AI-Powered Local Wake-Word SOS Activation System

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Abstract - Women's safety applications often fail in emergencies because they rely on manual input, internet connectivity, or GPS availability. In many critical situations, victims may not be able to use their phones, and poor network coverage decreases the reliability of existing SOS apps. To tackle these challenges, SOS Activation System offers an AI-powered Offline Women Safety Alert System that works without internet and with minimal user interaction. The system uses a TensorFlow Lite keyword-spotting model that constantly listens for phrases like "Help me" to trigger an emergency alert offline. Once activated, it sends distress signals to nearby devices through Wi-Fi Direct, Bluetooth Mesh, and ultrasonic high-frequency transmissions. This ensures message delivery even in areas with no network. Hands-free triggers such as shake detection, fall detection, and proximity activation further improve usability when the victim cannot reach the device. The SOS Activation system also automatically records audio, video, sensor data, and the last known location as evidence, storing it securely for transmission once connectivity is restored. This multi-layered approach offers a reliable, practical, and innovative solution for improving women's safety in both online and offline situations.

Key Words: Women's Safety, Offline SOS, TensorFlow Lite, Bluetooth Mesh, Wi-Fi Direct, Emergency Communication.

1. INTRODUCTION

Women's safety has emerged as a significant concern within both technology and society due to increasing reports of harassment, assault, and unsafe public environments. According to recent global surveys, up to 81 percent of women have experienced some form of sexual harassment or assault in their lifetime. The prevalence of such threats is further underscored by findings that many women report feeling unsafe when traveling alone at night. Although numerous mobile safety applications have been developed, studies indicate that only around 20 percent of women who download such apps are able to effectively use them in emergency situations. Most existing solutions depend on manual activation and require continuous internet connectivity. In critical situations, individuals may lack the time or capacity to unlock their phones, access an application, and activate the SOS function. Furthermore, inadequate network coverage in rural regions, underground settings, or disaster zones may prevent distress signals from reaching emergency contacts.

Recent advancements in Artificial Intelligence (AI), edge computing, and peer-to-peer communication provide novel approaches to address these challenges. For example, on-device machine learning models, such as TensorFlow Lite, enable real-time data processing without reliance on cloud infrastructure, directly addressing the issue of limited or unreliable internet connectivity during emergencies. Communication technologies such as Wi-Fi Direct and Bluetooth Mesh allow devices to transmit alerts directly to one another without needing traditional network access, ensuring that distress signals can still be sent in areas with poor coverage or network failure. By leveraging these technologies, the system can overcome key limitations found in many current solutions that depend on manual activation and continuous connectivity, offering more reliable and immediate responses in real-world emergency scenarios.

This study presents an AI-Powered Local Wake Word SOS Activation System that works without internet access. From the moment a woman becomes aware of a potential threat, the system is designed to guide her through each step of a crisis: recognizing danger, detecting distress, sending an alert, and ultimately seeking relief. If she is unable to act manually, the system's voice recognition and motion detection features can automatically identify signs of distress and begin sending alerts to trusted contacts using multiple communication methods. As emergency messages are transmitted, the user receives confirmations that help provide reassurance and reduce panic. Together, these features aim to deliver a seamless, reliable, and supportive safety experience that aligns with the real emotional and practical needs of women in emergency situations.

2. OBJECTIVE

The primary goal of this research is to develop a reliable, intelligent, and fully offline emergency alert system designed to enhance women's safety in real-world critical situations. Existing safety applications are largely dependent on internet connectivity and manual user activation, which significantly reduces their effectiveness during emergencies. In high-risk scenarios, victims may be unable to unlock their smartphones or manually trigger alerts due to panic, physical restraint, or immediate danger. To overcome these limitations, the proposed system integrates artificial intelligence, motion-based activation mechanisms, and decentralized communication technologies into a unified framework. The system is designed to ensure rapid emergency detection, secure evidence collection, and reliable alert transmission even in zero-network environments. By incorporating offline voice recognition and multi-layer communication protocols, the solution aims to reduce response time, improve transmission reliability, and provide an automated emergency response mechanism independent of traditional network infrastructure.

The specific objectives of this research are:

- Offline Voice Recognition Implementation.
- AI-Based Keyword Spotting Model Development.
- Sensor-Based Emergency Trigger Integration.
- Multi-Layer Communication Framework Design.
- Wi-Fi Direct Alert Transmission.
- Bluetooth Mesh Network Broadcasting.

- Ultrasonic High-Frequency Communication Mechanism.
- Automatic Evidence Recording System.
- Encrypted Local Data Storage Implementation.
- Performance Evaluation and Statistical Analysis.

3. LITERATURE

In women safety technologies, focus has been given on designing better emergency detection and alert systems through the usage of mobile applications and IoT technologies. Existing solutions heavily depend on internet connectivity and GPS tracking for accurate location services, and are largely activated manually, while many systems do not work reliably in low/zero network conditions where they are truly required, thereby leading to a decrease in its efficiency and reliability during real emergencies. AI-based models that facilitate automatic distress detection based on voice recognition and motion analysis have been introduced. Other approaches include sensor-based solutions which employ accelerometers and gyroscopes to enable the detection of falls and shakes, and decentralized communication systems like Bluetooth Mesh and Wi-Fi Direct to enable offline message exchange. However, most of these solutions work in isolation, instead of as a single framework. Dependence on the cloud and privacy concerns also remains to be major issues for mobile-based safety applications. The need for offline-based, non-centralized server independent systems are required and this work addresses these challenges with a single, offline, AI-powered emergency alert system.

- **AI-Enabled Smart Safety System for Women (Singh et al., 2024) -** A cloud-based machine learning system that detects emergencies using mobile sensors but depends heavily on internet connectivity.
- **Sensor-Based Fall and Shake Detection System (Rao et al., 2023) -** A motion-triggered emergency alert system using accelerometer and gyroscope data with SMS-based communication.
- **IoT-Based Women Safety Device (Patel et al., 2022) -** A hardware-driven safety solution utilizing GSM and GPS modules for panic-button-based emergency alert transmission.

4. EXISTING SYSTEM

Women's safety applications available in the market mostly work as emergency alerts on mobile phones, which need physical access and internet connectivity. Commercially available products rely on unlocking of the cell phone and pressing an SOS button; this then triggers SMS, mobile data or cloud-based services for sending out signals to designated emergency contacts. Though, all these applications provide minimum safety feature but they are less responsive and not that useful in real emergency situation.

The main weakness of these systems lies on strong reliance on stable connectivity; due to weak mobile signal strength or complete unavailability, especially in remote areas, underground, basements, multi-story parking spaces and during natural calamities, the distress signals do not reach emergency contacts or authorities. The dependency on this network structure is an important factor that weakens these security systems, and poses a reliability gap.

Another main weakness is the need for physical access; in case of an attack or threat, the victim may not be able to unbolt the phone due to fear, panic or due to restraint, this will cause loss of critical seconds that can be valuable during the response time. Most systems use GPS for location which is not precise in underground areas or in closed proximity. Privacy and data security is another major issue with the cloud-based services that send and store private information of user on cloud servers. Lastly, existing applications generally uses a single mechanism of activation without any redundant path of communication.

Thus, the existing systems lack the capabilities of proactive, offline and robust system. These characteristics prove a dire need to design and develop an automated offline emergency alert system.

Table -1: List of popular mobile application available for women safety

Popular Women Safety Applications

Application Name	Main Functionality
112 India	One-tap SOS alerts to emergency services with location and audio/video support.
My Safetipin	Provides GPS tracking, safe route mapping, and safety score analysis of locations.
bSafe	Sends SOS alarms, live location sharing, and automatic audio/video recording.
Smart 24x7	Panic button triggers alert messages and can call emergency contacts.
Shake2Safety	Sends emergency alerts by shaking the phone or pressing the power button—works offline.
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5. PROPOSED SYSTEM

The described AI-Powered Local Wake Word SOS Activation System represents a robust and accessible solution for women's safety by decoupling from reliance on Internet connectivity and manual triggers. The system combines artificial intelligence with motion detection technologies and a multi-layer communication structure to provide the highest level of certainty in detecting emergencies and transmitting alerts.

The voice recognition module within the system is implemented using TensorFlow Lite as a keyword spotting model, enabling the device to analyze audio inputs continuously without a connection to the internet and recognize predefined emergency phrases, such as "Help me" or "Emergency." The on-device processing of the audio and detection algorithms ensures privacy and real-time operation.

In addition to the voice detection capabilities, the system also takes advantage of a series of motion triggers. An accelerometer and gyroscope in the device detect the vibration of falls, physical attacks, or an impending threat through hand gesture, enabling women to activate the SOS alert without speech. The hands-free activation feature also improves user comfort and usability.

The communication infrastructure between the mobile devices and remote access points utilizes a multi-layer communication framework. It takes advantage of Wi-Fi Direct, Bluetooth Mesh networking, and high-frequency ultrasonic transmission. This framework ensures redundancy for an increase in certainty of delivering the message, especially in the absence of any cellular network, while maintaining the system's efficiency.

The system automatically records and saves the evidence in encrypted form in its memory for offline use. Once the internet connection is established, all collected data, including audio, video, sensor logs, and last known location data, are transmitted to the concerned authority.

6. RESEARCH METHODOLOGY

The research methodology outlines the systematic development and evaluation of the AI-Powered Local Wake Word SOS Activation System offline emergency alert framework. It includes problem analysis, system design, AI integration, communication implementation, and performance validation to ensure reliability and effectiveness.

i. Problem Identification and system design

A comprehensive gap analysis was conducted to evaluate limitations of existing internet-dependent women safety applications. The study identified critical failures in manual activation mechanisms and network-reliant communication models. Based on these findings, an offline-first emergency alert architecture was conceptualized. A modular and fault-tolerant system design was structured to ensure scalability, automation, and real-time responsiveness.

ii. AI Model Development and Sensor Integration

A lightweight keyword spotting model was developed using supervised learning techniques for offline distress detection. The trained model was optimized using TensorFlow Lite for efficient on-device inference. Accelerometer and gyroscope sensors were integrated to detect abnormal motion patterns such as falls and violent shaking.

iii. Communication Framework & Performance Evaluation

A decentralized multi-layer communication protocol was implemented to ensure redundancy and infrastructure independence. Wi-Fi Direct, Bluetooth Mesh networking, and ultrasonic high-frequency signaling were integrated for reliable alert propagation. Controlled experimental simulations were conducted under varied connectivity conditions. Statistical validation of response time, detection accuracy, and transmission success rate confirmed system robustness.

iv. Multi-Layer Communication Architecture

A hierarchical communication structure was engineered to ensure fail-safe alert transmission. Priority-based routing was implemented to dynamically select the most reliable communication channel. Peer-to-peer connectivity via Wi-Fi Direct enables direct device communication without infrastructure dependency. Bluetooth Mesh and ultrasonic signaling act as secondary and tertiary redundancy layers.

v. Data Security and Evidence Management Framework

An automated evidence capture module was integrated to record audio, video, and sensor logs during emergencies. All collected data is encrypted using standardized cryptographic techniques before local storage. Secure key management mechanisms were implemented to prevent unauthorized access. Deferred transmission ensures data synchronization once network connectivity becomes available.

vi. System Testing and Statistical Performance Analysis

Extensive testing was conducted across simulated real-world emergency environments. Performance indicators included activation latency, detection precision, false trigger rate, and communication reliability. Comparative evaluation was performed against traditional network-dependent safety applications. Statistical analysis using mean, variance, and reliability metrics validated overall system efficiency.

7. PROPOSED CRIME MONITORING, RESPONSE AND ANALYSIS SYSTEM

The framework describes an end-to-end solution for women's safety by leveraging automated detection, intelligent response and localized crime analysis. The AI-Powered Local Wake Word SOS Activation System stands out among similar safety applications by offering capabilities that are neither dependent on continuous internet access, nor manual intervention like the currently used ones. In integration with artificial intelligence, sensors that detects motion, ability to capture instant evidence of the situation, and analytics that analyzes local crime patterns. It enables the system to effectively detect distress situations, relay emergency alerts promptly, secure the incident evidence securely and analyze past crime incidents for proactive crime prediction. It also facilitates user registration, volunteer assistance, multi-lingual communication and priority-based dispatch. It offers capabilities of offline AI activation, wake word detection based alert system and crime analytics through spatial mapping of risk hot spots in combination with sensor data acquisition at the time of detection.

i. Intelligent Threat Detection and Behavioral Analysis Layer

The system's most distinguished characteristic lies in its intelligent threat detection layer that is powered by the offline wake word detection capability. The ambient audio feeds into a compact machine learning model that continuously processes and analyzes the sound locally in the device for the presence of a predetermined wake word. Since, all the processes are confined locally on the device, the privacy of the user is preserved. This also makes the system work independently of internet connectivity. The wake word recognition is backed by algorithms that apply a scoring mechanism to differentiate genuine alerts from environmental noise. It also takes into account other sensor readings to cross-verify and boost accuracy. This leads to minimal false triggers. The localized inference engine ensures prompt response even in regions with no network. The system aims to proactively recognize potential threats with minimal latency.

ii. Structured Local Emergency Escalation Framework

Once the wake word trigger has been identified and confirmed to be a genuine call for help, a predefined sequence of local emergency escalation is automatically triggered. Alert messages, along with the contextual information are sent to multiple prioritized contacts like law enforcement officials, guardians, local volunteers, etc. The system leverages both traditional and innovative communication technologies that function well in poor connectivity. The alert system follows a logical pattern where if the primary recipient is not reachable, the system automatically forwards the alert to a secondary contact. Timestamp and location of the incident is automatically generated as an alert metadata which facilitates faster response by dispatchers. All that is needed is an utterance once after detecting the threat. The framework is a step towards organized emergency response for victims at higher risk. This layered escalation strategy enhances reliability, reduces response time, and increases the probability of immediate assistance during critical situations.

iii. Secure Event Documentation and Digital Evidence Management

The system is equipped with an automated document generation tool to facilitate the preservation of all essential evidence during a criminal act or emergency situation. Upon activation, it begins to capture the audio, short video segments and other relevant sensor data at once. Each file captured by the system has a timestamp and is cryptographically protected and encrypted with standard encryption algorithms. All captured data remains stored on the device itself until safe conditions are encountered to transfer the data to a secure server for analysis. This assures data privacy and access rights, and also maintains its integrity in investigations. System logs also keep a record of all such activations and the system communication for better traceability. It establishes a highly secured environment for storing and managing all incident evidence.

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8. SYSTEM ARCHITECTURE

The proposed system architecture is designed as a multi-layered, edge-AI based framework that ensures reliable emergency alert activation even in zero-network environments.

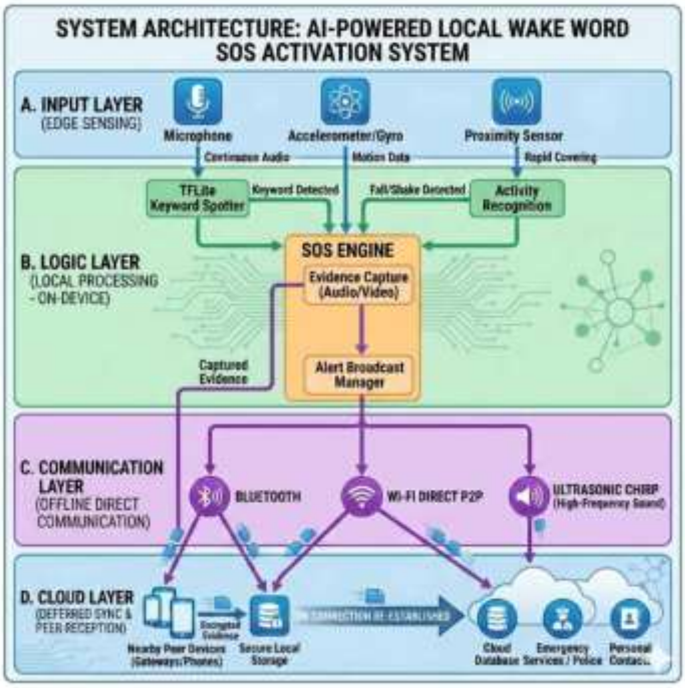

Fig -1: System Architecture Diagram

- **Input layer**

The input layer continuously collects real-time data from device sensors. The microphone captures live audio streams for wake word detection. The accelerometer and gyroscope monitor motion patterns to detect fall or shake-based triggers. The proximity sensor identifies sudden covering or abnormal environmental changes. These sensing components operate in low-power mode to ensure continuous monitoring without draining battery life.

- **Logic layer**

This layer performs all core intelligence locally using edge AI. A TensorFlow Lite keyword spotting model analyzes audio input to detect predefined distress phrases. Simultaneously, motion data is processed through activity recognition algorithms to identify fall or shake events. Once a trigger is validated, the SOS Engine is activated. The SOS Engine performs three critical functions:

i. Evidence Capture (audio and video recording)
ii. Alert Broadcast Management to prepare emergency packets

All computations occur on-device, ensuring fast response time and complete offline capability.

- **Communication layer**

The communication layer ensures alert transmission without internet dependency. It uses:

i. Bluetooth Mesh for multi-hop peer communication
ii. Wi-Fi Direct Peer-to-Peer for faster nearby device transmission
iii. Ultrasonic high-frequency chirp signals for short-range emergency signaling

This mesh-based architecture allows distress signals to propagate through nearby devices until they reach a connected gateway.

- **Cloud layer**

When internet connectivity becomes available, encrypted evidence and alert logs are automatically synchronized with secure cloud databases. The system then forwards notifications to emergency services, police authorities, and registered personal contacts.

9. EXECUTION COMPONENT

The AI-Powered Local Wake Word SOS Activation System is smart, internet-independent emergency assistance framework that offers instant and automatic trigger of alert. It constantly listens to audio and motion events with onboard sensors and on-device learning models. By operating without internet, it makes decisions locally and communicate with nearby devices in mesh topology. Once it detects an emergency trigger, it starts transmitting an alarm and recording a proof. The system is architected into several functional blocks in order to make it robust, scalable and responsive.

Fig -2.1, 2.2: Figure for system component of application Login page & main page

a. Wake Word Detection

The Wake Word Detection module acts as the primary activation means for the AI based local SOS system. This module keeps continuously analyzing surrounding ambient sounds via the device microphone for the presence of the programmed keywords to trigger the SOS alert. This module has been designed to function with the least possible power with an on-device inference, implementing an on-device ML deep learning model utilizing TensorFlow Lite. The extracted features then are input into a model trained on a corpus of keywords to check for matches with programmed SOS keywords.

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To achieve less false positive triggers from background noise or when in an audience, some confidence scoring has been implemented and since it is run entirely on the device it doesn't need any cloud connection and would work even in the presence of no internet connection.

Also, threshold based on noise is dynamically set to maintain accuracy and speed of detection based on the surrounding environment.

b. Shake-Based Trigger Detection

The Shake-Based Trigger Detection is another option of non-speech-based emergency signal triggering, utilizing the motion sensors of the smart phone. It takes advantage of accelerometer and gyroscope data to recognize intended shake movements that imply an emergency. The system monitors three-axis acceleration, and calculates resultant magnitude of motion to observe the abnormal movement.

An algorithm which uses dynamic threshold to distinguish deliberate shake gestures from ordinary movement of device, such as walking, carrying it and so on, has been adopted. We use temporal filtering and pattern recognition approach to detect the frequency and amplitude of motion over a given time period. When the value of motion exceeds amplitude and repetitive threshold, the motion is considered as intended movement.

To avoid accidental triggering of emergency mode, a multi-condition verification logic is imposed including duration judgment and motion regularity examination. The shake detecting system requires low latency, computational cost and power consumptions, so it is effective in situations in which user is not able to speak loudly or talk.

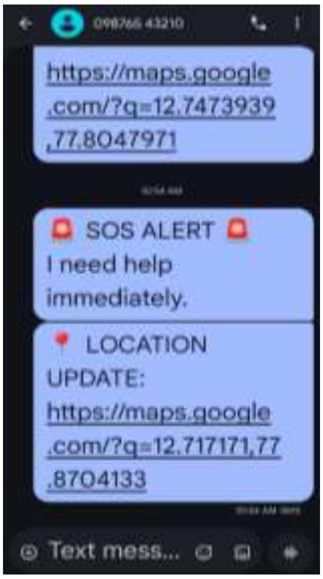


Fig -2.3, 2.4: Figure for system component (a & b) detection message

c. Audio-Video Capture

The Audio-Video Capture module allows for instant, immediate acquisition of real-time evidence immediately following the activation of the emergency. Once the trigger has been verified by the system, a background recording of audio and video from the device camera and microphone is activated, ensuring critical contextual information is acquired without the explicit knowledge or intervention of the end-user.

The system will gather data such as high-resolution video of the surroundings, the audio from the surrounding environment, timestamps of the video, and the geo-location information for when the evidence was captured. The system is designed to run discreetly, so as not to potentially tip-off potential aggressors, with the audio and video data being processed, stored efficiently, and compressed. Time synchronization should also be included to allow accurate data comparison with logs, providing robust evidence in forensic analysis.

In order to ensure the safety of the end-user and to secure data, recorded evidence should be encrypted utilizing recognized cryptographic methods. The file should be inaccessible to anyone but specific emergency contacts or monitoring stations who require access to the recorded material, should a connection be established over the network.

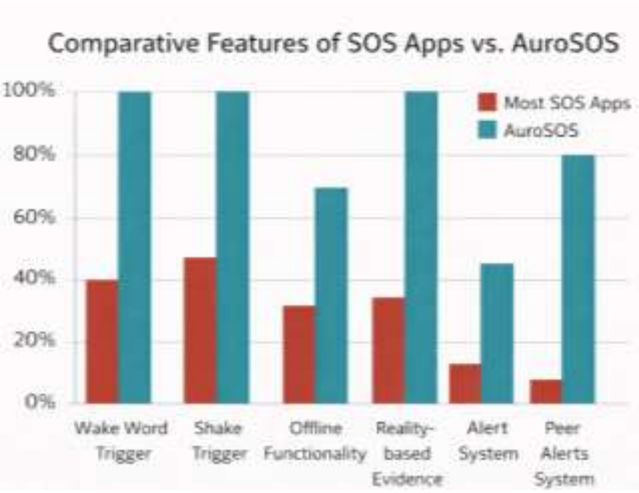
Fig -2.5, 2.6: Figure for system component (c) audio & video capture

d. Secure Storage & Wireless Communication

The Secure Storage and Wireless Communication module provides the means to safely store and effectively transmit the emergency data. Every bit of incident information (audio, video, sensor log files, GPS coordinates etc.) are locally encrypted using AES (Advanced Encryption Standard) encryption algorithms to eliminate data tampering and maintain user privacy. To transmit the alerts, it uses a mixture of SMS, mobile internet, Wi-Fi Direct and Bluetooth-based peer-to-peer connectivity.

Decentralized peer-to-peer communication is utilized for areas with no network or no internet access; wherein nearby registered devices can propagate the emergency alert among each other. Contacts are ordered according to the alert's priority level, making sure that the key recipients, police, and guardians are informed first. Each alert is transmitted as a packet, with relevant information such as the user's ID, GPS coordinates, time and level of risk involved, being embedded in the packet. Robust data redundancy measures guarantee that alerts are forwarded using other available channels if the primary ones are non-operational.

Chart



10. CONCLUSION

The proposed AI-based Local Wake Word SOS Activation System provides a stable, intelligent, and network-independent mechanism for effective emergency response and personal safety in threatening situations. It leverages wake word detection and shakes recognition to automatically activate an alarm; automatically record audio-video streams and communicate distress to specified contacts or authorities; and ensure a smart, touchless alert system. Integration of on-chip machine learning (lightweight models) aids in early and on-demand emergency detection while minimizing power and computational resources.

Unlike most existing emergency systems which are dependent on active network connectivity, the proposed system aims for network-independence and secured data storage via an encrypted local storage and decentralized communication (via short-range, personal networks if necessary) so that it works even in poor or no network conditions. With the use of multiple triggers for alarm activation, the system avoids false alarms and increases the system's accuracy, reliability, and usefulness. Automatic collection of data, such as audio-video footage, is beneficial for investigations and judicial evidence.

The proposed architecture represents a well thought-out and feasible strategy for the implementation of intelligent crime prevention and response. The combination of AI-based smart triggers and encrypted data storage provides a secure yet responsive platform to serve as a proactive force against crime, rapid emergency support, and improved overall security awareness.

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