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Research Article

Enhancing Flood Disaster Response Through Real-Time Monitoring and IoT: The Case of SentryLeaf

Md. Ragib Rawnak Rohan, Mst. Ayesha Khatun, Md. Ashfakur Rahman, Abhijit Pathak*

Department of Computer Science and Engineering, Sonargaon University, Dhaka, Bangladesh

Abstract

Floods are among the greatest natural disasters, causing immense destruction, particularly in flood-prone regions like Bangladesh. This study introduces SentryLeaf, an innovative IoT-based network for real-time flood monitoring and disaster response. The system integrates water-level sensors, environmental sensors, and communication modules to facilitate continuous monitoring, enabling quick identification of high-risk areas. The major findings of this research include the system's high accuracy in data collection, with water-level sensors providing measurements accurate to ±2 cm under ideal conditions. Additionally, SentryLeaf ensures real-time data transmission and reliable communication even in the absence of traditional networks, thanks to its decentralized architecture. The communication network remained stable over distances of 200 meters, despite obstructions, and the peer-to-peer communication protocol exhibited resilience under harsh conditions. Furthermore, the system's user interface received positive feedback for its intuitive design and responsiveness, allowing emergency responders to make informed decisions quickly. Overall, SentryLeaf significantly enhances Bangladesh's disaster preparedness and response capabilities, offering a scalable, cost-effective, and resilient solution for mitigating flood-related damages.

Keywords

Flood Monitoring, Internet of Things (IoT), Real-time Communication, Disaster Management, Predictive Modeling, Environmental Sensors

1. Introduction

Floods are among the world's most destructive natural disasters and inflict huge losses on human lives, property, and infrastructure. The SentryLeaf: Rescue Network and IoT Devices for Flood-Affected Areas project introduces a novel, scalable solution to aid flood disaster management in light of these problems, which are most severe in flood-risk regions like Bangladesh. Traditional flood monitoring and communication infrastructure tends to be based on centralized networks, such as cellular networks and internet connectivity that tend to be disrupted or even utterly non-functional during severe flooding. This can result in stranded communities being excluded from receiving important warnings or essential rescue information [5].

SentryLeaf guarantees dependable data transmission and continuous real-time monitoring by integrating Internet of Things (IoT) devices, such as sensors for monitoring water levels, temperature, and humidity, with a decentralized communication network. This decentralized System utilizes

*Corresponding author: a.pathak_cse@su.edu.bd (Abhijit Pathak)

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XAMPP servers, Range Extender Access Points (APs), and Mikrotik RB750r2 hEX lite routers to ensure adequate emergency communication, information accessibility, and seamless connectivity if traditional communication channels fail [8].

The prime objectives of the SentryLeaf project are as laid down below:

Installation and functioning of a decentralized fault-tolerant rescue network to provide fault-free communication during flood situations.

Utilization of Internet of Things (IoT) devices for taking precise real-time data of critical environmental conditions and then passing on this data to a centralized server to be processed and displayed.

Designing a web-based platform that is user-friendly and accessible to emergency responders, local officials, and citizens to enable prompt and well-informed decision-making during flood emergencies.

Providing scalability enables the System to scale up and effectively cover wider geographical areas.

The SentryLeaf program can go a long way in bridging serious gaps in managing flood catastrophes, above all by establishing a robust and independent communication infrastructure. This infrastructure helps reduce floods' effects on human life and property damage by allowing effective rescue operations and quick evacuation. Furthermore, the System's adaptability and simplicity help it to be a solution applied in many kinds of disasters, including hurricanes and wildfires. Effective real-time communication and advanced preparation improve readiness during a disaster and resource use.

2. Related Works

Raman et al. (2024) proposed an IoT-based flood early warning system using a mobile application and alert notification designed to improve disaster management by providing accurate flood alerts and improving response times. The System focused on enhancing flood warning accuracy, reducing response times, and reducing deaths and economic/social costs by collecting real-time data, accurate flood forecasting, and timely alerts. This System proves the improvement of disaster management through accurate flood alerts and real-time data processing. It highlights the potential of IoT technologies in enhancing community response to flood events [1].

Ismail et al. (2024) offered an IoT technology for flood-zone areas using solar-powered IoT sensors. This System collects real-time data on water quality, levels, and flow dynamics for early flood detection, urgent alerts, and improved disaster management. Using a robust IoT sensor network, this System successfully detects floods, monitors water quality, and implements improved disaster management strategies. It highlights the importance of IoT sensors for monitoring and mitigating flood impacts [2].

Damayanti et al. (2024) suggested an IoT-based Early Warning System (ROB-EWS) using ultrasonic sensors to measure sea levels. A microprocessor would process the data and send it in real-time to find high tide floods in Tambak Lorok, Semarang, Indonesia. This System gives real-time alerts through web applications and sirens, enabling timely evacuations and reducing disaster risks for flood-affected communities. The main focus of this System is to implement a disaster mitigation system for tidal flooding and reduce risks and impacts on affected communities. The results indicate that the IoT devices effectively measure sea levels and enable real-time alerts. This System could provide two alert levels, guide evacuation efforts during tidal flooding, and enhance regional disaster preparedness [3].

Dhebe et al. (2023) proposed an IoT IoT-based Flood Monitoring and Alerting System using LoRaWAN technology and ultrasonic or pressure-based sensors to measure water levels and transmit data wirelessly via a LoRaWAN network. The motive of this System is to provide flood detection, observe flood situations, and provide timely alerts. This System does all the tasks to ensure cost-effectiveness, extended range, and low power consumption, and it highlights the ability to deliver real-time flood monitoring and alerts efficiently. This System proves that a based system is adequate for early flood detection and timely response [4].

Wilson et al. (2023) present an IoT-enabled adaptive AI technique using IoT devices for real-time data collection and analysis and a hybrid model trained using six machine learning algorithms for flood-prone areas. This System creates an IoT-based flood management system and implements real-time flood visualization technology to monitor floods. This System successfully shows 99.64% accuracy in enabling flood monitoring and its ability to collect real-time data, give accurate flood predictions, and reduce flood-related damages. The System highlights the potentiality of integrating IoT and AI for advanced management [5].

Siddique et al. (2023) explore an IoT-based flood monitoring and early warning system using ultrasonic and rain sensors, Synthetic Aperture Radar (SAR) data, and cloud computing and machine learning for real-time data collection to create a secure system and an effective flood prediction and alerts. This project focused on IoT-based techniques and machine learning-embedded systems for analyzing atmospheric conditions. The System showed that IoT with SAR data improves flood monitoring throughout the project. The System tried to highlight the potentiality of IoT for early flood warning systems [6].

Sazali et al. [2023] offered an IoT-based Flood Monitoring and Detection System using a solar energy system as a backup power for flood-prone areas by real-time river water level monitoring. This IoT system helps with flood detection and solar energy to ensure system reliability and longevity. It shows how effectively the System monitors flood risks while the solar energy component enhances its efficiency and sustainability. The System focused on the capability of IoT and solar energy to improve flood detection and monitoring systems [7].

3. System Architecture of SentryLeaf

SentryLeaf is an initiative to establish a decentralized flood-affected rescue network using IoT devices and wireless technology. The system architecture comprises various components interacting in real-time flood monitoring, communication, and emergency response. The system can operate in an environment where traditional infrastructure, such as cellular networks or power grids, may be affected by flood conditions. Using Mikrotik RB750r2 hEX lite routers, Range Extender APs, XAMPP servers, and IoT sensors, SentryLeaf provides a scalable, robust, and efficient solution to deal with floods [12].

It is intended to be installed where it will be most beneficial in terms of monitoring floods. It utilizes peer-to-peer (P2P) communication among the devices, which creates connectivity without any outside network infrastructure. A web-based interface allows emergency responders, local authorities, and impacted residents access real-time data about water levels and other environmental conditions.

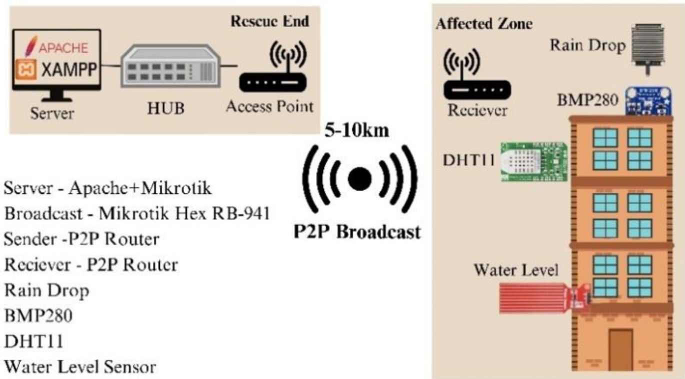


Figure 1. *Architecture of SentryLeaf.*

3.1. Components and Functions

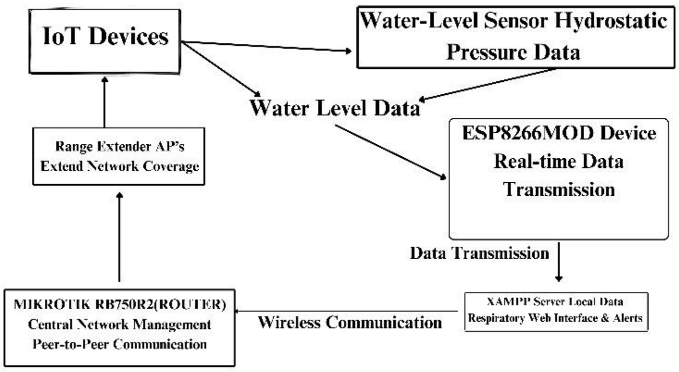


Figure 2. *System Components and Functions.*

3.1.1. Microtik RB750r2 hEX Lite Router

Mikrotik RB750r2 hEX lite router is the central hub of the SentryLeaf rescue network. The router, by using the services of more than one Ethernet interface and wifi, provides the convenience of connecting network nodes peer-to-peer. It provides a robust connection between the hub network and Range Extender Access Points (APs) to provide extensive coverage to flood-affected or distant areas where standard infrastructure is destroyed. Through constant and unbroken communication, the router subjects the devices, emergency services, and flooded area residents to communicate with one another [13].

3.1.2. Range Extender Access Points (APs)

Range Extender APs are designed to extend coverage networks, especially where the central infrastructure is malfunctioning or non-functional.

The devices collaborate with the Mikrotik router in re-broadcasting networks' signals so as to be effectively communicated through the flooded region. In addition to offering extended range, the Range Extender APs also provide a connection for the IoT devices and the XAMMP server at all times, hence an uninterrupted flow of data and connectivity to the Internet where traditional networks reach. This is an extra assurance of reliability in the system and renders the system an integral part of the flood management and emergency response program [14].

3.1.3. XAMPP Server

XAMPP on its machine, such as a laptop or small server enclosure, is the center of information handling and processing for the SentryLeaf system.

The web-based local XAMPP server uses real-time input data from IoT sensors to receive, store, and process. Connected to the Mikrotik router, the XAMPP server stores data entered into it and displays them to the users as a simple web interface. The web interface displays essential flood-related data like water level directions, weather, and warning notifications. Remote real-time flooding allows authorities, emergency responders, and directly involved individuals to make informed decisions and execute relief efforts well [15].

3.1.4. IoT Devices

IoT devices form the core of the SentryLeaf system, which delivers real-time environmental information to determine effective flood monitoring and response.

Two key IoT components of the system are the Water-Level Monitoring Sensor and the ESP8266MOD module.

3.1.5. Water-Level Monitoring Sensor

The water-level monitoring sensor is installed in flooding zones such as basins and lowlands to monitor rising water levels in real-time. Through hydrostatic pressure sensors, the device can measure water depth precisely and transmit real-time information to the XAMPP server via wireless communication. Employing this capability, the system can track flood occurrences closely and issue emergency alerts when water height surpasses previously set safety limits. Employing real-time situational awareness, the water-level sensor plays a crucial role in enhancing early warning systems and mitigating loss due to flooding [11].

3.1.6. ESP8266MOD Device

To serve as the communication interface for the XAMPP server and IoT sensors, ESP8266MOD is enabled to wirelessly transmit environmental data—water level, temperature, and humidity—through the decentralized system in real-time. Supported by the functions to support low power usage and efficient data transmission, enhancing the scalability and dependability of the SentryLeaf system, the module enables the system to run exceptionally well in disaster-struck areas even when conventional communication systems fail.

The SentryLeaf initiative uses these cutting-edge devices to offer a resilient, adaptable, cost-effective flood monitoring and response system. The network's distributed architecture ensures persistent functionality, which makes it an efficient measure to minimize the impact of floods in the affected region, such as Bangladesh [9].

3.2. Network Topology and Integration

The system also uses a hybrid network topology that combines peer-to-peer (P2P) and Wi-Fi-based connectivity to ensure effective, real-time data transmission. The architecture must be robust and scalable and facilitate seamless integration of IoT components to monitor water levels and send alerts.

3.2.1. Data Gathering and Transfer

The Water-Level Sensor gathers and transmits hydrostatic pressure data to the ESP8266MOD device for real-time processing. ESP8266MOD Transmit the data to the XAMPP server using a wireless network. Choose one data point uniformly at random as the first centroid.

3.2.2. Data Storage & Alert System

The XAMPP server is well-suited for locally storing data received. It is a web-based respiratory interface for monitoring. When it crosses threshold levels, alerts are generated, which are the backbone of its timely response mechanism.

3.2.3. Network Management & Expansion

The MikroTik RB750R2 router is at the heart of the network, allowing devices to communicate peer-to-peer. Thanks to Range Extender APs, which have become the few M2M network coverage in the area, the connection can be maintained in more expansive areas.

3.2.4. Integration of the IoT with Remote Access

Thus, the extended wifi network that every IoT device can receive and send data through ensures that it receives data from all the sensors and delivers it to the server. This allows for real-time monitoring, web-based control and automation, and a notification system.

3.2.5. User Interface

A simple web interface delivers real-time water levels, notifications of emergencies, interactive maps, and data visualizations. This makes it accessible on multiple devices, such as smartphones, tablets, and laptops.

To facilitate this System, IoT devices are equipped to wirelessly communicate with each other, even across long distances. This system is built around a Mikrotik RB750r2 hEX lite router that acts as the centerpiece of all network-related communication and is configured to use DHCP communication to manage IP address assignments and traffic on the network. To achieve seamless coverage in a 5KM range, a Point-to-Point AP Router is installed and configured to maintain connectivity to IoT devices used in diverse locations. The backbone of this setup is two primary IoT devices. The first device for water level monitoring uses an ESP8266MOD microcontroller and a water level sensor to determine environmental parameters, including water levels, temperature, and humidity. The obtained data is sent to a centralized XAMPP server in real time, which enables flood conditions to be continuously monitored. To this end, it is optimally placed on the floors of houses to detect ascending levels of water. The second IoT device was developed as a rescue request sender, and it also used ESP8266MOD to send emergency notifications to the rescue team. This device, positioned at key points in homes, helps provide real-time notices during flood events, thereby increasing response speed. A laptop or PC is the central data repository, hosting the XAMPP server.[/mark> It consists of a machine that connects via wireless or LAN, gathers data from IoT devices, and gathers data from it. It also provides an interface for flood-level monitoring and emergency needs. This combination results in a powerful and effective IoT-based flood monitoring and rescue system facilitating real-time information gathering, processing, and action against natural calamities [21].

3.3. Algorithm for SentryLeaf IoT-Based Flood Monitoring and Rescue System

Step 1: Initialize System

(1) Power on Router, Range Extender APs, XAMPP Server, and IoT devices.

(2) Establish DHCP communication for network setup.

Step 2: Collect Data from IoT Devices

(1) Water Level Sensor reads and transmits data

(2) The rescue Request Button sends an emergency signal when pressed.

Step 3: Transmit Data to Server

(1) IoT devices send MAC, Location, Water Level, and Alerts via wifi.

(2) Range Extender APs forward data to Mikrotik Router, then to XAMPP Server.

Step 4: Process Data & Trigger Alerts

(1) The server stores & checks thresholds for water level or rescue requests.

(2) If critical, send flood alerts & Rescue notifications.

Step 5: Display Data on Web Interface

(1) Users (rescue teams, authorities, residents) monitor real-time data.

(2) The graphical dashboard shows water levels & alerts.

Step 6: Send Emergency Alerts

(1) Trigger SMS/email notifications for critical water levels or rescue requests.

(2) Authorities and rescue teams receive immediate updates.

Step 7: System Monitoring & Troubleshooting

(1) Check device connectivity and data transmission logs.

(2) If failure is detected, restart the network/device & reattempt transmission.

Step 8: Log Data & Shutdown (if needed)

(1) Store water level history, alerts, and response logs for analysis.

(2) Gradually deactivate monitoring after flood risk subsides.

3.4. Data Flow and Communication Between Components

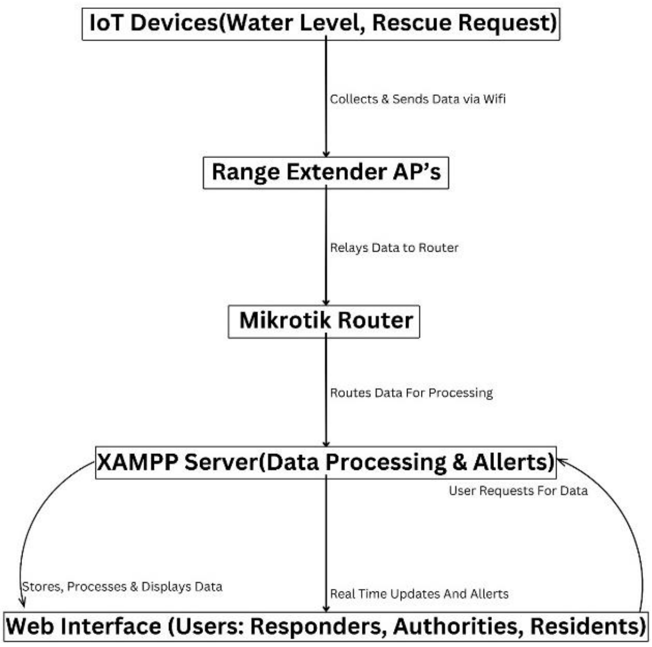


Figure 3. *Data Flow and Communication between Components.*

In Figure 3, IoT devices constantly monitor values (water levels, rescue requests) that are transmitted via wifi to the Range Extender APs. The Mikrotik Router connects all the APs to each other without any breaking connection and sends the data to the XAMPP Server. The server stores the data, analyzes it, and issues alerts when water levels exceed safety thresholds. Users such as emergency responders, authorities, and residents can use the web-based interface to stream real-time flood data, receive alerts, and act accordingly. Specifically, the designed system is low-latency, decentralized, and highly reliable, being able to work without interruption even in flood-affected areas [16].

4. System Implementation

4.1. Hardware Configuration

The SentryLeaf system is designed to ensure real-time flood monitoring and rescue operations through a well-structured hardware setup. At the network's core is the Mikrotik RB750r2 hEX lite Router, which acts as the central communication hub, enabling peer-to-peer (P2P) communication and stable connectivity across flood-affected areas. Range Extender APs are placed strategically to extend the network coverage, ensuring seamless communication between IoT devices, the XAMPP server, and end-users while minimizing interference through optimized wifi channel selection [10].

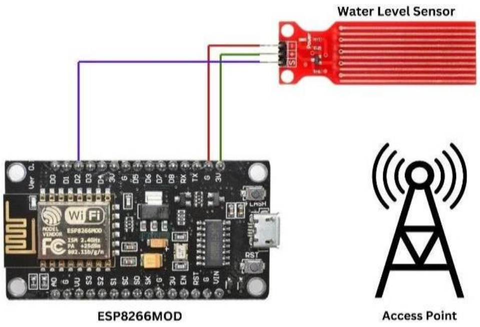


Figure 4. *IoT Device 1 (Water Level Monitoring).*

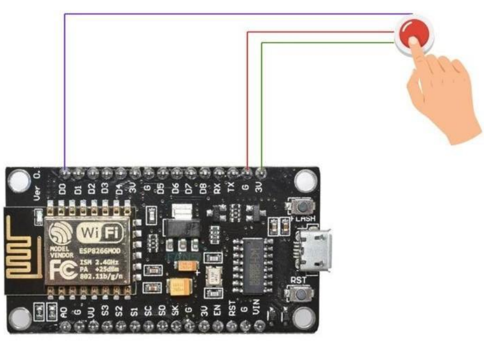


Figure 5. *Rescue Request Sender.*

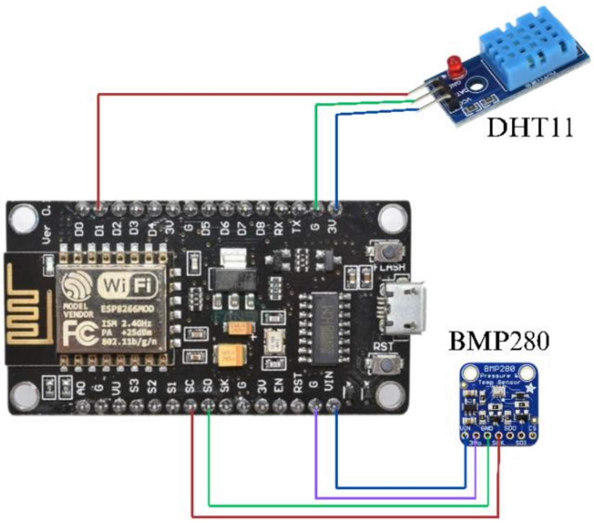


Figure 6. *Sensor Utilization and Data for Rescue Team.*

The system integrates IoT devices powered by ESP8266MOD, which are responsible for collecting and transmitting environmental data. IoT Device 1 (Water Level Monitoring) uses hydrostatic pressure or ultrasonic sensors to measure water levels in real time. When water levels exceed a critical threshold, the device sends an alert to the rescue center. Meanwhile, the Rescue Request Sender is designed as a personal emergency device that allows affected individuals to send distress signals by pressing a button. These signals, containing tracking device ID, MAC address, and location, are transmitted via Range Extender APs to the XAMPP server for immediate action by rescue teams.

This hardware setup ensures a decentralized and resilient network capable of providing real-time flood alerts and emergency rescue requests, even in areas where traditional infrastructure is compromised [18].

4.2. Software Configuration

The SentryLeaf system is systematically developed to ensure optimal programming on an IoT device for efficient communication with a server-side setup and vice versa. This involves utilizing appropriate communication protocols and following through with programming, testing, scaling, and integrating.

4.2.1. Programming & Configuration of IoT Devices

It consists of IoT devices programmed through the Arduino IDE and ESP8266MODWi-Fii module that perform live monitoring of water level and send a rescue request. This data is sent via Wi-Fi to the Range Extender APs, and these APs send the data to the XAMPPP server. To ensure long battery life, the devices use deep-sleep mode to enhance power efficiency. We structure data in JSON and transfer it too the server through HTTP requests [17].

4.2.2. Server Setup (XAMPP & Web Interface)

Data is processed through an XAMPP server on your desktop/laptop. It consists of:

(1) Apache Web Server is used to serve the web-based monitoring interface.

(2) Database MySQL to store water levels, environmental data, and alerts.

(3) The PHP scripts are used to process the data, serve the user's requests, and generate alerts when there is a flood.

In addition, interactive maps are an important way of popularizing data in a way that makes real-time visualization easily understandable for emergency workers and residents themselves, such as when there are alerts since the process is updated every minute.

4.2.3. Communication Protocols (P2P & Wi-Fi)

It utilizes P2P (Peer-to-Peer) communication for device-to-device communication, so it would work even without a centralized internet connection! With the power of Wi-Fi, IoT devices can push data to the Range Extender APs, which in turn transmits to the Mikrotik router and XAMPP server and provide seamless communication across flooded areas.

5. Testing & Troubleshooting

Hardware components, network connectivity, and the user interface were all subject to extensive unit testing. Everyday and failure scenarios (e.g., AP disconnections and server failures) were tested for network resilience. Some of the troubleshooting measures taken were:

(1) AP location control to reduce signal interference.

(2) Deep sleep type to extend the battery life of remote IoT devices

6. System Integration

The last step to integrate everything fluidly:

(1) Range Extender APs secure seamless communication with the Mikrotik router.

(2) Real-time processing of sensor data from IoT devices using XAMPP server.

(3) The user interface is designed to show live monitoring data, alerts, and rescue requests intuitively.

This full implementation allows SentryLeaf to run seamlessly 24x7 for all-time floods and onward to the automatic issuance of emergency alerts, helping ensure speedy and reliable disaster response.

7. Power Consumption and Cost Analysis

The SentryLeaf used an IoT based system which helps in monitoring the flood in low power consumption. The total consumption for the system is about 19,920mAh/day or 96.34Wh/day. This suggests that a typical 20,000mAh power bank can support the system for a whole day.

The power requirement is much smaller than normal communication infrastructure like cellular towers or satellite signals processing units, which require high-power transmission and signal processing capability.

Table 1. *Device Power Consumption Analysis.*

Device	Voltage (V)	Current (A)	Power (W)	Estimated Daily Consumption (mAh)
ESP8266MOD	3.3V	0.08A	0.264W	1920mAh
Water Level Sensor	5V	0.05A	0.25W	1200mAh
Mikrotik RB750r2	5V	0.3A	1.5W	7200mAh
Range Extender AP	5V	0.4A	2W	9600mAh
Total			4.014W	19,920mAh

Energy Cost Calculation

(1) *Monthly Consumption* = 0.09634 kWh/day × 30 = 2.89 kWh/month

(2) *Electricity Cost per Unit* = 4.60 Taka/kWh (as per Rural Electrification Board)

(3) *Daily Cost* = 0.44 Taka

(4) *Monthly Cost* = 13.29 Taka

(5) *Yearly Cost* = 159.48 Taka

Therefore, power infrastructure support is not a requirement for the uptime of the system, leading to a cost-effective and more efficient mechanism.

8. Comparison with Cellular Towers and Satellite Signal Processing

Table 2. Comparison with Cellular Towers and Satellite Signal Processing.

System	Power Usage	Operational Cost	Battery Backup	Infrastructure Requirement
SentryLeaf	96.34Wh/day	~159.48 Taka/year	Easily backed up with power banks	Minimal
Cellular Tower	1500-3000Wh/day	Over 5000 Taka/month	Requires industrial-grade batteries	Extensive – High power and fiber backhaul
Satellite Signal Processing	5000-10000Wh/day	Over 10,000 Taka/month	Requires specialized power sources	Very High – Requires specialized techniques

Only 1% of the energy consumed by a cellular tower and 0.1% by a satellite system, which makes SentryLeaf the most energy-efficient solution for monitoring flooding in rural areas. Being less power hungry makes it ideal for use in remote areas where it may be difficult to supply power and reduce operational costs.

9. Results and Discussion

The SentryLeaf flood monitoring system's performance was evaluated based on several metrics, such as the range and stability of communication, the accuracy of data collected by the IoT devices, and user experience and feedback from stakeholders. The system's performance in the real world was analyzed by comparing it with conventional flood monitoring systems and assessing the limitations and challenges faced at this small-scale deployment level [10].

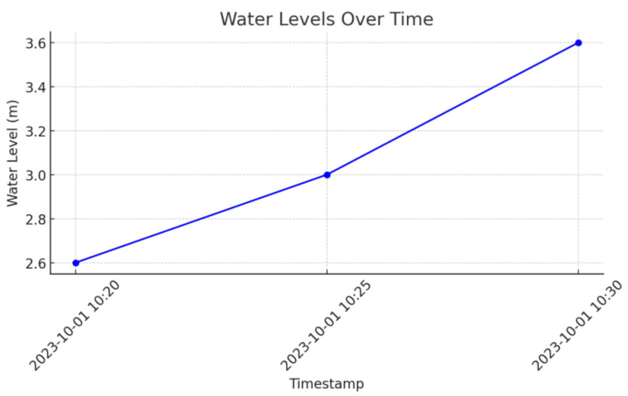


Figure 7. Water Level over Time.

Figure 7 is a graphical representation of the water levels over time based on the data from the image. The plot shows how the water levels increased from 2.6 meters to 3.6 meters over the timestamps provided.

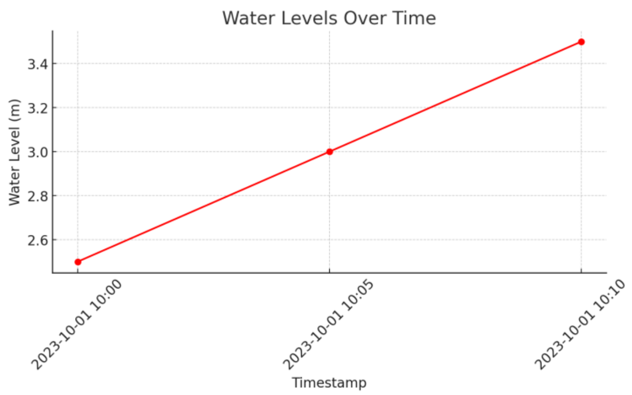


Figure 8. Water Level Progression from 2.5 meters to 3.5 meters.

Figure 8 is the updated graphical representation of the water levels over time, based on the new data extracted from the image. The plot shows the water level progression from 2.5 meters to 3.5 meters across the timestamps provided.

9.1. Communication Range and Stability

A significant challenge in realizing a flood monitoring system is to keep communication stable in a wide area with possible obstructions (i.e., buildings on its way). System performance was consistent under different conditions, ensuring flood data was transmitted to aid real-time decision-making.

9.1.1. Distance and Range

The network was able to communicate over distances of 200 meters, more or less, based on environmental factors like obstruction and interference. To overcome the limits of the Mikrotik RB750r2 hEX lite router and enable it to cover a larger area than usual, Range Extender APs ensured that communications didn't fail, even under arduous conditions.

9.1.2. Obstructions and Interference

We did notice some trees and buildings impacting communication stability, but in comparison to the long-range, we found that communication still remained fairly stable even over large trees and buildings, although signal strength was slightly affected. The range extender AP placement needed to be optimized to overcome signal degradation and provide uninterrupted coverage even in obstruction areas.

9.1.3. Communication Resilience

The system's P2P communication protocol turned out to be quite resilient despite the absence of regular cellular infrastructure in the area. When communication was momentarily lost due to environmental noise, the system successfully re-established contact when line-of-sight was reacquired, or interference ceased [20].

9.2. Data Accuracy

As the flood monitoring system was designed primarily for real-time and early warning alerts, the accuracy of the IoT devices was crucial for its operation success.

(1) *Water-Level Sensors:* The water-level sensors showed good precision, measuring water levels with a precision of ±2 cm under ideal conditions. Data was collected continuously, allowing for changes in the water levels to be in real-time and helping understand flood progression. Such precise measurements contributed to improving the reliability of the early warning system.

(2) *Environmental Data(Temperature, Humidity, and Pressure):* Environmental sensors on ESP8266MOD provided temperature, humidity, and atmospheric pressure data. The accuracy of these readings was well within acceptable limits, with differences usually less than ±3%. This environmental data complemented flood monitoring efforts, providing fuller picture of local conditions [19].

9.3. UX & Feedback

Input from local authorities, emergency responders, and test users was key in assessing how well the system worked for real-life flood conditions. The results pointed to several facets of the system's usability:

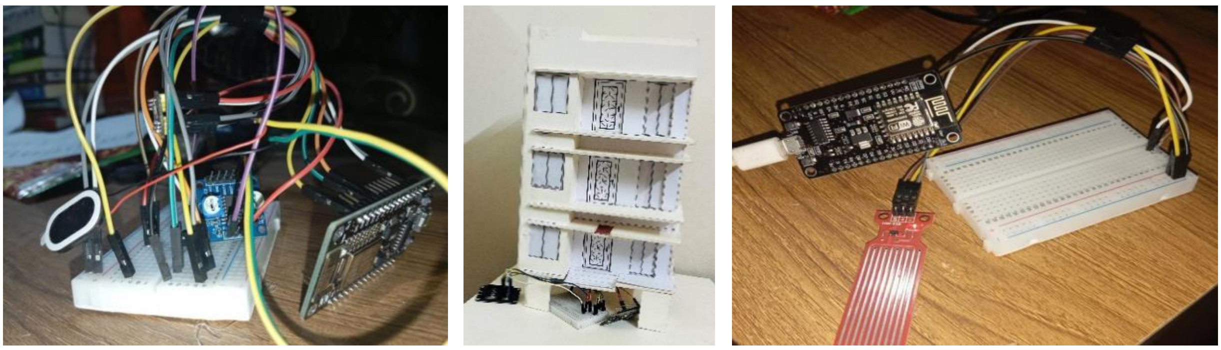
The web interface was praised for being intuitive, allowing users to easily obtain real-time data, viewplots of water levels, and interpret emergency alerts. And visualizations, from graphs to charts, were useful for understandingthe progression of flooding and the potential dangers.

Response Time: When responding to data sent in real time, the system's emphasis on speed was an attractive feature. Emergency responders found the system's ability to get data with minimum latency to be helpful in making timely decisions and interventions.

Alarm System: Emergency responders highly valued the alarm system, which sent notifications at pre-setwater levels. This early warning Preparedness led to the minimization of damage and timely rescue operations.

Mobile Friendly: The web interface was completely responsive, allowing users to access the system on a wide variety of devices, including smartphones, tablets, and laptops. This allowed users to track flood conditions from almost anywhere, increasing the mobility and accessibility of the system. In general, user feedback was overwhelmingly positive, with stakeholders mentioning the system's usefulness in helping with decision-making and flood management during emergencies.

Prototype of the Project:



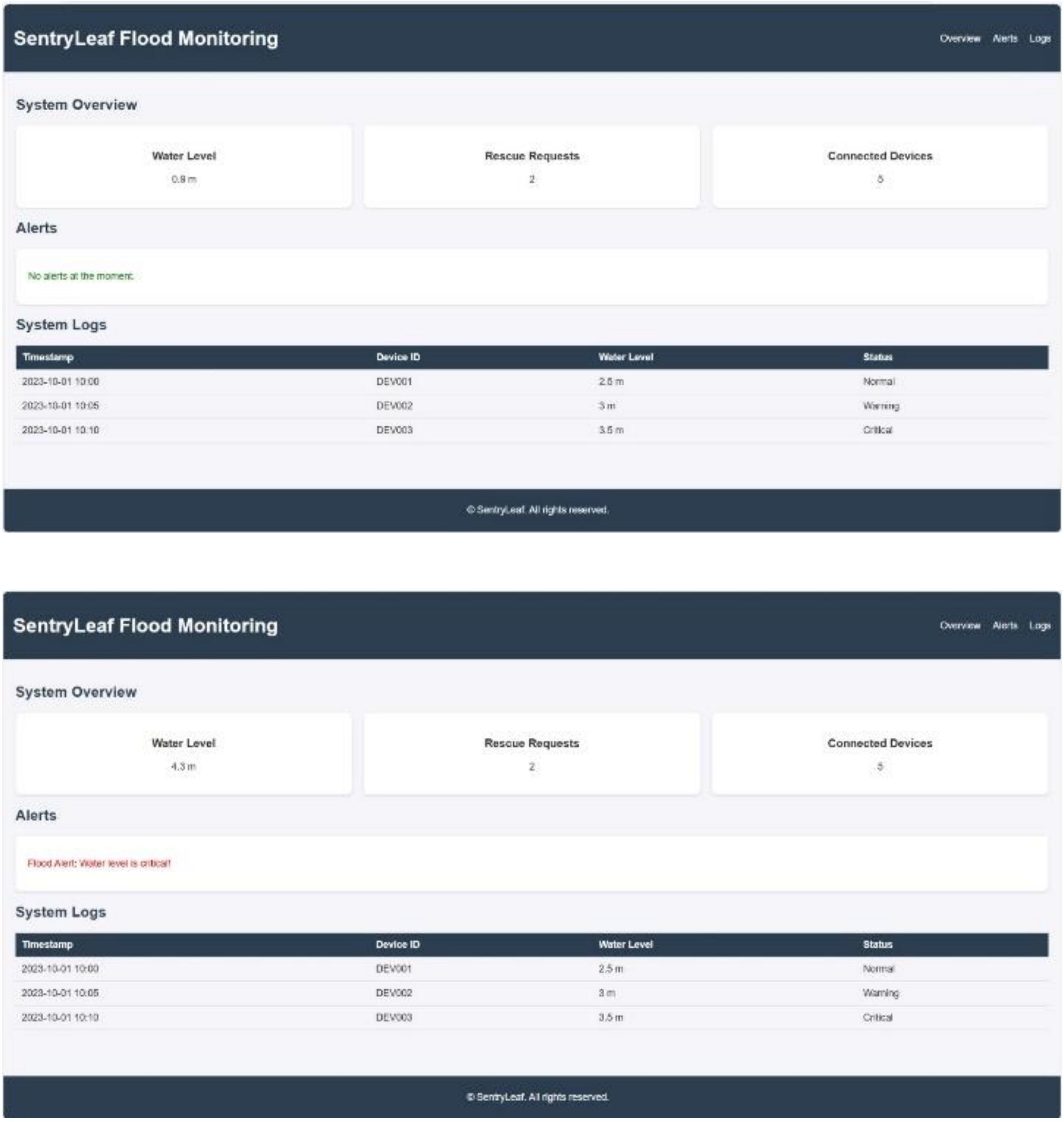


Figure 9. *Snapshots of SentryLeaf Project.*

Figure 9 is a graphical representation of the water levels over time based on the data from the image. The plot shows how the water levels increased from 2.6 meters to 3.6 meters over the timestamps provided.

9.4. Comparison with Conventional Flood Monitoring System

Cost-Effectiveness: Conventional flood monitoring systems often need costly infrastructure, like communication towers and advanced gadgets. Instead, SentryLeafrelied upon low-cost IoT devices (e.g., ESP8266MOD) and range extenders, significantly reducing initial implementation and long-term maintenance costs.

Decentralized: SentryLeaf does not depend on centralized infrastructure to function. The data is communicated in a peer-to-peer fashion (like the Internet), so in places where infrastructure may be damaged or unavailable due to flooding, the SentryLeaf network keeps going.

Real-Time Data: Traditional systems typically provide you with the data they don't have, which delays response efforts even further. This freezes responders to traditional data and communications outlets, while SentryLeaf offers reactivity with real-time updates, with which emergency responders may be informed with real-time information of flood conditions, making disaster management seamless and on point.

Resilience: Traditional systems are restricted to specific areas, hindering their ability to adapt to reactive flood scenarios. SentryLeaf, on the other hand, is mobile and scalable, enabling it to be quickly deployed in different flood zones as conditions change. This mobility allows emergency response teams to rapidly adapt to changing flood waters and affected areas.

While SentryLeaf has many strengths, the old systems still hold the upper hand in terms of long-term durability for large areas of flooding or complex flooding situations. However, SentryLeaf addresses an important gap by offering a more flexible and affordable solution than other services, particularly in economically challenged environments.

9.5. Sensitivity Analysis of Environmental Factors on System Performance

Under real-time flood monitoring, physical environmental conditions such as temperature, humidity, air pressure, and impediments (trees and structures) can significantly impact the operation of the SentryLeaf system. Sensitivity analysis was conducted to evaluate how such factors affect the precision and trustworthiness of the system components, particularly the IoT sensors and the communication network.

9.5.1. Temperature and Humidity

Water level sensors used in the SentryLeaf system are designed to detect water depth based on hydrostatic pressure. The accuracy of the sensors showed no significant fluctuation even with changes in temperature and humidity, and there was a difference of less than ±3% in environmental data readings (temperature and humidity). The fluctuations had no significant effect on overall performance, which indicates the sensors' reliability in varying environmental conditions.

9.5.2. Atmospheric Pressure

It was discovered that atmospheric pressure has a moderate effect on the accuracy of water-level sensors. The sensors used in the system measure hydrostatic pressure, which varies with atmospheric pressure. Under severe weather conditions, i.e., rapid pressure variations during storms, the readings of the system can vary by about ±5%. It can theoretically have an impact on real-time flood forecasting, and recalibration or compensation algorithms may be needed for precise measurements during storms.

9.5.3. Obstructions and Interference

The Wi-Fi and peer-to-peer (P2P)-based communication network of the SentryLeaf system had varying degrees of reliability depending on environmental obstructions. Physical obstructions like buildings, trees, and other similar obstacles resulted in signal weakening, particularly at distances greater than 200 meters. The Range Extender Access Points (APs) mitigated this issue by extending network coverage. The performance of the network was most affected when signal interference was induced due to heavy greenery or large metal objects, resulting in sporadic loss of signals. AP placement needed to be optimized in these areas to ensure communication stability.

9.5.4. Weather Extremes

Heavy rain and gusty winds, characteristic of flooding, impacted the physical integrity of some IoT devices and sensors. However, the system design made devices in more sheltered or elevated positions less vulnerable to damage. The hardware ruggedness was most critical to ensure functionality under moderate environmental stress, though more advanced weatherproofing methods, such as waterproof enclosures, could also enhance the system's performance in extreme conditions.

9.5.5. Power Supply in Remote Locations

The power consumption of the system is yet another parameter that changes with the environment. In remote flood-prone locations where power failures are common, the functioning of the system relies largely on the consistency of backup power sources. Solar-powered charging stations are being considered to overcome power supply problems so that the system can run round the clock in locations with unstable electricity grids.

This sensitivity analysis evaluates the effect of different environmental conditions on the performance of the SentryLeaf system and determines where additional steps can be implemented to improve robustness, especially in harsh weather conditions. The findings show that the system is acceptable under standard conditions but that additional enhancements such as environmental seals for hardware and improved signal management in obstructed environments can further improve its performance.

9.6. Limitations and Challenges

While the results are promising, there were several limitations and challenges during the deployment of the system:

Power Supply Problems: One of the key challenges to deal with was the reliability of the power supply for IoT devices in remote locations. Where batteries could not be replaced, power-saving options were enacted. The only question is how long they can keep going. The simple answer to this dilemma is solar-powered charging systems.

Signal Interference: The strength of wifi signals from the Range Extender APs proved inadequate in densely built or obstructed environments. Although optimizing device placement and suitable transmission frequencies reduced the impact, disturbances due to materials (e.g., metal) can occur.

Environmental Conditions: Extreme weather events — heavy rain or high winds — threaten the physical integrity of IoT devices and sensors. And though this system is designed to endure typical environmental exposures, it could benefit from additional ruggedness and environmental seals that would account for hardware fatigue in more intense climates.

More intensely: The System worked fine in small to medium flood zones, but when trying to scale to larger areas, issues appeared. As more and more devices were added to the network, its performance declined, requiring additional infrastructure, like a more significant number of Range Extender APs, to maintain communications over sizable distances.

SentryLeaf performed well across several critical factors — communication stability, data accuracy, user experience, and cost-effectiveness. This decentralized, real-time data transmission system is superior to traditional flood monitoring systems, especially in areas with limited infrastructure or when floods occur. Though this system is imperfect, as factors such as power supply and signal interference can still affect performance, it seems to be a valid approach to monitoring and responding to floods where traditional systems cannot provide usable data. These include developing sustaining power sources and robust and consistent signaling for the system [22].

10. Conclusion

SentryLeaf project proved the usage of IoT devices and wireless communication technologies to showcase an innovative low-cost flood monitoring system. Range Extender APs Mikrotik routers, inexpensive (IoT) devices were integrated in the system to provide the best reliable scalable solution for flood monitoring in places with bad infrastructures. Outcomes Key outcomes of the project were the accuracy of water-level and environment sensors, stability of peer-to-peer communication, and positive user feedback on the system's usability. The real-time data it gave to emergency responders significantly improved disaster response, producing timely decisions in the case of flooding. Perhaps the SentryLeaf system is even more significant in disaster management, especially in flood-prone regions, where traditional communication systems are either unavailable or destroyed. It is a promising alternative to more expensive and technically demanding conventional flood monitoring systems, especially in places with limited financial and technical resources. The system has been highly successful so far and has room for future enhancement and expansion. This system can be improved by providing solar-powered solutions for IoT devices, advanced communication networks for performance optimization, and advanced data analytics for predictive capabilities. Moreover, using more rugged hardware in extreme weather conditions and linking the system with government disaster response platforms would prove its reliability and response time. However, communication technologies such as LoRa, 5G, NB-Io, and further expansion of the monitoring environment monitoring system can be used in future studies. AI-powered real-time decision support system integration could assist the authorities in making more informed, proactive decisions. In emergency response scenarios, collaborative platforms for disaster management would further enhance the impact of the system, as multiple stakeholders would work collaboratively.

Abbreviations

IoT	Internet of Things
APs	Access Points
MAC	Media Access Control
XAMPP	Cross-Platform (X), Apache (A), MySQL (M), PHP (P), Perl (P)
P2P	Peer-to-Peer
DHCP	Dynamic Host Configuration Protocol
UV	Ultraviolet

Author Contributions

Md. Ragib Rawnak Rohan: Conceptualization, Resources, Project Administration, Writing – Review & Editing, Data Curation, Methodology

Mst. Ayesha Khatun: Software, Visualization, Formal Analysis, Investigation, Validation

Md. Ashfakur Rahman: Software, Writing – Original Draft, Data Curation

Abhijit Pathak: Methodology, Investigation, Supervision, Validation, Writing – Original Draft, Visualization, Funding Acquisition, Writing – Review & Editing

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The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Md. Ragib Rawnak Rohan has a lifelong passion for automation, robotics, and intelligent systems; with a B. Sc. in Computer Science and Engineering from Sonargaon University, he has spent years exploring Arduino, Raspberry Pi, and MicroPython development, tapping into creativity and imagination and transforming ideas into real-world innovations. His focus area is IoT-based automation and AI-based robotics, especially for disaster response and industrial automation. Apart from working with robotics, he has had good exposure to networking (CISCO & MikroTik RouterBoard), web development, and digital marketing. He loves combining hardware and software to develop innovative, efficient solutions to real problems." He keeps engaging, learning, and innovating out of curiosity and a keen eye for technology. Whether designing a new system or digging into the latest advances in automation, he always looks for ways to make technology more available and meaningful in daily life.

Mst. Ayesha Khatun is a beginner researcher who is hyper-enthusiastic about the Internet of Things, the Blockchain community, Social Sciences, and Sciences. At Sonargaon University, where she can develop her skills and pursue her area of research, she is obtaining a Bachelor of Science in Computer Science and Engineering. Based on her incredible scientific history, she researches the cross-section of emerging technologies and their societal implications. With a dedication to furthering her knowledge and making significant contributions in her areas of interest, she perceives her analytical thinking and intuition talent as the motivating element towards her ability to help the emergence of disruptive solutions.

Md. Ashfakur Rahman is strongly interested in AI and IoT-based works, exploring the intersection of intelligent automation and connected systems. Passionate about leveraging cutting-edge technology, Md. Ashfakur Rahman focuses on developing innovative solutions based on artificial intelligence and the Internet of Things to enhance efficiency, automation, and real-world applications.

Abhijit Pathak is a dedicated researcher and Assistant Professor in Computer Science and Engineering at Sonargaon University with over 16 years of experience in academia and research. His expertise includes Internet of Things (IoT), Machine Learning, Artificial Intelligence, and Software Development. He has significantly contributed to interdisciplinary research, focusing on automation, AI-driven solutions, and data analytics. Pathak has published over 30+ research papers in top-tier journals and international conferences. His research impact is reflected in a Google Scholar h-index of 9 and citations exceeding 632. He has been recognized among the top 7 scientists globally from BGC Trust University Bangladesh by the AD Scientific Index 2024. He actively mentors students' leads AI and IoT-driven projects and supervises undergraduate and postgraduate research. As a Commonwealth Scholarship recipient, he has received multiple awards for academic excellence and leadership in technological innovation.

Research Field

Md. Ragib Rawnak Rohan: Artificial intelligence, Machine learning, Cybersecurity, Smart cities, Big data analytics, Fault-tolerant computing, AI-driven surveillance, Human-robot interaction.

Mst. Ayesha Khatun: Quantum computing, Data science, Computational intelligence, Internet of Things, Pattern recognition, Deep learning, Computer vision, Reinforcement learning, Edge computing, Secure computing, Privacy-preserving AI, Neural networks.

Md. Ashfakur Rahman: Formal verification, Computational complexity, Cryptography, Artificial intelligence, Machine learning, AI ethics, Knowledge representation, IoT.

Abhijit Pathak: Artificial intelligence, Machine learning, Parallel computing, Internet of Things (IoT), Complex systems modeling, Adaptive algorithms, Evolutionary computation, AI-driven simulations, Computational fluid dynamics, AI for space research.