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Water quality monitoring via cloud application: Brief review

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Abstract. With the growing issue of water pollution and resources, the need for a remote water monitoring system has never been more crucial. The implementation of remote monitoring system has a growing interest in the current technology development. Evolution of wireless sensor networks, coding automation and control systems led to the introduction of Internet of Things. This paper aims to review a monitoring system via cloud application to make known of current available system. Cloud application system was studied extensively by various researcher, but research study focusing for water quality monitoring is still scarce. Two main objectives in the studies were designing low-cost system and ease of operation. Most of researchers designed their system using ZigBee, one of IoT system that is currently trending. Currently, cloud system was not widely applied in real industrial application due to lack of experimental evidence. Several enhancements that can be made were proposed.

Keywords: Monitoring System; Cloud Application; Distance Test; System Design.

1. Introduction

Water quality is mainly assessed to standards related to ecosystem's health, human contact safety and drinking water. Natural bodies of water (i.e. lake, river, sea and etc.) vary due to the environment around them. The International Organization for Standardization (ISO) has released guidelines for water quality. From the European Environment Agency (EEA) assessment, only 38% of the surface body water in the European Union (EU) are considered to have good chemical status [1]. As urban population increases, multiple cities have resorted to drawing fresh water from distant watersheds as local surface and groundwater sources has either become depleted or polluted. Water quality monitoring has been a primary way of identifying water pollution problems. Monitoring has also provided data that shows the trends over time. Water monitoring for large water bodies has always been one that requires a lot of time and effort. Real time data collecting from the water source is necessary to ensure its quality. The data collection requires professional personnel to go out to the field and collect the data during that time. The data collected covers only as of that time. There is no continuous data collection done. This makes it difficult to detect contamination in the water as there is no way to update on the current water quality. Several studies have demonstrated remotely sensed data can be used to map water quality parameters that meet the application needs [2]. However, the use of remotely sensed data on an operational basis for monitoring water quality is limited to areas that are within the range of cellular coverage. The environment that is off grid is generally located in areas that are far from civilization. It also makes it difficult to return and collect data after several months. One method implemented to retrieve the data is using satellite applications.

Most deployed systems store the data collected internally. The data would then need to be obtained every few weeks or months where personnel would have to physically return to the deploy site. This would not be an issue for deployment within a close and safe area. However, it becomes a problem when the system is deployed further. The journey itself would add up to the cost of the deployment. Water quality monitoring for isolated and remote areas can be quite an expensive task. In the very least it would require personnel to visit the site and manually monitor the parameters using probes. The visits would add up to become a costly operation. There is no real time data collection method available for an affordable price. Available products in the market are designed for professional uses thus carry a heavy price tag with it. With it comes with the charge of setting it up.

2. Past studies on water quality monitoring

Among previous research and projects done on the topic of long-distance monitoring, there has been quite a number covering the design and development of LoRa implementation. However, most of these papers only cover the theory of the system. At present, most domestic water quality monitoring is still using manual methods. The detection process involved sampling, sample transportation and preservation, laboratory data measured. The Internet of Things (IoT) brings the promise of constant monitoring of objects with wireless devices to improve everyday aspects of life. Wireless sensor network (WNS) is an evolving field with an extensive range of applications. It packs sensing, computation, and communication into a single sensor node [3]. This typically consists of large numbers of sensor devices with processing capability, sensor and/or actuator, a power source, multiple types of memory and a radio frequency (RF). The sensors are deployed over a large field and inter-networked together, monitoring physical or environmental conditions that generate readings and deliver them to a sink node to be further processed [4]. The wireless network industry has a growing interest towards low power wide area wireless network (LPWAN) [5]. LPWAN technologies have in fact successfully proposed wide area connectivity to tens of kilometers for low data rate, low power and low throughput applications. The market is expected to be huge. About a quarter of 30 billion IoT/M2M devices are predicted to be connected to the Internet using LPWAN [6].

2.1. Long Range (LoRa)

LoRa is an LPWAN protocol for IoT applications. Semtech Corporation introduced extensive utilization of advanced spread spectrum technologies with the LoRa product line [7]. LoRa runs with the spread spectrum modulation technique which offers an increase link budget and better immunity to network interferences. LoRa has multiple orthogonal spreading factors (SF); numbered between 7 to 12. The SF provides tradeoff between data rate and range. Lower SF means more chirps are sent per second; therefore, more data can be encoded per second. Having a higher SF can increase the range but decreases the data rate and vice versa [8]. Relationship between spreading factor and airtime for LoRa modulations can be referred in Figure 1 below. LoRa uses the forward error correction (FEC) to increase the receiver sensitivity. Code rate (CR) defines the amount of FEC which ranges between 0 and 4. CR=0 means that there are no FEC. The code rates are as shown in the Table 1 below. The redundancy provides the receiver with information to detect and often correct errors in the message. The downside of it is that it also reduces the effective data rate. As the CR value increases, the data rate decreases in each bandwidth spectrum. LoRa offers the usage of scalable bandwidth; 125 kHz, 250 kHz or 500 kHz [9]. Wider band usage in LoRa makes it resistant to channel noise, Doppler effects and fading. Transmitter sends spreaded data at a chip rate equal to the systems' bandwidth in chips per-second-per-Hertz [8].

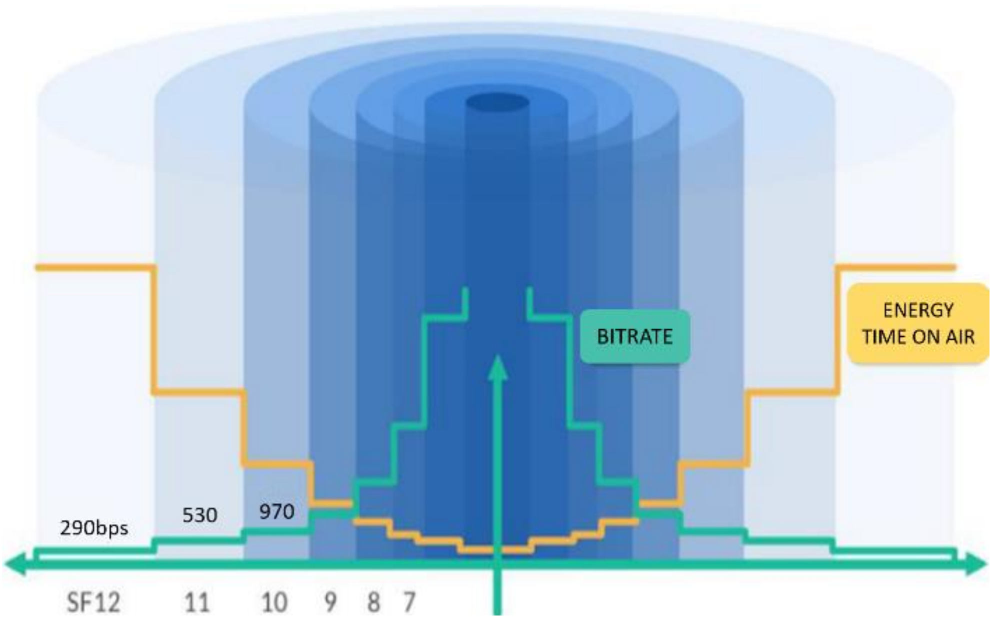

Figure 1. Relationship between spreading factor and airtime for LoRa modulations.

Table 1. Code rates in LoRa.

CR Value	No. of redundant bits	Coding rate
1	1	4/5
2	2	2/3
3	3	4/7
4	4	1/2

LoRa has a maximum packet size of 256 bytes. The packet consists of 4 fields; preamble field, header field, payload field and CRC [7]. The preamble field is used to synchronize the receiver with the incoming data from the receiver. Depending on the choice of operation modes, the header field could specify the number of bytes for code rate and payload or have it fixed. In the latter, the frame does not contain this field thus reducing the transmission time. The header also carries 2 bytes of cyclic redundancy check (CRC) field, allowing the receiver to ignore packets of invalid header. The payload field varies from 2 to 255 bytes. Within this field are 3 sub-field; Message Authentication Code (MAC) header, MAC payload and Message Integrity Code (MIC). MAC header defines the frame type, protocol version and its direction. The actual data is located in MAC payload. MIC is the digital signature of the payload. The last field which is 2 bytes, CRC, is optional. It comprises cyclic redundancy check bytes for error protection of the payload. Free space path loss (FSPL) is the attenuation of radio energy between the feedpoints of two antennas that results from the combination of the receiving antenna's capture area plus the obstacle free, line-of-sight path through the free space. FSPL is used to predict the strength of an RF signal at a particular distance. It is crucial to find the balance between battery performance and long-range communication. Higher SF requires longer airtime to send data compared to lower SF thus consuming more battery power. However, the extended airtime allows for better sensitivity.

2.2. Literature review survey

We have reviewed some of researchers which has designed system that implemented wireless sensor network (WSN). Wang et al. [10] in their publication has designed a monitoring system for sewerage based on ZigBee. To overcome communication issue between sensor and base station and to increase the communication distance, multi-distributed nodes was proposed by them which resulted in 80% of reliability. On the other hand, Geetha and Gouthami [11] presented a smart IoT-based water quality monitoring system in their paper. It was less complex and is cost-effective. Cloete et. al. [12] provided a thorough system design which is also IoT-based for water monitoring. The system can detect water contamination in the water bodies. ZigBee module was used as communication system between the nodes in which it will gives off alarm when unsafe levels of water quality is detected. The farthest distance that the system can work in non-line-of-sight is 13m, a very big achievement for small scale study. Similar with Cloete et. al. [12], Rekhi et. al. [13] published their research work on monitoring pollution in water system.

Jiang et. al. [14] took into account the water temperature in their water monitoring system. They reported that their system can monitor the temperature and pH of water with high accuracy. Similar with other reported researches, they also used ZigBee protocol to design the monitoring system software. However, they did not report on how far their wireless communication will be able to work. Table 2 below outlined the summary of researches done by various authors. The trend that can be observed was that all the systems aims to monitor the data from longer distance with different settings input. Based on the table, most researchers reported on using ZigBee transmitter and receiver due to its long-range distance and ease of operation. It was known that ZigBee usage in the automation (monitoring) system possess many advantages such as low power consumption, battery that can lasts longer and can be easily tailored according to needs [15]. When there is low power consumption, overall cost can be lowered which is good for industrial purpose. There is another module that currently is gaining attention, named XBee ZB [16, 17].

Table 2. Summary of past research by various authors.

Method	Result	Ref.
● Wireless sensor network based on ZigBee	A monitoring system of WSN and GPRS technology was successfully designed.	[10]
● UART protocol ● Data stored in Ubidots cloud	A low cost and less complex monitoring were proposed.	[11]
● ZigBee receiver and transmitter modules	Wireless communication of 13 m was achieved.	[12]
● Platformed on WSNs and RFID systems	Tags to be deployed on the waterway banks to allow sensor to detect position of pollution.	[13]
● Main processor: MSP430F1611, co-processor: CC2430 ● Zigbee Radio Frequency Module ● LCD display	The system successfully performed online auto-monitoring of an artificial lake.	[14]
● 3G network and Winsock MySQL database	Data transmitted using 3G network to the server	[18]
● Microcontroller: Arduino Uno R3 ● LabVIEW as a front panel for the user interface	The parameters are observed through direct connection of the Arduino and LabVIEW successfully.	[19]
● ZIC2410 single-chip microprocessor ● ZigBee protocol system	Designed a real-time monitoring of inpatient physiological signal within hospital.	[20]

3. Future perspectives

Water parameters to be measured include water salinity, conductivity and temperature. A cloud server is to be configured as a data repository. In the future, data collected should be displayed in a remote PC. Also, the system needs to be cost effective and requires minimum maintenance. This system is still new in terms of its development. There are still room for improvements to be done on it. Some of the suggestion includes PCB fabrication of the electrical components in used. Eventhough the use of electronic parts is considered minimum, a PCB fabrication would provide better and more secure connection between the components as opposed to jumper cables. There are four main components that needs more focus which are mechanical, electrical, software and documentation. The software component consists of the Arduino IDE and a user interface in which the Arduino IDE serves as a platform to code the program. The user interface should act as a front end to monitor the water parameters without having to read through lines of data. The electrical component of the system includes the PCB design, microcontroller, power source, sensors and display should be capable of long-distance wireless communication. The power source must be able to provide for long periods of time. The display is not a necessary part but would be helpful for early detection of any issue. In the mechanical part, there is the system housing. Existing research provides a better understanding of what the market needs. The products that are currently available in the market either store their data in a local storage, in their brands' cloud system or both. There is a redundancy of data stored and this results in waste of data space. For domestic uses, there is no data collection for observation as it is only available for products of professional uses. Therefore, a system that allows users to monitor current and past readings and obtain the data for their own analysis should be designed.

4. Conclusion

Currently, usage of LoRa is very limited despite of volume of research done. Most deployed systems stored the data collected internally and can only be obtained every few weeks or months where personnel would have to physically return to the deploy site. In this paper, we have briefly reviewed the current available system for water quality monitoring. LoRa system is one of the promising technology due to its competitiveness, technical advantage and its potentiality for IoT application which is using wireless sensor networks. Two main objectives in the existing studies reported were designing low-cost system and ease of operation. Future improvements that can be made include extensive study on the components that can provide better and secure connection such as PCB fabrication, able to work in longer periods and able to monitor current and past reading easily.

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References

[1] European Environment Agency (EEA) 2018 *Environmental Indicator Report 2018* (Luxembourg: Publications Office of the European Union)
[2] Avdan Z Y, Kaplan G, Goncu S and Avdan U 2019 *ISPRS Int. J. Geo-Inf.* **8** 553
[3] Cho S, Akyildiz I F, Bender M D and Uzunalioglu H 2002 *Wireless Networks* **8** 403-415
[4] Shen H 2001 *Applied Mathematics and Mechanics* **22** 270-281
[5] Slauson J 2016 *The Bloomsbury Encyclopedia of Design Volume 2* (London: Bloomsbury Academic)
[6] Mikhaylov K, Petajajarvi J, Makelainen M, Paatelma A and Hanninen T 2015 *IEEE Sensors*
[7] Semtech Corporation 2014 *Annual Reports* (Washington D.C.: United States Securities and Exchange Commission)
[8] Noreen U, Bounceur A and Clavier L 2017 *3rd International Conference on Advanced Technologies for Signal and Image Processing (ATSIP2017)* pp. 1-6

[9] Reynders B, Meert W and Pollin S 2016 *23rd International Conference on Telecommunications (ICT)*
[10] Wang S, Horoshenkov K, Tait S, Abd-Alhameed R, Hu Y, Elkhazmi E and Gardiner J 2009 *Asia Pacific Microwave Conference*
[11] Geetha S and Gouthami S 2016 *Smart Water* **2** 1-19
[12] Cloete N A, Malekian R and Nair L 2016 *IEEE Access* **4** 3975-3990
[13] Rekhis S, Ellouze N and Boudriga N 2012 *8th ACM Symposium on QoS and Security for Wireless and Mobile Networks*
[14] Jiang P, Xia H, He Z and Wang Z 2009 *Sensors* **9** 6411-6434
[15] Tomar A 2011 *Element 14: the knode* 1-24
[16] Piyare R, Lee S R 2013 *International Journal of Scientific & Engineering Research* **4**
[17] Kuzminykh I, Snihurov A, Carlsson A 2017 *14th International Conference The Experience of Designing and Application of CAD Systems in Microelectronics* pp. 133-136
[18] Huang Y, Chou C, Jau J and Sandnes F E 2010 *7th International Conference on Autonomic and Trusted Computing*
[19] Taru Y K and Karwankar A 2017 *International Conference on Computing Methodologies and Communication*
[20] Song A, Si G 2017 *29th Chinese Control and Decision Conference* pp. 2618-2621