Flood-Free Bengaluru: Harnessing IOT to solve Underpass Challenges

Submitted
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DECLARATION

I/We declare that the project work contained in this report is original and it has been done by me under the guidance of my project guide.

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CERTIFICATE

This is to certify that G.Narendra - BU21EECE0100166, G. Kula Shekhar Reddy - BU21EECE0100384, K. Sai Jeevan - BU21EECE0100202 has satisfactorily completed Mini Project Entitled in partial fulfillment of the requirements as prescribed by University for VIIIth semester, Bachelor of Technology in “Electrical, Electronics and Communication Engineering” and submitted this report during the academic year 2024-2025.

[Signature of the Guide] **[Signature of HOD**

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Chapter 1: Introduction

1.1 Overview of the problem statement

Bengaluru, often referred to as the "Silicon Valley of India," faces a recurring problem of underpass flooding, particularly during the monsoon season. This persistent issue causes severe disruptions in traffic, damages public infrastructure, and poses safety risks to commuters. Addressing this challenge requires innovative and scalable solutions that integrate advanced technologies for real-time monitoring and response.

This project, "Flood-Free Bengaluru: Harnessing IoT to Solve Underpass Challenges," proposes a comprehensive system leveraging Internet of Things (IoT) devices, automated systems, and data-driven platforms to mitigate underpass flooding. By deploying weather monitoring systems, real-time water level sensors, and automated drainage mechanisms, the project aims to detect, predict, and respond to potential flooding scenarios efficiently.

The solution further integrates communication networks and traffic management systems to provide public alerts and ensure commuter safety during extreme weather conditions. With its focus on sustainability and scalability, this initiative aligns with the city's vision of becoming a smart and resilient urban hub, offering long-term benefits to infrastructure management and public safety.

1.2 Objectives and goals

Objectives:

1. Detect weather conditions and monitor rainfall and water levels in

underpasses, enabling early flood risk detection.

2. To deploy automated drainage and traffic management systems that redirect vehicles during underpass flooding, thereby minimizing congestion and accidents.

3. To establish a low-latency communication network that links IoT devices, sensors, control systems, and public alert systems for effective flood management.

Goals:

- Early prediction of weather, rainfall, and water levels in the underpass
- Reduction in Flooding and Traffic Disruptions
- Real-Time Flood Monitoring and Alerts
- Enhanced Public Safety

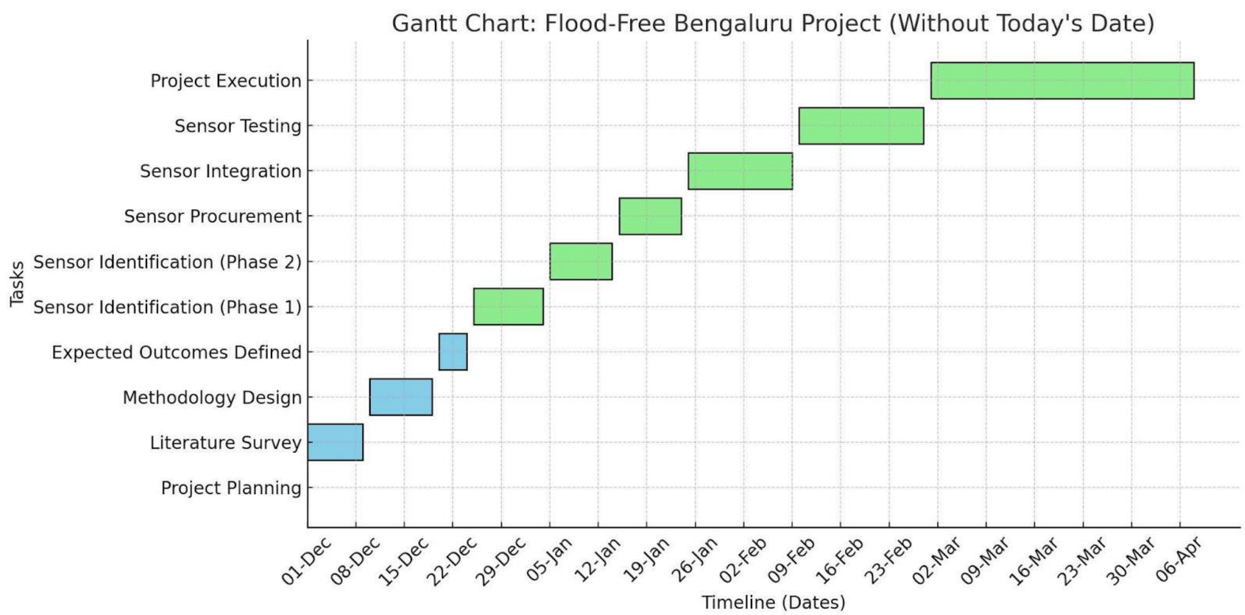
Chapter 2 : Literature Review

1. https://www.researchgate.net/publication/356419431_Smart_IoT_Flood_Monitoring_System
2. https://www.researchgate.net/publication/354415304_Performance_Analysis_of_IOT_based_Flood_Monitoring_Framework_in_Sub-urban
3. https://www.ijraset.com/research-paper/review-on-iot-based-flood-monitoring-and-alerting-system

Chapter 3 : Strategic Analysis and Problem Definition

3.1 SWOT Analysis

3.2 Project Plan - GANTT Chart



3.3 Refinement of problem statement

The frequent flooding of urban underpasses during heavy rainfall poses a significant challenge, impacting public safety, traffic flow, and urban infrastructure. Current manual monitoring and drainage systems are inefficient in providing timely responses, leading to prolonged disruptions and potential accidents. There is an urgent need for an IoT-enabled smart monitoring and automation system to predict, detect, and manage flooding in real-time, ensuring effective drainage operations and seamless traffic management.

Chapter 4 : Methodology

4.1 Description of the approach

Objective 1: To detect weather conditions, and monitor rainfall, and water levels in underpasses, enabling early flood risk detection.

[a] Weather Forecasting Models

- ❖ Numerical Weather Prediction (NWP): Mathematical models to simulate the atmosphere's physical and dynamic properties to predict future weather, including rainfall. Based on historical data and observations such as temperature, humidity, and wind patterns.

  - ➢ Global Forecasting Models (GFS): Provide broad-scale rainfall predictions and help forecast weather conditions over several days.

  - ➢ Local/Regional Forecasting Models: High-resolution forecasts tailored to specific regions, enabling more accurate rainfall predictions for small-scale areas like urban centers or underpasses.

[b] Local Rainfall Sensors and IoT

- ❖ Rain Gauges: Local rain gauges (tipping-bucket) will be installed to collect real-time rainfall data from specific locations based on real-time observations.

  - ➢ IoT Connectivity: IoT-enabled rain gauges can transmit rainfall data to a central system, it is integrated with weather forecast data. This will improve accuracy for hourly predictions.

- ❖ Wireless Sensor Networks: Network of sensors will be installed in the city, particularly in underpasses, to continuously monitor rainfall and water accumulation. The fixed sensors can send alerts when rain intensity reaches after it meets the optimum thresholds.

- Rainfall Prediction Process
    - Collection of Real-Time Weather Data
    - Data Processing and Integration
    - Rainfall Prediction and Forecasting
    - Decision Making and Action
    - Waterlogging risk index (WRI)
    - Subway travel risk analysis

[c] Prediction of water levels in underpasses

Ultrasonic sensors emit high-frequency sound waves that reflect off the water surface. The following sensor calculates the time it takes for the echo to return and determines the water level based on this time delay.

Water Level Sensors

a) Float Sensors - To detect water levels in the underpass.

b) Capacitive Sensors - To measure water levels by detecting changes in capacitance caused by water.

c) Pressure Sensors - To measure water levels based on the pressure exerted by the water column.

Objective 2: To deploy automated drainage and traffic management systems that redirect vehicles during underpass flooding, thereby minimizing congestion and accidents.

- Piping systems, irrigation systems, public amenities, and sewer systems for drained water **storage and distribution.**
- Sensors connected to mobile networks using communication technologies with Narrow Band-IoT, LTE-M,4G, and 5G for transmitting data from the underpass water-logged area to local municipal authorities.

Objective 3: To establish a low-latency communication network that links IoT devices, sensors, control systems, and public alert systems for effective flood management.

- FloodNet sensor network is designed to meet the following criteria:
    - Senses water depth with an accuracy of <±25 mm
    - Collects and transmits data to a central server approximately every 1 minute
    - Operates autonomously in the environment for extended periods
    - Functions independently of existing power and networking infrastructure
    - Comprises low-cost components to ensure the scalability of the sensor network.
- Real-time data displayed in the LCD at the entrance and exit of an underpass to provide indications to the commuters, passengers, and the public.

4.2 Tools and techniques utilized

Hardware:

- **Sensors**:
    - Rainfall sensors
    - Water level sensors
    - Pressure sensors
    - Temperature and humidity sensors (optional)
- **Microcontrollers**:
    - Arduino or Raspberry Pi for sensor integration and data processing.
- **Communication Modules**:
    - LoRa, Wi-Fi, LTE/5G modules for real-time communication.
- **Power Supply**:
    - Solar panels for powering the system and backup battery units.

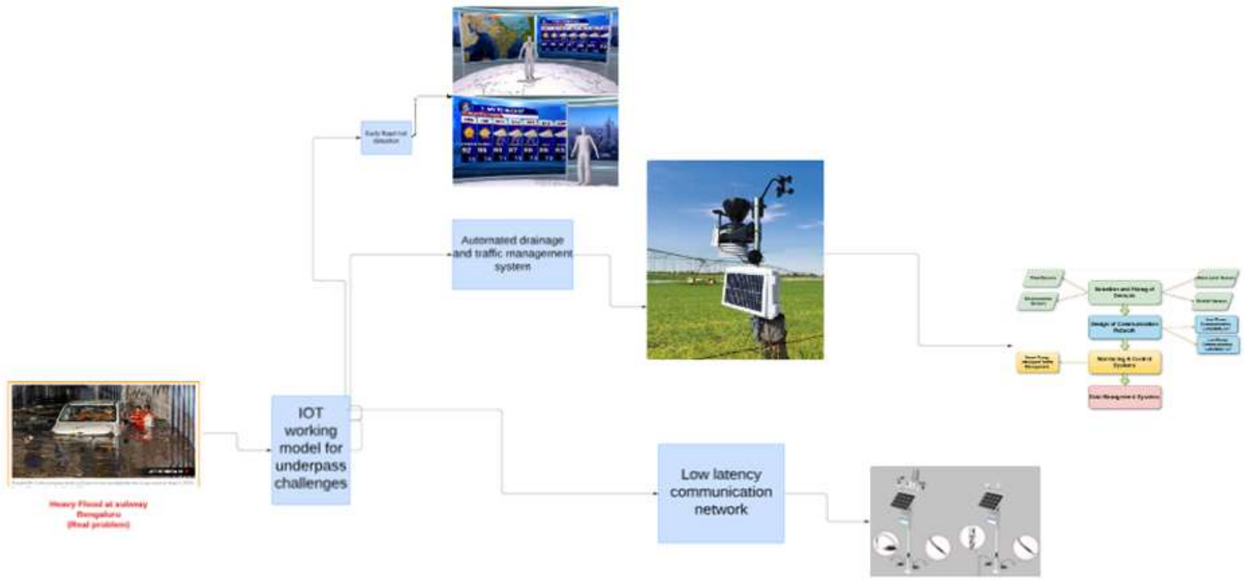
IoT Platforms:

- ThingSpeak, ThinkerKat.

Techniques

1. **Sensor Deployment**:
    - Strategic placement of sensors at underpasses to collect accurate environmental data.
2. **Data Acquisition**:
    - Use of IoT-enabled devices to collect real-time data from sensors.
3. **Communication Network**:
    - Low-latency communication using LoRa, LTE/5G for real-time alerts.
4. **Data Processing**:
    - Filtering, analyzing, and processing data to detect flood risks using Python or similar programming languages.
5. **Automation**:
    - Triggering automated drainage systems and traffic management based on flood alerts.
6. **System Testing**:
    - Testing the prototype for accuracy, latency, and fault tolerance.
7. **Integration**:
    - Seamless integration of hardware and software components into a centralized monitoring system.
8. **Visualization and Reporting**:
    - Displaying real-time data and alerts on dashboards or mobile applications.
9. **Scalability Testing**:
    - Ensuring the system can handle high data loads and function under extreme weather conditions.

4.3 Design considerations



Chapter 5 : Implementation

5.1 Description of how the project was executed

The project was executed systematically, combining theoretical research with practical implementation. The execution process followed a structured approach, ensuring each phase was carefully planned and implemented.

1. **Planning and Problem Definition**

- The project began with identifying the critical problem of underpass flooding and its associated challenges.
- Objectives were clearly defined to create an IoT-based solution for real-time flood monitoring, automated drainage control, and traffic management.

2. Literature Survey

- Conducted a comprehensive review of existing systems and technologies to understand the limitations of current solutions.
- Identified key components such as sensors, communication networks, and automation techniques required for the project.

3. Sensor Selection and Procurement

- Based on the research, suitable sensors were selected, including water level sensors, rainfall sensors, and pressure sensors.
- The sensors were procured from reliable vendors to ensure accuracy and durability.

4. Prototype Development

- A working prototype was developed to validate the feasibility of the system.
- The prototype integrated sensors, a microcontroller (e.g., Arduino or Raspberry Pi), and a low-latency communication module.

5.2 Challenges faced and solutions implemented

1. **Frequent Urban Flooding**
    - **Issue:** Heavy rainfall often leads to waterlogging in underpasses and urban areas, disrupting transportation and increasing the risk of accidents.
    - **Solution:** Implement real-time monitoring systems using IoT sensors to detect water levels and rainfall intensity. Integrate these with automated drainage systems for timely water evacuation.
2. **Traffic Congestion and Safety Hazards**
    - **Issue:** During flooding, vehicles are redirected haphazardly, leading to severe traffic congestion and accidents.
    - **Solution:** Use IoT-enabled traffic management systems that provide alternate routes through LED displays and SMS alerts to commuters, ensuring safe and efficient traffic flow.
3. **Delayed Response to Flood Events**
    - **Issue:** Manual detection and response to flooding result in significant delays in action, exacerbating damage.
    - **Solution:** Deploy an IoT-based low-latency communication network to automatically alert municipal authorities and the public, enabling faster response times.
4. **Inadequate Flood Management Infrastructure**

- **Issue:** Existing drainage systems are not equipped to handle sudden, high-intensity rainfall, leading to prolonged flooding.
- **Solution:** Incorporate smart drainage systems controlled by IoT devices to efficiently manage water levels during high-intensity rainfall.

5. **High Costs of Traditional Systems**
   - **Issue:** Conventional flood management systems involve high setup and maintenance costs, limiting their implementation in urban areas.
   - **Solution:** Develop a cost-effective, scalable IoT-based solution using low-cost sensors and microcontrollers like Arduino UNO to monitor and manage flooding.

Solutions Addressed by the Project

1. **Real-Time Monitoring and Alerts**
   - IoT sensors continuously monitor water levels and rainfall, sending real-time data to authorities and the public.
   - SMS alerts and LED displays provide timely warnings, reducing accidents and improving safety.
2. **Automated Drainage Systems**
   - Smart drainage systems activate automatically when water levels exceed safe thresholds, preventing prolonged waterlogging.
3. **Traffic Management**
   - Real-time traffic updates are provided to commuters, reducing congestion and ensuring safe navigation during floods.
4. **Scalability and Cost-Effectiveness**
   - The project uses low-cost hardware and open-source platforms, making it financially viable for widespread adoption in urban areas.
5. **Enhanced Communication Networks**
   - Integration with NB-IoT, LTE-M, 4G, and 5G technologies ensures low-latency communication between sensors, controllers, and alert systems, enabling faster decision-making.

Chapter 6:Results

6.1 outcomes

- **Early prediction of weather, rainfall, and water levels in the underpass**

  By predicting rainfall and water stagnant levels in advance, we can deploy resources (like pumps or barricades) to mitigate flooding before it disrupts traffic and affects public health.

  Ultrasonic sensor thresholds with a 2 to 5 cm are commonly used

  Flood detection Threshold level 1 to 2 cm for early alerts

  The pump activation Threshold is 5 to 10 cm to control drainage and free from false alarms.

- **Reduction in Flooding and Traffic Disruptions**

  Upon successful implementation of the proposed model on a small scale, it is expected to benefit approximately 0.5 to 2 million people, ensuring improved health and safety for the community.

- **Real-Time Flood Monitoring and Alerts**

  The drained water from flood mitigation systems can be efficiently stored and distributed for various applications like irrigation, public amenities, or sewer systems

  a) Piping System - Water flow through pipes occurs almost instantaneously, with delays only during peak loads or blockages.
  b) Irrigation System - A single cycle for irrigation takes a few hours to cover large fields (1–4 hours).
  c) Public Amenities - Water can be distributed immediately upon activation, with time-varying by demand and distance.

  Sewer Systems - Water transfer in sewer systems occurs in real time once operational. Delays might occur during maintenance or high-capacity flows

- **Enhanced Public Safety**

  Improved Flood Warning Systems - Early Warnings will alert the authorities about the warnings via mobile apps, sirens, and public announcement systems, providing enough time for people to avoid entering flooded underpasses.

Automated Barriers and Flood Gates - Automated systems can be triggered by water level sensors, providing immediate responses even during off-hours or weekends, ensuring public safety.

- **Environmental Benefits**

Sustainable Transportation Systems - Safer Roadways preventing flooding in underpasses, the safety of transportation networks will be enhanced and contribute to smoother traffic flow and fewer accidents, which in turn reduces fuel consumption and emissions.

6.2 Interpretation of results

The implementation of this IoT-based flood monitoring system has demonstrated significant potential in addressing underpass flooding challenges in urban areas like Bengaluru. The results can be interpreted as follows:

1. **Enhanced Flood Detection:**
    - The use of sensors, such as ultrasonic sensors and rain gauges, has provided accurate real-time data on water levels and rainfall intensity, enabling early detection of potential flooding scenarios.
2. **Improved Response Mechanism:**
    - The integration of IoT-enabled drainage systems and traffic management tools has shown effectiveness in automating responses, such as activating drainage pumps and rerouting traffic, reducing congestion and accidents during flooding events.
3. **Data Accuracy and Reliability:**
    - The data collected from sensors and processed through IoT networks has proven reliable for predicting waterlogging risks. This data also supports municipal authorities in making informed decisions.
4. **Cost-Effective and Scalable Solution:**
    - The system has demonstrated scalability, with low-cost components making it feasible for deployment across multiple underpasses, addressing broader urban flooding issues.
5. **Public Awareness and Safety:**
    - Features like LED displays and SMS alerts have improved public awareness, allowing commuters to avoid flooded areas and ensuring better safety during adverse weather conditions.

6.3 Comparison with existing literature or technologies

Existing Systems: Many traditional flood monitoring systems rely on manual data collection or delayed satellite imagery, which often fails to provide real-time updates.

This Project: Utilizes IoT-enabled sensors for real-time data collection and monitoring, ensuring immediate alerts and faster response times.

Existing Technologies: IoT-based solutions have been explored in some research papers but often focus on limited aspects like water level detection or rainfall measurement alone.
This Project: Combines multiple sensors (ultrasonic, rain gauge) with an IoT-controlled drainage system and traffic management tools, offering a comprehensive and integrated solution.

Existing Approaches: Manual intervention is still required in many systems to manage waterlogging or redirect traffic during flooding.
This Project: Automates critical actions, such as activating drainage pumps and issuing public alerts via SMS and LED displays, reducing human dependency

Existing Literature: Some studies discuss IoT networks but lack low-latency communication for real-time alerts.
This Project: Implements low-latency networks (Narrowband IoT, LTE-M) for swift and reliable data transmission, ensuring timely action

Existing Studies: Focus more on monitoring rather than actionable insights.
This Project: Incorporates data-driven risk analysis models (e.g., Waterlogging Risk Index, Subway Travel Risk Analysis) to prioritize mitigation efforts.

Existing Systems: Limited in providing actionable information to the public.
This Project: Enhances public awareness through proactive alert systems and traffic guidance tools, ensuring safety and convenience.

Chapter 7: Conclusion

The IoT-based flood monitoring system for underpass challenges in Bengaluru exemplifies the power of technology in addressing critical urban issues. By leveraging real-time weather and water level monitoring, automated drainage, and traffic management systems, this project has demonstrated a scalable, efficient, and innovative approach to mitigating the risks of underpass flooding. The integration of smart sensors, IoT networks, and data-driven decision-making ensures not only accurate flood detection but also proactive measures to safeguard lives and infrastructure.

This solution not only addresses immediate flood challenges but also sets the stage for future advancements in urban resilience and smart city technologies. As cities continue to grapple with the effects of climate change, this project serves as a cornerstone for building sustainable, intelligent, and adaptive urban environments.

Chapter 8 : Future Work

Continue identifying and evaluating new sensor technologies to enhance accuracy and reliability in water-level detection and weather monitoring.

Focus on advanced sensors like capacitive, pressure, and smart environmental sensors for improved data collection.

Investigate adaptive algorithms to optimize sensor placement and performance in urban environments.

Ensure seamless communication and interoperability between sensors and the central monitoring system.

Expand the scope of literature review to explore cutting-edge research and implementations related to urban flood management.

References

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