IoT Application in River Monitoring: Methods and Challenges

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Abstract - Water pollution is a major threat both locally and globally to the sustainability of clean water. In Malaysia, river is a major source of water. Industry output, chemicals from agriculture sectors and constructions, sewage and water waste make sustainability of clean water a big challenge. Hence, the need for continuous and effective monitoring of river in order to maintain the water quality (WQ) of river. The existing methods of river water quality monitoring in Malaysia are Manual Water Quality Monitoring (MWQM) and Continuous Water Quality Monitoring (CWQM). These methods are non-real time, less effective, inaccurate of data collection and also costly to be implemented. The use of internet of things (IoT) for real-time monitoring and analysis of water quality in rivers in Malaysia. Also has becoming famous these days because it provides solution to the consumer cover from short-range communication until long range communication technology. The aim of this paper is to identify different method for river monitoring and discuss the challenges of these methods so that more effective solution can be produce.

Keywords - IoT. River Monitoring, Water Quality, Challenge, Methods, LPWAN

I. INTRODUCTION

River is considered to be very important as a source of water, for habitat, agriculture, and recreation[1]. Over the past few years, water quality issue has been critical issue that needs to be solved with an excellent solution. Malaysia is a country whereby its urbanization and population shows a rapid growth. This means that clean water demand is increasing as well as increased threat of water pollution. World Wide Fund (WWF) Malaysia has stated that water pollution is a major problem instead of other factor that affect water sustainability.

Water pollution can be caused by waste from industry, agriculture, human life and Eco life. The need to get a clean water resources has led to a various inventions and solutions [2]. In order to maintain the quality of water, monitoring must be done but traditional monitoring is time consuming and not efficient this day as it may be costly and need more man power to take the sample of water and test the quality in the lab. Currently, Malaysia uses two types of monitoring which are manual water quality monitoring (MWQM) and continuous water quality monitoring (CWQM) [3].

There are also plenty of solution that utilize the use of IoT for monitoring purpose and every existing method have their own challenges. Hence, this paper aims to differentiate the methods and challenges for smart river monitoring and propose a better implementation for real-time river monitoring. Internet of Things has been recognized as one of the most famous solutions for monitoring and it is spanning from short range communication until long range communication. There are some drawbacks from the use of short-range communications such as WIFI, ZigBee and Bluetooth for communication technology that it costly, power consuming, short range of coverage and mostly is for the flexibility of this technology. Therefore, Low Power Wide Area Networks (LPWANs) are the most suitable communication technology to be implemented for this project. The new implementation method, water sensors are used to monitor important parameters for water quality and the use of cloud server. The main idea for this project will be smart water monitoring system using Sigfox as one of the LPWANs communication technology with water sensors and use of IoT cloud server.

The rest of this paper is Section II of this paper will discuss about previous existing method while section III will discuss the challenges of existing methods. Section IV covers the proposed method and section V concludes the paper.

II. METHODS

In this section, the existing method of monitoring river is presented. There are three existing method that is manual water quality monitoring, continuous water quality monitoring and IoT methods for real time water quality monitoring. All these methods are discussed further in this section.

A. Manual water quality monitoring

In manual quality water monitoring (MWQM), over 1064 manual stations in 146 rivers in Malaysia that are being monitored and the time the monitoring take per station is only four to twelve time in one year [4]. There are six parameters that being used for MWQM. That is temperature, salinity, dissolve oxygen, turbidity, conductivity and pH. These parameters are taken as in-situ measurement. After that, the sample of water will be taken for lab analysis and it includes 24 chemical and biological parameters.

The water then needs to be classified using water quality index (WQI) which then it will be rooted to Interim National Water Quality Standard (INWQS). The INWQS define the class of river and the beneficial use of water. Table I will show the beneficial use of water based on their classes. WQI show the extensive of data on water quality to be simplified and put it into an aggregated set of parameters[5][6]. Table II shows the DoE-WQI classification.

| TABLE I |
but with different communication technology and use of IoT that is purposes, there are plenty number of solutions that utilize the of IoT for monitoring purposes covering all aspects like

C. Internet of Things Method

Internet of things has been known as the latest technology and the main idea of this IoT is to keep everything connected to the Internet. Many people have applied the use of IoT for monitoring purposes covering all aspects like agriculture, environment, smart city etc. For river monitoring purposes, there are plenty number of solutions that utilize the use of IoT that is [7],[8],[9],[10],[11],[12],[13],[14],[15],[16],[17],[18] and [19] but with different communication technology and different implementation method. The communication technology spans from short range until long range and each of them has their own pros and cons. Some example of short-range communication technology is Bluetooth, Wi-Fi and ZigBee. While some example of long-range communication technology is Sigfox, LoRa and NB-IoT. Table III and Table IV show each specification and difference of the communication technology. These table are based on the research that has been done by [20],[21],[22] and [23].

### Short Range Communication Technologies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOQI</td>
<td></td>
<td>I 10-15</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>I &gt;7</td>
</tr>
<tr>
<td>TSS</td>
<td>mg/l</td>
<td>I &gt;25</td>
</tr>
<tr>
<td>Water Quality Index (WQI)</td>
<td></td>
<td>I &gt;92.7</td>
</tr>
</tbody>
</table>

### Long Range Communication Technologies

<table>
<thead>
<tr>
<th>Modulation</th>
<th>Up: D-BPSK</th>
<th>Down: GFSK</th>
<th>sigfox</th>
<th>NB-IoT</th>
<th>Lora</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>Depends on country</td>
<td>Licensed LTE frequency</td>
<td>Depends on country</td>
<td>200kbps</td>
<td>LoRa: 0.7-37.5kbps FSK: 50kbps</td>
</tr>
<tr>
<td>Range</td>
<td>Urban: 10km Rural: 50km</td>
<td>Urban: 1km Rural: 10km</td>
<td>Urban: 5km Rural: 15km</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Short-range communication has their own pros and cons and one of the disadvantages is that it covers only for short distance and it is not suitable to be used for wide area space that require long coverage. Therefore, there is a need for long-range communication technology, and we must choose what communication technology is the best to be used for monitoring purposes.

III. CHALLENGES

In this section, challenges from different methods are identified and this section is crucial because once the challenges are being identified, a new effective solution can be proposed. The challenges that have been identified are as follows:
A. Cost

All the methods that have been mentioned in section II that is costly for river monitoring, whether manual or automatic these challenges are crucial for monitoring purposes. For MWQM require to have some equipment which is costly, and we are required to take different sample in different location which are also time consuming[24]. Same goes to CWQM, they need to deploy at the station and consider the cost for equipment installation which also time consuming[25]. The location to build CWMQ and maintenance of the station needs to be considered. Even though IoT has brought some solutions that low in cost from the other method but there are some of the communication technology that are costly and use a lot of energy which is also not effective to be applied for river monitoring purposes.

B. Flexibility

MWQM and CWQM are not flexible because as for MWQM human personnel are needed to come there for in-situ parameter measurement and then take the sample to the lab for lab analysis which manual reading were undertaken in MWQM. CWQM needs the equipment to be installed at the station and cannot be used for other monitoring purposes otherwise it will require a lot of budget[26]. Some of the IoT solutions for monitoring river are also not flexibility because of the design it can only be used for river purpose especially when we used short-range communication that have limited coverage which can only cover small area. Moreover, short-range communication consume a lot of battery usage and it make it even more inflexible.

C. Accuracy of Data

Some drawbacks of utilizing MWQM and CWQM is the accuracy of the data. In the MWQM taking and report of measured data is prone to human errors. In addition, the low frequency of taking MWQM of rivers leads to late detection of water pollution. This result to late action by respective authorities. On the other hand, in the CWQM, the accuracy of the in-situ measurement is prone to errors due to covering of the probes either by dirt or organism[26]. That is why real-time monitoring system are needed because we can get the data that we want in good time. The use of IoT is considered a perfect solution for these problems. However, there are some IoT communication technology that not support real-time data. Although IoT solutions promised real-time data monitoring, the accuracy of data still an issue and it all is depending on the method on how the sensors are mounted on the river. For example, the authors in [27] proposed that sensors are mounted in the river continuously. This situation will affect the sensors reading which also can affect the accuracy of data.

IV. PROPOSED METHOD

The proposed method for this study comprises of the implementation of LPWANs communication technology that is Sigfox, multiple water sensors, robotic arms and platform for monitoring that is android application and web monitoring tools. The proposed method is shown in Figure 1. The data that has been gathered from several sensors that include several parameters will be send to the Sigfox gateway via Sigfox IoT device. The gateway will send the data to the Sigfox backend server. From the backend server, the data are forwarded to the application server. The IoT device will be developed by using Pycom-Fipy that act as microcontroller and has some features of ultra-low power usage and it can switch to different communication technologies such as Bluetooth, LoRa, NB-IoT, Wi-Fi and Sigfox. Several sensors include temperature sensor, pH sensor, Dissolved Oxygen sensor, Turbidity sensor, Waterproof water level sensor and Electrical Conductivity sensor are used to carry out the parameter value of river for water quality. The IoT device will be mounted with the robotic arm to measure the in-situ parameter of the river for monitoring. Every 15 minutes the robotic arm alongside with the IoT device will automatically set to measure the parameter of the river. The reason why it is set to 15 minutes is because Sigfox can only send 140 messages per day, so it means that if it was divided with 24 hours it will be 15 minutes per message. Data that has been collected can be monitored using mobile device. Figure 2 show the microcontroller architecture and Figure 3 show the use case design.
A. Sigfox

Sigfox communication technology is one of the LPWAN technologies that provide some features like provide long range of communication, long power that can lead to long battery life and low-cost communication characteristics [23]. Sigfox can listen to billions of objects without the need to establish and maintain network connections. Instead of managing the entire network and computing complexity on the devices, Sigfox offer some communication solution whereby it can be done in the cloud. Thus, provide more efficiency in term of energy used and connected devices cost. Sigfox base station connected to end devices using D-BPSK modulation for uplink transmission in ultra-narrow band (100Hz) sub-GHz spectrum with maximum of 100bps. The reason for using D-BPSK modulation is because it is easy to implement, then low bit rate enabled low cost component and high sensitivity of base station. As Sigfox signal power focus on narrow band, it provides great robustness against interference. The energy concentration of Sigfox signal enables the base station to easily demodulate even if more powerful but more spread interference signals are received simultaneously. Sigfox utilizes unlicensed ISM band and uses default channel at 868.130 MHz and different frequency in another country for example 868 MHz in Europe, 915 MHz in North America and 433 MHz in Asia. Sigfox also utilizes lightweight protocol for small messages that bring more benefit in term of energy efficiency because less data sends led to less energy consumption hence longer battery life. The maximum uplink transmission data is 12-bytes payload, that means 140 messages per day and for the downlink it is restricted to 8-bytes payload which means 4 messages per day. The transmission will take an average of 2s on the air to reach the base station which can monitor the spectrum that look for UNB signals to demodulate. Overall summary for uplink transmission is for payload it will be 0 to 12 bytes payload, the modulation will be D-BPSK, the bitrate will be 100 or 600 bps depends on operation region and the device transmission power will be 22dBm ERP max (RCZ 2) as for the downlink transmission the payload will be 8 bytes of payload, the modulation will be GFSK modulation, bitrate will be 600 bps and lastly the device receiver sensitivity -132dBm for optimal service level [7]. Sigfox uses star topology which billions of objects transmit messages to Sigfox network, when the radio signal sent reaches the base connected within the range. Every single base station deployed around the world by Sigfox network operators is directly connected to Sigfox cloud thanks to point-to-point link. These base stations detect demodulate and report the messages to one and only Sigfox cloud. The Sigfox cloud pushes the messages to many customer servers and IT platform.

B. IoT Device

The IoT devices have been customized with the use of new implementation method and to be used as river monitoring tools for water quality. The new implementation is to use the robotic arm and the IoT device will be mounted on the robotic arm to monitor the quality of river efficiently. The water quality parameters are based on [3] work which has been used currently in Malaysia. There are six parameters that are chosen to be monitored that is the electrical conductivity, turbidity, pH, dissolved oxygen, water level and temperature. The deployments of this proposed system are to be used with the IoT central unit that is Pycom, LiPo battery power supply, and several sensors.

C. Cloud Server

After some measurement of the water quality data has been taken by the sensors with different parameters. The cloud server which is Sigfox backend server will be used to get the data, processed and send to the customer system. The cloud infrastructure is constituted of Sigfox server and an application program interface (API) where data can be retrieved by mobile application.

D. IoT platform

IoT platform such as dashboard are created and can be used to collect the data, analyse and give the data to users. It also provides some features where we can create our own dashboard, customize the dashboard and just monitor through the dashboard. From the dashboard we can create our own API for monitoring using mobile application. For this project, Wondernica monitoring dashboard has been used as monitoring tools. We can just monitor from the dashboard that has been already created based on the parameters from the water sensors and can customize it so that it is eye catchy. So, at the end of the day we can monitor it effectively.
E. Algorithm for operation of IoT Water Checker Device

First, the water sensors will be put into the river and we need to wait for 2 minutes because the time taken for sensor to get the stable reading is 1 minute and consider time taken for the sensor reading to be send to the Sigfox backend server. Next, retrieve back the data from Sigfox backend server for monitoring purposes and wait until 15 minutes for next data. Lastly, repeat all the steps for the algorithm.

IV. CONCLUSION

In this paper all the different method of water quality measurement in river have been identified and discussed. Some of the challenges of the existing method have been discussed. The use of low power wide area communication technology Sigfox has been proposed for overcoming some of the limitation of existing methods. In the future the proposed solution will be implemented and evaluated.

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[6] O. Access, “We are IntechOpen , the world ’ s leading publisher of Open Access books Built by scientists , for scientists TOP 1 %.”