TEST Engineering & Management

January-February 2020
ISSN: 0193-4120 Page No. 8827 - 8834

5G Network Design for Water Quality Monitoring using Agricultural IoT

T. C. Jermin Jeaunita, Department of Computer Science and Engineering, RMK Engineering College, Thiruvallur, India. Email: tcj.cse@rmkec.ac.in

A. V. Kalpana, Department of Computer Science and Engineering, RMK Engineering College, Thiruvallur, India. Email: avk.cse@rmkec.ac.in

M. P. Karthikeyan, Department of Computer Science and Engineering, RMK Engineering College, Thiruvallur, India. Email: mpk.cse@rmkec.ac.in

Article Info
Volume 82
Page Number: 8827 - 8834
Publication Issue:
January-February 2020

Article History
Article Received: *5 April 2019*
Revised: *18 Jun 2019*
Accepted: *24 October 2019*
Publication: *08 February 2020*

Abstract:
"IoT revolution" is a disruptive phrase that is being a reason for the emergence of many other new technologies learned and practiced. This is due to its seamless connectivity features that enable any type of devices to communicate using any type of the underlying network. The overwhelming data generated from massive Internet of Things applications kindles the curiosity of data scientists and analysts to collect and store the data at remote clouds. Some applications require or given no time to act upon, which may purely based upon the data generated. The supporting technology for this sort of communication plays a vital role for achieving the required efficiency and applications to achieve its purpose. In this paper we discuss the design requirements of 5G cellular network support for agricultural IoT. We also discuss a low-cost water quality monitoring system for the benefit of high yielding crops. The designed system consists of various sensors for monitoring temperature, pH value, turbidity, conductivity and dissolved oxygen of the water sample. Using the data collected through this measure, water flow to the farm can be controlled, based on water quality.

Keywords: *5G Network, Agricultural IoT, Water Quality Monitoring.*

I. Introduction

Internet of Things(IoT) technology through its capability to connect anytype of devices, is revolutionizing the world by providing solutions to various applications and problems. IoTs nature of connecting low power and low memory devices with other similar or heterogeneous devices makes it suitable for various real world usages. This feature hence attracted the attention of researchers in various fields to discover wearable devices, interactive home appliances, and smart health care systems and so on of the kind. These devices can interact with each other called as Machine-to-Machine (M2M) communication can be done with or without human intervention. This communication and its efficiency is all possible due to its standardized underlying communication facility. The impact of IoT application in the near environment, business requirements and its touch in everyday life is really to be appreciated. IoT is also used for mission critical applications, traffic control, environmental monitoring and industrial monitoring. All these critical and non critical or real time, or non real time application specific efficiency and performance can be achieved as expected only by the higher availability, reliability, lower delay and safety at the level of transportation mechanism. Failure in achieving such expected outcomes may result in serious consequences. As the vicinity of applications increases and the number of devices connected to the network grows, the potential of the technology is highly realized and utilized.

An efficient water supply system is required for utilizing water in irrigation without any wastage and maintaining the water quality. Irrigation is a science of water management through proper planning,

January-February 2020
ISSN: 0193-4120 Page No. 8827 - 8834

designing, deployment of water resource usage system for agricultural purpose. Rainfall is the most essential source of water for agriculture. Plants especially the food crops require adequate amount of water throughout its growth period. But rain water may not be adequate to satisfy the complete water requirement of crops from seeding to harvesting. So it is necessary to learn the factors that necessitate the importance of irrigation even further. They are insufficient rainfall, uneven distribution of rainfall, improvement of perennial crops and development of agriculture in desert area [1]. Proper planning and utilization of irrigation systems help in good crop yield during the low rainfall and drought periods and to improve cash crops. This in turn helps to prevent famine in our country and leads the farmers to earn better. Excessive water usage through irrigation should be avoided which will otherwise leads to the downside of water utilization. During the supply of water, leakage or overuse may constantly settle the water near plant roots and spoil the crop or induce more soil alkalinity. When this also forms marshy lands, it may become the source of mosquito breeds and becomes the reason for various diseases.

Water application in agriculture varies based on the type of crop, season, time in a day, duration, climate, ground slope variability and method of ploughing. Water requirement for crops may be collectively viewed as for consumptive use, unavoidable water losses and water for special requirements [2]. Consumptive use of water is the sum of the quantities used by the plant for its vegetative growth in transpiration from germination to ripening, water evaporation from soil and metabolic activities for tissue building in plants. Unavoidable water losses may be due to water seepage, deep percolation and evaporation of water at its storage area. Water requirement for agriculture is met from rainfall, irrigation, ground water and dew. If rainfall is untrustable, ground water level is very low and the quantity of dew is ignorable, then agriculture has to mainly depend on irrigation.

Pure water is mostly distributed for drinking and cooking purpose in residential areas. So feasibility of pure water supply for irrigation purpose is totally rare.

At the same time quality of water also directly or indirectly affects the crop yield in various ways. Fine silt sedimentation improves the soil fertility. But the other sediment types decreases the fertility of the soil. These other sediments can be due to various reasons and particles. Due to acid rain various types of gases and suspended particulate matters of the air can mix with water drops before it reaches the earth [3]. And before this water reaches the canals, rivers or water tanks, many kinds of organic or inorganic matters may add up with it. Many kinds of salts like calcium, magnesium, sodium and potassium are also found dissolved in it. If these salts crosses the permissible limits, that may affect the growth of crops. The chemical or biological impurities are found more during rainy seasons compared to other seasons. The discharges from chemical factories, production industries and mines in the vicinity also influences the water stored for irrigation. Electrical conductivity of saline water from 250 to 750 micro mho/cm is found to be very injurious for crops. Concentration of boron above 0.3ppm may be harmful to plants. Bacterial contaminated water, irrigated for food crops may be very dangerous for human beings.

It is essential to mind water is the nutrient carrier into the plant body. The water quality is determined by the pH level, hardness, turbidity, specific gravity and conductance. For irrigation, tolerance limits of pH value is 6.5 to 8.5, total dissolved solids (TDS) in mg/l is 2100, chlorides is 600 mg/l, sulphate is 1000mg/l, sodium absorption ratio is 26mg/l, boron is 2mg/l and sodium is 69% maximum. Poor water quality leads to deterioration of land. The different periods of plant growth like germination, vegetation, reproduction also requires varied tolerance levels of water quality. If the salinity of the soil is affected by the water used for irrigation, this leads to poor or delayed germination. Some crops are tolerant to alkali, but more sensitive to salts and some acts vice versa.

When agriculture is concentrated in large scale of around 5000km^2area, the level of irrigation required goes complex [4]. To reduce the irrigation cost sewage irrigation is a better choice. Domestic sewage may contain relatively harmless bacterias but few being pathogenic or disease inducing. Even more harmful is the industrial waste that depends whole on the manufacturing process. Issues that may occur with sewage irrigation for some crops are delayed harvest, low quality product and lower disease resistance capacity.

Internet of Things(IoT) technology is used for connecting the agro based sensors and actuators to coordinate with each other and send and receive data through Internet. The data collected can be used for analysis and decision making activities. In case of decision making applications, the sensing side of the network is made smart to control the environment. This automation can be optimized for reducing manual investigations in the farm, water, air and soil quality monitoring, better crop yield [5], agricultural resources saving, live stock monitoring and logistics tracking. Through water quality monitoring, the crop stages and the required water quality can be mapped for decision making on irrigation control.

This helps in the protection of soil from deterioration and crops from damages and diseases. Inclusion of such a system in farm land automation system should be highly cost efficient through the sensor and actuator components used and the communication technology that lies behind.

Section II gives a discussion of other related works in the field of water quality assessment. Section III explains the design requirement and scope of IoT and 5G for agricultural applications. Section IV demonstrates the proposed system design and implementation. Section V discusses the outcome of the work and section VI concludes the paper.

II. Related Study

The literature has demonstrated the benefits of IoT and its use in agricultural monitoring purposes. Based on the application requirement and on the nature of the components used, various surveillance or monitoring systems has improved the way farming has been concentrated. Water quality assessment can be done for irrigation purposes, to check the quality of water for drinking and cooking or for domestic household usages or livestock feeding. The quality test can be done using laboratory methods and can be linked with an application, and through network connectivity the data can be stored in the cloud. Due to the advent of MEMS and nano technology, and the anytime and anywhere networking technologies, sensor based water quality assessments make the system of surveillance processes faster and low-cost.

The authors of [6] have proposed a system to identify the changes in the quality of pond water and notify it to the users through SMS. Using temperature and pH sensors it was shown to transfer the sensed data without loss, but to save energy at nodes. M. Parameswari and M. Balasingh Moses [7] have proposed a water quality assessment system to assess the pond water quality using temperature sensor, pH sensor, dissolved oxygen sensor and turbidity sensor connected to the ArduinoGenuino 101 and using HTTP protocols the data is sent to the application waiting for this data. As ground water is an important source of water for irrigation, an assessment of the quality of ground water was performed [8]. Through this research the authors have found that some stations show high salinity hazards. They have suggested to take proper measure to avoid crop spoilage due to water salinity. The water quality monitoring system developed by the authors of reference [9] aims at monitoring electrical conductivity, turbidity, water level and pH. TI CC3300 microcontroller with an inbuilt WiFi is used for controlling the sensors. The sensor values read, are stored in the cloud and at the same time displayed in the LCD. Even though various sensors and microcontroller are used, a low cost system will be more beneficial for building a scalable system.

January-February 2020
ISSN: 0193-4120 Page No. 8827 - 8834

III. IoT WITH 5G: DESIGN REQUIREMENTS AND SCOPE

Agricultural applications require both small scale networks to large scale network. Monitoring water level for irrigation, actuating sprinkler, monitoring temperature

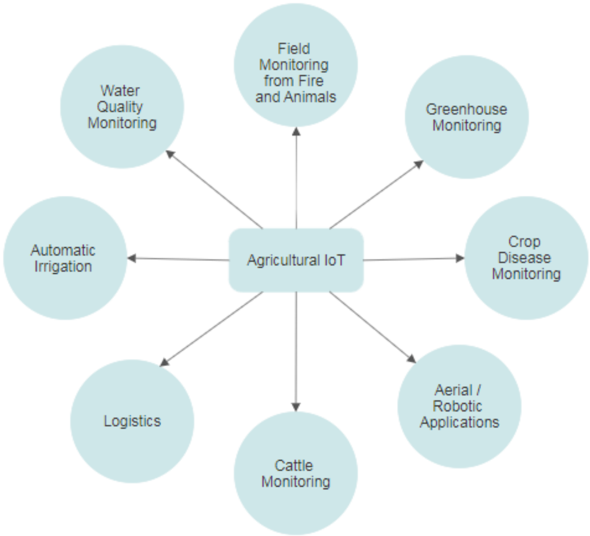

Fig.1. Agricultural IoT Design Scope

Table 1. 5G-IoT Design Requirements

APPLICATION	ACCEPTABLE DELAY	UPDATE DURATION	DATA RATE
Greenhouse Monitoring	5 min	15 min	Low
Crop Disease	½ day	Once in a day	Low
Aerial /Robotics	Seconds	Real Time	High
Cattle Monitoring	30 min	Adhoc Conditions	High
Logistics	5 min	1 report per hour/day	Low
Automatic Irrigation	5 min	Twice a day	Low
Water Quality Monitoring	5 min	Once in a day	Low
Field Monitoring	Seconds	Real Time	High

and humidity, measuring light intensity will all need one or more but very few number of sensing components. Cattle monitoring, greenhouse monitoring, like the sort of agricultural applications require large scale deployment of sensor nodes. Data collection and processing in IoT implementation for agricultural applications thus has to overcome challenges like the characteristics of the low cost devices and its count, long battery power, less implementation cost, security and privacy issues and extendibility and scalability. Some of such applications in the field of agriculture is shown in fig. 1.

A. Low Cost Sensing Devices

To encourage the use of agricultural IoT in the farming community it is expected that the cost of the devices used and the implementation cost should be extremely low. This will also induce mass-market applications.

B. Long Battery Life

Long network lifetime is highly expected as frequent repairs and modifications in the network may lead to loss of interest in the system. As the devices may be needed to be deployed in remote sites and where frequent recharging may not be possible, it is expected to have light weight protocols in every layer of the architecture. Transmission of data consumes more battery power than it is required for the reception of data by a device. But, as the IoT networks generates more volume of data and the data is transmitted to the cloud for storage and decision making, every node expends it's battery power. The design of hardware and software which consumes less device power is hence a major concern on agricultural IoT.

C. Network Coverage Area

As the number of nodes in the network should be sufficient for covering the application's purpose, and should not be too high to reduce the cost of the network, it is also important to deploy a fault tolerant sensor node placement. Poor network coverage leads to the wastage of agricultural

January-February 2020
ISSN: 0193-4120 Page No. 8827 - 8834

resources and loss of sensed information within the sensed node itself.

D. Security and Privacy

Security of the data generated and privacy of the location of the device are crucial aspects to be maintained as tampering or revealing of data leads to malfunction of the automated system and location privacy of devices, cattle or humans lead to the threat to the system in many ways. Along with the security of sensed data and devices, security of data upstream and downstream should also be equally monitored.

E. Communication System

Low power and long range network connectivity benefits the low cost, low memory and low battery power availability devices. The communication system can be broadly classified as long range communication technology, short-range communication technology and cellular network technology. Some of the long range networks are Sigfox and LoRa. Short range networks are Bluetooth, IEEE 802.15.4, Zigbee and WiFi. 2G, 3G, 4G and 5G are cellular network technologies.

F. 5G Enhancements for IoT

The challenges with the currents cellular technology are its short range communication facility and the ability to connect only a small number of devices. As the number of connected devices in the network increases, there comes the real challenge in connecting those diverse networks, variation in the device features and connectivity requirements, difference in the packet sizes generated by the different devices connected to the network, the mobility nature of the devices, activeness of the devices based on its mode of operation like active, idle or sleep. The requirement on the speed of the underlying network technology can be realized from Table 1. It shows the acceptable delay requirements for the downlink response, duration of information retrieval from the network and the data rate requirement.

IV. System Design and Implementation

The challenge in developing a water quality monitoring system lies in the selection of hardware and software components that gives the real efficient solution in an affordable cost at the development side. This will eventually motivate and encourage lot more such researches and deployments for the usage of IoT in the field of agriculture. Identification of the physical and chemical properties of water helps in the identification of the quality of water. With this intention is this work, on water quality monitoring, was designed and developed. Such systems will also help in the development of automated systems without or with less intervention of man power. This together gives assurance of the faster and economical water quality monitoring systems.

A. Components Used

The system consists of Arduino and Rasperry Pi boards, pH sensor, temperature sensor and turbidity sensor. For testing the water quality, its different forms like soap water and muddy water, and from different sources like lake, sea, tank and tap water are used.

The amount of suspended particles or foreign bodies like sand or fungus, is assessed using the turbidity sensor. Fig 2 shows the turbidity sensor SEN0189. Turbidity generally refers to the cloudiness of the water, which is the dirt or solid particles in water. Turbidity is measured using optical devices as the measurement is done based on the amount of light received or scattered. The pH sensor used is shown in the fig.3. pH sensor SKU:SEN0161 is a sensor which detects pH of water. The term “pH” refers to the power of hydrogen termed from Latin. It measures the hydrogen ions in water that helps us to identify the acidity and alkalinity in the solution. The pH sensor is connected to the Arduino to capture the

January-February 2020
ISSN: 0193-4120 Page No. 8827 - 8834

values and then connected to Rasperry Pi. This step helps in the conversion of analog values to digital values. pH value between 6-8 is the measure accepted for plants and trees. As the temperature and pH are dependent, measuring the temperature of the water is considered appropriate. Also the ionization process in water increases with increasing temperature. Hence these three parameters are considered in our work for water quality monitoring. The temperature sensor (DS18B20) used is shown in fig. 4.

B. Steps Involved

The diagrammatic representation of the overall

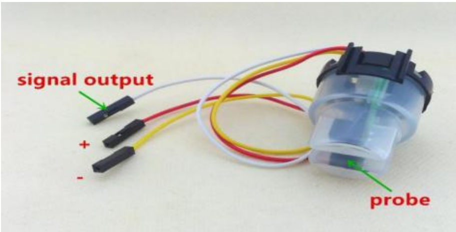

Fig.2. Turbidity Sensor

Fig.3.pH Sensor

Fig. 4. Temperature Sensor

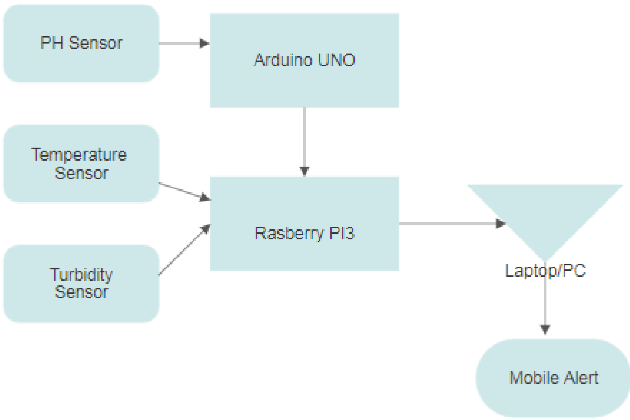

Fig.5. System Architecture

architecture is shown in the fig 5.

The following steps are followed for measuring the required data.

1. All sensors except the pH sensor are connected directly to the Rasperry Pi.

2. The sensors are immersed in to different water sources and the values are sensed continuously.

3. Threshold limits are preset and if the values go below or above the limit, the same has to be informed to the user.

4. For the messaging service Twilio application is used. The message sent to the user helps the user to protect his crops from any harmful contaminants.

V. Result and Discussion

The system is tested with water collected from different sources such as lake, river, muddy water, soapy water, water tank, ground water, etc. The microcontroller device is first connected with the required sensors and the sensing is started. The temperature measure is a factor that even varies the pH of water. Fig. 6 helps us to learn the variation in the pH value of different types of solutions, as the temperature varies. Acidic solutions seem to show a very minute variation in the pH value with various

January-February 2020
ISSN: 0193-4120 Page No. 8827 - 8834

temperature levels. But a drastic change is noted in other solutions.

The turbidity of varied levels is measured by adding dirt particles in to water of different quantity. The sensor gives a qualitative analysis of turbidity by measuring the voltage levels. It was found that if turbidity is increased, the voltage levels decreased.
Finally, the pH value measurement involves analysis

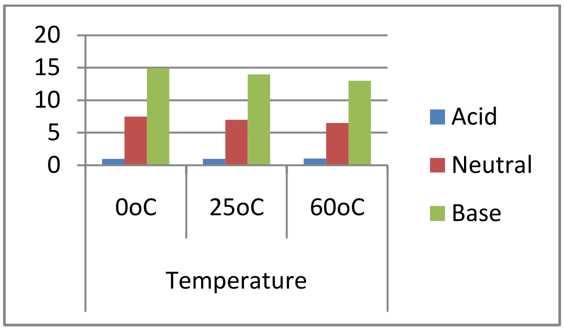

Fig. 6. Change in pH due to change in temperature

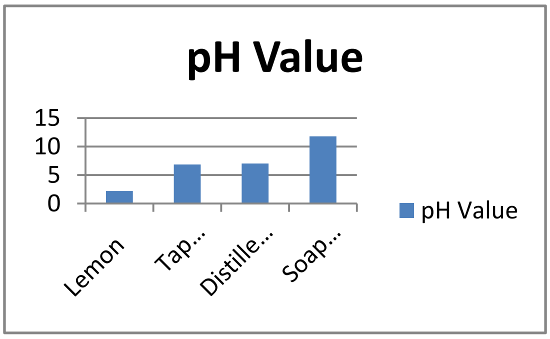

Fig. 7.pH value of different solutions

Fig.8. Turbidity Test

with various types of water solutions- acidic, neutral and base. Fig. 7 shows the pH of different liquids. Fig.8 shows the measurement of turbidity with various levels of dirt particles.

VI. Conclusion

There are various sensors available in the market for the measurement of water quality deciding parameters. Efficient sensors with low cost are chosen for monitoring pH, turbidity and temperature of water. It was shown that as the temperature increases, this shows variation in the pH value too. Thresholds are set for the parameters and an unexpected range of sensing notifies the user immediately through the messaging service. This data can be stored in cloud for visualization and analysis. The system is also scalable for measuring various other parameters in future. This requires very less improvement in the implementation.

VII. References

[1] N NBasak, Irrigation Engineering, Tata McGraw Hill Education Pvt. Ltd.1999.

[2] D. Lenka, Irrigation and Drainage, Kalyani Publishers, 1991.

[3] T. C. JerminJeaunita, Sarasvathi V, Saritha, 2019, “Internet of Things based Low Cost Air Quality Surveillance”, Proceedings, WiSPNET ’19, 2019.

[4] T. C. JerminJeaunita, Sarasvathi V, “Fault Tolerant Sensor Node Placement for IoT based Large Scale Automated Greenhouse System”, International Journal of Computing and Digital Systems, UoB, Volume 8, Issue 2, 2019.

[5] T C JerminJeaunita, Sarasvathi V, Harsha M S, Bhavani B M, Kavyashree T, “An Automated Greenhouse System using Agricultural Internet of Things for Better Crop Yield”, IET, 2018.

[6] Dung Nguyen and Phu H. Phung, “A Reliable and Efficient Wireless Sensor Network System for Water Quality Monitoring”, 13th International Conference on Intelligent Environments, 2017.

[7] M. Parameswari, M. Balasingh Moses,“Online measurement of water quality and reporting system using prominent rule controller based on aqua care-IOT”, Springer Science and Business Media, LLC 2017, 2017.

[8] A. JafarAhamed, S. Ananthakrishnan, K. Loganathan, K. Manikandan, “Assessment of groundwater quality for irrigation use in Alathur Block”,

Perambalur District, Tamilnadu, South India, Springer, Volume 3, Issue 4, pp 763–771, 2013.
[9] S. Geetha and S. Goutham, “Internet of things enabled real time water quality monitoring system”, Smart Water, Springer,2017.

AUTHORS PROFILE

T. C. Jermin Jeaunita is currently an Assistant Professor in the Department of Computer Science and Engineering at RMK Engineeing College. She completed her B. E in Computer Science and Engineering from St. Xavier's Catholic College of Engineering, Tamilnadu, India in the year 2003 and M.E in Computer Science and Engineering from Noorul Islam College of Engineering, Tamilnadu India in the year 2005. Her research interestsarePeer to Peer networks, Wireless Sensor Networks, IoT and Machine Learning.

A. V. Kalpana is currently an Assistant Professor in the Department of Computer Science and Engineering at RMK Engineering College. She obtained her B.E. in Computer Science &Engineering in the year 2004from University of Madras, Chennai, Tamilnadu, India. She obtained her M.E. in Computer Science &Engineering in the year 2011 from Anna University, Chennai, Tamilnadu, India. She has guided many B. E.and M. E projects. She has published many papers in international journals. Her research interests include Wireless Networks, Mobile Computing, and Wireless Sensor Networks.

M. P. KARTHIKEYAN is currently an Assistant Professor in the Department of Computer Science and Engineering at RMK Engineering College. He completed his B. E in Computer Science and Engineering from S. A. Engineering College, Tamilnadu, India in the year 2011 and M.Tech in Computer Science and Engineering from SRM University, Kattankulathur, Tamilnadu India in the year 2013. His research interests are Medical Image Processing, Peer to Peer networks, Network Security, and Artificial Intelligence.