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Bluetooth –Based Emergency System and ML for enhanced Public Safety

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ABSTRACT –

Public safety concerns, particularly for vulnerable populations including women, children, and elderly individuals, have intensified in contemporary urban environments. This Abstract views a solution to a critical Problem in emergency Communication systems. An Emergency Communication System follows a pattern of network infrastructure (internet and cellular networks) and depends on it. That traditional network may get fail during emergency. We are going to propose an alternative solution for communication, specially defined to check and work. The system provides real-time location sharing through GPS integration, automated emergency contact notification, proximity-based alert broadcasting to nearby users, and seamless integration with existing emergency response frameworks. During the times there is conventional networks are unavailable. Addressing critical gaps in emergency response systems by providing network-independent communication capabilities. Enhances safety measures for vulnerable populations in both urban and remote environments.

Keywords— **Bluetooth Low Energy 1st** :- Energy- efficient wireless standard.
Mesh topology 2nd :- Multi-node network.
Machine Learning 3rd :- Predictive models.
Random Forest 4th :- Classification forest model.

Introduction

Public safety has emerged as a paramount concern in modern society, with vulnerable populations including women, children, and elderly individuals facing disproportionate risks in public spaces. Statistical data reveals that over 88% of women report feeling unsafe in public environments, while children and elderly populations experience heightened vulnerability due to their physical limitations and dependency on others for assistance.
Existing SOS systems predominantly rely on internet connectivity and mobile networks for emergency communication and alert dissemination. While these systems have demonstrate effectiveness under normal operating conditions, they exhibit significant limitations during infrastructure failures, natural disasters, network congestion, or in areas with limited cellular coverage.

The proposed Bluetooth-based emergency SOS system addresses these critical limitations by creating network-independent communication capabilities that can function effectively in compromised or infrastructure-limited environments.
This research contributes to the field of emergency
communication systems by proposing a novel approach that combines the reliability of peer-to-peer networking with the ubiquity of consumer devices. The system is designed to enhance existing emergency response frameworks rather than replace them.

ML ALGORITHM ASSISTANT IN BLUETOOTH- BASED EMERGENCY SOS SYSTEM

The Bluetooth-Based Emergency SOS System, implementing strategies in a most effective manner of ML Algorithm, specifically tailored for emergency detection systems.
For your Bluetooth-based emergency SOS system, There are three core ML components:

Component 1: Safety Zone Classification (Random Forest) Real-time location safety assessment to provide proactive warnings
Random Forest creates multiple decision trees and combines their predictions to assess location safety with high accuracy (90- 95%).
The time required is two-three days. Runs efficiently on any devices(Low).

Component 2: Audio Distress Detection (CNN) Automated emergency activation through voice/scream recognition

Convolutional Neural Networks excel at detecting distress signals from audio with 92%+ accuracy.
The time required is five-seven days. Requires
optimization for mobile devices.

Component 3: Behavioural Anomaly Detection (LSTM) Temporal pattern analysis to detect unusual behaviour indicating emergencies.
LSTM networks capture temporal patterns to detect unusual behaviour sequences indicating emergencies.

intelligence.

This ML framework transforms your Bluetooth-based SOS system from a reactive alert mechanism to an intelligent, predictive safety platform that protects vulnerable populations through automated threat detection, location-aware warnings, and behavioural monitoring—all operating independently of traditional network infrastructure.

HARDWARE AND Software Specification

Hardware Requirements: Processor: Intel Core i5 (8^th Gen), RAM: 8GB DDR4, Storage:, 50 GB (SSD recommended), Network: Stable internet connection for downloading datasets and libraries Edge devices and Mobile deployment: Bluetooth: BLE 4.0 or higher support, Sensors: GPS, Accelerometer, Microphone, Gyroscope Deployment: Android 8.0 (API Level 26) or higher, Raspberry Pi OS(IoT edge devices).

Software Requirements:- (Algorithm Specification) Random: Forest for Safety Zone Classification, CNN for Audio Distress Detection ,LSTM for Behavioral Anomaly Detection.

Existing System

Traditional emergency SOS systems rely heavily on cellular and internet connectivity to function. The most common implementations include mobile apps and wearable devices that trigger alerts via SMS, voice call, or internet-based messaging when users press a panic button or use voice commands. Public alert infrastructures like Wireless Emergency Alerts (WEA) and Commercial Mobile Alert System (CMAS) broadcast geographically targeted notifications during large-scale emergencies; however, they require functioning cellular towers and can suffer from network congestion.

Bluetooth-based panic buttons exist for last-meter communication within limited range but typically pair with a smartphone to relay messages over cellular networks.

While these systems have improved response efficiency and situational awareness, they exhibit significant limitations when infrastructure fails—during natural disasters, remote-area emergencies, or network outages.

IV. PROPOSED SYSTEM

The Suggested architecture introduces a Short-range The time required is four-six days. Enhances overall system communication-based sos emergency framework that provides Steady and dependable alert transmission in the absence of internet or network. It utilizes BLE technology mesh topology to create a distributed, self-healing network that enables nearby devices to exchange emergency alerts seamlessly without relying on a fixed infrastructure. This framework is composed of three essential functional modules: Monitoring and Recognition, Message Broadcasting, and Emergency Response. The Detection module applies advanced Predictive models — Classification forest model for assessing environmental safety, Visual pattern model for processing and detecting stress audio, and Recurrent neural networks for identifying anomalous behaviour patterns. Upon identifying an emergency, alert transmission model leverages BLE mesh to broadcast the alert signal across interconnected devices in the area.

Each node in the system acts as both a transmitter and receiver, ensuring multi-hop message delivery and continuity even if some devices fail. This decentralized design enhances data privacy, reduces latency, and lowers energy consumption. Ultimately, the proposed SOS network serves as a robust intelligent infra free structure, ensuring timely support and safety for vulnerable groups — including women, children, and elderly individuals — during emergencies or connectivity disruptions.

Abbreviation:-

CNN - Convolutional Neural Network
LSTM - Long Short-Term Memory
SOS - Save Our Souls
IOT- Internet of Things

Objective

The primary objective is to develop a network-independent safety communication that ensures uninterrupted emergency support in the absence of traditional cellular connectivity or internet connectivity. To design a Bluetooth with low energy networking that would enhances energy- efficient system to solve the real-time alert through nearby devices. This would enhance public safety for vulnerable individuals—especially women, children, and the elderly— who often face threats in public or isolated spaces.

Additionally, the system integrates machine learning algorithm for intelligent threat prediction, automatic emergency activation, and behavioral anomaly detection. By combining Random forest and CNN, LSTM models, the system provides predictive insights.

Ultimately for project's objective we use Bluetooth connections within a mesh topology autonomously. The system also incorporates sensors for environment monitoring, GPS for location tracing, and audio detection for emergency recognition. This increases reliable, scalable and privacy-preserving, as compare to old practices and finds the alerts instantly.

Methodology:

The Workflow begins with existing SOS mechanisms through literature review and user feedback to define system objectives and technical parameters.

Data acquisition involves collecting audio, GPS, behavioral, and Bluetooth connectivity data. The machine learning pipeline comprises three phases: feature extraction, model training, and evaluation. Random Forest algorithms assess location safety using statistical and spatial indicators, while Convolutional Neural Networks(CNNs) process real-time audio inputs for distress recognition. Behavioral anomalies are analyzed through LSTM models, identifying irregular activities such
as unusual movement.

System to System (Communication-side) employs Bluetooth mesh Networking. Each device acts as a node within the network, automatically retransmitting alerts through multi-hop broadcasting until the signal reaches available responders. The Software architecture follows Agile Development principles, allowing for iterative refinement through simulation, prototype deployment, and user testing.
Testing phases include performance evaluation under different network conditions, assessing latency, packet loss, and energy efficiency. The methodology emphasizes modularity, ensuring that machine learning, Bluetooth communication, and user interface components work synergistically, creating a robust, adaptive system capable of functioning under diverse emergency conditions.

|User Mobile Device |

- |ML Processing Unit|
- |GPS & Sensor Interface|
- |SOS Activation Button|

|
| V
| Bluetooth Low Energy (BLE)
| Nearby Node 1 (Mobile) |
| Receives & Broadcasts |
|
| V
| Nearby Node 2 (IoT Device) |
| Forwards Emergency Signal|
|
| V
|Emergency Responders/Server|
|Receives Alert & Location|

IMPLEMENTATION OF PROJECT

The system is implemented using architecture comprising data acquisition, ML processing, and Bluetooth communication layers. The core platform is developed in Python for model training and Android Studio for mobile application deployment.

The Bluetooth Mesh Module establishes short-range, infrastructure-free communication by allowing nearby devices to relay messages through multi-hop transmission, ensuring coverage extending beyond direct range. Each mobile device acts as a Bluetooth node that relays messages further across the mesh using BLE packets. A server component logs alerts for future analysis, though local communication continues autonomously if network access is unavailable. The mobile interface includes panic buttons, emergency contacts, and visual indicators showing alert propagation within range.

ADVANYAGES

The proposed Bluetooth-based emergency SOS system introduces several critical advantages over existing network- dependent models. The most significant benefit is complete independence from internet and GSM networks, allowing the system to function effectively during network failures, disasters, or in remote areas with poor connectivity.

Built upon Bluetooth Low Energy (BLE), the framework ensures low power consumption, enabling continuous background functionality without adversely impacting device performance. Through Bluetooth mesh networking, the system establishes self-healing communication pathways, meaning alerts can propagate dynamically via multiple devices even if individual nodes go offline.

This design substantially reduces the likelihood of message loss compared to centralized architectures. The machine learning- driven modules offer intelligent, real-time decision-making, distinguishing between accidental button presses and actual distress events through behavioral analytics and audio recognition, thus minimizing false alarms. Another major advantage lies in community-based safety enhancement. Since devices near the emergency location receive immediate alerts, they can provide faster response than centralized services.
Privacy is ensured as communication is encrypted end-to-end, and data is processed locally, minimizing exposure to external servers.

The modular design allows for seamless integration with IoT sensors and wearable, expanding functionality to contexts like vehicles and smart homes. Together, these features create a lightweight, autonomous, and robust emergency communication system, capable of providing reliable protection for individuals in both urban and remote environments.

FUTURE WORK

Future enhancements of the Bluetooth-based emergency SOS system will focus on expanding functionality, scalability, and intelligence to adapt to emerging safety and IoT ecosystems. One key direction is the integration of the system with 5G and satellite communication frameworks, ensuring hybrid connectivity that automatically switches between Bluetooth and higher-bandwidth channels when available.

The inclusion of wearable devices such as smartbands and health trackers will enable biometric-based emergency detection, like abnormal heart rate monitoring or motion anomalies, triggering automatic alerts during accidents or assaults. The system could also integrate with autonomous vehicles and IoT infrastructure, allowing emergency broadcasts to connect with roadside sensors, public displays, or drones for rapid situational awareness in smart cities.Another promising direction is predictive safety analytics, leveraging historical data to map high-risk zones and notify users in real time before entering unsafe regions.

Future versions may include solar-powered or battery-optimized Bluetooth relays for rural areas. Overall, the system's continued development aims to deliver ubiquitous, intelligent, and resilient safety communication, making public environments safer for vulnerable individuals under all conditions.

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