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Designing of Real-time Communication Method to Monitor Water Quality using WSN Based on IOT

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Abstract- Data accuracy has always been the essential and foremost requirement of any communication. A Real-time Water quality-monitoring system (WQMS) needs high-level data accuracy to process the water perfectly for the desired usage in any specific purpose. Exponential growth in man-made processes, human activities, Industrialization, and economic growth along with depleting safe water resources has made the water pollution issue a foremost threat to human survival and human civilisation as a whole. The Conventional WQMS lacks in providing data accuracy while testing and analysing the water samples at sites due to improper data transmission, human intervention, instrument node working and calibration issues. Therefore, monitoring the quality of the water is essential with a prime focus on data accuracy through proper testing, data analysis and data transmission methods to provide real-time data accuracy. In this research work, an IOT-based wireless sensor network (WSN) is proposed that uses mesh networking to connect the sensor nodes and message queuing telemetry transfer (MQTT) protocol to send the acquired data to a cloud server ADDA Fruit IO. ESP32 standalone microcontroller with in-built Wi-Fi is used as a transceiver on sensor nodes and master nodes. As far as sensor and master node power is concerned, a self-adapting power generation system is incorporated using solar power and water energy harvesting techniques. The sensor nodes are calibrated as per WHO standards using deionized water and buffer capsules. Five random samples are collected from river water, pond water, Borewell water, R.O water and Municipal committee water to analyse the proposed system's accuracy. The accuracy test and analysis is done using statistical tools on water sample measurements by the proposed sensor node, and the same is compared with the actual certified instrument, hardware manual-based measurement, Laboratory value check and transmitted value on Cloud Server. The proposed WQMS is designed to measure various WQM parameters i.e. Total Dissolve Solid (TDS), pH, Temperature and turbidity and to ensure data accuracy.

Keywords- Message queuing telemetry transfer (MQTT), Wireless sensor network (WSN), Total Dissolve Solid (TDS), pH, Temperature.

I. INTRODUCTION

Water contamination is a source of many deadly diseases, which can harm human civilization [1]. Being a universal solvent water can dissolve more substance than any other available liquid and is highly vulnerable to contamination [2]. In non-urban areas, people do not have access to clean drinking water and are forced to drink polluted water, which causes various issues related to health issues [3]. In a conventional system, the sample gets contaminated or its parameter properties change in manual sample taking and sample transfer and it does not give the report in real-time resulting in delayed decision-making and analysis of the sample [4].

The most successful system is that which provides accurate data. The WSN provide physical security and can work in an acute environment [5]. IOT-based WSN provides accurate results with real-time of WQM parameters continuously [6]. The water quality parameter measurement using a wireless sensor network provides high detection accuracy with low power consumption [7].

The WSN not only provide freedom of movement at low maintenance cost but also provide accurate data collection that meets the system's reliability [8]. The proposed research objective is to provide an effective communication of data to ensure high data accuracy [9]. In the suggested work a smart IOT based system using WSN is designed to monitor the quality of water to measure various WQM parameters i.e pH, TDS, and EC and to ensure data accuracy.

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II. RELATED WORK

The creation of a remote monitoring system consistently tracks moisture levels of the soil in organic farming using WSN and IOT. The researcher's primary concern was the limited network lifespan, which they addressed by implementing the Exponential Weighted Moving Average event detection algorithm. This algorithm successfully removes noise and conserves energy, resulting in a more efficient monitoring system. The system includes pH, conductivity, and temperature sensors, as well as a ZigBee module that allows for wireless data transfer to a microcontroller. The microcontroller then sends the data to a smartphone or PC using a GSM module. In addition, proximity sensors are incorporated into the system to notify officials in the event of water pollution, which is detected through the GSM module by sending a message [10-11].

An approach for the smart system to check the quality of water. Featuring a warning system that sounds if water contamination is found, alerting the responsible staff. Four parameters are measured by the system using commercially available sensors: conductivity, temperature, dissolved oxygen concentration, and pH level. Recorded data are communicated to a station through GPRS. A researcher presented a wireless system to check water purity based on the controller Arduino and a WIFI Zigbee module that is inexpensive and easy to use a signal-conditioning circuit connected the Arduino board to water-quality sensors. The Zigbee module was used to transmit acquired data wirelessly to a server. The transferred data was received by a Raspberry Pi on the server, and the findings are displayed graphically [12-14].

A system based on CEP intelligent program for water supply systems to detect water purity in real time that can foresee dangers and remotely operate devices. The work does not show how the system might scale in a real context, despite having the goal of real-time monitoring. investigation to develop and put in place a transportable, movable, reasonably priced, and reliable water level management system. The authors developed a trans-receiver system working on two types of radio frequency, to measure various parameters such as pH, Temperature, and TDS with a trans-receiver mounting on a tank and sump to determine the quality of the water. Wireless connections to internet servers are made possible by radio frequency transceivers. The system is programmed by the user, except draining the water bottle, which is done with the aid of a microcontroller [15-16].

A suggested framework of publisher-subscriber architecture can be a highly effective approach for water quality checks in real-time in IoT-based applications. The team conducted a comparative analysis between the proposed architecture and the widely used MQTT protocol, and showed the result in terms of throughput, and network latency, regardless of the message payload size. Moreover, the study explores the interconnection between water quality parameters, specifically temperature, pH, and DO, which can provide valuable insights for promoting sustainability and managing water quality. The researchers employ WSNs as the primary network layer, and IoT is used to track essential parameters such as deviation in level of pH, deviation in turbidity, and temperature. The data acquired from the sensors can be accessed through a mobile application and a server on the cloud, which includes visualizations that aid in better comprehension of the data. The system is powered by solar energy and utilizes Wi-Fi for long-distance communication. The general public can access the system through a user-friendly Graphical User Interface (GUI). The integration of WSNs and IoT technology can improve pollution monitoring and potentially aid in preventing further environmental degradation [17-18].

The researchers suggest an affordable and efficient method of monitoring water quality using IoT and WSN based on the LoRaWAN protocol, which has long-range and scalable with low power consumption. The study emphasizes that current wireless technologies are not well suited for WSN sensor nodes, which require low power consumption and long-range connectivity. The suggested system combines sensors with a microcontroller, uses a wireless LoRa module to transmit and receive sensor values, and makes use of the Thing Speak IoT platform to analyze and display the sensor data [19]. The system focused on keeping track of numerous factors including parameters like temperature, level of pH, DO, and EC that are crucial for ecosystem and human safety with the help of the WSN node. The author described a special microcontroller-based sensor node at can monitor the rate of water flow and level of water for environmental and flood alerts while meeting water quality regulations [20].

To address the issue of water pollution, particularly in Selangor, Malaysia. The study examines various WQM methods with a focus on using IoT and WSN technology to achieve real-time data measurements. The developed WQM system uses an Arduino UNO as the microcontroller to communicate with the sensor, which measures TDS and EC. The cloud server thinks to speak is used to analyze and display the data at a remote place. The system's effectiveness is confirmed through statistical analysis, which shows a significant difference between the paired sample populations. Overall, the study presents a valuable contribution to the field of water quality monitoring, particularly in the context of environmental challenges in Malaysia, offering a practical

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and effective solution that can improve the management of water resources and protect public health [21].

The importance of monitoring water quality is due to its critical role in sustaining life and the detrimental effects of water degradation caused by rapid development and urbanization. As India relies on underground sources for 65% of its drinking water, monitoring the quality of water is imperative. The system is designed to be power-efficient and effective, providing an alarm to remote users in case of any deviation from the expected water quality parameters. The monitoring system makes use of WSN to measure physiochemical parameters like oxidation-reduction potential, EC, pH and turbidity. Numerous microsystems are used by the system for data conditioning, aggregation, analysis, and fuzzy logic-based decision-making based on the degree of contamination in the distribution pipeline [22-23].

The creation of a system that can track metrics to analyze various parameters i.e., temperature, turbidity, and pH value, utilizing sensors attached to an Arduino Uno microcontroller, Wi-Fi wireless transmission, and an LCD display. The data is wirelessly transmitted to the management system for analysis and effective decision-making. The proposed system is tested and evaluated at different locations, and the results demonstrate its effectiveness in detecting parameters of water quality in real time. The authors suggested a prediction model that accurately predicts the future trends of water quality based on historical data. The scholars examine the water quality parameter of the Yangtze River. The performance of the model was evaluated by comparing the predicted values with the actual values. The results of the study show that the developed prediction model for drinking water quality using LSTM deep neural networks accurately predicted the future trends of water quality [24-25].

III. PROPOSED SYSTEM DESIGN

In this research work, an IOT-based wireless sensor network (WSN) is proposed that uses mesh networking to connect the sensor nodes and message queuing telemetry transfer (MQTT) protocol to send the collected data to the cloud server ADDA Fruit IO. ESP32 standalone microcontroller with in-built Wi-Fi is used as a transceiver on sensor nodes and master nodes. As far as sensor and master node power is concerned, a self-adapting power generation system is incorporated using solar power and water energy harvesting techniques. The sensor nodes are calibrated as per WHO standards using deionized water and buffer capsules. The accuracy test and analysis are done using water sample testing by the proposed sensor node, and the same is compared with the existing actual certified instrument and with a manual-based theoretical measurement sensor. The proposed WQMS is designed to measure various WQM parameters pH, TDS), and EC.

The proposed design integrates data collection, data processing and data transmission. The proposed real-time WQMS makes use of two slave sensor nodes installed before and filtration, a master node and a Cloud server as given below in Figure 1. The slave nodes are connected to the master node using mesh networking. The master sensor node transfers the collection to the cloud server ADDA fruit IO using ESP 32 and MQTT protocol. The WSN sensor node consists of a self-powered system, ESP32 wifi module, a microcontroller with display and three sensors i.e. pH, TDS and EC to measure water quality as shown in below Figure 2.

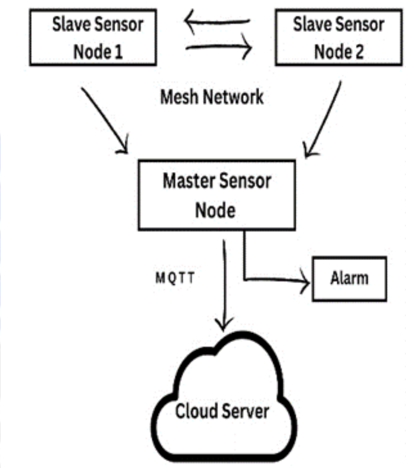

Figure 1. Proposed system Overview

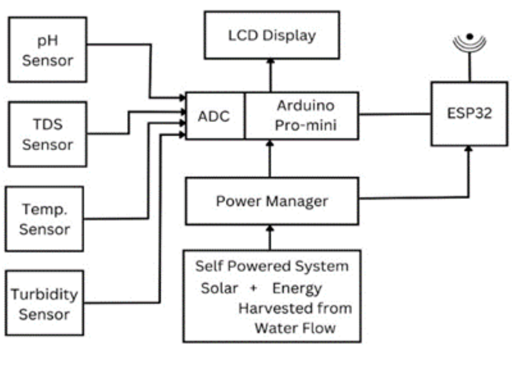

Figure 2. Design of Proposed Sensor Node

The sensor's accuracy, range and methods of measurement are shown below in Table 1. ESP32 is used in the designed system for fast data transfer to achieve quick response for deviation in water quality parameters.

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Table 1. Proposed Sensors Specification

Parameter	Range	Power Consumption	Accuracy @ 25 °C	Method
pH	0-14 pH	5 V	± 0.1 %	Glass Electrode
TDS (TDS=500 x EC)	0-1000 PPM	3/5V	± 10 %	Conductivity Measurement
Turbidity	0-1000 NTU	5V	± 1 %	Spectro Photometer
Temperature	-10℃ to + 85℃	3/5V	± 0.5 %	Thermister

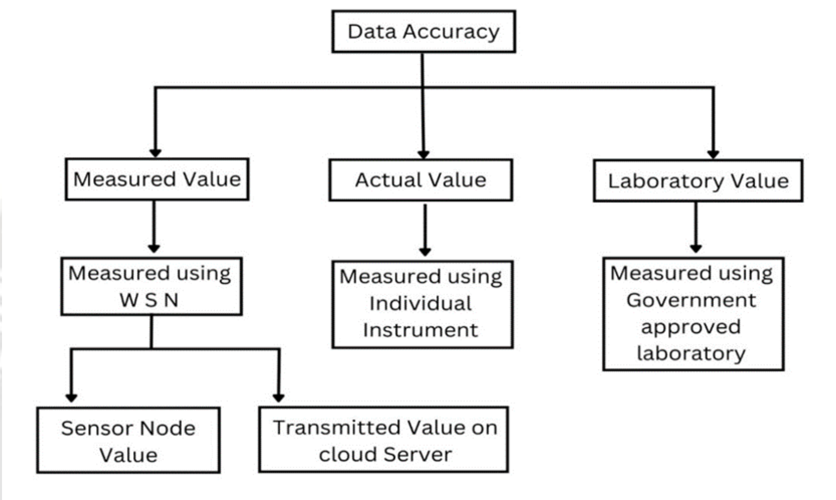

Figure 3. Data Accuracy Flow Chart

IV. DATA ACCURACY FLOW CHART

The data accuracy test flow chart is given in Figure 3. The data accuracy check is done using three methods i.e., measured value check, actual value check and Laboratory value check. Further, the data accuracy is also checked on the cloud server ADDA Fruit IO Server. The accuracy test and analysis are done using statistical tools on water sample measurements by the proposed sensor node.

V. HARDWARE EXPERIMENTAL SETUP CLICK

The hardware setup of the proposed system is given in Figure 4. The system consists of the slave sensor node, master sensor node and an eco-friendly power management system with data display at both the slave and master end. Five random samples are collected from river water, pond water, and Borewell water, R.O Water and Municipal Committee Water to analyse the proposed system's accuracy.

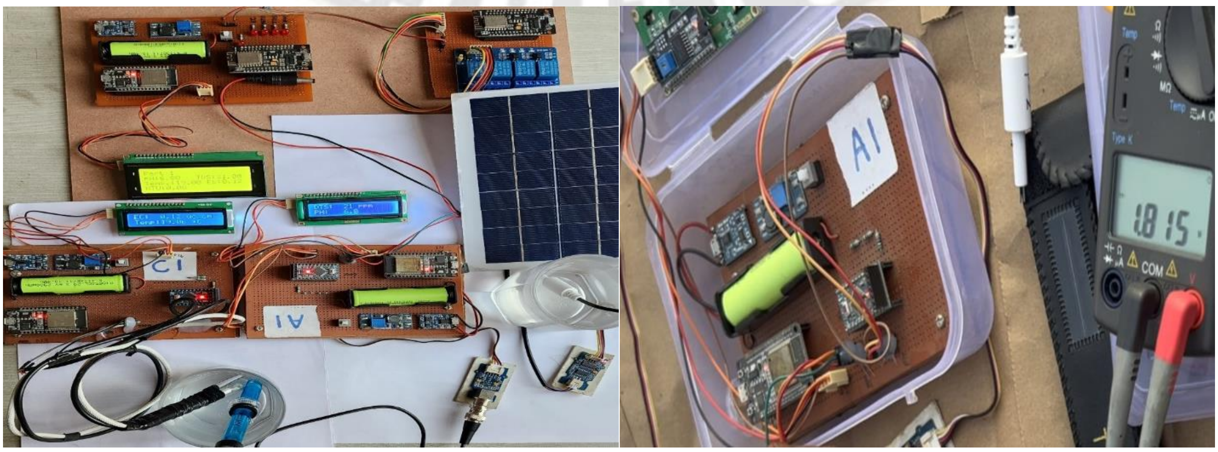

Figure 4. Hardware Setup

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VI. RESULT AND ANALYSIS

The data is collected from five water samples. Water samples are taken using random sampling from different water sources to give the results universal appeal. Water samples taken fits in normal distribution assumed for the population.

Five water samples taken are:

1. Western Yamuna River water, Barwasni Village: Lat 29.011076°, Long 76.965768°
2. Pond Water, Karewari Village: Lat 29.044593°, Long 76.911884°
3. Borewell Water, Gateway Education Sonipat: Lat 28.993642°, Long 77.049253°
4. R.O water, Fortis Hospital Noida: Lat 28.618888°, Long 77.372459°
5. Municipal Committee Water, Sector 14 Sonipat: Lat 28.9976084°, Long 77.033187°

Data collected is then analysed using the statistics tool in the Microsoft Excel workbook. Statistical analysis used to ensure data accuracy and data accuracy measurement involves three-tier analysis:

1. Error Percentage
2. Mean, Standard Deviation (SD) and Standard Error (SE)
3. Paired T-test, Pearson Correlation(PC), Hypothesized Mean Difference (HMD)

Data analysis is done using statistics and results as described are obtained

TDS values as shown in Table-2 are obtained from samples. The measured value/ Sensor node value is compared with the Actual value using the instrument for data accuracy testing. Data accuracy is measured in a three-layer analysis.

% Error = {Absolute value (sensor node value – actual value)/Actual Value} * 100%

% Error in data sets here varies from 0.2% to 8.6%.

Further Analysing Mean, standard deviation and standard error, the below results, are obtained in Table 3. To show this in terms of statistics, the paired t-test is performed to show the statistical significance of the data accuracy test as given in Table 4.

Table 2. Measured TDS Data

Water Samples	Measured Value	Actual value	Measured Electrical Conductivity	Hardware Manual	Transmitted Value	Laboratory	% Error
River Water	124	134	215	137.82	124	129.0	7.5%
Pond Water	135	138	219	140.38	135	136.5	2.2%
Borewell Water	627	628	970	621.79	627	627.5	0.2%
R.O water	76	70	119	76.28	76	73.0	8.6%
Municipal Committee Water	655	661	1026	657.69	655	658.0	0.9%

Table 3. Statistical TDS data analysis

	Measured value	Actual Value
Mean	323.4	326.2
SD	290.9438	292.0499957
SE	130.114	130.6087287

Table 4. T-Test (Paired Two Sample for Means) of TDS Data

	Measured Value	Actual value
Mean	323.4	326.2
Variance	84648.3	85293.2
Observations	5	5
PC	0.999797	0
HMD	0	0
df	4	0

t Stat	-1.04787	0
P(T<=t) one tail	0.176918	0
t Critical one tail	2.131847	0
P(T<=t) two tail	0.353836	0
t Critical two-tail	2.776445	0

P value is greater than 0.5 signifying that the null hypothesis is proved, i.e., the difference in sample means is not statistically significant. This shows that data accuracy is totally maintained using the sensor node.

Temperature values as shown in Table 5 are obtained from samples. The measured Value/ Sensor node value is compared with the Actual value using the instrument for data accuracy testing. Data accuracy is measured in a three-layer analysis.

% Error = {Absolute value (sensor node value – actual value)/Actual Value} * 100%

% Error in data sets here varies from 0.9% to 11.5%.

Further Analysing Mean, standard deviation and standard error, the below results are obtained in Table 6. To show this in terms of statistics, the paired t-test is performed to show the statistical significance of the data accuracy test as given in Table 7.

Table 5. Measured Temperature Data

Water Samples	**Measured Value**	**Actual value**	**Measured voltage**	**Hardware Manual**	**Transmitted Value**	**Laboratory**	**% Error**
River Water	22.81	22.6	1.78	23.28	22.81	22.7	0.9%
Pond Water	26.6	26.3	1.8	26.35	26.6	2.5	1.1%
Borewell Water	25.75	23.1	1.79	24.82	25.75	24.4	11.5%
R.O water	24	25.9	1.79	24.82	24	25.0	7.3%
Municipal Committee Water	26	26.5	1.8	26.35	26	26.3	1.9%

Table 6. Statistical Temperature Data Analysis

	Measured value	**Actual Value**
Mean	25.032	24.88
SD	1.574284	1.874033084
SE	0.704041	0.838093074

Table 7. T-Test (Paired Two Sample for Means) of Temperature Data

	Measured Value	**Actual value**
Mean	25.032	24.88
Variance	2.47837	3.512
Observations	5	5
PC	0.553358	0
HMD	0	0
Df	4	0
t Stat	0.205885	0
P(T<=t) one tail	0.423468	0
t Critical one tail	2.131847	0
P(T<=t) two tail	0.846935	0
t Critical two tail	2.776445	0

P value is greater than 0.5 signifying that the null hypothesis is proved, i.e., the difference in sample means is not statistically significant. This shows that data accuracy is totally maintained using the sensor node.

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Turbidity values as shown in Table 8 are obtained from samples. The measured value/ Sensor node value is compared with the Actual value using the instrument for data accuracy testing. Data accuracy is measured in a three-layer analysis.

% Error = {Absolute value (sensor node value – actual value)/Actual Value} * 100%

% Error in data sets here 33.3%

Further Analysing Mean, standard deviation and standard error, the below results are obtained in Table 9. To show this in terms of statistics, the paired t-test is performed to show the statistical significance for the data accuracy test as given in Table 10.

Table 8. Measured Turbidity Data

Water Samples	Measured Value	Actual value	Measured voltage	Hardware Manual	Transmitted Value	Laboratory	% Error
River Water	0	0	4.55	0.48	0	0.0	
Pond Water	2	3	4.53	2.71	2	2.5	33.3%
Borewell Water	0	0	4.55	0.48	0	0.0	
R.O water	0	0	4.55	0.48	0	0.0	
Municipal Committee Water	0	0	4.55	0.48	0	0.0	

Table 9. Statistical Turbidity Data Analysis

	Measured Value	Actual Value
Mean	0.4	0.6
SD	0.894427	1.341640786
SE	0.4	0.6

Table 10. T-Test (Paired Two Sample for Means) of Turbidity Data

	Measured Value	Actual value
Mean	0.4	0.6
Variance	0.8	1.8
Observations	5	5
PC	1	0
HMD	0	0
df	4	0
t Stat	-1	0
P(T<=t) one tail	0.18695	0
t Critical one tail	2.131847	0
P(T<=t) two tail	0.373901	0
t Critical two tail	2.776445	0

P value is greater than 0.5 signifying that the null hypothesis is proved, i.e., the difference in sample means is not statistically significant. This shows that data accuracy is totally maintained using the sensor node.

PH values as shown in Table 11 are obtained from samples. The measured value/ Sensor node value is compared with the Actual value using the instrument for data accuracy testing. Data accuracy is measured in a three-layer analysis.

% Error = {Absolute value (sensor node value – actual value)/Actual Value} * 100%

% Error in data sets here varies from 1.2% to 6.5%.

Further Analysing Mean, standard deviation and standard error, the below results, are obtained in Table 12.

Table 12 shows the variance in standard deviation but the means are around the same. To show this in terms of statistics, the paired t-test is performed to show the statistical significance for the data accuracy test as given in Table 13.

Table 11. Measured pH Data

Water Samples	Measured value	Actual value	Measured Voltage	Hardware Manual	Transmitted Value	Laboratory Test Value	% Error
River Water	6.4	6.8	2.58	6.63	6.4	6.6	5.9%
Pond Water	7.2	7.7	2.48	7.20	7.2	7.5	6.5%
Borewell Water	9.1	8.7	2.1	9.37	9.1	8.9	4.6%
R.O water	8.5	8.4	2.28	8.34	8.5	8.5	1.2%
Municipal Committee Water	6.5	6.9	2.6	6.52	6.5	6.7	5.8%

Table 12. Statistical pH Data Analysis

	Measured Value	Actual Value
Mean	7.54	7.7
SD	1.209545	0.85732141
SE	0.540925	0.38340579

Table 13. T-Test (Paired Two Sample for Means) of pH Data

	Measured value	Actual value
Mean	7.54	7.7
Variance	1.463	0.735
Observations	5	5
PC	0.986047	0
HMD	0	0
Df	4	0
t Stat	-0.91466	0
P(T<=t) one tail	0.20606	0
t Critical one tail	2.131847	0
P(T<=t) two tail	0.412119	0
t Critical two tail	2.776445	0

P value is greater than 0.5 signifying that the null hypothesis is proved, i.e., the difference in sample means is not statistically significant. This shows that data accuracy is to be maintained using a sensor node.

VII. CONCLUSION AND FUTURE SCOPE

The sensor node is designed with temperature, turbidity, pH, TDS and EC sensors that are used to measure water quality. The measured value by sensors is sent to cloud ADDA Fruit IO using ESP32 and MQTT protocol for data visualization and analysis. The accuracy test and analysis done using statistical tools on water sample measurements by the proposed sensor node, its further comparison with the actual certified instrument, hardware manual-based measurement and transmitted value on Cloud Server showed no statistical significance in data differences. Therefore, these results show data accuracy is intact. The test result shows that the system can obtain the water quality parameter with high accuracy in real-time. In the future scope, we can connect the real-time data with a water supply and distribution sections to take real-time operations and decisions for water treatment and purification.

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REFERENCES

[1] Boelee, E., Geerling, G., van der Zaan, B., Blauw, A., & Vethaak, A. D.Water and health: From environmental pressures to integrated responses. Acta tropica, 2019, 193, 217-226.
[2] Srivastav, A. L., & Ranjan, M. (2020). Inorganic water pollutants. In Inorganic Pollutants in Water, 2020, (pp. 1-15). Elsevier.
[3] Yasam, S. ., H. Nair, S. A. ., & Kumar, K. S. . (2023). Machine Learning based Robust Model for Seed Germination Detection and Classification . International Journal of Intelligent Systems and Applications in Engineering, 11(2s), 116–124. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2515
[4] Li, P., & Wu, J. Drinking water quality and public health. Exposure and Health, 11(2), 2019, 73-79.
[5] Ahmed, U., Mumtaz, R., Anwar, H., Shah, A. A., Irfan, R., & García-Nieto, J. Efficient water quality prediction using supervised machine learning. Water, 2019, 11(11), 2210.
[6] Chowdury, M. S. U., Emran, T. B., Ghosh, S., Pathak, A., Alam, M. M., Absar, N., ... & Hossain, M. S. IoT based real-time river water quality monitoring system. Procedia Computer Science, 2019, 155, 161-168.
[7] Adu-Manu, K. S., Katsriku, F. A., Abdulai, J. D., & Engmann, F. Smart River monitoring using wireless sensor networks. Wireless Communications and Mobile Computing, 2020, 1-19.
[8] Li, S., Da Xu, L., & Wang, X. Compressed sensing signal and data acquisition in wireless sensor networks and internet of things. IEEE Transactions on Industrial Informatics, 2012, 9(4), 2177-2186.
[9] Auma, G., Levi, S., Santos, M., Ji-hoon, P., & Tanaka, A. Predicting Stock Market Trends using Long Short-Term Memory Networks. Kuwait Journal of Machine Learning, 1(3). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/136
[10] Raza, M., & Nguyen, H. X. Industrial wireless sensor networks overview. Wireless automation as an enabler for the next industrial revolution, 2020, 1-17.
[11] Ketshabetswe, L. K., Zungeru, A. M., Mangwala, M., Chuma, J. M., & Sigweni, B. Communication protocols for wireless sensor networks: A survey and comparison. Heliyon, 2019, 5(5), e01591.
[12] Ezhilazhahi, A. M., & Bhuvaneswari, P. T. V. IoT enabled plant soil moisture monitoring using wireless sensor networks. In 2017 Third International Conference on Sensing, Signal Processing and Security (ICSSS), May 2017 (pp. 345-349). IEEE.
[13] Das, B., & Jain, P. C. (2017, July). Real-time water quality monitoring system using Internet of Things. International conference on computer, communications and electronics (Comptelix) 2017, (pp. 78-82). IEEE.
[14] Jiang, P., Xia, H., He, Z., & Wang, Z. Design of a water environment monitoring system based on wireless sensor networks. Sensors, 2009, 9(8), 6411-6434.
[15] Robles, T., Alcarria, R., de Andrés, D. M., de la Cruz, M. N., Calero, R., Iglesias, S., & Lopez, M. An IoT based reference architecture for smart water management processes. J. Wirel. Mob. Networks Ubiquitous Comput. Dependable Appl., 2015, 6(1), 4-23.
[16] Khatri, P., Gupta, K. K., & Gupta, R. K. Smart water quality monitoring system for distribution networks. In Proceedings of International Conference on Sustainable Computing in Science, Technology and Management (SUSCOM), Amity University Rajasthan, Jaipur-India 2019, February.
[17] Zhuzhou, P. R., & Hengyang, P. R. Edge-centric Computing for Smart Water Supply: Management and Service, International Conference on Material Science and Civil Engineering, 2016.
[18] Lambrou, T. P., Anastasiou, C. C., Panayiotou, C. G., & Polycarpou, M. M. A low-cost sensor network for real-time monitoring and contamination detection in drinking water distribution systems. IEEE sensors journal, 2014, 14(8), 2765-2772.
[19] Pranata, A. A., Lee, J. M., & Kim, D. S. Towards an IoT-based water quality monitoring system with brokerless pub/sub architecture. In 2017 IEEE International Symposium on Local and Metropolitan Area Networks (LANMAN) ,2017, (pp. 1-6). IEEE.
[20] Prof. C. Ranjeeth Kumar. (2020). Malware Detection Using Remedimorbus Application. International Journal of New Practices in Management and Engineering, 9(01), 08 - 15. https://doi.org/10.17762/ijnpme.v9i01.82
[21] Puneeth, K. M., Bipin, S., Prasad, C., Kumar, R. J., & Urs, M. K. (2018, May). Real-time water quality monitoring using WSN. In 2018 3rd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT) (pp. 1152-1156). IEEE.
[22] Simitha, K. M., & Raj, S. (2019, June). IoT and WSN based water quality monitoring system. In 2019 3rd International conference on Electronics, Communication and Aerospace Technology (ICECA) (pp. 205-210). IEEE.
[23] Kadir, E. A., Siswanto, A., Rosa, S. L., Syukur, A., Irie, H., & Othman, M. (2019, April). Smart sensor node of WSNs for river water pollution monitoring system. In 2019 International Conference on Advanced Communication Technologies and Networking (CommNet) (pp. 1-5). IEEE.
[24] Sulaiman, M. S., Abd Rahman, M. F., & Adam, A. F. M. (2023). Variance of total dissolved solids and electrical conductivity for water quality in Sabak Bernam. International Journal of Electrical and Computer Engineering, 13(2), 2259.
[25] Gokulanathan, S., Manivasagam, P., Prabu, N., & Venkatesh, T. (2019). A GSM based water quality monitoring system using Arduino. Shanlax International Journal of Arts, Science and Humanities, 6(4), 22-26.
[26] Amin, M. H., Sajak, A. A. B., Jaafar, J., Husin, H. S., & Mohamad, S. (2022). Real time water quality monitoring

system for smart city in Malaysia. ASEAN Journal of Science and Engineering, 2(1), 47-64.

[27] Abdul Karim, S. N. A., Ahmed, S. A., Nischitha, V., Bhatt, S., Kiran Raj, S., & Chandrashekarappa, K. N. (2013). FAO 56 model and remote sensing for the estimation of crop-water requirement in main branch canal of the Bhadra Command area, Karnataka State. Journal of the Indian Society of Remote Sensing, 41, 883-894.

[28] Gu, Y., Zhang, Y., Luo, M., Zhang, H., Liu, X., & Miao, C. (2019). Dynamic volume change rate and aspect ratio are correlated to the formation of an irregular morphology of unruptured intracranial aneurysm. Journal of Computer Assisted Tomography, 43(2), 294-299.