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Smart Drainage System using Zig Bee and IoT

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Abstract—Early detection of drainage leakages are utmost important to avoid mixing with pure water. Leaving a clogged pipe unattended can prompt expanded pressure inside pipes, which would then be able to split and blast. This leads to an expensive problem that can cause significant damage. The other major problem faced mostly during rainy season is breeding of pests at roads due to drainage overflow which causes several waters borne diseases. Besides the traditional methods of identifying a leakage which incurs a high cost but low efficiency, this project presents with flow sensor and ultrasonic sensor which detects leakage and overflow respectively with the help of Wireless Sensor Network (WSN) which is based on ZigBee technology and Internet of Things (IOT) and an alert is sent through the mobile app to the authorities in Municipal Corporation prior overflow or any blockage to avoid leakage.

Keywords-Smart Drainage; Leakage detection; Overflow detection; IoT; ZigBee

I. INTRODUCTION

The quick development of populace and industrialization has cleared its way for the utilization of advances like the Internet of Things which offered ascend to the idea of keen urban communities. [1India is seeing quick urbanization. As indicated by statistics 2011 of India, around 377 million Indians including 31.14% of the nation's populace lived in urban regions. The urban populace here is estimated to develop to around 600 million (40%) by 2031.Due to this rapid growth, there is a huge demand on infrastructure maintenance and advancement in technology.

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As India has reported an undertaking of making 100 savvy urban areas and for making a brilliant city one needs to consider numerous parameters, for example, shrewd water, keen power, brilliant transportation and so on. There will be a need of keen underground foundation which incorporates underground water pipelines, gas pipeline,
correspondence links, electric stream, and so on. The present seepage framework in India isn't innovative. And census 2011 of India [2] also states that only 18.1% of closed drainage is available and 33% of open drainage. Therefore, this paper studies real time drainage system as a part of Smart City. The vast majority of the urban areas in India have received the underground waste framework and it is the obligation of Municipal Corporation to look after tidiness, wellbeing and security of urban areas. In the event that there is no legitimate support of the waste framework, at that point unadulterated water get tainted with seepage water and irresistible illnesses, for example, diarrhea, cholera may spread. During rainy season the drainage gets blocked and it will create the problems to routine life like traffic may get jammed, environment will become dirty and totally it will upset the public. In this way, if there is any blockage it is hard to make sense of the precise area of the blockage. Early alarms of the blockage are not received and in this manner detection and repairing of the blockage become tedious. It turns out to be tricky to deal with the circumstance when pipes are blocked completely. Because of such failure of drainage system individuals face a ton of issues. Sensor system has risen as a promising device for monitoring the physical world that can detect, process and communicate. A node in a sensor system is a network of little dispensable low control devices. A wireless sensor network consists of sensing, computing, communication, actuation, and power components. Observing the quality and level of seepage water incorporates numerous exercises, for example, checking the nature of underground water and guaranteeing a nation's legitimate underground waste pipeline to support human, creature and condition. ZigBee which is a standard-based remote innovation created to empower ease, low-control remote machine-to-machine (M2M) and Internet of things (IoT) systems is utilized here. The ZigBee to ZigBee correspondence can occur through different system topology, and cluster tree topology best characterizes for this work. So extraordinary sort of work has been displayed to distinguish, keep up and deal with these underground frameworks. Thus, this framework proposes to distinguish the area, to administer the progression of sewage from the pipes, to recognize the varieties in the stream,

and get earlier alarms of blockages and flood and find them utilizing IOT and wireless sensor network. Other use of this topology can help in water distribution management system which follows the same technique and method.

II. RELATED WORKS

Many cities across the world are facing drainage system problems despite the use of technology and cost-effective solutions. The underground drainage system has its own limitation. The two main most pointed limitations are poor maintenance and contaminating water bodies. Poor maintenance is generally related to difficulty in identifying leakages. The main cause of leakage is clogging. High pressure due to excess clogging can lead to minor leakage which in turn cause a major breakage in drainage pipe. Replacing a drainage tile is yet another a difficult process. Expelling water-cherishing trees, for example, pear, stick oak, willow, delicate maple and cottonwood, from inside 100 feet of the pipe will keep your pipe from blockages brought about by fallen leaves, branches and congested roots originating from these trees. Ochre for instance, an iron oxide that can square deplete pipe, may likewise develop and in this manner, there is a steady need to lookout for it. Then again, drainage systems can likewise add to defilement issues, particularly when not appropriately kept up. Subsurface drainage systems can help nitrate through the drain pipes, diverting it straightforwardly into the waterways, for example, lakes, waterways and streams. Upon clogging, the drainage water will face penetration and in case of excess clog in the pipe, the water does not penetrate. This can cause increase in the level of drainage water and thereby causing overflow. It could lead to hefty cost for manpower and resource for replacing. Therefore, the process of identifying a blockage in underground drainage pipe still remains a tiresome and time-consuming process if done manually that is by using traditional methods. The Internet of Things (IoT) consists of real-life objects and communication devices attached to sensor networks in order to provide communication and actions between real world and information world. Various methods using IoT and prior studies have been proposed for the same for improvisation for drainage systems.

The advancement objective of Smart city is to screen the nature of asset in the city to improve great administration and quicker advancement of the city expects need to overhaul sound and safe urban areas that conveying continuous administrations and most recent office to actualize the idea of brilliant city use IoT idea by which simple remote correspondence is conceivable. Prof. S A. Shaikh et al [3] have proposed Monitoring Smart City Applications utilizing Raspberry PI Based on IOT. The framework comprises a lot of sensors which gather various sorts of information from sensors and move to the Raspberry Pi3 controller. At that point yield from the controller is sent to the control room through the E-mail and furthermore show on the PC.

Yash Narale et al [4] has proposed Underground Drainage Monitoring System Using IoT by using flow sensor, level sensor, temperature sensor and gas sensor to detect flow rate of water with respect to speed, the level of liquids and other fluids, temperature in Celsius, and to sense CO concentration in air respectively. It traces location utilizing GPS and send SMS through GSM. This venture speaks to various methodologies of the usage and configuration capacities for checking and overseeing underground drainage system and gives a depiction of water wise system and detection method to detect leakage defects in sewer pipeline. To beat the restricting components of human entered information, and to accomplish cost, precision and simplification factors, IoT appeared on the grounds that, without human connection, PCs had the option to get to information from objects and devices. In regard to this, Muragesh et al [5] proposed Automated Internet of Things for Underground Drainage and Manhole Monitoring System for Metropolitan Cities. The IoT comprises of real-life objects and communication devices attached to sensor networks so as to give correspondence and computerized activities between real world and information world. Sensor Network is a key empowering influence for IoT worldview and represents the implementation and design function of an Underground Drainage and Manhole Monitoring System (UDMS) for IoT applications [4-5]. This structure incorporates factors, for example, minimal effort, low upkeep, fast deployment, and a high number of sensors, long life-time and high caliber of service. The model of proposed framework gives a system to observing the water level, atmospheric temperature and pressure inside a manhole and to check whether a manhole cover is open. The complaints regarding overflow of sewage water is not properly answered or taken into account. To solve this issue, Sumathy et al [6] has developed Sewage Level Maintenance using IOT which provides a system design includes a sensor to sense the level, a controller to command, a communication network to register the complaints on blockage and continues increase in the level of sewage. The system simply monitors the level and provokes alarm signals via complaints to the required departments through mail and SMS prior to overflow.

Recent studies demonstrated that storm water coagulates into sewer system and causes sewer overflow problems. Storm Water Management Model (SWMM) is examined by Hussein et al [7] for reenacting precipitation driven stream in a sewer framework that could cause flood in sewer systems. The reenactment was done in a local location where storm water network was not so much created. The report calls attention to that serious precipitation causes sewer flood and surface immersion in the zone. Various activities have been proposed, for example, capacity upgrading of sewer system, decline of discharge peak and reduction of exfiltration as a counter measure to tackle this issue.

Karbala, a city situated in focal Iraq, experiences enormous pressure on its sewer framework because of huge visiting populace during religious gatherings. The issue frequently ends up critical because of overwhelming precipitation as the social affair more often than not occurs during rainstorm season. Obaid HA et al [8] presents a paper Modeling Sewer Overflow of a City with a Large Floating Population.

This paper concentrates to reproduce the spatiotemporal dissemination of the sewer water amount and quality with a differing populace and precipitation for the expectation of sewer flood and conceivable contamination weakness. The Storm Water Management Model (SWMM) will be utilized in this examination. This examination has distinguished the conceivable specialized estimates that can be taken to alleviate this issue with regards to the developing populace.

Fujitsu [9] have built up a Technology for Low-Cost Detection of Potential Sewer System Overflows by making a detecting framework to identify social foundation chance. He has created innovation that uses ICT for minimal effort discovery of early science sewer framework so as to moderate harm in urban areas originating from heavy downpours, for example, Japan. They have prepared manholes in which sensors can measures water levels so as to precisely identify early indications of flood. This innovation can likewise decide the area and number of manholes where sensors are introduced, in light of an investigation of the time required for water to spill out of upstream pipes to downstream area as per land geology and the shape and length of sewer pipes, which makes it conceivable to follow and foresee the flood through a sewer framework utilizing just a single fifth the same number of sensors. This innovation diminished power utilization by roughly 70%.

With the rapid technological development of sensors, WSN has become one of the key technologies for IoT. To overcome irregular and manual monitoring process, Retno Tri Wahyuni et al [10] discusses about the plan of drainage systems expected to screen conditions at a few points in drainage system utilizing remote sensor systems. It comprises of a few phases: plan of sensor hub, structure of correspondence unit, plan of spread out sensor hub, and plan of information base framework. The sensors utilized are rainfall sensor, water level sensor, and water release sensor. The significant part on sensor hubs comprise of sensors unit, processor, RTC (Real time Clock), SD cards, remote correspondence unit, and supply units which speak with one another utilizing the Radio Frequency module (XBeeTM). The GSM module is utilized for correspondence among passage and server and the recorded information will be put away into a database that can be pictured by Geographical Information System (GIS).

Ka-Heng Chan et al [11] suggested ZigBee Wireless Sensor Network for Surface Drainage Monitoring and Flood Prediction. A Wireless Sensor Network (WSN) in view of the ZigBee is proposed and executed for the water level location utilizing ultrasonic sensor and give flood prediction. The constructed sensor hubs report under 0.52% average error for the separation inside 0.20m to 4.00m. All model sensor nodes utilized in this work are fueled up by a single standard 3.70V battery. An experiment is arranged utilizing variable stream in water and drainage at the same time to check execution of water level detection and shows the flood forecast capability. A similar process is carried out by Li Xiaoman et al [12] for monitoring aquaculture using ZigBee Wireless Sensor Network. The structure of aquaculture remote sensor organize for information transmission is done utilizing ZigBee technology. The equipment configuration utilized are ZigBee RF module node, the parent node correspondence module, and the child node communication module. The design of the correspondence software are ZigBee node coordinator device, the ZigBee terminal device, and the control software of terminal device. The capacity of remote sensor systems to gather, process, and transmit aquaculture natural data dependably fills in as strong specialized help for remote continuous observing by joining sensor innovation and ZigBee remote network technology.

Early stages of identifying any blockage can be helpful in preventing both leakages and overflow of drainage water and thus location and repairing of the blockage moves toward becoming tedious. In our proposed system, we detect the location by using IoT and the live data for each area is monitored continuously by using ZigBee. The data are then transmitted to the mobile app designed especially for the authorities in municipal corporation via sensors. In case of any occurrence of blockage or overflow, an alert is sent to the app.

III. PROPOSED SYSTEM

The main aim of this project is to acquire a viable ease and adaptable answer for condition monitoring and infrastructure management in the city by detecting drainage water level and blockages to prevent overflow and leakage by excess clogging in drainage. It also monitors water flow rate continuously using ZigBee technology and alert the concerned authority by sending a notification cum message in the event that the water level is outside a normal typical range. This helps in cleaner cities and smart management of drainage in city.

A. System Architecture

The system architecture diagram in Fig. 1 represents the major components used in the proposed system.

B. Components

1) ZigBee

ZigBee is an IEEE 802.15.4 based handset with RF4CE capacities that coordinates an industry-driving RF handset, a standard upgraded 8051 CPU, a 128KB programmable flash memory, and an 8KB RAM.

2) Ultrasonic Sensor

Ultrasonic sensors work by emitting sound waves from the transmitter at a frequency too high for humans to listen to. They then wait for the sound to be reflected back at the receiver, calculating distance based on the time required. The ultrasonic sensor used here is HC-SR04 and is shown in Fig. 2 as taken from [13]. It offers astounding non-contact range recognition with high accuracy and stable readings in a simple to-utilize package [13].

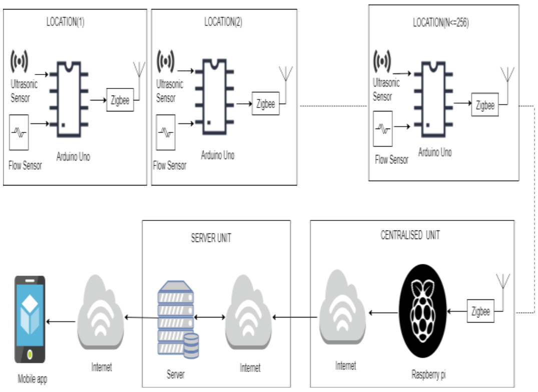


Fig. 1 Proposed System Architecture Diagram

Fig. 2 HC-SR04 Ultrasonic Sensor

The ultrasonic sensor of dimension 45mm x 20mm x 15mm provides +5V DC power supply and 15mA working current [13]. The ranging Distance is approximately 2cm – 400 cm/1″ – 13ft. The resolution is around 0.3cm. It provides a trigger input pulse width of 10us [13].

3)Flow Sensor

Water flow sensor in Fig. 3 as depicted in [14] comprises of a plastic valve body, a water rotor, and a hall-effect sensor. At the point when water moves through the rotor, rotor rolls. Its speed changes with various pace of stream. The hall-effect sensor yields the comparing pulse Signal. Flow sensor is compact and is easy to install with high sealing performance

Fig. 3 Flow sensor YF-S201B

It has high quality Hall Effect sensor and RoHS complaint. The minimum working voltage of flow sensor is DC 4.5V and maximum working current is 15mA (DC 5V). It provides a flow rate range of 1~30L/min [14].

4) Raspberry Pi

The raspberry pi is a low cost, minimal effort, credit card measured computer that plugs into a PC screen [15]. The Raspberry Pi 3 B+ as shown in Fig. 4 is 1.4 GHz 64-bit quad core processor, onboard Wi-fi, Bluetooth and USB booth capabilities.

The Raspberry Pi Foundation gives Arch Linux ARM and Debian appropriations for download, and advances Python as the fundamental programming language. In the internet gateway device, we use raspberry pi model 3 B+, it includes a quad-core ARM Cortex-A7 CPU is running at 900MHz. It is created utilizing Python Library for Communication of RPI with Xbee ZB.

Fig. 4 Raspberry Pi 3 B+

5) Microcontroller – Arduino Uno

Arduino, a microcontroller board based on the ATmega328P is an open-source gadgets platform and a simple to-utilize hardware and software. Arduino rearranges the way toward working with micro-controllers. Arduino boards can ready to peruse simple or computerized information signals from various sensors and transform it into a yield and can control board functions by sending a set of instructions to the micro-controller on the board through Arduino IDE [16]. Arduino doesn't require an additional bit of equipment (called a software engineer) so as to stack another code onto the board and should be possible by just utilizing a USB link.

IV. WORKING OF PRPOSED SYSTEM

The functional block diagram illustrates the monitoring of drainage lines in the underground drainage system. The remote sensor network for drainage monitoring comprises of three sections: the sensor nodes for drainage monitoring, the server, and the mobile application.

The sewage of domestic and industrial sites is disposed of together on to the drainage system. During heavy rainfall, the excess rain water will increase the flow rate of water which will exceed the range of the drainage pipe line which in turn causes overflow. The other reason for overflow is clogged pipe which does not allow to penetrate water. This increases in the level of drainage and is monitored using an ultrasonic sensor. The signal from the ultrasonic sensor is fed to the micro controller where the controller commands the IoT module.

The controller is programmed such that the complaint alarms about the level would be triggered repeatedly unless it reaches the minimum set. The increased pressure of clogged pipe can lead to blockage and can break the pipe causing leakage. The amount of pressure and water flow rate is measured through flow sensor and is continuously monitored. Both flow sensor and ultrasonic sensor are interfaced with microcontroller Arduino Uno with ZigBee in order to make the system smart. The drainage monitoring sensors transmit the gathered culture condition data information to the ZigBee remote nodes through the CAN bus, and this information is then transmitted to the Raspberry Pi and to the server by means of the ZigBee remote system. The Raspberry Pi could refresh with live information under the particular region utilizing ZigBee and triggers a caution on the off chance that it surpasses a specific range.

When the server monitoring platform gets the information, the mobile checking application gets the drainage environmental data by signing in to the server.

Appropriate steps will be taken by the officials upon seeing the notification displayed through the mobile app. An underground drainage monitoring system won't just help in keeping up the correct wellbeing and security of the city but also in reducing the manpower. Fig. 8 indicates the flow chart that explains the complete scenario in the smart underground drainage system.

A. Input Unit

The sensor nodes used in the proposed system are ultrasonic sensor and flow sensor. These sensors are interfaced with Arduino Uno. The Arduino Uno board is shown in Fig. 5 [17]. The V_{cc} in ultrasonic sensor is connected to 5V pin in Arduino and Ground is connected to GND pin. An ultrasonic sensor estimates the separation to the objective by estimating the time between the emission and reception. An ultrasonic sensor utilizes one ultrasonic component for both emission and reception. The trigger pin in ultrasonic sensor is used for emission and echo pin is used for reception. The trigger and echo pin are directly connected to 7^{th} and 6^{th} pin in Arduino Uno Board respectively. The trigger pin emits ultrasonic signal and is reflected back from the object. The reflected signal is passed to the echo pin wherein which is taken as input to the Arduino Board. The information of both the sensor is sent to the centralized unit.

A flow sensor is a device used to measure the instant flow rate of a liquid passing through a pipe line. When drainage water in the pipe line flows through the rotor, the rotor rolls. It's speed changes with different rate of flow. Thus, the output of the flow sensor is determined using the given three wires red, black and yellow. The red wire and black wire is connected to the 5V pin of Arduino Uno board and to the ground respectively. The yellow wire is connected to the 2^{nd} pin of the Arduino Uno board for the use of pulse width modulation (PWN). ZigBee collects the sensor data from the Arduino. The baud rate for serial data transmission is taken 9600 for communicating with the computer. The flow rate of drainage water is calculated by,

flow rate in L/hour= (flow frequency * 60min/ 7.5) (1)

where, sensor frequency (Hz) = 7.5Q and Q is flow rate in L/min. The sensor will produce 7.5 pulses per second for every 1 litre/ minute of water flowing. The sensor frequency is the number of pulses per second originating from the water flow sensor.

B. Centralized Unit

The main purpose of the centralized unit module is to get the information from location module and update to user module. ZigBee protocol is secure and stable and the ZigBee devices can easily be incorporated into systems across the IOT via ZigBee gateways. Therefore, ZigBee is the perfect decision of protocol for smart drainage monitoring because different ZigBee devices can be connected. As more ZigBee devices are connected, communication parts between devices multiply which eliminates the risk of single-point signal failure. In addition, ZigBee is built on 2.4GHz and supports a data transfer rate of 250kbit/s across 16 distinct channels. ZigBee is predominantly utilized for two-route communication between a sensor and control framework. It is a short-extend communication and offers a network between 700 meters. ZigBee can transmit data by passing through a network such as mesh, tree, star and hybrid etc.

The network model used for Zigbee to Zigbee communication is based on tree called the cluster tree (Fig. 6) network defined in 802.15.4 standard [18]. The advantage of cluster tree topology is efficiency in terms of energy consumption. The cluster tree follows parent and children relationship hierarchical topology [19]. Several clusters in this topology, can communicate using multi-hop routes and are controlled with the PAN coordinator [19]. A cluster head(parent) is given to each cluster and can communicate with the PAN coordinator. The cluster topology performs as follows: Upon association request and association response a network is constructed as the parents of the clusters form a tree structure and act as an intermediate router. Raspberry Pi 3 B+ is a 1.4 GHz 64-bit quad core processor with onboard Wi-fi capabilities is used to consolidate all the data received by the ZigBee nodes. The platform used to access the Raspberry pi is Raspbian. Python is the programming language which is used to process and transfer this data. Finally, all the data is updated to user module.

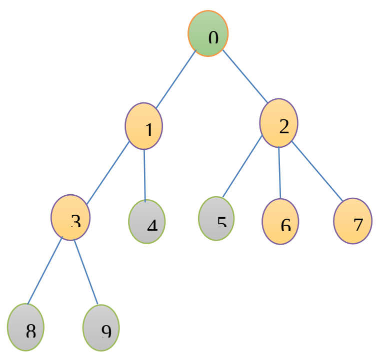
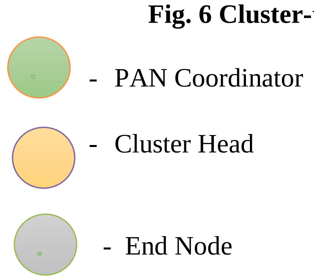


Fig. 6 Cluster-tree topology



C. User Interface

The user module receives the information from the centralized unit and updates about individual location status. This is done by transmitting the information to the server which replaces the existing values with the updated current value via Internet. According to the threshold values defined which depends upon the radius of the drainage pipe, an alert is sent to the authorities at the Municipal Corporation through mobile app. The app also displays the authorities about the current live data of each area.

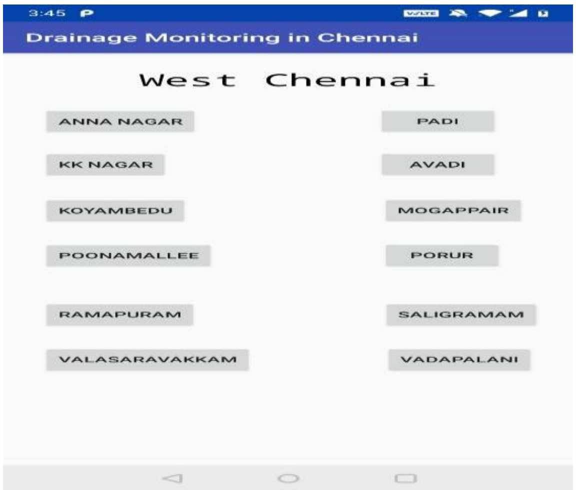


Fig. 7 Screenshot of the mobile app displaying areas in West Chennai

In Fig. 7 shows the screenshot of the app displaying the list of areas in Chennai, India. Upon clicking any area, it shows whether the underground drainage system in that particular area has any blockage or overflow.

V. EXPERIMENTAL RESULTS

For time constraints, we implemented a single unit (location) for demonstration. The system is thereby composed of

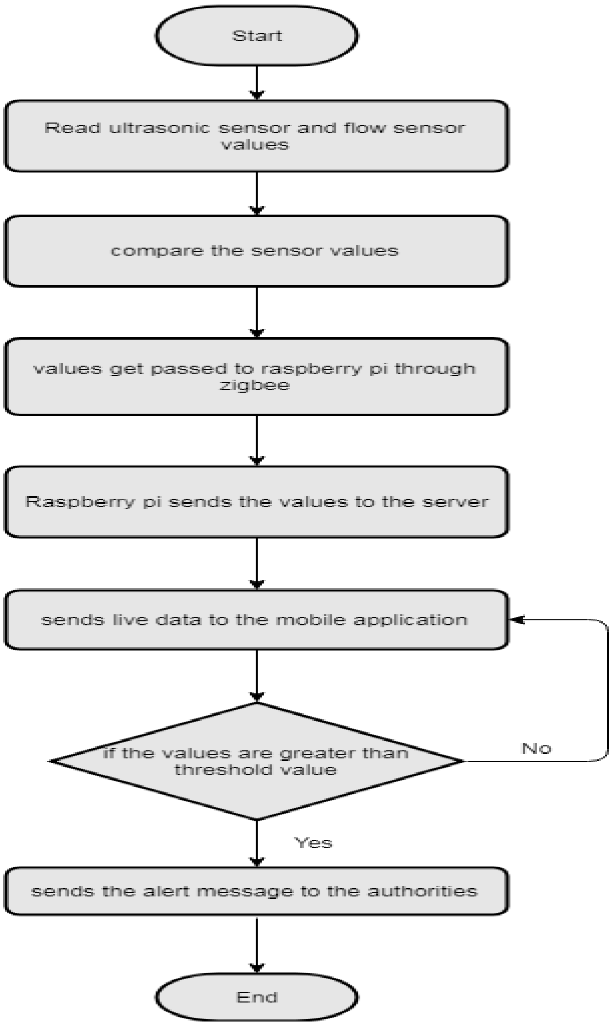


Fig. 8 Flowchart

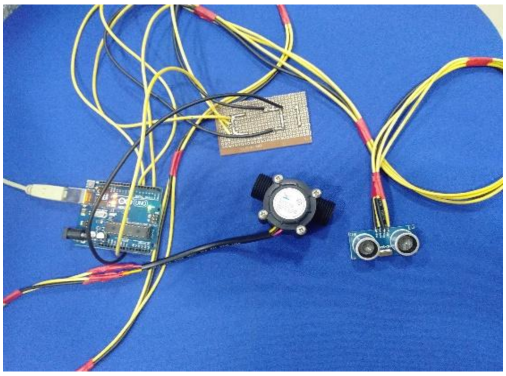


Fig. 9 Hardware Setup

ultrasonic sensor which comments on the level of drainage and flow sensor to detect any clog in the drainage pipe. The experimental setup is done using a 1.5-meter-deepdrainage pipe thus delivers a report where the minimum level was set to 0.5 meter and the maximum was 2.5 meters where the sensor would keep sensing and thus the maximum signal will generate an alarm using an IoT module. The IoT module is also connected with a gateway network where, the levels measured are together collected in a server. Fig. 9 shows the hardware setup for the proposed system.

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A vessel with level surface is utilized with customizable water flow is feed into the vessel through channel with valve. The sensor node is fixed on the cover of the vessel and zero level was aligned. In this manner, when vessel is loaded up with certain level of water, the ultrasonic sensor can distinguish the range distinction and decide the associated water level. In this figure, the water level in the vessel can be logged and observed. By controlling the flow-in water amount in various time occurrences, the water level was raising, kept up and decreasing at various time.

The threshold value for ultrasonic sensor is 10 inches. Any values above 10 inches, for e.g. 28.8,33.42 inches are considered as normal values. Values below the threshold is considered as overflow. The value decreases as the flow increases. The distance between the sensor and the rate of the water flow is calculated. Table I shows the result of values obtained for ultrasonic sensor. As the drainage water increases its speed due to blockage in the pipe, the value decreases. If the values drop below the threshold value then, message is sent to the authorities via mobile app with respect to location. Likewise, the threshold value for flow sensor is 10 litres/ hour (L/hour) and the result of values obtained from flow sensor is shown in Table II.

The flow of water is monitored continuously. If any blockage occurs then, the rate of water changes. As the blockages size increases, the rate of water flow decreases. As the values from flow sensor drops below the given threshold value, an alert is sent to the authorities via the same mobile app. Fig. 10 shows the alert message in mobile app as the value fall below the specified value. As the values 9 and 7 arrives, as shown in Table II, a message is sent continuously to the authorities as displayed in Fig. 10 till the blockage is repaired

TABLE -I: Ultrasonic Sensor Values

Values (inches)	Outcome
60.75	Normal
80.44	Normal
77.0	Normal
6.98	Overflow
4.44	Overflow

TABLE –II: .Flow Sensor Values

Values(L/hour)	Outcome
240	Normal
129	Normal
55	Normal
9	Blockage detected
7	Blockage detected

VI. CONCLUSION

With IOT and ZigBee WSN a drainage leakage and overflow detection is proposed and developed by using ultrasonic sensor and flow sensors respectively. This system avoids or eliminates the issue of drainage overflow on roads which is being a vital problem in many cities. The advantage of the project is that clogs in drainage pipes can be revealed as soon as it is formed rather than detecting it after the drainage water starts overflowing into the roads causing serious disruption to the public and revenue loss to the government. The system further does not require any human labor to detect the clog. The ultrasonic and flow sensors are efficiently used and system is designed in a social relevant idea thus to create an impact on cleanliness and hygiene by purely avoiding the problem of overflow on streets and also to ensure compulsory cleaning of blockage which causes the increase in drainage level by registering repeated complaints to random departments unless action is taken.

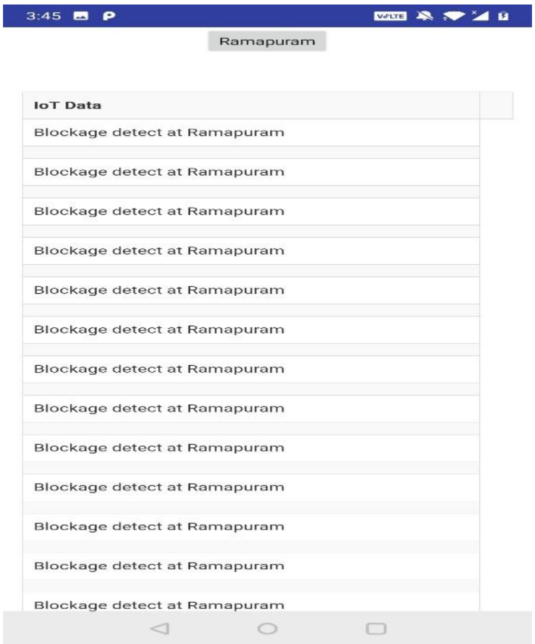

Fig. 10 .Screenshot of mobile app displaying continuous alert messages regarding blockage detected in Unit Ramapuram, an area in Chennai.

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