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IoT Based WSN Ground Water Monitoring System with Cloud-Based Monitoring as a Service (Maas) and Prediction using Machine Learning

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Abstract: ***The main source of water in the Indian Subcontinent is Groundwater. It is also the most rapidly depleting resource due to various reasons such as rampant unchecked irrigation and exploitation of groundwater by industries and other organizations. The current system is limited by short communication range, high power consumption and the system monitors only the water level and the report is available only to the consumer i.e. it is a single-user system. Due to the unavailability of a centralized system to monitor and prevent overuse of water resources, sudden water crises have become a major issue in India. This project aims at implementing an IoT (Internet of things) based water monitoring system that monitors the water level and the quality of groundwater and updates real-time data to the database. This system is designed to monitor the groundwater level of an entire village or a town. It updates the people and the concerned government authorities in case of any decrease in water level and water quality below the threshold value, and also monitors the water consumption during a period and predicts exhaustion time. This system predicts the availability of water in the future based on current demand and usage and the recharge rate using machine learning algorithms. The data collected and the analysis of the data is made available in a Public Cloud. The modules are based on Raspberry Pi Zero, sensor nodes and LoRa (Long Range) Module or Wi-Fi module according to the network requirement for connectivity***

Keywords: Internet of Things, Water Resource Monitoring, Agriculture, Smart village, Smart city, Wireless sensors net- work, Environmental monitoring, Cloud.

I. INTRODUCTION

Water is a very important resource; it is needed for life to exist. Due to population explosion consumption and demand for water are growing and the major sources of water are depleting faster than ever before.

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Also, in this decade climate change will have a significant impact on water resources throughout the world. The water resource is closely related to the connection between climate and hydrological cycle. The climate is already disturbed due to global warming. Water demand already exceeded supply in many regions of the world, more areas are expected to face the same soon. It is estimated that 70% of world-wide water use is for irrigation in agriculture. Many pollutants threaten water supplies, but the most widespread, especially in underdeveloped countries, is the discharge of raw sewage into natural waters. Ground water is a major source of water in plains. It is also the most rapidly depleting resource and most affected by pollution and overuse. This project aims at implementing a system for monitoring the ground water remotely and wirelessly. To implement this system low-cost hardware and open-source devices have been used. The collected data will be made available in the public cloud and will be accessible by anyone. Also, the data will contain information about the water level, salinity, pH, TDS, etc. This will give us the upper hand to counter groundwater pollution by taking the necessary steps as the groundwater condition will be known to us.

II. LITERATURE REVIEW

Water Level and Quality Monitoring systems are one of the major tools involved in ensuring the proper quality of water is maintained and along with the that the consumption of water is kept in check for preventing cases such as total depletion of water from the certain specified level leading to the unwanted water crisis. Various technologies are being used for the Water Level monitoring system and this paper discusses how various WSN systems are being used presently to deploy and implement WQM systems. It also shows a glimpse at the traditional methods of water quality monitoring system which required the scientists to first collect the sample from the source and then transport that to the related lab and then perform the testing operations on the water sample and then do the analysis of the results obtained. Not only those methods were inefficient but also it the results obtained were of little value since the information obtained was not in real- time hence the applicability of such data in some reflective way was not possible.

So, to replace such a system and implement some improved and useful WQM system paper discussed various WSN systems designed to handle such issues. Various WSN systems that are presently used by the system are mostly having issues regarding power, range, and cost. It was showed that if a given system has a good range then it will have issues pertaining to either its cost or power or maybe both and if a system has lower power requirement then it will have a short-range. The paper extends its study to such technologies related to the WSN system which can be or is currently used despite their shortcomings such as cellular networks for long-range communication between sensor nodes, ZigBee for short-range low power communication. And other generic communication technologies such as Wi-Fi, etc. The survey also mentioned about the various shortcomings of these systems along with their advantages or features. It also mentioned the various other possibilities of implementing these systems for purposes such as environmental monitoring, battlefield surveillance, agriculture monitoring, and precise agriculture, industrial monitoring and smart-homes, etc. Since our work is related to water

level and quality monitoring, we will stick to that. The paper talked about the various technologies which can are been worked on to implement a WSN system that is low power and has better range and is more compatible the analog or digital sensors that are used for measuring various physical phenomenon. Now coming to the WQM system, the paper gave a detailed overview of the need for a proper WQM system that can be used for monitoring the water quality. Since water affects every aspect of every living being on this planet work must be done in this field to maintain a certain standard of the water. The most common factors that are being used for monitoring the water quality are such as dissolved Oxygen, pH level, salinity, turbidity or any other physical, chemical or any other microbiological factor. These factors vary depending on the purpose of the water being used. Like in the case of agriculture there are certain parameters that water needs to satisfy for the proper yield of the crops these include the presence of important nutrients and clear water. In case humans or animals alike, the water needs to have certain dissolved minerals along being free from unnecessary contents which may affect or endanger the lives of the livings. There must be an effective water treatment facility to filter out unwanted and harmful contents from the water. These contents are into the various waters due to various factors. Such as surface runoffs from the agricultural fields in which farmers are using a large number of fertilizers for a better harvest. These chemicals after being washed of not only leach into groundwater and pollute it but also affect marine life. The waste that is being dumped by the industries directly into the water sources such as rivers lakes seriously endangers the marine lives also this affects the whole food chain in turn affecting humans. The pollutants being dumped are not only just carcinogens such as heavy metals like mercury etc. but also chemicals such as nitrate (NO3), nitrite (NO2) and many other types of chemicals involving sewage waste, dead animal bodies, human wastes, and many more things. Some of these chemicals are not only just outright harmful to the living being in taking them in some form but also, they affect the water quality and affect the whole marine lives. It causes the increase of unwanted micro-organisms such as E. coli, etc. which not only reduce the dissolved oxygen contents but also affect the quality of water in general hence affecting the reproduction cycle of animals living in water such as fishes. Apart from marine life, it affects humans too because this contaminated water can cause various health issues among humans related to kidney, liver, infections even cancer. Paper also explained the various technologies and processes required to enable a fast and efficient water quality monitoring system. Also, various sections present in the WQM sensors such as including sensors, microcontrollers, transceivers, and power sources. Also, how ADC tech is being needed since many sensors are analog so to convert the analog signals to digital. How data is generated by the sensors and then sent that to the microcontroller after being converted via ADC where microcontroller sends it to some storage device for further processing. Also, not only that microcontroller is used for coordinating the various process of WQMs, like managing sensor nodes, establishing the coordination between various parts of the WQM system while maintaining the link with the storage devices to transfer the data. These microcontrollers are mainly like Arduino UNO, etc. Sometimes some single board processors are also used for processing and analysis of the data.

III. EXISTING SYSTEM

The existing system consists of Wireless Sensor Networks which are used to establish a communication network between various sensors that are used to measure diverse physical factors, WQM systems, and various connecting modules. These sensors are used to monitor factors such as water level while WQM systems are used to monitor factors related to water quality. Unlike traditional systems when the people had to go through the process of collecting the insitu water for various testing purposes which involved a long duration of testing and effort leading to the results which don’t provide much value because it is not in real-time.

To counter that issue currently, various water monitoring systems are coupled, implemented and deployed over a large area with the help of the WSN system. Though WSN provides a solution, it is not the most feasible, simple and resource-friendly system. It has various drawbacks that prevent these systems from being fully implemented.

At present, the technologies used for short-range and long-range communication between various sensors nodes are primarily Cellular Networks (GSM, 2G, 3G, 4G networks), Zigbee, Wavenis, Wi-Fi, Z-Bee and few others. These systems are common to most of the projects related to IoT and precisely WQM. And each of these systems have their pros and cons. Let’s consider the cellular networks 3g,4g, these are currently being used for long-range communication between devices these systems though provide the ability to have data transferred between systems located at long distance but they come with the cost of being not only expensive but also there are various compatibility issues with these systems and the sensors that are used to monitor physical factors.

Also, these have a very high-power requirement which makes them not very power efficient along with the fact that they have various reliability issues. Now coming to power-efficient systems such as Zigbee, etc. which though require less power to operate, it provides communication over a very short range.

So, despite being power efficient and more compatible with the low- level analog sensors these have issues related to range and bandwidth. Along with these, one of the common systems used is Wi-Fi that allows us to connect the various sensor nodes to the internet and share data via it.

A. Water Level Monitoring

Exiting systems that are used to measure water level are:

- Continuous float level transmitters
- Differential pressure transmitters
- Load cells
- Radar level transmitters
- Radio frequency
- Ultrasonic level transmitter.

Continuous float level transmitters operate on the buoyancy principle for continuous measurement of water level. These transmitters are categorized into two types:

- Magneto astrictive float level transmitters
- Magnetic Float Level Transmitters

Magneto strictive Float Level Transmitters works on the principle of Buoyancy and Tangential Magnetic Fields. It is a very capable monitoring system in terms of accuracy and the application of the data achieved through this mechanism for various purposes. But it is quite expansive. For a continuous monitoring system, this system is best for accurate measurement. Usual Magneto astrictive setups consist of electronics, a stem and a magnet sealed inside the float that moves up and down along the stem/rod depending upon the depth of the liquid. These components work together to provide accurate measurements of the liquid level.

Magnetic Float Level Transmitters are the second category of the continuous float level transmitters being used for measurements of the level of a given liquid. Unlike Magneto astrictive float level transmitters these units use Reed switches, covering the whole length of the rod/stem. These switches are sensitive to magnetic fields and can change their state to open or close depending on the absence or presence of the magnetic field. Apart from this everything is pretty similar to Magneto astrictive float level transmitters. When float containing the magnetic moves up or down along the rod due to change in water level the magnetic field interacts with the reed switches causing them to be in open state and this changes the resistance value causing a change in the output current. This change in the output of the current can be used to assert the level of the concerned liquid. Differential Pressure Transmitter widely used for various applications. It can be used to monitor the fluid levels by comparing the pressure between the high- pressure point and the low- pressure point of the equipment. The difference is achieved as the output which can be used to deduce the water level of the liquid.

Load Cells is a technique based on transducers that can be used to measure the weight, a mechanical force or a load and relay the measurement as an output signal. This output signal can then be used to the levels of the liquid. These systems are can have custom designs and it depends on the usage, complexity of the system and utility. Usually, liquid level monitoring is less complex. Radar Level Transmitters is a contact-less method that involves sending a pulse of Electromagnetic waves towards the surface of the fluid and receive the reflected pulse. The time elapsed in the whole process can be recorded and since the speed of the EM wave is already known the depth of the liquid can easily be deduced and output can be shown by the transmitter. Also, this radar system works best when the vessel containing the water is made of metals. And this is also one of the drawbacks too of this system that is not every fluid can be monitored using this method. Fluids that are corrosive in nature cannot be monitored using this method. Also, this method sometimes is the only way to measure the fluid level in cases such as when the process materials are flammable and dirty or the material's composition and temperature vary with time. In those cases, there is no other system that can be used apart from this method. Radio Frequency (RF) Capacitance is used to map the contours of the surface area. This helps in creating a contour representing the granules, slurries, and fluids with different densities. It is similar to continuous float level probe except that instead of magnets it uses the probe as the second conductor. This technology is based on electrical capacitance. A conducting device can store a certain amount of charge. It is affected by the medium between the layers of the conductors especially by the presence of fluids or some other material. Since due to different medium across the surface of the probes there will be different capacitance throughout the surface of the probe. This variation in the capacitance value hence can be used to deduce the level of the fluid. One of the drawbacks of this system is that over time materials clog onto the surface of the equipment which can affect the reading of the instrument. So, one needs to properly maintain the instrument for good reading.

B. Water Quality Monitoring

Unlike the traditional system that relied on manually collecting the samples from the source and performing tests such as Temperature testing, pH testing, Salinity, etc. The current system through the use of the WSN system has incorporated the suite of sensors that automatically monitor the various water-related factors such as pH, dissolved oxygen, etc. Depending upon the usage of the source water like whether it is being used for irrigation, drinking purposes or something else. The current system uses sensors such as CDOM, Salinity sensors, TDS sensors, Dissolved Oxygen, pH sensors, Nutrients sensors, Turbidity Sensors, etc. to monitor the factors related to water quality. These sensors which are being used to monitor the water level and water quality are analog and so they need a medium module which most of the time are Arduino boards which are connected to single-core or maybe a multi core processors such as raspberry which allows the sensors data to be fetched and sent to the destination database for further analysis.

These modules are also responsible for coordinating the various tasks process carried out by these sensors. The currently used most common modules for these purposes are Arduino Uno, Arduino Mega, and Raspberry Pie computers and for database, there is the use of cloud computing.

IV. PROPOSED SYSTEM

Modules:

- On-site module
- LoRa Gateway module (Remote module)
- Cloud

The proposed system consists of an onsite module and a remote module i.e. LoRa Gateway module. The onsite module will communicate with the LoRa gateway through LoRa WAN Network, it has a network capacity of several hundred connections at a time. The gateway is connected to the internet through an ethernet connection or Wi-Fi. The onsite modules communicate with the LoRa Gateway.

A. System Architecture (Hardware)

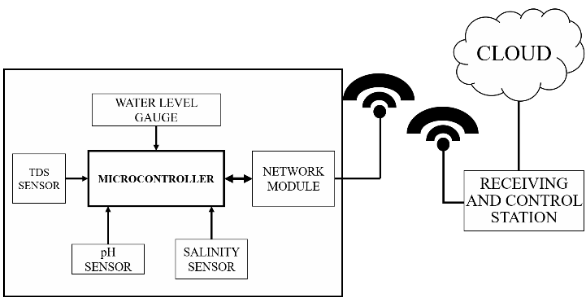

Fig 1: Architecture of the hardware module

The onsite module consists of the following components:

Raspberry pi: Raspberry pi is a single-board computer with all the necessary components for basic computing at a cheap and affordable price. It has a range of development boards; Raspberry Pi Zero is a super ultra-low-cost computer board and has an incredible amount of utility comparing to its teeny-tiny size and form factor. Specifications:

- BCM 2835 (32-bit ARM-based processor) SoC running at1GHz
- 512MBRAM
- Mini-HDMI, micro-B OTGUSB,
- 40-pinGPIO
- 802.11n Wireless LAN

HAT Modules: HAT is an add-on module for RaspberryPi. It connects at the GPIO header It is compatible with almost all models of raspberry pi pins. It stands for “Hardware attached on top”. HATs have several advantages.

- No soldering
- Robust mechanical design
- Open-source hardware and library.
- Large community

Sensors Used:

- Ultrasonic water level sensor
- Salinity sensor
- TDS sensor
- pH sensor

LoRa WAN: LoRa WAN is a MAC (Media access control) protocol for WAN. Facilitates communication between low-powered IoT devices Internet-enabled applications over long-range wireless connections. LoRa Alliance defines the LoRaWAN protocols.

LoRa Module: RN2483 LoRa Transceiver module provides a low-power solution for long- range wireless data transmission. The RN2483 module complies with the LoRaWAN Class A protocol specifications. It integrates Radio Frequency, a baseband controller, command Application Programming Interface (API) processor, making it the best long-range solution currently. The RN2483 LoRa module is suitable for simple long-range sensor applications. Features:

- ASCII Command Interface over UART.
- Compact Form Factor. RoHS Compliant, Environmentally Friendly.
- Device Firmware Upgrade (DFU)over UART.

LoRa Gateway: For communication between LoRa Modules, LoRa Gateway is required. It works as a server for several LoRa Nodes for sharing data. This gateway forms a simple WAN for communication. Each gateway has a temporary storage device for holding the data before uploading it to the cloud data certain pre specified time.

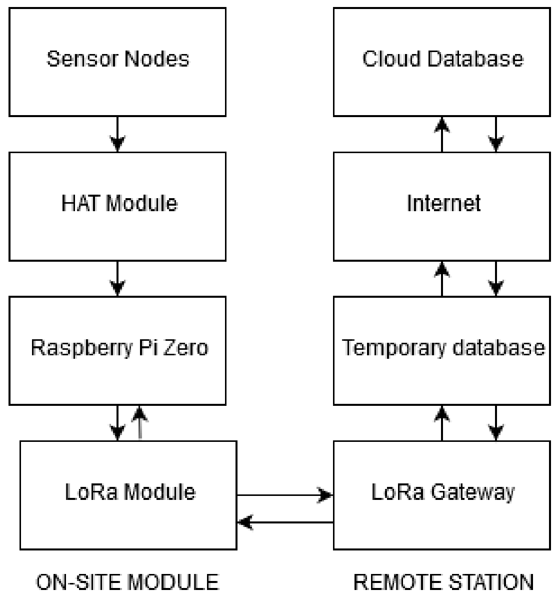

Fig 2: Data flow diagram

The data received by the LoRa Gateway will be uploaded to the cloud with a timestamp, module ID and other information to identify the source of data collection.

Cloud: The cloud model used in this system is MAAS (Monitoring as a service).

MAAS is one of the cloud delivery models whose framework provides a deployment facility for monitoring systems. It provides online state monitoring i.e. it continuously tracks state of systems.

V. ALGORITHM

A. Linear Regression Model:

The whole process of collection of data from the sensor modules to the prediction of the water level in near future on the basis of consumption rate of the user consists of following steps:

i. At first sensors such as, Magneto astrictive float level transmitters, will record the change in water level of the source. The recorded recording of these sensors will be converted to digital values through the micro-controller, in our case it is Arduino board.

ii. The information gathered by the micro-controller will then be transferred to the centralized hub where it is stored and then transferred to the cloud. To enable this facility a network module is connected to the micro-controller which allows it to connect to the LoRa based centralized network.

iii. Before going further, it is important that we make it clear that through LoRa(Long Range) module various sites in a given region are connected to the centralized hub, where their data is stored and analyzed and result is shown at the web interface which can be accessed through any desktop or mobile interface on the android devices which are widely in use nowadays so that not only the user but authorities can also monitor the data of a region or a location depending upon the need or interest.

iv. After the data is received at the centralized hub, there it is stored in the database containing the information about not only just water level but it's various quality parameters. There's one more database that keep the summary of these information for the authorities for the topmost level view of the situation.

v. From the database historical data of only water level is extracted for a certain location and to train a regression, linear, model. This will help the system to predict the future scenario.

vi. After the regression model devised is trained with the training set and then tested with the test set then it will predict the future scenario that is how long will water last given the consumption rate and fluctuation in water level depicting it.

vii. For prediction of the water level, we used linear regression, in which the water level recorded at different time- stamp acts as an independent variable and then after applying linear regression to this dataset the system was able to predict the water level at upcoming days and how long it will last, after adding condition for the minimum allowable water level at the source.

vii. Then the predicted value is sent is updated in the database for the concerned user and this is performed at every 24hrs cycle for each site.

viii. And the web and mobile interfaces are designed in a way to directly access the needed information from the databases to the authorized users.

The proposed system collects various information such as Recharge Rate, Consumption rate, and Water level. These data sets are further used to predict future water levels using Linear Regression Algorithm. Linear regression is an approach to modeling the relationship between a dependent variable and an independent variable. In the present model, we plot the water level against the time period. And the predictions are made using recharge rate and consumption rate. If the Consumption rate is greater than the recharge rate the water level starts to decrease or vice-versa. And on this basis, the future conditions are predicted for a particular area. The equation has the form

$$Y = a + bX \qquad (1)$$

- Y=independent value
- X=dependent value
- b=slope of line
- a=y-intercept

The graph is plotted between time and water level. X-Axis: Water level Y-Axis:Time

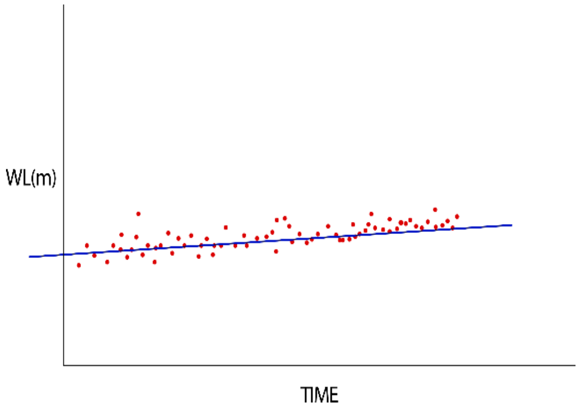

Fig 3: Sample Plot for normal recharge rate

First the system is trained using the data collected over a period. After training using the training-set. The system is analyzed for errors and variations from real data using the test cases.

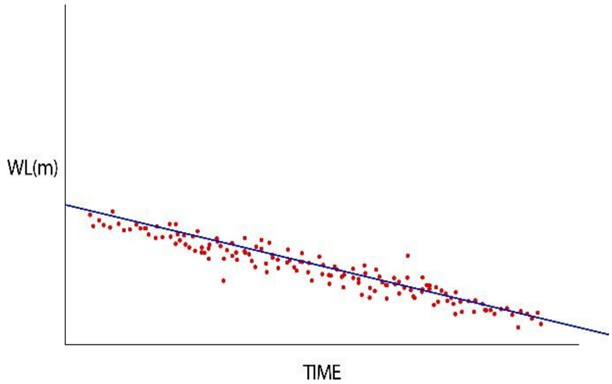

Fig 3.1: Sample Plot for low recharge rate over a long period

VI. IMPLEMEMTATION, RESULT AND DISCUSSION

The experimental set-up of the proposed WSN based water level and quality monitoring system is shown in figure 4. Figure 4 depicts the setup of the modules and the way they are connected to the WSN based network. While figure y depicts the proposed Layout of the system application which will show the relevant data to the user and the authorities.

It depicts the real-time information about the water level and the status of water quality along with the prediction of the future value of water level in the coming days depending upon the given rate of consumption.

The proposed system. consists of an onsite module and a remote module i.e. LoRa Gateway module. The onsite module will communicate with the LoRa gateway through LoRa WAN Network. The LoRa Gateway has a network capacity of several hundred connections at a time. The gateway will be connected to the internet through an ethernet connection. The onsite modules will communicate with the LoRa Gateway. The data received by the LoRa Gateway will be uploaded to the cloud with timestamp, module ID and other information to identify the source of data collection.

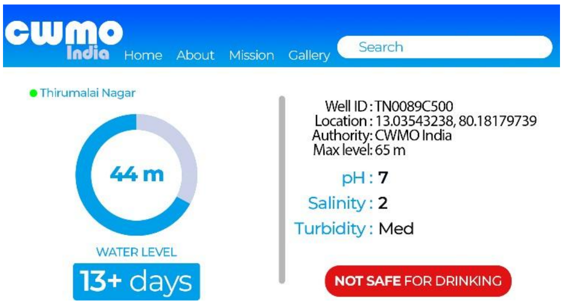

Fig 4: Interface with simulated data

The given figure 4 depicts the various information that will be displayed by the system about the water source that is being monitored.

Such as starting with a uniquely defined well id, in case of this example TN0089C500, to distinguish between various systems located throughout a given region. Along with the location of the system, latitude, and longitude, in this case, 13.03543238, 80.18179739, and the authority providing this facility. Now coming to the data being monitored, it will depict the max level of the water,65m in this case, in the given source ever recorded and the current status of the water level via a graphic donut chart, 44m in this case, depicting how much water is present. It will also show information about various WQM factors such as pH,7, salinity,2, turbidity, Med depending upon the need and user. From this gathered information about the water quality, the system will show the warning or use case of the water, in this case, water is not safe for drinking since it is too much saline(salinity>1). One of the most important features of the system is that it will predict the future status of the water level, 13days in this case, at the current rate of consumption and no recharge case. It will also show the status of the system whether it is online or offline by a single indicator at the top-left corner.

VII. CONCLUSION

The proposed method of water level and quality monitoring allows not only the real-time monitoring of water level but also water quality. By this, we mean that we will be able to obtain real-time data regarding the water level and its various quality parameters such as pH, amount of nutrients, etc. depending upon the need of the user. Also, it allows a centralized system to store and monitor data regarding these factors which allows not only just the user but also the concerned authorities to access these data and be aware of the status of water sources in a given region. The centralized system also enables us to do further analysis which can be helpful in optimization of the total consumption rate of water and predicting the future status of various water sources according to consumption.

VIII. FUTURE SCOPE

In the future, the Machine Learning technique can be extended to study the various physical factors of the water and predict the location of the water source having a sudden abnormal change in water quality which can be helpful in detecting and prevention contaminants leaking or dumped into a water source.

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