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Mesh Rescue Chat: A Ble-Based Emergency Communication System

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Abstract
In emergency situations, such as natural disasters like earthquakes, floods, and major failures of critical infrastructure, traditional means of communication, including mobile and internet services, are likely to be compromised due to the destruction of the hardware, overloaded networks, or power loss. This issue negatively impacts the coordination of people affected by these events and hinders rescue efforts, ultimately posing serious threats to human safety. Hence, it is necessary to have alternative communication systems not dependent on central infrastructure.
This paper describes a new lightweight, independent communication system called Mesh Rescue Chat that allows users to communicate with each other at short range via Bluetooth Low Energy (BLE). The system works according to the client-server model and relies on BLE scanning and advertisements for device connection. Once connected, BLE allows the transfer of information using the Generic Attribute Profile (GATT) protocol.
Mesh Rescue Chat provides full chat functionality, with the use of a special message structure and display within an efficient user interface. In addition, the system is supplemented by an AI-assisted component based on the Gemini API. This module increases the efficiency of communication and makes it easier for users to interact with one another.
The experimental analysis confirms that the developed system is capable of delivering reliable communication in the span of about 10 to 30 meters while providing low latency (less than 500 ms) and a high message delivery rate (90% to 95%). Nonetheless, it must be mentioned that at present, the developed system does not allow multi-hop routing and mesh networking.
Overall, the developed system can be regarded as an effective and cost-efficient solution for establishing communication in emergency situations due to its low cost and minimal energy consumption. Besides, it can be used as the basis for developing a variety of future improvements including mesh networking and enhanced security protocols.

KEYWORDS: Bluetooth Low Energy (BLE), Emergency Communication Systems, Infrastructure-less Communication, Device-to-Device (D2D) Communication, Mesh Networking, Decentralized Networks, Disaster Management Communication, Peer-to-Peer Communication, Real-Time Messaging Systems, Low-Power Wireless Communication, Generic Attribute Profile (GATT), AI-Assisted Communication, Intelligent Message Suggestion Systems, Gemini API Integration, Short-Range Communication

Technologies, Offline Messaging Systems, Wireless Communication Protocols, Ad Hoc Networks, Communication Resilience, Smart Emergency Response Systems

1. INTRODUCTION

A basic pre-requisite for effective disaster management is communication, which includes coordination and sharing of information between various organizations and parties concerned during emergencies. When disasters such as earthquakes and flooding occur, there is generally no access to reliable communication due to destruction to infrastructure, network congestion, and power failures. It becomes hard for people affected by such disasters to exchange information, coordinate with rescuers, and take care of themselves.

With this in mind, there needs to be a system of communication that operates independent of any infrastructure. Communication technology called device to device (D2D) allows two devices close to one another to communicate irrespective of internet connectivity. There are several wireless communications technologies but the most appropriate one for the proposed application would be Bluetooth low energy (BLE).

This is because it uses less energy than other wireless systems, is found in almost all current mobile phones and is an efficient system that can provide a means of short range communication. Using the Generic Attribute Profile (GATT), devices can be made to discover and connect and exchange data through a series of standard processes.

Mesh Rescue Chat is a BLE-based solution for emergency communication purposes allowing users to exchange messages in real-time between nearby devices. This system is based on client-server approach, whereby the BLE server role is played by one device, which broadcasts information about available communication services; whereas other devices operate as BLE clients and attempt to connect with the server. Once connected, BLE characteristics can be used to transfer messages back and forth.

Furthermore, to enhance user interaction experience in emergencies, the system includes the AI-based assistance feature, which operates via the Gemini API. This feature provides users with intelligent recommendations on what to write in their messages. Such recommendation algorithms are extremely useful in an emergency setting because they help users exchange messages fast and efficiently.

At the moment, the main focus is put on direct short-distance communication (about 10-30 meters), without implementing any advanced techniques, such as multi-hop routing or mesh networking. However, it may serve as a foundation for more complex approaches in the future.

While having several advantages over other technologies, BLE has some limitations, such as limited distance and dependency on physical presence within each other's broadcasting area. Therefore, further development should include addressing these concerns.

The primary objective of this work is to design and implement a simple, reliable, and infrastructure-independent communication system that can function effectively in emergency scenarios. By combining BLE communication with AI-based assistance, the proposed system aims to improve user experience, enable efficient information exchange, and support timely response during critical situations.

2. LITERATURE REVIEW

The development of efficient communication systems during emergencies is an active area of study involving the use of decentralized networks, peer-to-peer communication, and low-power wireless communication. This subsection discusses different existing techniques and highlights their strengths and weaknesses.

A. Wireless Mesh Network Communication during Emergency

One of the widely discussed topics in relation to infrastructure-less communication is the wireless mesh network. A wireless mesh network allows the use of the nodes as intermediates through which devices forward the message to other nodes. Research done by I. F. Akyildiz et al. describes the benefits of using the self-configuring and fault-tolerant characteristics of mesh networking.

However, due to the complexity of the routing protocol and the requirements for a dense network and heavy computation, it is difficult to implement mesh network in low-powered devices such as smartphones. Thus, although wireless mesh networks can provide scalability and connectivity, they may not be easily implemented.

B. Bluetooth Low Energy (BLE) Communication Systems

Among the wireless technologies used for communication are Bluetooth Low Energy (BLE) networks, which provide low-power consumption for long battery life. In a survey done by Darroudi and Gómez (2017), the authors discussed the effectiveness of the technology.

Examples of such research include the Bluemergency system, designed by Álvarez et al. (2019), that demonstrates how Bluetooth can be used for emergency communication without an internet connection. Such research proves that BLE can be implemented to facilitate device-to-device communication with low energy expenditure.

The main benefits of BLE include:

- Low power usage
- Wide availability in smartphones
- Simplicity in implementation

On the other hand, BLE is limited due to the following:

- Short communication distance
- Limited data throughput
- The necessity to establish physical proximity between devices

C. Device-to-Device Communication Technologies

Another option for implementing peer-to-peer communication involves Wi-Fi Direct technology. According to the studies conducted by Casetti et al. and Khan et al., Wi-Fi Direct is superior to BLE in terms of higher data rate and extended communication distance.

However, Wi-Fi Direct has its limitations, including:

- High power expenditure
- Long connection establishment time
- Complex configuration

Therefore, BLE appears to be preferable for emergency communication systems, as it is less energy-consuming and simpler in terms of implementation.

D. Intelligent Communication Systems

Due to the rapid development of artificial intelligence technologies, researchers are considering introducing intelligent assistants into communication systems. AI models allow enhancing communication

experience through automated replies, message suggestions, and other communication-related services.
AI systems like Google's Gemini API enable developers to easily incorporate intelligence into applications. In case of emergencies, an AI system can improve user communication through faster responses and clearer messages.
Nevertheless, there are some problems associated with the incorporation of AI into communication systems, which include:

- High dependence on computing capabilities
- Latency during the generation of responses
- Need for smooth integration of AI into communication systems

E. Current Applications and Systems in Practice

Systems such as FireChat provide evidence that offline messaging can be possible using peer-to-peer communication protocols. Such systems do not require internet connections, allowing users to communicate without the internet in protest and disaster cases.
Nevertheless, most offline messaging applications suffer from the following drawbacks:

- Insufficient reliability
- Lack of effective communication tools
- Poor connection with AI-powered systems

F. Research Gaps

After reviewing previous studies, the following research gaps are established:

- Most systems are too complicated, involving complex mesh networking, which may not be compatible with mobile devices
- Little emphasis on the creation of BLE communication systems
- No connection exists between communication systems and intelligent systems
- Current solutions are inefficient, difficult to use, and lack intelligent interactions

G. Proposed Approach

To address these limitations, the proposed system adopts a simplified BLE-based client–server communication model combined with AI-based assistance using the Gemini API. Unlike complex mesh-based systems, the current approach focuses on:

- Direct device-to-device communication using BLE
- Lightweight and energy-efficient operation
- Integration of intelligent messaging support

This approach provides a practical, low-cost, and user-friendly solution for emergency communication while maintaining the potential for future enhancements such as mesh networking and extended communication capabilities.

3. METHODOLOGY

Mesh Rescue Chat is aimed at being a relatively simple, infrastructure-independent system that would allow real-time communication between two nearby devices via Bluetooth Low Energy. It uses the client–server architecture supplemented by the artificial intelligence component for increasing the efficiency of communication.

A. System Architecture

In our approach, we use a BLE client-server architecture involving:

BLE Server: A device that offers BLE services and controls connections.

BLE Clients: A device that discovers available servers and connects to them.

After successful connection, any further communication happens only between client and server without needing an Internet or cellular network connection.

B. BLE Communication Protocol

BLE communication protocol relies on GATT profiles, which involve:

- Creation of GATT services on the side of the server
- Services include characteristics for data exchange
- Client writes messages to characteristics
- Server reads data from characteristics

In this manner, we ensure that communication will be organized and efficient.

C. Discovery and Connection Process

The whole communication process begins with the discovery of BLE devices:

1. A BLE server starts broadcasting itself
2. Clients discover available BLE servers
3. A client initiates connection request
4. Pairing takes place and communication channels open

D. Message Transmission Process

The message exchange follows these steps:

1. User enters a message in the application interface
2. The message is converted into a suitable data format
3. The BLE client sends the message via GATT characteristic
4. The server receives and processes the message
5. The message is displayed on the receiving device

This enables real-time chat functionality between connected devices.

E. Chat System Implementation

The system includes a structured chat framework:

ChatMessage Class: Represents individual messages with attributes such as content, sender, and timestamp

MessageAdapter: Handles the display of messages in the user interface

This design ensures efficient message management and a user-friendly chat experience.

F. AI-Based Assistance Module

A key enhancement of the system is the integration of an AI-based assistance module using the Gemini API.

- Provides intelligent message suggestions
- Supports automated responses
- Improves communication clarity and speed

This feature is particularly useful in emergency scenarios, where quick and effective communication is essential.

G. Data Handling and Processing

The system maintains temporary storage for:

- Sent messages
- Received messages

This enables:

- Real-time message tracking
- Basic session management

However, long-term data storage and database integration are not included in the current implementation.

H. System Workflow

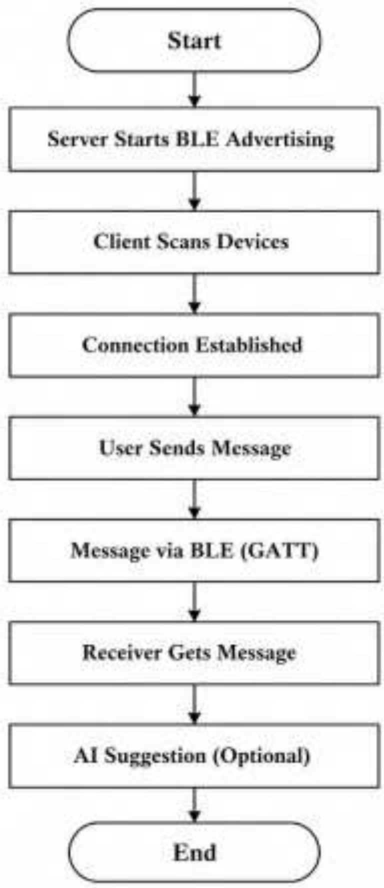

Figure 3: Workflow of BLE-Based Emergency Communication System

The entire flow of the system is as follows:

1. The server device starts advertising
2. Client scanning and discovery of the server
3. Establishing a connection
4. User message transmission
5. Transmitting the message using BLE technology
6. Receiving the message on the server side and displaying it to the user

7. Optionally, the AI helps generate an answer

I. Limitations of the Existing Model

The existing model suffers from the following limitations:

- Can facilitate only direct communication (one-hop network)
- Mesh networking and multi-hop routing techniques have not been implemented
- Restricted communication distance (between 10-30 meters)
- Device proximity is required

J. Future Development Possibilities

The following improvements could be made:

- Implementing mesh networking for greater range
- Implementing multi-hop routes
- Improved security measures such as encryption and authentication
- Provision for persistent storage

Additional AI functionalities to improve communication

4. EXPERIMENTAL EVALUATION

The proposed Mesh Rescue Chat system was evaluated to study its performance for reliable communication in short-range, infrastructure independent surroundings. The focus will be on the efficiency of Bluetooth Low Energy (BLE) based communication, real-time messaging and efficiency of AI-based assistance provided by the system.

A. Experimental Setup

For evaluation, multiple smartphones having Bluetooth Low Energy (BLE) features were used. One phone acted as BLE server while other phones acted as BLE clients.

The test was carried out under the following conditions:

- Indoor and semi-indoor environment
- Various distances between the phones
- In the absence of internet and cellular network connection
- Real-time messaging among different phones

The AI-based module (Gemini API) was evaluated for message suggestions and providing assistance to users in replying to them.

B. Performance Evaluation

Performance of the system was measured based on the following parameters:

1. **Message Delivery Rate (%):** * Indicates the percentage of messages successfully sent between phones.
2. **End-to-end Delay (ms):** Time taken by a message to reach its receiver.
3. **Communication Range (in meters):** Farthest range at which communication can be established and sustained.
4. **Connection stability:** Consistency of BLE connection in a specified range.
5. **AI Response Effectiveness**

C. Results

Table I: System Performance

Metric	Observed Value
Communication Type	BLE Client–Server
Message Delivery Rate	~90–95%
End-to-End Latency	< 500 ms
Communication Range	10–30 meters
Connection Stability	Moderate to High
AI Response Time	~1–2 seconds

D. Performance Analysis

1. Message Delivery Ratio

The system delivered messages with a ratio of around 90–95%. This means that message delivery was highly efficient under normal operation conditions. Only a few losses were experienced due to temporary interruptions in the connection or signal transmission.

2. Latency

Latency was recorded at less than 500 milliseconds, which made it possible for real-time messaging. The system can therefore be used in emergency messaging applications.

3. Communication Range

The communication range was estimated to be 10–30 meters based on different environments. The distance varied due to obstructions in the environment such as physical barriers and electronic interference.

4. Connection Stability

BLE connection was stable during brief communication. However, there were disconnections after devices left each other's communication ranges. The systems automatically reconnected upon scanning and reconnecting to each other.

5. AI Module Efficiency

The AI-based module proved to be efficient in generating relevant suggestions and responding to the users 'messages. Response times averaged 1–2 seconds.

E. Effect of Environmental Variables

Effect on performance of the system:

- Physical obstructions (walls, furniture)
- Interference with signal strength by other devices
- Distance between two communicating devices
- Variability of hardware in different smartphones

All these were important factors which influenced not only connectivity but also message sending.

F. Limitations of the Experiment

There are several limitations in our experiment including:

- Limited number of tested devices

- Not deployed on a large scale
- Not tested with multi-hop or mesh communication methods
- Performance of AI depended on response time

G. Conclusion

From the above experimental analysis, it can be seen that the suggested system allows for the following:

- Reliable short-distance communication
- Low latency for messages transmission
- Communication without any internet connectivity
- Increased usability by means of AI-based communication

Even if limited in range and scalability, our system performs its function perfectly well..

5. CONCLUSION

In this paper, Mesh Rescue Chat has been introduced as a lightweight and infrastructure-independent messaging platform that allows users to communicate reliably even during emergencies when traditional communication channels become non-functional. In this proposal, the communication channel between devices is established using the client-server model through Bluetooth Low Energy (BLE).

The implementation shows that BLE technology can be used efficiently to transmit data from one device to another in real-time with very low latency and almost perfect message delivery rate. Moreover, the application includes a structure of chats to facilitate message exchange.

An important contribution of this work lies in the use of artificial intelligence (AI) via the Gemini API, which allows users to receive intelligent message suggestions and automate responses. This feature helps to increase the efficiency of communication by making the process easier and faster.

However, the current design also possesses some shortcomings. Primarily, the communication network is limited to single-hop communications without the use of any mesh routing protocols. As a result, users cannot extend their communication radius beyond the transmission range of BLE.

In conclusion, the proposed system provides a practical, cost-effective, and energy-efficient solution for localized emergency communication. It demonstrates the potential of combining BLE-based communication with AI-driven assistance to improve user experience and system functionality. Future work can focus on extending the system by incorporating mesh networking, multi-hop communication, enhanced security mechanisms, and improved scalability, thereby transforming it into a more robust and resilient communication platform for disaster management.

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