation Systems:** Systems like GPS (Global Positioning System), GLONASS (Global Navigation Satellite System), and Galileo provide precise positioning and timing information worldwide, supporting a wide range of applications including navigation, transportation, and precision agriculture.
9. **Secure Communication Protocols:** Advanced encryption techniques and secure communication protocols are being implemented to enhance the security of satellite communication systems. This helps protect against interception, tampering, and unauthorized access.
10. **Integration with 5G Networks:** Satellite communication is increasingly being integrated with terrestrial 5G networks to extend coverage, improve network resilience, and support new use cases such as IOT (Internet of Things) connectivity and high-speed broadband services in remote areas.

5.1 ADVANTAGES OF SATELLITE COMMUNICATION

Satellite communication provides several advantages that make it a preferred choice for various applications. Some of the key advantages include:

1. **Global Coverage:** Technology allows satellites offer global communication coverage to virtually any location on Earth, including remote and inaccessible areas where terrestrial infrastructure lacks or isn't practical. This global coverage makes satellite communication ideal for reaching populations in rural or underserved regions.
2. **Scalability:** Satellite communication systems can easily scale to accommodate a wide range of users and applications. Whether it's broadcasting television signals to millions of viewers or providing internet connectivity to a small community, satellite networks can be tailored to meet diverse needs.
3. **High Bandwidth:** Satellites can support high-bandwidth communication links, making them suitable for applications requiring the transmission of large amounts of data, such as high-definition video streaming, broadband internet access, and enterprise networking.
4. **Reliability:** Satellite communication systems are inherently resilient to natural disasters, infrastructure failures, and other disruptions that may affect terrestrial communication networks. Satellites operate independently of ground-based infrastructure, providing a backup communication option during emergencies.
5. **Rapid Deployment:** Satellite communication systems can be deployed relatively quickly compared to building or upgrading terrestrial infrastructure. This rapid deployment capability makes satellite technology particularly valuable for temporary or mobile communication needs, such as disaster response, military operations, and live event broadcasting.
6. **Ubiquitous Connectivity:** With satellite communication, users can stay connected while on the move, whether traveling by land, sea, or air. Mobile satellite services enable voice, data, and messaging capabilities in remote or mobile environments, including ships, aircraft, and vehicles.
7. **Security:** Satellite communication can offer secure and encrypted communication channels, making it suitable for sensitive applications such as military and government communications, financial transactions, and corporate networking.
8. **Support for Multicast and Broadcast:** Satellites can efficiently distribute content to multiple recipients simultaneously using multicast and broadcast transmission techniques. This capability is especially advantageous for broadcasting television and radio signals to large audiences over wide geographic areas.
9. **Flexible Network Design:** Satellite communication networks can be designed with various configurations, including point-to-point, point-to-multipoint, and mesh topologies, to accommodate different communication requirements and optimize network performance.
10. **Interoperability:** Satellite communication systems can seamlessly integrate with existing terrestrial networks and infrastructure, enabling hybrid communication solutions that combine the strengths of both satellite and terrestrial technologies to deliver comprehensive connectivity solutions.

5.2 DISADVANTAGES OF SATELLITE COMMUNICATION

While satellite communication offers numerous advantages, it also comes with several disadvantages:

1. **Latency:** Signals traveling to and from satellites are incurring latency because of the distance they have to travel. This can be significant drawback for real-time applications like online gaming, video conferencing, or even certain financial transactions.
2. **Cost:** Building, launching, and maintaining satellites is quite expensive. This cost is often passed on to consumers, making the price of satellite communication services relatively expensive when compared to other forms of communication, especially in remote or underdeveloped areas.
3. **Susceptibility to Environmental Factors:** Satellite communication signals can be affected by weather conditions like heavy rain, snow, or storms, which can degrade the quality of the connection or even disrupt it entirely.
4. **Limited Bandwidth:** The available bandwidth for satellite communication is limited, especially when compared to terrestrial alternatives like fibre optics. This limitation can result in slower data transfer speeds and congestion during peak usage times.
5. **Risk of Signal Interference:** Satellite signals can be easily susceptible to interference from other signals, or objects in space, which can degrade communication quality or potentially cause disruptions.
6. **Security Concerns:** Satellite signals can possibly be intercepted, leading to potential security breaches or unauthorized access to sensitive information.
7. **Dependency on Line of Sight:** Satellite communication needs an unobstructed line of sight between the transmitter and the satellite. This can pose problems in areas with tall buildings, dense foliage, or mountainous terrain, limiting the effectiveness of satellite communication in certain locations.
8. **Limited Coverage:** While satellite communication has the ability to reach remote or rural areas where other forms of communication infrastructure are lacking, the coverage may still be limited in certain regions, particularly in extreme latitudes, or densely populated urban areas with tall buildings.
9. **Environmental Impact:** The launch and operation of satellites contribute to space debris and environmental pollution. Additionally, the manufacturing and disposal of satellites can have negative environmental consequences.
10. **Regulatory Challenges:** Satellite communication services may be subjected to regulatory restrictions or licensing requirements imposed by governments, adding complexity and uncertainty to the operation of satellite networks.

Even with these disadvantages, satellite communication remains essential for global connectivity, especially in areas where terrestrial infrastructure is lacking or impractical to deploy.

5.3 APPLICATIONS OF SATELLITE COMMUNICATION

Satellite communication has a wide range of applications across various industries and sectors. Here are some of the key applications:

1. Telecommunications
2. Broadcasting
3. Internet Access
4. Navigation and Positioning
5. Remote Sensing
6. Weather Forecasting
7. Surveillance and Security
8. Emergency Communications
9. Agriculture and Resource Management
10. Scientific Research

These applications demonstrate the versatility and importance of satellite communication in modern society, providing essential services and facilitating economic, social, and scientific progress.

5.4 LIMITATIONS OF SATELLITE COMMUNICATIONS

Satellite communications have many advantages but also limitations:

1. **Cost:** Satellites are expensive to build, launch and maintain. This fee may affect access to certain organizations or countries that prohibit the use of satellite communications equipment.
2. **Propagation Delay:** Signals to and from satellites have propagation delays due to the distance they have to travel. This delay can be seen especially in instant messaging such as voice or video calls and causes delay problems.
3. **Limited Bandwidth:** Satellites have limited bandwidth for communication. This restriction may cause congestion, slow data, or disconnection, especially in areas with high demand.
4. **Weather interference:** Weather conditions such as heavy rain, snow or cloudy weather can affect satellite signals, reduce communication quality or even cause temporary outages.
5. **Line of sight requirements:** Satellite communications require a line of sight between the satellite and the ground station or user terminal. Terrain such as mountains or tall buildings can block signals, limiting coverage in some areas.
6. **Limited Coverage:** Although satellite communications provide worldwide coverage, they may not be able to transmit radio signals effectively in certain areas, which may result in service variation.
7. **Power Limitations:** Satellites depend on solar panels for power, which limits the power available for communications, especially during solar eclipses or when solar panels fail over time.
8. **Security issues:** Satellite signals are easily interrupted or interfered with, which can raise concerns about the security and confidentiality of transmitted data.
9. **Orbital Debris:** The amount of space debris poses a risk to satellites in orbit. Collisions with debris can damage or destroy satellites, disrupting communications services.
10. **Legal Rights:** Radio communications are subject to restrictions from governments and international organizations, which may affect distribution, operations and spectrum allocation.

6. FUTURE SCOPE OF SATELLITE COMMUNICATION

- The future of satellite communications has the potential to bring major changes in many ways. Satellite communications will continue to play an important role in providing global connectivity, especially in remote and underserved areas where terrestrial coverage is limited or unavailable. With next-generation High Throughput Satellites (HTS) and Low Earth Orbit (LEO) deployments, satellite networks will deliver high-speed Internet access to even the most remote parts of the world.
- Satellite communication will support terrestrial 5G communication to expand coverage to rural and remote areas and provide stable communication in situations such as disaster recovery and emergency response. In the future, satellites will play a key role in converging terrestrial and satellite 5G networks, supporting a variety of applications such as the Internet of Things (IOT), autonomous vehicles, and immersive multimedia experiences.
- Satellite communications will promote the development of the Internet of Things (IOT) by providing connectivity to a variety of devices and sensors in remote and mobile areas such as maritime, aviation, agriculture, and energy. Satellite IOT networks will support applications such as asset tracking, environmental monitoring, and smart agriculture, improving efficiency and innovation across all industries. Overall, satellite communications will play a key role in shaping the future of communications, innovation and research, opening up new opportunities for technological business development, social development and international research.

7. CONCLUSION

In this review paper an attempt has made to describe the essentials of satellite communications. Its constituent's, advancement in the satellite communication, past, present and future applications are briefly discussed. Furthermore, we discuss a brief study of satellite communications, their types, advantages, disadvantages, and applications. We have also discussed about artificial intelligence, using (AI) future work should aim to achieve more efficient, secure, reliable, and high quality communication systems. Satellite communication play an important role in connecting the world and facilitate many applications in various industries. Despite competition, continuous development and advancement has ensured its importance in global communication. In essence, satellite communication is a cornerstone of modern telecommunications, enabling global connectivity, supporting diverse applications, and shaping various aspects of society, economy, and security.

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