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Application of IoT: Smart Manholes Based Underground Drainage System

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Abstract: Underground drainage system (UDS) and the manholes in cities of our country India is one of the major issues, due to its poor maintenance. The drainage water contains sewage, domestic and industrial waste. When such thing gets blocked within sewers, UDS is overflowed on the roads causing water logging and sometimes gets mixed up in the drinking water which causes health hazards to common people. The sewers gases make manholes a lethal environment, when UDS requires maintenance. To overcome these issues, a model called "Smart Manhole Based UDS" is proposed here, which will monitor various parameters related UDS & manholes such as drainage fluid level and sewer gas level in the drainage system, manholes lid or cover conditions; location of the underground blockage by using Node MCU and the measured values will be stored in the cloud for future analysis. The real time monitored data will be analyzed and conditions of UDS and manholes will be sent to nearby municipal corporation office as emergency notifications through IoT systems.

Keywords: IoT- internet of things, UDS- underground drainage system, sewer gases, WSN- wireless sensor network, Node MCU- Node microcontroller unit, CPU- central processing unit, GUI- graphic user interface, RFID- radio frequency identification.

I. INTRODUCTION

In India, most of the cities has underground drainage systems (UDS) which are maintained by municipal corporation of the respective cities to make clean healthy surroundings and hence environment. Fig. 1.1 details the outline of underground drainage systems, sewer atmosphere and its surroundings [1]. It consists of drop structures, pipelines, manholes and ventilators.Often due to poor maintenance of the UDS, the drainage water gets mixed up with the potable water and consumption of this polluted water leads to water borne diseases. Due to sudden changes in the atmosphere and variations in the climate specially during rainy seasons the drainage gets blocked or water logged, making environment unhealthy and disturbs the healthy routine of common people. To overcome all these issues in the UDS and to notify the municipal corporation about the condition of the UDS and the open or closed manhole covers by sending notifications, so that the official personnel can take the necessary action to repair the drainage system and cover the manholes with properly designed lids or covers.

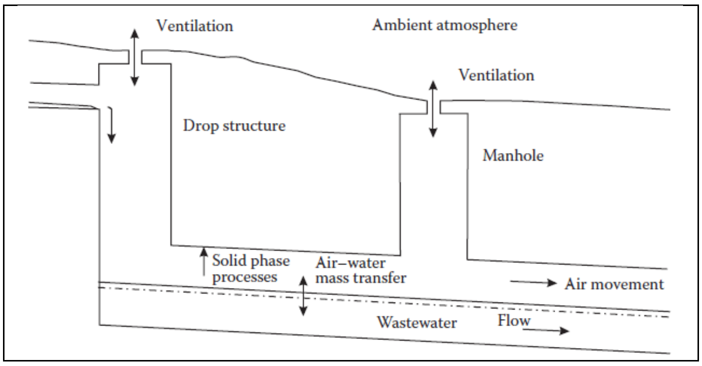

Fig. 1.1Outline of underground drainage systems, sewer atmosphere and its surroundings.

Also, various sewer gases[1] are formed inside the drainage system due to domestic and industrial waste, that makes environment inside manholes as lethal, will also be detected using the array of gas sensor so that we can avoid any fatal conditions inside the drainage system as well as in the manholes. Drains contain abundant organic matter [2]. When they decompose in the absence of oxygen, they produce hydrogen sulphide, especially if the environment is warm and the sludge has been stagnating. Hydrogen sulphide is soluble in water and becomes trapped in sewage matter. When the latter is disturbed, the gas leaks out and cause nausea, delirium and convulsions, which can all imperil self-rescue. It is also a skin and eye irritant.When absorbed through the lungs, it causes pulmonary oedema. If it is present in the sludge at 1 mg per liter or more, it can accumulate in the air at hundreds of parts per million and knock a person out. According to one estimate, workers shouldn't beexposed to 2 parts per million of the gas for more than 30 minutes. At over 1,000 parts per million, hydrogen sulphide can kill in a single breath.

Another thing to consider is the relative density of gases. When fuel is burnt inside, in that already oxygen-poor environment, the combustion process uses up the gas and releases carbon monoxide. (If fuel is combusted in the presence of hydrogen sulphideand methane, there can also be an explosion.) And when methanogenic bacteria are present in the biofilm lining the plumbings inside, methane is produced.

When all three gases – hydrogen sulphide, methane and carbon monoxide – are present, they don't assault the worker at the same level. Instead, they become stratified by height. Methane rises to the top because it is the least dense. Carbon monoxide becomes sandwiched in a layer between the methane on top and the hydrogen sulphide below. The latter two are both denser than air. Finally, because methane is also less dense than air, it displaces air.

Thus main aim of this proposed model is to monitor the UDS and manholes conditions. If there is any kind of issue in the drainage system or manhole, it will be monitored using the wireless sensors and the acquired information will be sent to the nearby municipal corporation official and the sensed information are stored in the cloud storage for the later analysis purpose.

A. Ovwerview of WSN

Wireless sensor network (WSN) [3] can be defined as a network of nodes that work in a cooperative way to sense and control the environment surrounding them. These nodes are linked via wireless media. Nodes use this connection to communicate among each other. The architecture of a typical WSN consists of following three components: sensor nodes, gateway and observer (user). Sensor nodes and gateways constitute the sensor field. Gateways and observers are interconnected via special networks or more commonly via internet as shown in fig.1.2. Conceptually a WSN is based on a simple equation which depends on the fact that Sensing + CPU + Radio = Lots of Potential [3]. Sensing Unit is necessary to monitor surrounding environment and its conditions. After completing monitoring and sensing processes, necessary computations are accomplished in microprocessor or controller unit. Lastly, computed environmental data are transferred by Radio Unit through the wireless communication channels among the nodes. Finally, these data are sent towards the Gateway.

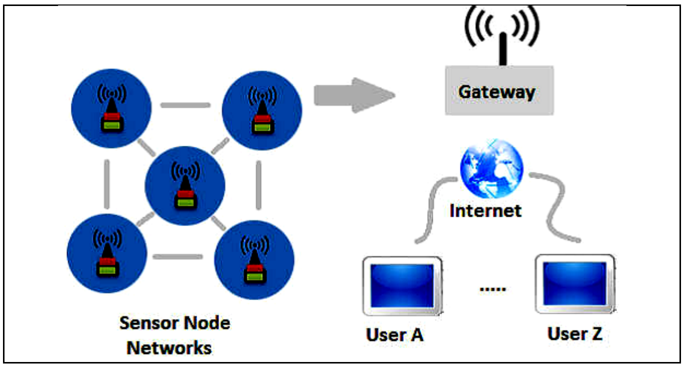

Fig. 1.2 Wireless Sensor Network (WSN)

WSNs can also be considered as collection of nodes and these nodes are individual small computers that work cooperatively to form centralized network systems. There are some requirements for nodes to be used in these networks such as efficiency, multi-functionality and being wireless. Each node in any network has a predefined goal. For example, if it is aimed to collect information about various sewer gases within a manhole, these nodes are placed in different manholes to form a network. The sensor nodes are placed in a connected network according to a certain topology such as linear, star and mesh. Nodes of the network in any topology have a limited broadcast range which is generally 50 meters to several kilometres depending upon power utilization of wireless access point devices.

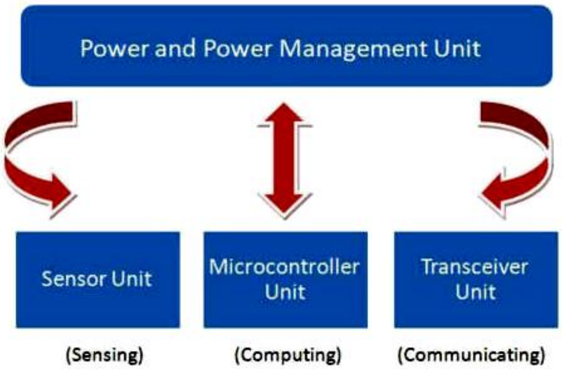

Fig. 1.3. Data collection and data transfer within a Node

Within a node of WSNs, data collection and data transfer are accomplished in 4 steps: collecting the data by various sensors, processing and packaging the data by microprocessor or controller unit and transferring the data as shown in fig. 1.3. Power management for WSN node is very important and essential as it requires dc supply that must be ultra-portable and must have long battery life. WSN is actually a subset of IoT. IoT exists at a higher level than WSN. A large collection of sensors, as in a mesh network, can be used to individually gather data and send data through a router to the internet in an IoT system. WSN consists of a network of only wireless sensors. When this is connected to the internet then this device is termed as IoT device. An "IoT system" can therefore be interpreted as a group of many IoT devices.

B. Overview of internet of Things

TheInternet of Things (IoT) [1, 4, 5] is a sprawling set of technologies and use cases that has no clear, single definition. One workable view frames IoT as the use of network-connected devices, embedded in the physical environment, to improve some existing process or to enable a new scenario not previously possible.

These devices, or things, connect to the network to provide information they gather from the environment through sensors, or to allow other systems to reach out and act on the world through actuators. They could be connected versions of common objects that might already be familiar with, or new and purpose-built devices for functions not yet realized. They could be devices that one can own personally and carry with or keep in home, or they could be embedded in factory equipment, or part of the fabric of the city you live in. Each of them is able to convert valuable information from the real world into digital data that provides increased visibility into how your users interact with your products, services, or applications.

II. LITERATURE SURVEY

Numerous studies [6] have led to actualize the idea of IoT to make the urban areas, more intelligent with the usage of sensors which collects and measures vast information. Some of these are looked into as under:

Chan H. See suggested Gully pot monitoring system [7] which was able to transfer and process data effectively by using variety of low cost sensors and it also gives solution to monitor sewer. UDS or sewer system [8], which was the part of Smart City monitors changes in climates affect storm drainage system. There are numerous problems in existing UDS that requires the modification of existing drainage infrastructure [9]. A system is presented in [10] by DimitrisKaradimas, et al for smart city framework for solid waste collection. S. Ravichandran,[11] proposed architecture thatexploit RFID communication to reduce costs, and support scaling at urban level. L. García, et al.[12] presented a review paper where some relevant RTC(Real Time Control) strategies applied to UDS, which can be divided into optimization based and heuristic-based algorithms. R. Girisrinivaas, V. Parthipan [13] presented a model for Drainage Overflow Monitoring using IoT. The proposed model focuses on monitoring of underground drainages and the manholes conditions and enables cleaning operators to better plan their cleaning schedules and routes.routes.

III. PROBLEM ANALYSIS AND PROPOSED SOLUTION

The irregular monitoring and poor maintenance has contribution on the clogging of the drainage that imply to the siltation which trigger the flooding in the drainage. Drainage water clogging also leads to development of sewer gases in UDS and within manholes. Due to sewer gases which is fatal to human beings as well as animals, lead to the slow handling for problems in drainage manholes and in extreme conditions it costs a human life. UDS finds their paths mostly beneath the roadways, and there are manholes to monitors the conditions of UDS. If manholes are not covered properly then these manholes are really fatal. Manual monitoring is not efficient for this purpose. It needs a lot of manpower who are only able to record limited report.

This system not only detects these conditions at local end and also at remote end and it also alerts municipal corporation officials through visual notifications and emails. This proposed system uses following components:

a) Various gas sensors which are capable of detecting gases such as LPG, carbon monoxide, methane and hydrogen sulphide.
b) Level sensor is used to detect the level of substances that can flows in the underground sewers. Such substances include liquids, slurries and granular material.
c) Suitable sensor is used to detect opening or covering of manhole lids or covers.
d) Wireless node for communication with access point.
e) Access point for internet connectivity.
f) IoT platform for desktop based application and or mobile based application for remote monitoring of the parameters inside the drainage system and manholes.

IV. OBJECTIVES

The proposed system will be able to:

a) measure the concentration of various sewer gases, underground drainage water level
b) transfer various sensor signals in real time by using suitable node microcontroller unit.
c) monitor the condition of manhole lids or covers that are closed or open in position.
d) integrate wireless sensory network and IoT.

V. PROPOSED METHODOLOGYAND IMPLEMENTATION

As shown in fig. 5.1 the proposed model for node is based on Wireless sensor network (WSN) for underground drainage water and manholes management system that has many benefits. In this system to monitor the drainage water level inside the UDS drainage water level indicator is utilized which is basically ultrasonic level sensor. This ultrasonic sensor (water level indicator) monitors the drainage water within the pipeline network as well as the inside the manholes on real time basis.

The main reason behind the selection of node MCU is thatthis tiny cheap module has a dual core 32-bit CPU architecture with built in Wi-Fi and dual-mode Bluetooth with sufficient amount of 30 input-output pins for all basic IoT based systems. All these featuresare very easy to use, since it can be programmed directly from the Arduino IDE. Hence, we do not require discrete microcontroller development boardand Wi-Fi module and Bluetooth module; all things are integrated on a single board.

As the level indicator to indicate the level of drainage underneath the manhole, it is programmed to two different levels of drainage. The first level is marked under the manhole will be a warning zone indicating the rise of the level. The main control room will be notified in case there is an increase in this level. The second level is marked under the manhole at a height of to indicate the personnel that further rise in the level indicating the blockage; an alarm (email and visual notification) will be triggered in case any such situation regarding the emergency or blockage is detected.

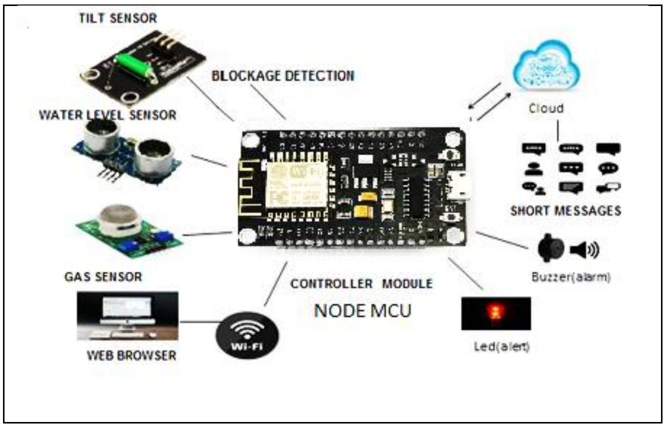

Fig. 5.1.Proposed model of the node

Implementation of the proposed system is shown in fig. 5.2. Whenever there is blockage in the drainage, the level indicator will send information to the main server with the help of communication module. The end user can monitor the exact location of blockage (if drainage water level rises above warning level) in a particular manhole that will be visualized in the map also. The manholes will be highlighted in various colours depending whether the manhole lids are open or closed.

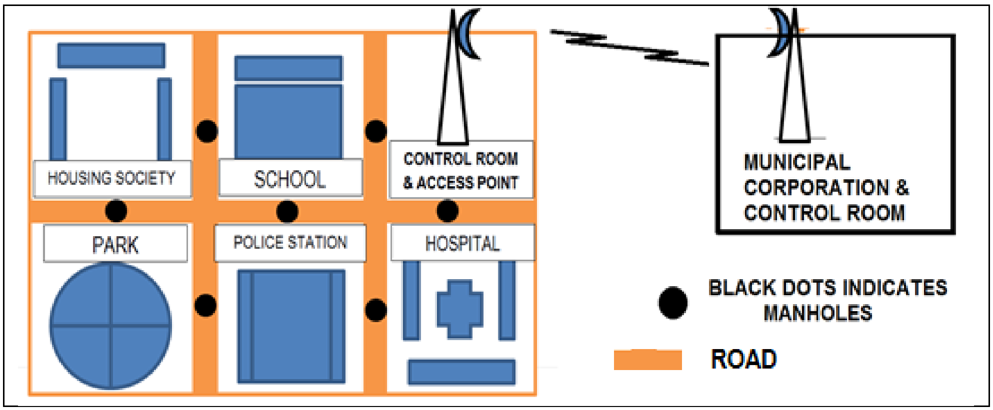

Fig. 5.2. Implementation of the proposed system

If the gas sensor detects the leakage of any hazardous gas then it will be highlighted in the map showing the status along with the manhole location on the map. This is achieved by allocating the exact location of manhole in the program code of node MCU [14] which is accessed by developed graphical user interface on basis IoT platform. After getting the information regarding the blockage, the end user can clear the blockage with the help of electrical machines or in extreme conditions, manually. Also, if there is sewer gas leakage or the concentration of sewer gases increases above the safe limits or if manhole is open, warning alarms or signals will be raised for at local end as well as remote end, so that people are aware of the hazardous conditions.

Based on the proposed system, sensor nodes response to sample the physical parameter to measurable voltage level through corresponding sensors; then node MCU module digitalizes and codes the voltage level to network information; sent these acquired data to the organizer through the established wireless links (here wireless link is established using integrated module of Wi-Fi in node MCU and access points with are further connected to internet service provider).

The sensor array collects data and transfer the reassemble information to the cloud storage using the internet connection. For the working of this system effectively, we require IoT platform. Open WSN Cloud data storage platform that can be used such as Ubidots, Blynk, Xively, Thinkspeak, etc. These platforms offer versatile data assortment and visual image; therefore ease the support of enormous number of sensor data streams and processing.

To control the power consumption, the battery of the node MCU system installed in manhole is connected to the solar panel which is placed above the respective nearby public street lights.

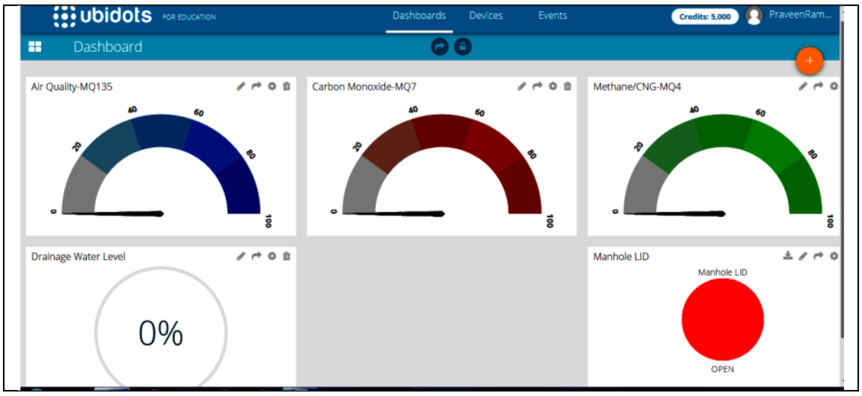

Fig. 5.3. GUI interface for monitoring the sewer or manhole environment (Representational image only)Source:https://app.ubidots.com/ubi/insights/#/list

As shown in the fig. 5.3[15] data related to drainage water and sewer gases, such as air quality, hazardous gases, condition of manholes can be managed elaborately and visually by IoT platform such as Ubidots (based on MQTT[16] protocol)to enhance the capabilities of UDS. The development of this system has been restricted by network communications technologies such IoT and access point Wi-Fi networks.

VI. APPLICATIONS

The proposed system has wide range of applications. This system can be implemented not only to manage or monitor the underground drainage water systems (sewers) or manhole conditions but it can also be implemented in water purification plants, underground tunnels, underground mines, oil and natural gas refineries, chemical factories, various biogas plants etc.

VII. CONCLUSIONS

The proposed system provides a smart underground drainage management system that monitors various hazardous parameters under the manholes, drainage water level within pipelines and manholes in real time and can broadcast proper notifications regarding any emergency situations to the municipal corporation personnel (end users). The proposed system can controls power consumption by the utilizing solar power. This is achieved by installing solar panels for the various nodes.

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