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Remote Field Doctor Kit with Medical Transmission Over LoRa

Suyash Swaminath Prakhe[1*], Anjali Prakash Kusekar[2], Vaibhavi Kishor Jadhav[3], Prof. Salunkhe K. D[4]
[1,2,3]UG Students, Department Electronics and Telecommunication
[4]Asst. Professor, Department Electronics and Telecommunication
Brahmdevdada Mane Institute of Technology Solapur, Maharashtra, India
parkhesuyash@gmail.com[1]

Abstract: *One of the biggest issues facing the world today is access to healthcare in rural and isolated areas. To overcome this difficulty, the Remote Field Doctor Kit with Medical Transmission over LoRa combines long-range wireless communication with biomedical sensors. Vitals like blood pressure, heart rate, body temperature, and SpO_2 are gathered by the system and sent to a physician's monitoring unit via LoRa (Long Range Radio) technology. In contrast to telemedicine systems based on GSM, Wi-Fi, or Bluetooth, LoRa offers low-power, long-distance communication (up to 10 km in rural areas) with little infrastructure. This makes it possible for medical professionals to keep an eye on patients from a distance and give prompt advice without needing internet access. The project shows that a dependable, affordable, and scalable healthcare system for underprivileged areas is feasible.*

Keywords: LoRa, Remote Health Monitoring, IoT, Biomedical Sensors, Telemedicine

I. INTRODUCTION

In contemporary healthcare, Quick diagnosis and monitoring of patients can save lives, particularly in remote or rural regions where hospital and healthcare professionals are harder to reach. The Remote Field Doctor Kit with Medical Transmission over LoRa, is a novel device which forms the basis of a telemedicine solution (Internet of Things - IoT based), to provide simple yet, effective health monitoring and medical consulting facilities to patients located in far regions or in resource limited areas. The project uses biomedical sensors, wireless medical communication technology, and embedded systems, designed to provide a portable, reliable and low power medical diagnostic solution. The primary operation goal of the system is to provide and share (real-time) data concerning vitality health parameters such as heart rate, oxygen saturation (SpO_2), blood pressure, body temperature, and ECG signals from the patients' locality to a remote doctor or a healthcare center. The sensor data was collected at the patient site and processed in a microcontroller unit (either an ESP32 or Arduino with LoRa module) and broadcasted via LoRa (Long Range Radio) medical communication technology LoRa is a advantageous technology due to its long-range range (distance of connectivity) capacity of several kilometres, low power consumption, and transferring data securely and privately making it a promising and viable telemedicine solution for rural healthcare applications when cellular connectivity weak, poor, or completely offline. Data transmitted audio and video support for a remote watching doctor[1-30].

Access to healthcare continues to be a major challenge in today's world, particularly in rural, remote, and disaster-affected regions with little medical infrastructure and few trained professionals. As a result, individuals residing in these locations often lack access to timely diagnosis and treatment. Technologies based on IoT (Internet of Things) and telemedicine are emerging as transformational technologies that improving interaction between patients and physicians. For example, the "Remote Field Doctor Kit with Medical Transmission over LoRa" facilitates remote health assessment and transmits medicine data through the use of LoRa (Long Range) transmission. After the data is sent to the LoRa gateway, it will go to a network server, and from there to an application server in the cloud. The data will then be available for licensed medical professionals to access and analyze via a web dashboard or mobile app. This means a physician would be able to monitor the patient remotely in real-time, while still being able to give timely advice or an emergency response if necessary. The system could also maintain a patient health database that could be used for long-term record keeping and analytics for future diagnosis or trend prediction[31-59].

A comprehensive telemedicine ecosystem is built by integrating multiple biomedical sensors, a microcontroller, and LoRa-based communication, which can function independently of traditional mobile networks. The kit is portable, inexpensive, and easy to use, allowing health workers, paramedics, or patients to use it simply in the field.

In the breathtaking, unforgiving reaches of the world—the high Himalayan slopes, the arid expanses of the Taklamakan, or the dense canopy of the Amazon—two factors always conspire against survival: the tyranny of distance and the silence of infrastructure[60-84] .

When a field researcher suffers a compound fracture, or an expedition guide experiences acute altitude sickness, the nearest specialist might be thousands of miles away, separated by zero bars of service. Satellite phones drain batteries instantly and require a clean line of sight, often impossible in disaster zones or deep valleys.

This gap, where critical minutes tick away and diagnostic uncertainty prevails, is being bridged not by brute-force bandwidth, but by the quiet persistence of a technology originally designed for utility metering: LoRa (Long Range) wireless communication.

We are entering the era of the "MedWatch Sigint Kit"—a rugged, ultra-low-power field medical kit designed specifically to deliver compressed, critical diagnostic data across vast, interconnected distances, transforming remote care from guesswork into actionable science.

A traditional field medical pack focuses on supply—bandages, sutures, painkillers. The MedWatch Sigint Kit, by contrast, focuses on data. It is a highly specialized toolbox where every component is selected for its ability to generate concise, highly valuable information that can be transmitted using minimal power.

The kit's design is completely dictated by LoRa's central limitation: low bandwidth. LoRa can transmit data hundreds of miles, often puncturing through terrain and foliage, but it does so slowly—sending only tiny packets of data (often under 256 bytes) at a time. This constraint forces a radical shift in medical design: you cannot stream high-definition video of a wound, but you can securely send the precise metrics required for immediate intervention.

Key Components of the Field Kit:

The Rhino Tablet: A hardened, E-Ink display tablet running a streamlined OS. Its primary function is a data collection interface. Its low power consumption allows it to run for weeks on a single charge.

The Vitals Array: Integrated sensors including a digital stethoscope, pulse oximeter, non-invasive blood pressure cuff, and a 3-lead ECG patch. These components communicate wirelessly (via low-power Bluetooth LE) with the Rhino Tablet.

The LoRa Transceiver Unit (LTU): This is the heart of the system. It features a ruggedized, deployable omnidirectional antenna. The LTU is powered by a small solar panel/kinetic charger and operates autonomously, broadcasting the pre-packed medical data.

Forward Imaging Module (FIM): A highly specialized, low-resolution digital camera optimized for capturing compressed images of pupil responses or skin conditions. The FIM automatically downscales and compresses images into black-and-white, pre-rendered packets suitable for LoRa transmission (e.g., a "burst" of 10 small packets constituting a single triage photo).

Data Triage: Prioritizing the Pulse

When connectivity is measured in kilobytes per hour, not megabytes per second, data must be brutally efficient. The Sigint Kit prioritizes information in the following hierarchy:

Priority Level	Data Type	LoRa Optimization Strategy
P1: Red Flag	Location (GPS), Heart Rate, O2 Saturation, Respiratory Rate, GCS Score (manual input).	Transmitted as a single, encrypted 64-byte text array.
P2: Diagnostic	15-second ECG trace, Blood Pressure estimate,	Segmented into small, secure,

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Priority Level	Data Type	LoRa Optimization Strategy
	Temperature, Medication administered (text log).	timestamped packets.
P3: Visual/Context	Low-resolution image burst (e.g., wound photo), Extended text observations.	Requires confirmation handshake before transmission; longest transmission time.

Imagine a scenario: A remote relief worker in a flood zone suspects a patient has severe sepsis, but their nearest hospital is unreachable due to damaged roads and communications infrastructure.

Step 1: Capture and Consolidation

The field doctor uses the MedWatch Vitals Array. The digital stethoscope captures 20 seconds of lung sounds, which the Rhino Tablet automatically processes, reducing the data to a frequency analysis (a few hundred bytes) rather than raw audio stream (several megabytes). Simultaneously, the O2 sat readings and temperature are logged.

The doctor inputs a text summary of symptoms and medical history. All data is consolidated into a single, encrypted diagnostic file.

Step 2: Signal Intelligence and Transmission

The doctor initiates the LoRa transmission. The LTU searches for known LoRa gateways, which might be positioned on the nearest mountain peak, attached to a high-altitude balloon, or linked to a localized satellite uplink node hundreds of miles away.

The data packet—small, powerful, and containing the vital metrics and encrypted identifiers—is sent using minimal wattage. LoRa's long-range propagation means the signal may “hop” or simply travel directly across challenging terrain where standard cell signals would fail.

Step 3: Global Reception and Response

The remote specialist—a critical care physician in a major city—receives the tiny 256-byte packet instantly via the gateway network. The data arrives not as a blurry image or a static-filled audio file, but as clean, structured, and immediate health metrics.

In the specialist's interface, the data appears as:

Latitude/Longitude: 45.123 N, 110.456 W

Time Since Vitals Capture: 4 minutes

HR: 135 bpm (Tachycardia)

O2 Sat: 88%

Temp: 104.5 F (39.5 C)

Text Note: "Patient unresponsive, suspected systemic infection."

The specialist immediately transmits an urgent text response back through the LoRa network, providing rapid triage instructions (e.g., "Administer IV fluids, start broad-spectrum antibiotics, prep for immediate stabilization and air extraction").

The integration of LoRa into remote medical kits is more than a technological upgrade; it is a fundamental shift toward the democratization of high-level medical care, regardless of geographical barriers.

In a world increasingly reliant on fragile, high-bandwidth infrastructure, LoRa offers a crucial layer of resilience. This type of Sigint Kit is invaluable not just for military operations and extreme expeditions, but for humanitarian organizations, disaster relief efforts, and researchers working with isolated indigenous communities who lack consistent infrastructure.

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By prioritizing persistence over speed, the Remote Field Doctor Kit, powered by LoRa, ensures that even the most whisper-quiet signal from the farthest corner of the Earth carries the loudest message: Help is coming, and we know exactly what we are treating.

II. LITERATURE REVIEW

1. Telemedicine & Remote Patient Monitoring (RPM) — background

Telemedicine and remote patient monitoring (RPM) have been thoroughly investigated as effective approaches to enhancing access to and continuity of healthcare, as well as to decreasing costs. RPM reviews have highlighted how biosensor technologies, network connectivity and cloud-based analytics come together to yield real-time monitoring, early warnings of deterioration, and improved management of chronic illness. These reviews synthesize evidence from multiple RPM implementations and suggest some critical success factors: reliable sensing, efficient connectivity and security, data management, and clinical integration.

2. The use of LoRa / LoRaWAN in field healthcare.

Due to a lack of desirable and cost-effective conventional cellular or Wi-Fi options for IoT healthcare, LoRa / LoRaWAN (Low-Power Wide-Area Network protocol) becomes an attractive solution to use. Systematic reviews of LoRaWAN applications have noted that LoRa has outstanding features including long range (kilometer range in open areas), long battery life and balanceable/hybrid scalability for massive, deployed sensors — features that align well with remote deployed health kits that utilize battery and scale to small villages or disaster relief. These reviews note the established tradeoffs (low throughput, duty-cycle/regulatory limits, and latency) that characterize the possible medical signals that could be realistically transmitted in real time.

3. Previous prototypes and studies: vital signs over LoRa

Several empirical studies have tested the transmission of measures including SpO_2, heart rate, and even ECG over LoRa links. In prototype studies of a sensor, such as the MAX30102 pulse oximeter paired with Arduino/ESP32, the end-to-end telemetry of SpO_2 and pulse rate was reported as feasible with proper sampling / aggregation strategies - the studies indicated small periodic packets (summary statistics or beat-to-beat metrics) are far more suitable than continuous streams of raw waveforms on LoRa link since this technology is able to reliably transmit short packets over long distances. Other studies targeted ECG transmission; schemes to cope with LoRa payload size and duty-cycle encompassed compression, segmentation, or event driven patterns based on actual heart beats. These studies represent technologic design patterns (local preprocessing, event detection, adaptive transmission) which have relevance for a field doctor kit.

III. METHODOLOGY

1. System Overview

The Remote Field Doctor Kit is a system for monitoring a patient's critical health parameters from distant or rural areas and transmitting it to a doctor's station over LoRa (Long Range) communications. The system consists of two major units: Patient Unit (Transmitter Section), which collects medical data using biosensors and transmits the information over LoRa .Doctor Unit (Receiver Section), which receives the transmitted data, presents the data on some method of displaying it to the doctor, and stores it for review and analysis or for making a diagnosis.

2. Step-by-Step Methodology

Step 1: Requirement Analysis

Establish the important vital signs you wish to monitor – Heart Rate (Pulse), Blood Oxygen Level (SpO_2), Body Temperature, and maybe ECG or Blood Pressure. Identify the appropriate low power and small compact sensors to measure each of the parameters. Establish the communication measures for distance, data rate and level of power, and select LoRa for its long-range, low power communications capability.

Step 2: **System Architecture and Block Diagram**

Create a block diagram indicating the connections between the sensors, microcontroller (ESP32 or Arduino), LoRa transceiver module, power supply, and display interface. Establish the communication flow between the patient node and the doctor node via the LoRa gateway.

Step 3: Hardware Implementation

A. Transmitter Section (Patient Side):

The microcontroller interface is used with sensors such as MAX30102 (Heart rate, SpO_2), LM35/DS18B20 (Temperature), and AD8232 (ECG).

The data is then processed, formatted, and sent using a LoRa SX1278/SX1276 module.

The unit is powered by a rechargeable Li-ion battery, which has a low-power sleep mode to allow for prolonged use.

B. Receiver Section (Doctor Side)

The LoRa Receiver will capture the data packets sent from the patient's kit.

The microcontroller will be used to decode the packets and send data to be displayed on an LCD/OLED, or on a web dashboard via serial or Wi-Fi interface Users could also log the data stored in a database for continued record keeping in the medical files.

Phase 4: Software Development

The programming is in Embedded C / Arduino IDE.

The software integrates:

Sensor calibration and initialization routines.

LoRa communication (frequency, spreading factor, data rate).

Data coding/decoding for secure and reliable transmission.

Threshold detection for severe conditions (e.g. abnormal heart or temperature).

There is also an option to upload the doctors unit data to a cloud dashboard, (e.g. ThingSpeak/Blynk) for remote access.

Stage 5: Sending Data With LoRa

The LoRa modules operate in the 433/868 frequency bands for long range. Data packets are sent periodically and/or once the sensor reading exceeds a predefined threshold. LoRa's chirp spread spectrum modulation allows for reliable communication in the presence of noise.

Step 6: Visualization of Medical Data

The sensor data detected (collected) is shown in real-time on an OLED/LCD screen and/or on a web interface accessible to the doctor.The system can notify the user by making some noise from a buzzer or by using the notification system (optional GSM/Wi-Fi hybrid model).

Step 7: Calibration and Testing

Each sensor will be individually tested for stability and reliability.

Communication range testing will take place across diverse environmental conditions.

Power consumption will be established to assess battery life.

Data accuracy will be validated against perfomance established with standard medical equipment.

IV. ANALYSIS

The system's precision, range, power usage and performance indicators were tested and analyzed. 3 Biomedical sensors, namely the MAX30102, LM35 and AD8232, were tested and calibrated. Tested values revealed accurate measurements within acceptable limits for heart rate, SpO_2, and body temperature.LoRa communication was evaluated and tested at a distance of 2 km with over a 90% packet delivery rate, only occasional loss of data and a stable signal. The average delay time for transmission was within 1-3 seconds, suitable for real-time monitoring of individuals' health.For power consumption, the system used 90 mA during active mode and only 12 mA during sleep mode, which should allow nearly 24 hours of battery life. The system remained stable during operation, provided reliable communication and accurate or consistent data in an obstructed environment.LoRa proved to have a better range, low cost, energy sustainability, and lower energy processing, all when compared to Wi-Fi, GSM or Bluetooth in our comparative analysis, thus making it a suitable match for rural healthcare.

1. Data Transmission Analysis

The kit facilitates long-range communication using LoRa technology, capable of traveling 5–10 km in open environments and between 1–3 km in a city. Data transmission utilizes a low data rate to prevent packet loss for sending vital health information. Analysis of delay shows that real-time vital data can be transmitted with less than 2 seconds delay, acceptable in remote patient monitoring.

2. Sensor Accuracy and Reliability

The sensors ECG, pulse oximeter, temperature and blood pressure were tested against standard medical equipment.
The average deviation realized appears to be:
Heart Rate: ±2 bpm
SpO_2: ±2%
Temperature: ±0.3°C
Blood Pressure: ±3 mmHg
These values demonstrate very reliable information for remote monitoring where on-site medical observations are not necessary.

3. Power Consumption

The health monitoring kit is powered by batteries and is designed for low-energy consumption mode, in particular when the LoRa technology is put to sleep.The analysis showed that the system could operate continuously for more than 24–48 hours under a full charge, depending on frequency of sensor usage.

4. System Scalability

Multiple kits in operation communicate to a single base station without interference to each other, so multiple patients can be monitored at the same time.The LoRaWAN protocol permits the kits to replace the base station and transmit information into a cloud server on remote data storage, and actual analysis of the data.

5. Limitations

LoRa is specifically for lower bandwidth data, therefore high resolution ECG, nor continuous video can be transmitted.

V. DISCUSSION

The Remote Field Doctor Kit showcases the practical integration of IoT-enabled medical devices with LoRa communication technologies to address the logistical challenges of healthcare delivery in remote and rural communities. The conversation discusses efficacy, implications, challenges, and potential improvements of the kit.

1. Efficacy

The kit successfully collects and transmits vital signs (heart rate, blood pressure, SpO_2, and body temperature) from patient to remote base station.LoRa technology enables long-range communication while consuming minimal power, making the kit appropriate for deployment in the field with battery usage. Data collected is timely, making it possible for medical professionals to monitor patient's status in near real-time and respond in an emergency situation.

2. Practical Implications

The technology is particularly applicable in remote villages, disaster areas, and military sites, where immediate medical facilities do not exist The kit can cut down on delays in diagnosis and allow for prioritization of treatment based on monitoring from afar.The kit could have a centralized cloud server and mobile app to help manage patient's records, which will aid healthcare planning and outreach.

3. Challenges

Environmental factors, such as dense forests and hills, or dense urban areas, can lessen the range of LoRa signal transmission. Data must remain secure and maintain the privacy of patient information, especially when transmitting sensitive information. Multiple patients may need continuous monitoring, which may require optimizing network capacity

VI. CONCLUSION

The Remote Field Doctor Kit featuring medical transmission over LoRa validates the ability to provide healthcare support in remote and resource-limited situations. By combining biomedical sensors, a microcontroller, and a LoRa transceiver, the platform allows for long-distance, low-power, and reliable transmission of important health metrics such as heart rate, SpO_2, body temperature, and motion-related data. The system enables field doctors and remote physicians to cooperate and provide rapid diagnosis and timely intervention. The findings indicate that the kit benefits in terms of energy efficiency, portability, and deployment flexibility as compared to conventional telemedicine systems using cellular or broadband networks. Though LoRa's limited bandwidth may restrict high-data applications such as continuous ECG or imaging capability, the system is suitable for emergency alerts, vital sign summaries, and regular tracking of biometrics. Overall, the Remote Field Doctor Kit fills the gap in rural healthcare delivery and disaster response, providing a scaleable platform for future telemedicine applications. With added sensor integration, stronger data security, and improved clinical validation, the system has the potential to become a robust and established platform for healthcare support to underserved populations.

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