

A Comprehensive Review of Real-Time Safety Alarm Systems Using GPS, LoRa, IoT, and Satellite Communication for Emergency SOS Applications

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Abstract

Real-time emergency communication systems have become increasingly important in military operations, disaster management, remote healthcare, trekking safety, and rescue missions. Conventional communication infrastructures such as GSM and cellular networks often fail in remote areas, war zones, mountainous regions, and disaster-affected environments. This has motivated researchers to develop advanced safety alarm systems integrating Global Positioning System (GPS), Long Range (LoRa) communication, Internet of Things (IoT), and satellite communication technologies. This review paper presents a comprehensive analysis of recent research works related to emergency SOS communication systems, LoRa-enabled monitoring frameworks, military IoT architectures, GPS navigation systems, and satellite-based rescue technologies. The paper critically reviews multiple research contributions including LoRa-based soldier support systems, Iridium satellite communication security studies, Cospas-Sarsat search and rescue systems, encrypted military IoT frameworks, and LoRa-based navigation alternatives.

Comparative analysis is performed on communication range, power consumption, latency, reliability, scalability, and security aspects of existing technologies. Furthermore, major research gaps such as satellite communication vulnerabilities, GPS signal interference, lack of encryption, and high operational costs are identified. Finally, future research directions involving hybrid LoRa-satellite communication, artificial intelligence integration, edge computing, and self-healing emergency networks are discussed. The study highlights that combining LoRa, GPS, IoT, and satellite communication can significantly improve the reliability and effectiveness of modern emergency SOS systems.

Keywords— LoRa, GPS, IoT, Satellite Communication, Emergency SOS, Iridium, Cospas-Sarsat, Military IoT, Rescue Systems, Real-Time Monitoring.

1. Introduction

Emergency communication systems play a crucial role in saving human lives during natural disasters, military operations, remote expeditions, and medical emergencies. In many critical situations, traditional communication systems such as GSM, Wi-Fi, and cellular networks become unavailable due to infrastructure failure, geographical limitations, or intentional signal disruption. This issue becomes more severe in mountainous regions, forests, remote border areas, oceans, and disaster-prone zones where reliable communication is essential for rescue operations and situational awareness.

Modern emergency safety systems are increasingly integrating technologies such as Global Positioning System (GPS), Long Range (LoRa) communication, Internet of Things (IoT), and satellite communication to overcome these limitations. GPS enables real-time location tracking, while LoRa provides low-power long-range communication suitable for remote monitoring applications. Satellite communication technologies such as Iridium and Cospas-Sarsat offer global communication coverage even in isolated regions where terrestrial networks are absent.

Recent advancements in IoT have enabled the development of intelligent safety monitoring systems capable of

collecting and transmitting physiological, environmental, and location-related data in real time. These systems are particularly important in military applications where soldier health monitoring, emergency SOS alerts, and battlefield communication are critical for mission success and personnel safety.

Several researchers have proposed LoRa-based monitoring systems, encrypted military IoT frameworks, and satellite-assisted rescue systems to improve emergency communication reliability. However, challenges such as security vulnerabilities, high operational costs, communication latency, signal interference, and energy constraints still limit the efficiency of existing systems.

This review paper provides a comprehensive analysis of current research related to LoRa communication, GPS tracking, satellite communication, and IoT-based emergency safety systems. The study also identifies research gaps and future opportunities for the development of secure, energy-efficient, and globally accessible emergency communication infrastructures.

II. Literature Review

A. Enhanced Soldier Support System Using LoRa Technology

Rajan Singh et al. proposed an Enhanced Soldier Support System (ES3) utilizing LoRa technology integrated with an emergency SOS feature for military applications. The proposed system monitors soldier health parameters such as heart rate, oxygen levels, body temperature, and location tracking using GPS modules and sensors. The collected information is transmitted to the base station using LoRa and MANET communication technologies. The system aims to improve battlefield situational awareness and emergency response efficiency.

The major advantage of the ES3 framework is its low-cost implementation and long-range communication capability. The use of LoRa enables uninterrupted communication in mountainous and remote regions.

However, the system mainly focuses on monitoring and lacks advanced encryption and secure authentication mechanisms. The study also highlights the need for lightweight wearable sensors to reduce the burden on soldiers during military operations.

B. Cospas-Sarsat Satellite System for Search and Rescue

The Cospas-Sarsat satellite system represents one of the most successful satellite-assisted search and rescue infrastructures. The system utilizes low-Earth-orbit satellites to detect emergency distress signals transmitted by Emergency Locator Transmitters (ELTs) and Emergency Position Indicating Radio Beacons (EPIRBs). The research demonstrates how global satellite networks can significantly improve rescue operations in remote areas.

The major contribution of this system lies in its global coverage and free-of-cost emergency support. The introduction of 406 MHz distress beacons improved location accuracy and enabled identification-based rescue operations. However, limitations such as communication delays in low-Earth-orbit coverage and dependence on satellite infrastructure remain important challenges.

C. Security Analysis of Iridium Satellite Communication

Eric Jedermann et al. presented a systematic security analysis of the Iridium satellite radio link. The research identified major vulnerabilities in Iridium communication protocols including lack of encryption, weak authentication mechanisms, and susceptibility to spoofing and jamming attacks.

The study revealed that a significant portion of Iridium communication traffic remains unencrypted, exposing sensitive data such as login credentials and location information. Researchers demonstrated SIM cloning attacks using the COMP128-1 algorithm and developed software-defined radio tools capable of spoofing and jamming satellite communication channels.

Although Iridium provides global communication coverage, the study emphasizes the urgent need for secure authentication and encrypted communication frameworks in satellite-assisted emergency systems.

D. LoRa Technology as an Alternative to GPS

Marcin Staniek and Ireneusz Celiński investigated the possibility of using LoRa technology as an alternative to GPS navigation in mountainous environments. The research focused on navigation support for off-road vehicles intended for people with special needs.

The authors highlighted that GPS systems may become unreliable during warfare or intentional signal interference. The study proposed LoRa-based reference point navigation systems capable of functioning without traditional satellite positioning infrastructure.

The research demonstrated that LoRa communication can provide effective information exchange in difficult terrains, although limitations related to transmission latency, environmental interference, and communication range still exist.

E. Evaluation of LoRa Wireless Technology for Military Applications

Uroš Pešović et al. evaluated LoRa wireless technology for battlefield monitoring, friendly force identification, and military localization systems. The study focused on Chirp Spread Spectrum (CSS)-based LoRa modulation and frequency hopping spread spectrum techniques.

The research demonstrated that LoRa provides high interference immunity, low power consumption, and long-range communication suitable for military applications. The adaptive spreading factor and forward error correction mechanisms improved reliability under hostile communication environments.

Despite its advantages, LoRa communication suffers from low data rates and high latency compared to conventional wireless systems.

F. End-to-End Encrypted IoT System for Military Communication

Muhammad Masud Ur Rahman et al. proposed a hybrid IoT communication system integrating ESP-NOW and LoRa technologies for military operations. The system implemented AES-128 encryption, HMAC-SHA256 authentication, GPS-synchronized key rotation, and self-healing mesh topology.

The proposed framework achieved secure low-latency communication with strong resilience against jamming and network failures. The integration of edge-fog-cloud architecture improved real-time battlefield situational awareness.

The study represents a significant advancement in secure military IoT communication systems, although challenges related to scalability and power optimization still require further research.

III. LoRa Communication in Military and Emergency Systems

LoRa (Long Range) communication is a low-power wireless communication technology designed for long-distance data transmission using Chirp Spread Spectrum (CSS) modulation. It operates in license-free frequency bands and supports communication over several kilometers while consuming minimal energy.

LoRa technology is particularly suitable for emergency and military applications due to the following advantages:

1. Long communication range
2. Low power consumption
3. High interference immunity
4. Support for remote monitoring
5. Cost-effective deployment
6. Scalability for IoT systems

In military systems, LoRa is used for battlefield monitoring, soldier tracking, environmental sensing, and emergency SOS communication. Its resistance to Doppler frequency shifts and adaptable spreading factors improve communication reliability in hostile environments.

However, LoRa systems also have limitations including:

- Low data transmission rates
- High communication latency
- Limited bandwidth
- Environmental interference sensitivity
- Security vulnerabilities in unencrypted implementations

Researchers have proposed hybrid LoRa architectures integrated with mesh networking, GPS tracking, and satellite communication to overcome these limitations.

IV. GPS and Navigation Technologies

The Global Positioning System (GPS) is a satellite-based navigation system that enables accurate real-time location tracking using signals transmitted by orbiting satellites. GPS has become an essential component in emergency rescue systems, military navigation, transportation management, and IoT monitoring frameworks.

GPS operates by calculating the distance between a receiver and multiple satellites using signal propagation time measurements. Accurate positioning requires signals from at least four satellites.

Advantages of GPS include:

- Global positioning capability
- High location accuracy
- Real-time tracking support
- Wide commercial availability

Despite its advantages, GPS systems face several challenges:

- Signal blockage in mountains and forests

- Vulnerability to jamming and spoofing
- Dependency on satellite visibility
- Reduced performance during warfare and disasters

Researchers have proposed LoRa-assisted navigation systems and hybrid localization methods to improve reliability when GPS signals become unavailable.

V. Satellite Communication and Iridium-Based SOS Systems

Satellite communication systems provide global connectivity independent of terrestrial infrastructure. They are widely used in aviation, maritime communication, disaster management, military operations, and emergency rescue applications.

A. Iridium Satellite Communication

Iridium is a low-Earth-orbit satellite constellation providing worldwide voice and data communication services. The system consists of 66 active satellites operating in polar orbits.

Iridium-based communication systems support:

- Global SOS messaging
- Emergency voice communication
- Remote IoT monitoring
- Maritime and aviation communication
- Military communication systems

However, recent security analysis revealed critical vulnerabilities including:

- Weak authentication protocols
- Lack of encryption
- SIM cloning attacks
- Spoofing and jamming attacks

These findings indicate the importance of secure encryption and authentication in future satellite emergency systems.

B. Cospas-Sarsat Rescue System

The Cospas-Sarsat system is an international satellite-assisted search and rescue system designed to detect emergency distress signals from aircraft, ships, and remote users.

The system uses:

- Low-Earth-orbit satellites
- Geostationary satellites
- Distress beacons operating at 406 MHz
- Global rescue coordination centers

The system has successfully saved thousands of lives since its deployment and remains one of the most important humanitarian satellite rescue systems.

VI. IoT-Based Soldier Monitoring and Emergency Alert Systems

IoT technologies enable real-time monitoring of physiological and environmental parameters using interconnected sensors and wireless communication frameworks.

Modern soldier monitoring systems typically include:

- Heart rate sensors
- Temperature sensors
- Oxygen level monitoring
- GPS tracking modules
- Emergency SOS buttons
- Wireless communication interfaces

These systems improve:

- Battlefield situational awareness
- Medical emergency response
- Soldier safety
- Operational efficiency

Recent military IoT frameworks also integrate:

- Edge computing
- Cloud monitoring
- AI-based analytics
- Self-healing communication networks
- Encrypted communication protocols

The combination of IoT with LoRa and satellite communication significantly improves emergency communication reliability in remote environments.

VII. Security Challenges in Satellite and IoT Communication

Security remains one of the most critical challenges in modern emergency communication systems. Major security issues include:

1. Lack of end-to-end encryption
2. Weak authentication protocols
3. GPS spoofing and jamming
4. Satellite communication interception
5. SIM cloning attacks
6. Data privacy violations
7. Denial-of-service attacks

The Iridium security analysis demonstrated how unencrypted communication exposes sensitive information to attackers. Similarly, IoT systems remain vulnerable to unauthorized access and network attacks.

To improve security, researchers recommend:

- AES-based encryption
- HMAC authentication
- Secure key rotation
- Multi-factor authentication
- Blockchain-assisted communication
- AI-based intrusion detection

Future emergency communication systems must prioritize cybersecurity alongside communication reliability.

VIII. Comparative Analysis of Existing Systems

Technology	Range	Power Consumption	Reliability	Security	Cost	Latency
GSM	Moderate	High	Medium	Medium	Medium	Low
Wi-Fi	Short	High	Medium	Medium	Low	Very Low
LoRa	Long	Very Low	High	Medium	Low	Medium
Satellite Communication	Global	High	Very High	Medium	Very High	High
Hybrid LoRa-Satellite	Global Local	+ Medium	Very High	High	High	Medium

Comparison of Navigation Technologies

Navigation System	Accuracy	Infrastructure Dependency	Reliability in Remote Areas	Vulnerability
GPS	High	Satellite	Medium	Jamming/ Spoofing
LoRa-based Navigation	Medium	Local Reference Points	High	Interference
IMU Systems	Medium	Internal Sensors	Medium	Error Accumulation

IX. Research Gaps and Limitations

Although significant advancements have been made in emergency communication systems, several limitations remain unresolved.

Major research gaps include:

1. Lack of secure satellite communication frameworks
2. High cost of global satellite connectivity
3. Limited battery efficiency in wearable devices
4. Low data rate of LoRa communication
5. GPS vulnerability during warfare
6. Limited interoperability between communication systems
7. Inadequate cybersecurity mechanisms
8. Communication latency in satellite systems
9. Lack of AI-assisted emergency prediction systems
10. Limited real-time analytics capability

Addressing these challenges is essential for the development of future intelligent emergency communication infrastructures.

X. Future Scope and Emerging Technologies

Future emergency communication systems are expected to integrate advanced technologies including:

A.Hybrid LoRa-Satellite Communication

Combining LoRa with satellite communication can provide both local low-power connectivity and global emergency coverage.

B.Artificial Intelligence Integration

AI can improve:

- Emergency prediction
- Threat detection
- Network optimization
- Rescue decision-making

C.Edge Computing

Edge computing enables low-latency local data processing, reducing dependency on centralized cloud servers.

D.Self-Healing Networks

Future systems may automatically recover from communication failures and dynamically reroute emergency data.

E.Secure Military IoT Systems

Advanced encryption and post-quantum security frameworks will play an important role in protecting sensitive battlefield communication.

F. Energy-Efficient Wearable Devices

Low-power wearable sensors integrated with intelligent power management systems will improve operational endurance.

XI. Conclusion

This review paper presented a comprehensive analysis of modern emergency communication systems integrating LoRa, GPS, IoT, and satellite communication technologies. Existing research demonstrates that LoRa communication offers low-power long-range connectivity suitable for remote monitoring and military applications, while satellite systems such as Iridium and Cospas-Sarsat provide global emergency communication coverage.

The study identified critical challenges including security vulnerabilities, communication latency, signal interference, and energy limitations. Security analysis of Iridium communication revealed the importance of implementing robust encryption and authentication mechanisms in future satellite systems.

Hybrid communication architectures integrating LoRa, GPS, IoT, and satellite communication appear highly promising for next-generation emergency SOS systems. Future research should focus on secure communication frameworks, AI-assisted monitoring, self-healing networks, and energy-efficient wearable technologies to improve reliability, scalability, and operational effectiveness.

Overall, the integration of modern communication technologies has the potential to significantly improve emergency response systems, military communication infrastructures, and global rescue operations.

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