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Water Level Monitoring and Leakage Detection System using Long Range Module (LoRa)

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Abstract

Rising global environmental issues and rapidly growing population demands a massive need for water supply. These issues in-turn have made water conservation and water management an emergency aspect of human survival. Water level detection and leakage detection are paramount aspects of these issues. Therefore, a system is required to adequately manage the water resource by tracking the water level and to detect damage when there is a leak. The detection of water level will use "state-of-art" VL53L1X technology and leak detection will use a flow meter based on a hall sensor. Data transmission will be through long-range (LoRa) and real-time retrieving of data can be done using cloud server and various display units. LoRa provides increased coverage areas with high accuracy in data transmission. The results show that the proposed system works effectively in varied environmental conditional.

Keywords: Leakage detection, LoRa gateway, LoRaTM, Time of flight (ToF), VL53L1X, Water level.

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Introduction

Water is a crucial part of our everyday life and due to global environmental issues, water management and conservation are vital for human survival. In many of the places, such as, offices, residential, and industrial area water resources and distribution systems of premises, such as, water tanks and pipelines are monitored by a human being. Human surveillance is always accompanied by some errors and negligence that leads to wastage of water. Hence, an effective system is required to monitor the water resource of the premises. VL53L1X is one of the sensors used for the monitoring process. VL53L1X is a distance sensor that measures the water level of the tank. It is a state-of-art, time-of-flight (ToF), laser ranging sensor with accurate ranging up to 4 meters and a fast ranging frequency up to 50 Hz. The sensor is placed at the top of the tank and the level of water is detected based on the time taken by the emitted infrared laser light to reach back to a detector after reflecting from the nearest object. The sensor is not affected by the color or texture of the reflecting object, and also has good tolerance towards temperature variance. A micro-controller is required to process the obtained data from the sensor and perform specific operations to know the level of water in the tank. The data will be sent to the gateway via the LoRa transmission module. Gateway is responsible for encryption and transmission of data to the end node, i.e., server and display units via internet access.

Flow liquid meter sensor is another sensor used in the system to determine the flow rate of water and detect leakage in pipelines. Flowmeter is based on the hall effect that contains a pinwheel sensor to measure the amount of water passed through it. The sensor has integrated hall sensor that converts one revolution in an electric pulse. The sensor will retrieve water flow data by analysing rotation count of the wheel. A micro-controller is required to process this data in order to know how the rate of water flows through.[4] This data from micro-controller is transferred to gateway for further encryption and transmission via internet access.

Water management is a critical requirement for water conservation. Commonly, inefficient management and undetected damage in the pipeline serve to be a major drawback in the conservation of water. From a customer perspective, water monitoring and conservation is an important utility service that often faces many challenges. Therefore, there is a need for an efficient system that will

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enable us to remotely monitor the water resource and detect damage in time.

Previous Research

Abdullah Kadri, and Adnan Abu-Dayya[1] has analyzed the characterization of an acoustic wire-less sensor based on hydrophone for leakage detection in underground pipes. Noise spectrum of the pressurized pipes is constantly measured by the hydrophone to detect the water leakage. Acoustic sensors have been used in this research which have the ability to detect leakages of different volumes and at various locations. The data is transmitted wirelessly to the gateway on real- time basis. Leakage detection is performed by using liquid flow meter sensor in the research of reference.

B Siregar *et al.*,[2] where Arduino chip-based ATmega328P is utilized to detect the location of leaks in pipes by using a data rate of water flow. The maximum range of the system to determine the leakage efficiently is 2 meters and the system can determine the location of the leak closest to the actual location of the leak with an average flow rate of 10 liters per minute.

A potential leak-region detection for feasible use is exhibited using an error-domain model falsification methodology in 'Leak detection of water supply networks using error-domain model' by Gaudenz Moser,[2] Stephanie German Paal,[3] which calculate approximately the demand at smaller number of nodes. All of the case studies in this research, the network was dependent on a single reservoir or tank which can be further modified in various ways including intermediate reservoirs.

A review is presented by a comprehensive survey done in 'Leak Detection in Pipeline System Based on Flow Induced Vibration Methodology in Pipeline' by Immanuel Dinesh Paul, Mohammad Rizwan[4] which compared the existing leakage detection techniques Also, a research is being performed in the area of using wireless sensor networks for real-time leakage detection and localization in pipelines.

A smart water meter system is designed by Jan Fikejz and Jin Rolecek in 'Proposal of smart water for detecting sudden water leakage'[5] which involved pulse water meter for measuring and analyzing the water consumption patterns. Central control system based on raspberry pie zero and ZigBee communication module was implemented in the system. Also, an application layer is designed with access to the cloud database within web services which allows the remote management and configuration of water meter.

Md Nasir Sulaiman, Thinagaran Perumal 'internet of things (IoT) enable water monitoring system'[6] performed the research on water monitoring using ultrasonic sensors and by applying IEEE802.11 communication standards and controller board based on the ATmega328P. The communication of data was done by integrating a wireless gateway within the consumer network. The article reviewed that in the future the ultrasonic sensor could be replaced by water level sensors as it will provide high accuracy. Also, basic IEE802.11 communication standard came with its drawbacks and would be replace with more efficient and fast communication module.

Methodology

Hardware

Water Level Detection

This section shows that various sensor nodes are created to cover the entire premises. Each sensor along with a micro-controller and LoRa transmission module is established at each tank of water. VL53L1X continuously senses the water level and provides real-time data. This data is sent to controller, where it processes the data and provides it to LoRa module for transmission and further to the gateway. LoRa transmission is one-way devices and can only send data to the gateway but cannot receive a message from the gateway. Each LoRa device is authenticated via a unique identification code before it connects to the LoRa gateway. LoRaTM does not send data continuously rather it compiles the data into stacks and forwards it in the form of packets.

Flowmeter

This flowmeter is based on the hall effect. The sensor is placed in the line of flow and water passes through a pinwheel sensor. There is an integrated magnetic hall effect sensor that converts the rotation of the pinwheel into an electric pulse. The output pulses can be converted and water flow can be calculated from it.

Pulse frequency (Hz)/7.5 = Flow rate in L/min

Gateway

The gateway performs the function of a bridge between the LoRa nodes and the network. Devices use LoRa wide area network (LoRa WAN) to connect to gateway and gateway connects to the network via Wi-Fi or cellular connection. Gateway act as a router in between LoRa nodes and network, this enables them to receive data from nodes. All

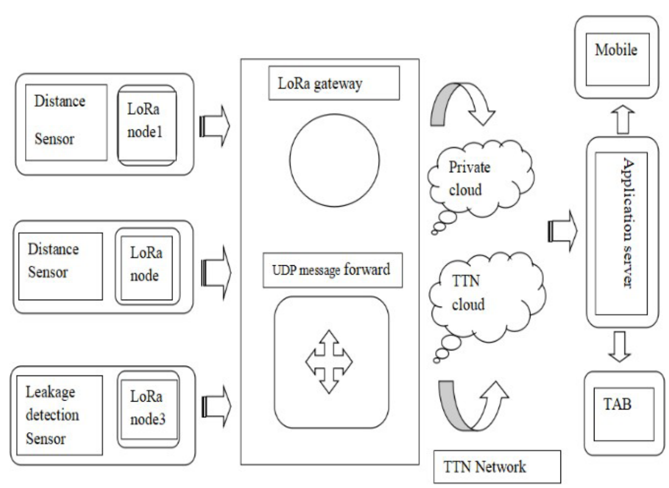

Figure 1: General system architecture

the gateways nearby to the devices will receive the data from nodes. The gateway forwards this data in the form of UDP message to the network to be further pushed on to the webserver.

The Things Network (TTN)

TTN receives messages from various gateways registered on the network. These messages contain data from the nodes and are in the form of UDP messages. TTN collects this data and deduplicates it to avoid repetition and selects the best of all duplication and discards others. It decodes UDP messages and forwards it over to the network server for storage and other operations. Only the members subscribed to the particular channel can receive data from TTN. Hence, TTN acts as a black box that receives data from the gateway and provides it to subscribed users of the channel.

Webserver

The webserver will act as a storage device along with cloud service and perform data processing on the information obtained from the network. The server will save the data records along with the time and compare it with the threshold data set provided by the user. Webserver performs data processing and displays data in various visuals, such as, graphs and charts. These data records can be used to calculate the monthly and yearly usage also the occurrence of damage in premises. This data can be used for further estimations and planning for water management of a particular area. Also, the data on the webserver will update itself after every particular set of intervals and provide real-time tracking of the resource.

Real-Time Monitoring Client

The client will be accessing the data from the sensors through a web page. Only selective clients will be allowed to retrieve data from the resource and data security will be done using a unique identification code and password. The client will be able to retrieve information on a mobile or a PC via an internet connection. The web page will display water flow graphs and tank water level charts with a time graph. The client can also access previously saved records from the webserver.

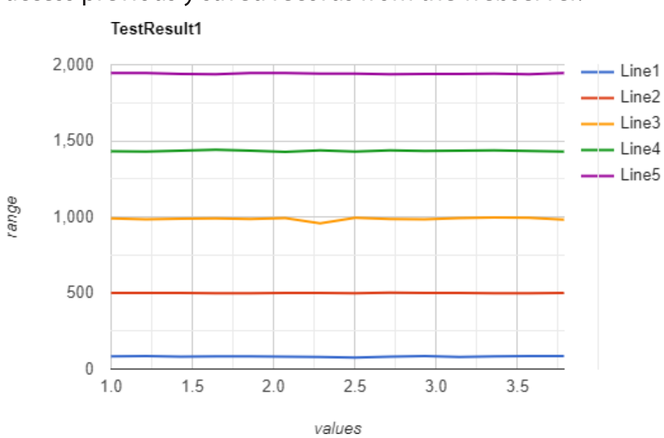

Figure 2a: Water level detection test-1

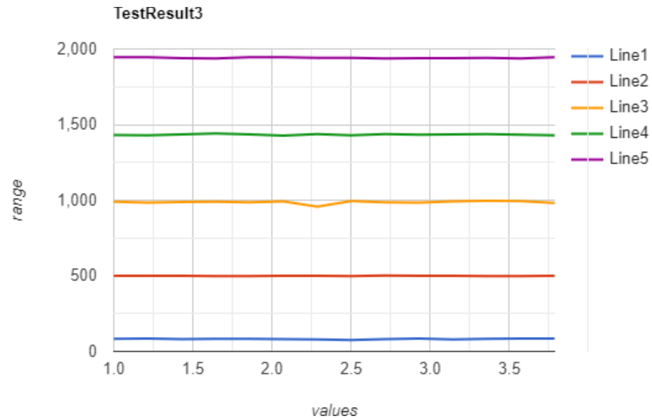

Figure 2b: Water level detection test-2

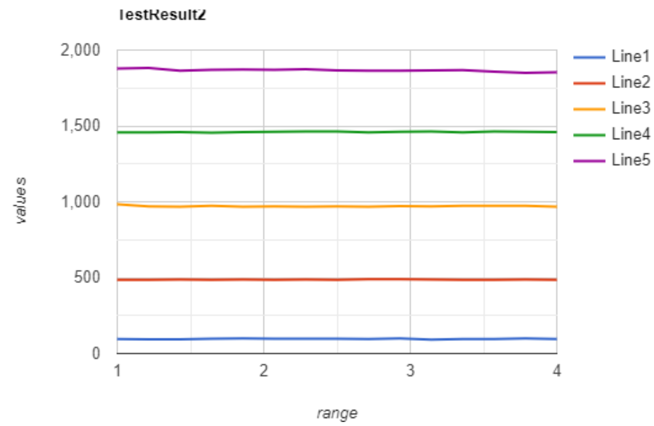

Figure 2c: Water level detection test-3

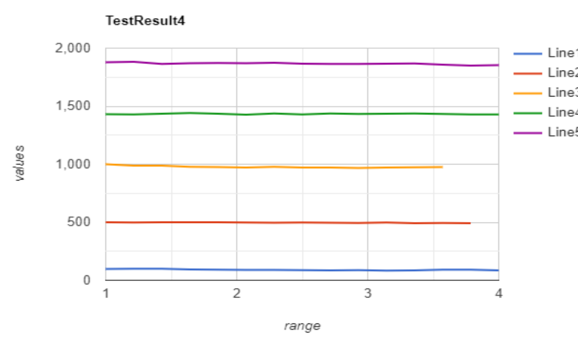

Figure 2d: Water level detection test-4

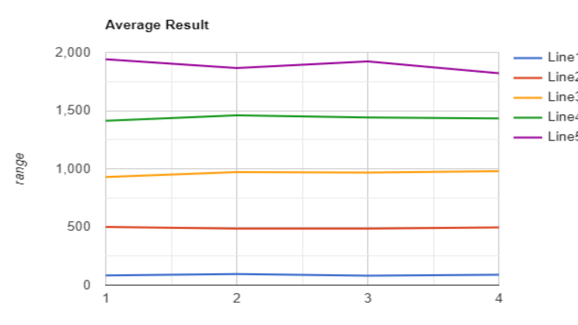

Figure 2e: Average result of all tests

Table 1: Average values of test result of water level detection

Value	*100*	*500*	*1,000*	*1,500*	*2,000*
Test-1	82.8	499	928	1,412	1,941
Test-2	96.2	486	971	1,459	1,866
Test-3	81.4	485	968	1,440	1,922
Test-4	90.3	496	979	1,433	1,820

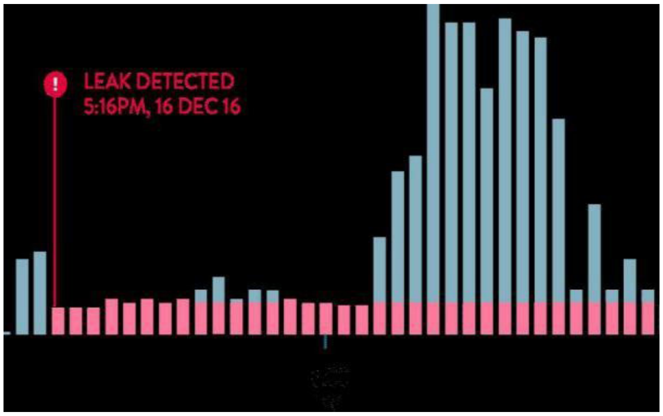

Figure 3: Leakage detection bar chart on webserver

Results

Figure 1 shows the architecture of the system in the form of block diagram. The basic architecture consists of three major sections firstly sensing and detection section, secondly gateway and connectivity and lastly application and data retrieval.

System performance testing is done to check the working of system and its efficiency in the output. Prototype is developed for both water level detection and leak detection system for testing.

Water level detection testing is performed at various water levels in various environmental conditions. Four different tests are performed with presence and absence of light with still and disturbed water. Following graph plots shows the test results where X- axis represents time interval whereas Y- axis represents level of water in millimetres. Each graph plotted has 25 variables taken over time-span for each level of water. Different test results are shown below for varied conditions. Figure 2a presents the graphical plot of test results obtained in water level detetction in still and clear water in presence of light. Figure 2b shows the graphical plot of still and clear water in absesnce of light. Figure 2c graph represents water level detection results for distubed water movement in the tank in presence of light. Figure 2d shows test results for dirtubed water flow in absence of light. In Figure 2e an average of all readings has been plotted to check overall behaviour of the system.

The difference in average result of the water level detection of the prototype testing is shown in the below table1. Table 1 depicts the comparison of real-time values obtained in four different experiments.

For water flow sensor testing a prototype is designed using a PVC pipe connected to water supply with a flow sensor placed in the line of flow. The flow sensor gives output pulses which are converted by micro-controller to give total flow of water through the pipe and flow rate.

The flow rate is represented in visuals using bar graph or line graph on the server page. When the value of flow rate matches to the probable leakage data set the leak detected message appear with time notification.

Below Figure 3 is an example of bar chart visualization on the web server page.

Conclusion

The LoRa based water resource measurement system is more precise than any other water resource measurement system, as the communication module used in any other system restricts the range. Using the LoRa based communication module, the research has reached a better level in terms of accuracy and accessibility. In the distance sensing module, we can obtain about 82% accuracy. The project has efficiently implemented a flow detecting system using a flow meter, which provides us with easy installation and high precision in the working area. The whole system is equipped with "state-of-art" technology, which allows one to attain maximum precision and takes advantage of the best technological facilities currently available. One major advantage of the project is scalability and easy maintenance. The project can be scaled according to work premises without alternating the basic structure and functionality of the system. It can be easily equipped with several different kinds of monitoring devices and display gadgets.

Further Work

Further work regarding the project would be extending the number of nodes involved in the system and create multiple gateways capable of handling thousands of nodes covering a large area and manage effective and efficient data communication within the system. Also, another added sensors and start/stop command switches can be implemented in the system for automatic control using threshold values. In this way, one can extend the application of this project and scale its implementation for large-scale industrial setup.

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