Low-Cost Garbage Level Monitoring System in Drainages Using Internet of Things in the Philippines

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Abstract

A common problem in a developing tropical country like the Philippines is the flooding during downpours. One of the causes is the clogging of drainages due to garbage accumulation, which results in overflowing. A countermeasure to minimize this problem is the deployment of an internet of things-based garbage monitoring system. In this system, the ultrasonic sensors were used to provide input data on the level of the garbage in the drainage. These data were then transmitted to the web application for visualization. A message, informing the status of the garbage level in real-time, was sent to the registered user. Also, a strainer was used to serve as a stopper of the accumulated garbage in the drainage. This strainer was set up in the middle of the manhole so that the detected level of garbage and water would be compared. In addition, the ultrasonic sensors were mounted on the top and the back of the strainer to detect the garbage level and serve as a comparative sensor, respectively. Furthermore, to assess the performance of the developed system, several tests were conducted in Cebu City, Philippines. These tests included the short message service delay, internet speed, and the garbage level. The results showed that the developed system can effectively deliver its desired operations. However, since the system is reliant on internet connectivity, it is highly recommended to use such in a 5G network.

***Keywords**:* garbage monitoring, garbage collection, IoT-based garbage system, flood control, flood monitoring

1. Introduction

As a tropical country, the Philippines experiences heavy rainfall from August to December. Because of these heavy downpours, flooding is a perennial problem in the lowland urban areas (Chen *et al*., 2017) like that in Cebu City. In this city, flooding in the downtown areas is common even in times of minimal downpours. As observed, the drainages easily overflow because of the very noticeable accumulation of garbage (Thanvisitthpon *et al.*, 2020). Several countermeasures had been implemented by the local government units to address this garbage accumulation. Some of these were the scheduled cleaning of the drainages. Also, the national government invested millions to reconstruct the drainages to improve the performance of flood management system. Also, several city ordinances had been passed for implementation by the stakeholders. However, such problem has been recurring over the years. In this light, it is crucial to develop a system that can monitor the garbage level in real-time such that the concerned agency can be advised on the actual status of garbage in the drainages. In this manner, timely garbage collection in drainages can be achieved. The system should be low-cost so that the government can install it in all drainages in Cebu City.

To effectively develop this garbage monitoring system, a thorough literature review was done. Several articles had presented about the garbage monitoring using electronic means. Shyam *et al*. (2017) developed an IoT-based system for trash bins with smart features. It has an ultrasonic sensors to determine the level of the garbage inside the bin. With IoT, the user can have a real-time monitoring of garbage level status. One of the limitations of the system was the inability to distinguish solid ond liquid wastes. Also, similar innovations had been created that include the sending of short message service (SMS) using the global systems for mobile (GSM) module to the users containing the key information about the status of the trash bin (Ghadage and Doshi, 2017; Jain and Bagherwal, 2017; Malapur and Pattanshetti, 2017; Kumar *et al.*, 2017). Their works excluded the use of visual indicators to advise the user on the status of the trash bin and a feature that is capable of segregating the types of wastes. Moreover, these inventions had no real-time monitoring on the trash bin status since they were not cloud-based.

A more sophisticated innovation with a real-time monitoring system was presented by Sathish *et al*. (2017). It incorporated a flame sensor to detect the fire and a moisture sensor to segregate the wet and the dry garbage. A future enhancement of the innovation was to use solar panels to conserve energy utilization.

Another garbage monitoring system was made by Idwan *et al*. (2016). It utilized general packet radio service (GPRS) in providing the details of the trash bin. Such system maximized wireless networking technologies to optimize solid waste management through the use of smart dumpsters coupled with waste level sensors. Despite its more advanced features, the system was not tested in large-scale settings.

A trash monitoring system in a trash bin with a force sensor application was developed by Aziz *et al*. (2015). The purpose of this sensor was to monitor the weight of the trash bins. The system utilized image processing concepts to monitor garbage levels. An identified possible improvement of the system was to add color information to further enhance its classification accuracy.

Created by Bharadwaj *et al*. (2016), a more advanced garbage monitoring system used Long Range (LoRa) technology. It can send data via the gateway and then transmit it to the cloud over the internet utilizing the Message Queue Telemetry Transport (MQTT) protocol. The system could be further developed by including a feature that provides an automatic visual indicator to the user regarding the status of the trash bin. Integrating spectroscopy technology, a garbage monitoring was made by Thakker and Narayanamoorthi (2015). It primarily relied on the gathered data of the server as the user's ultimate source of information to have an effective route of garbage collection. Despite its more cutting-edge features, it cannot send SMS at critical stages of the bin.

Also investigated was the trash bin application of Gutierrez *et al*. (2015). In this system, three Light Emitting Diodes (LED) were used to indicate the three different levels of the trashes present in the trash bin. The system was based on the Internet of Things (IoT) for the storage and processing of data. However, the system failed to use sensitivity analysis of the different parameters. This could have provided the system's performance under different operating conditions. A related system was also created by Haribabu *et al*. (2017). It integrated a buzzer to give an alarm once the trash bin is full. This system had the capability of segregating plastic dry waste and biodegradable waste through the integration of methane and smell sensors. For further advancements, the system needs to incorporate an automated mechanism to pick the wastes in and around the trash bin.

Another innovation was published by Muyunda and Ibrahim (2017). This innovation collects sensor data from each trash bin. It then displays the collected data on the webpage to notify the concerned on the status of the dedicated trash bins in target areas. Such innovation can also provide the best route plan for effective garbage collection by the authorities. However, this innovation lacks the basic features of alarm and visual indicators of garbage status. Folianto *et al*. (2015) developed a system that incorporated mesh network and duty cycle features. It exploited the use of ZigBee technology in garbage monitoring. It had three main components: smart bin, gateway, and control station. The identified limitation of this work was that it was not tested in indoor conditions.

The smart garbage monitoring and collection systems were quite numerous in the extant literature. A good example of this was the one developed by Ramson and Moni (2017). In this system, Wireless Monitoring Units (WMU) was utilized in trash bins. The sensor in the WMU can detect the unfilled trash level in the bin. The data were then sent to the Wireless Access Point Unit (WAPU) for processing in the monitoring station. A possible improvement in the evaluation of the system was to test it using both 4G and 5G networks. Another IoT-based system for waste management was the works of Aleyadeh and Taha (2018) and Mirchandani *et al*. (2017). The ultimate feature of these works was its ability to provide an optimal solution for waste collection by minimizing the time length of waste collection through smart means. However, the architecture proposed by the work of Aleyadeh and Taha (2018) is yet to be prototyped for actual implementation and testing. As to the contribution of Mirchandani *et al*. (2017), there is a need to further test the system using different types of wastes and dustbins to ensure that the weight sensor used can effectively function in different types of wastes and dustbin materials.

Other smart garbage monitoring developments were crafted by Chowdhury and Chowdhury (2007), Hong *et al*. (2014), Karadimas *et al*. (2016) and Vasagade *et al*. (2017). These works integrated the Radio Frequency Identification (RFID), GSM, and Geographic Information System (GIS), which provided advantages such as power minimization, low cost, and accurate estimation with a tiny-load fingerprint. However, several loopholes were identified. The communication between waste tags and readers, and readers and back-ends were unidirectional in the system of Chowdhury and Chowdhury (2007). The waste tags used were passive with a minimal storage capacity. Also, there existed a disadvantage in the system developed by Hong *et al*. (2014). It was noted that it needed maintenance cost and there was an identified trade-off owing to the proposed system's battery-based power structure. As for the work of Karadimas *et al*. (2016), the tests conducted should have been done at more granular level to consider the different types of wastes. In the work of Vasagade *et al*. (2017), only basic features namely audio alarm and visual indicators, the wastes segregation capacity, and the online monitoring of garbage status were incorporated.

Another smart system equipped with ultrasonic sensors and GPS features was presented by Fei *et al*. (2017). It was dedicated to an efficient garbage collection of garbage trucks. It could help in waste management by keeping track of trash bin status and the location of trash collection trucks. Like any other online system, there is still a need to test this system in both 4G and 5G environments since it is primarily dependent on a cloud connection. Tiwari and Nagarathna (2017) developed a solar-powered monitoring system that could send its status to the Collection, Logistics, Efficiency, and Notification (CLEAN) system dashboard. It could crush the garbage by the use of Advanced Reduced Instruction Set Computer (RISC) Machines (ARM) 7 controllers. The ARM 7 controllers actuated if the ultrasonic sensor detected a full trash bin. It then triggered the motor for the crushing process. The system was also capable of sending SMS to the registered user to inform the status of the trash bin, allowing the motor to be activated. It had also the capability to segregate the garbage as biodegradable or non-biodegradable. However, the system was not subjected for testing with regards to the different types of garbage to be crushed.

Cloud-based garbage monitoring innovations were also developed. Talha *et al*. (2017) made a cloud-integrated wireless garbage management system for a smart city. This could centrally monitor the temperature, humidity, flammable gas concentrations, and garbage fill volumes. It could detect the presence of fire in trash bins using wireless sensing nodes. The data were gathered by the sensors and then sent to the central station using transmission control protocol (TCP) or internet cache protocol (ICP) via GSM or GPRS. The data was then monitored, analyzed, and stored in the cloud server for real-time retrieval. Based on the evaluation, the system needs to integrate alarm mechanisms and not just real-time monitoring. A similar system with similar features but with added machine learning capability was created by Baby *et al*. (2017). The built-in ‘machine-learning’ can gather data daily on the amount of garbage generated in the area. Based on the gathered data, it could predict the daily amount of waste that can be accumulated in the future. The analyzed data were stored in the cloud in the form of a graph. The system could also send emails and text messages to the users whenever the level of the waste in the trash bins had exceeded the set threshold level. A good improvement of the system was to implement it in a large scale scenario.

A web-based garbage monitoring development was presented by Wijaya *et al.* (2017). This could enable the authorities to graphically check the status of the wastes on a daily, weekly, and yearly basis. It used a weight sensor to determine the number of wastes inside the trash bin. A minimal limitation of the system was the absence of a feature that segregates the types of wastes inside the bin. Reddy *et al.* (2017) developed a similar and embedded system that could detect the presence of harmful gases in trashes and inform the people nearby. This innovation was a good example of garbage monitoring using an embedded system. One disadvantage of the system was its inability to monitor in real-time the status of the trash bin. Also, more sophisticated system was carved out by Hannan *et al.* (2016). It maximized the usage of content-based image retrieval features. It used the Gabor wavelet filter, gray level co-occurrence matrix (GLCM), and gray level aura matrix (GLAM) in determining the level of the trash present in a bin and its surroundings. A technical limitation of the system was its image acquisition. There were areas inside the bin that were considered as blind spots.

The concepts and applications of garbage monitoring and collection are very well-pronounced in the extant literature. Numerous authors and inventors had presented several works in the field of effective garbage management. However, these contributions are mostly focused on trash bins with a minimal development specific to garbage monitoring in urban drainages. Hence, it was the primary intention of this paper to put forward a literature that describes the deployment and installation of a low-cost garbage monitoring system in urban drainages. The system as presented in this paper provided a solution in the clogging of drainages due to the accumulation of garbage. In this manner, the paper could contribute to the alleviation of floods in a developing country like the Philippines.

2. Methodology

2.1 System Overview

The system overview is shown in Figure 1a. The monitoring and alert systems as deployed in the actual drainage locations transmit the drainage status to the cloud using the Internet of Things features. The user can do real-time web monitoring via the smartphone. Also, the user can receive updates on the drainage status via SMS. The interconnectivity of the specific elements used in the system is shown in Figure 2b.

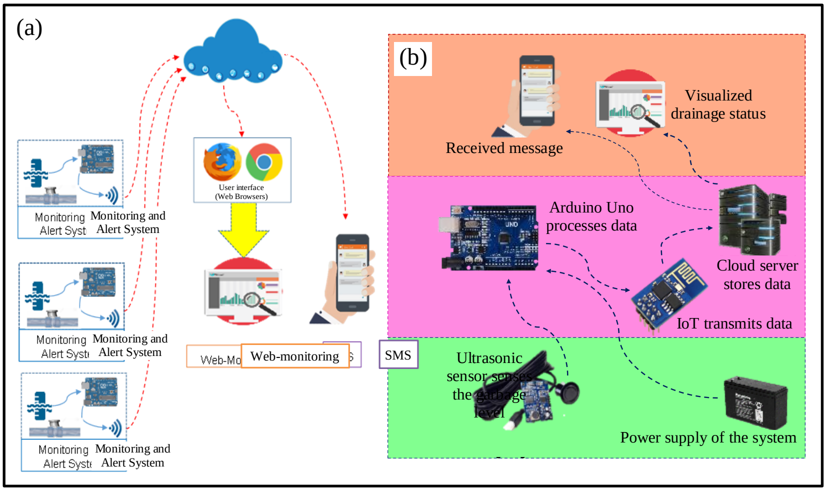

Figure 1. The interconnectivity of the system elements

The monitoring and alert system consists two ultrasonic sensors as input elements, Arduino Uno microcontroller, and IoT module. The power supply is used to provide energy to the system. Such supply includes a buck converter. Moreover, the ultrasonic sensors are used to detect the garbage level in the drainages in real-time. These garbage level data are processed by the Arduino Uno microcontroller. Such data are then transmitted to the cloud through the IoT module. IoT module sends the data to the cloud server so that the monitoring station with the web application can visualize the status and condition of the drainage. Through the same IoT module, such a status of the drainage is forwarded to the user in real-time using SMS notification. The transmitted status includes the specific location of the drainage and its garbage level. A pictorial diagram of the placement of elements of the monitoring and alert system is shown in Figure 2.

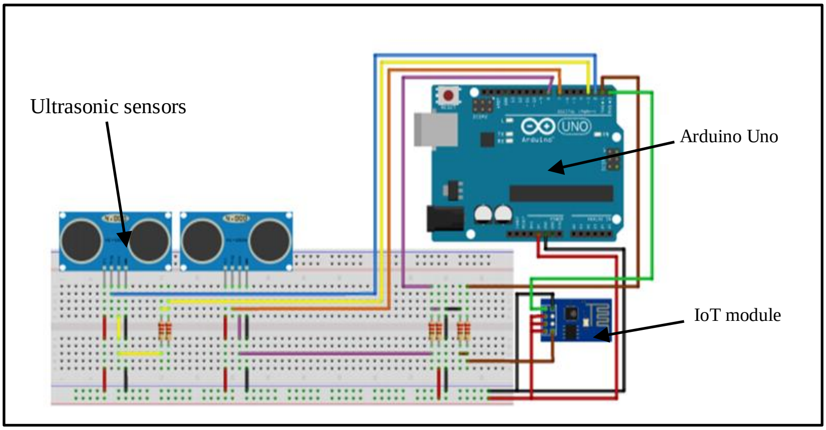

Figure 2. The system board with the connectivity of elements of the deployed monitoring and alert system

2.2 Drainage Structure

The system was deployed in the three different locations within Cebu City, Philippines: M.J. Cuenco Avenue, Eduardo Aboitiz Street, and Bonifacio Street. The actual pictures of the drainages from the three locations before the actual deployment are shown in Figures 3.

Figure 3. The actual drainage status of the manhole in M.J. Cuenco Avenue (a), Eduardo Aboitiz Street (b), and Bonifacio Street (c) before actual system deployment

Before the actual deployment, the actual sizes of the manhole per drainage were determined are indicated in Table 1.

Table 1. The actual dimensions of the manholes of the three drainages

Area	Size (cm)
M.J. Cuenco Avenue	91.44 x 78.74 x 92.71
Eduardo Aboitiz Street	127 x 55.88 x 66.04
Bonifacio Street	91.44 x 55.88 x 66.04

2.3 System Placement Model

The system model during deployment is shown in Figure 4. The system cabinet (Figure 5) consisted the power supply system with the buck converter. Such a cabinet also contained the Arduino Uno microcontroller and the IoT module. Fixed in the traffic signpost, the cabinet was placed 2 m above the ground to prevent it from submerging in water in cases of floods. Also, a strainer was used as a stopper of the accumulated garbage in the drainage. The strainer was set up in the middle of the manhole so that the detected level of garbage and water would be compared. Furthermore, the ultrasonic sensors were mounted on the top of the strainer and the back of the strainer. The sensor on the top of the strainer was used to detect the garbage level while the sensor at the back of the strainer was used as a comparative sensor.

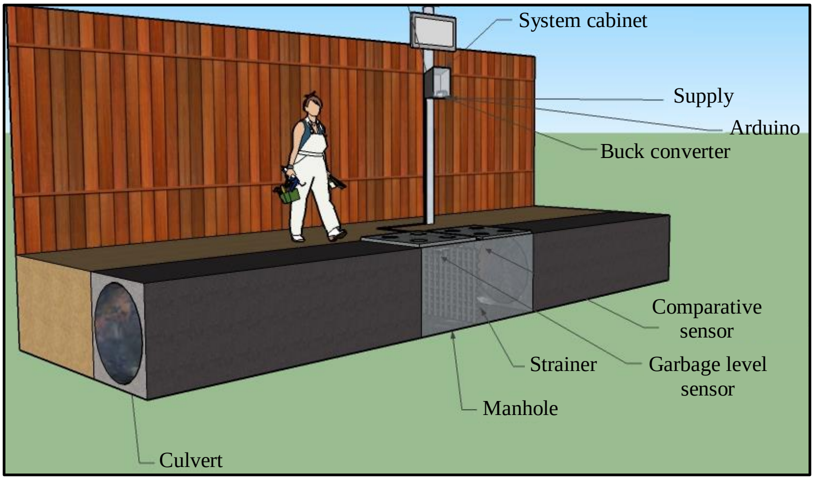

Figure 4. The system deployment model

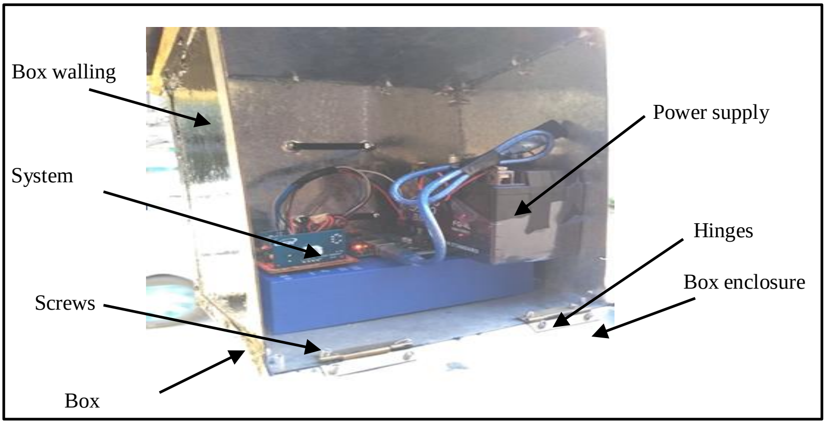

Figure 5. The system cabinet containing the Arduino Uno microcontroller, IoT module, and power supply

2.4 System Deployment

The system was deployed in the three different locations as shown in Figure 6. The deployments were done on a sunny day. Before the actual mounting of ultrasonic sensors and the strainers, the garbage inside the drainages was removed.

Figure 6. Actual system deployment at M.J. Cuenco Avenue (a), Eduardo Aboitiz Street (b), and Bonifacio Street (c)

2.5 System Cost Consideration

In the construction of the system cabinet, the researchers used recycled and disposable materials for the box frames, box walling, box enclosure, screws, and hinges. Also, the connector wires as used were taken from the disposable connector wires from an electronics engineering laboratory. With the utilization of these available recycled materials in the system, it can be considered as lower in cost compared to those systems created from brand new materials.

2.6 Garbage Levelling

The leveling of the garbage in the drainages was standardized as shown in Table 2. Regarding the Department of Engineering and Public Works, the standard size of the drainage in Cebu City is 60 cm in height, 60 cm in width, and 60 cm in length. Based on these dimensions, in the absence of water, the maximum computed volume of garbage that can be accumulated in the drainage beneath the manhole's cover is 216, 000 cm^3. Furthermore, the depth was considered as the distance from the ultrasonic sensor to the garbage. When the garbage level reaches level 3 (critical level), a notification is sent via SMS in real-time informing the user that the drainage needs to be cleaned up. Since the drainages had different dimensions, the garbage leveling differs in each location.

Table 2. The garbage level with a corresponding equivalent status

Level No.	Garbage Level		Status
	(M.J. Cuenco)	(Aboitiz & Bonifacio)	
1	93 cm	66 cm	Not critical
2	75 cm	53 cm	Slightly critical
3	56 cm	40 cm	Critical
4	38 cm	27 cm	Highly critical
5	19 cm	13 cm	Very Highly Critical

2.7 Actual System Data Gathering Procedure

Figure 7 shows the actual setup of the data gathering from the hardware system to the SMS notification. The hardware system was composed of the Arduino Uno microcontroller, ultrasonic sensors, and the IoT module. The collected data were transmitted by the IoT to the web application at a two-minute interval. The web application received the data and stored these in the database. Through the query process, the web application extracts the needed data from the database. Moreover, via the same web application, a text message containing the garbage level status is sent to the registered user via the subscriber iTexmo.com.

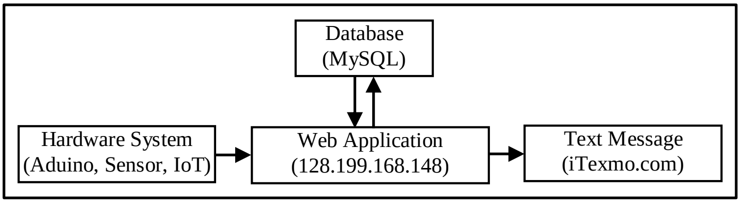

Figure 7. The data gathering procedure

2.8 Validation of the System Connection

Before the deployment of the system, validations of the system connection using the internet were performed. The validations were done to determine the number of errors and failures occurred when the system sends data to the web application. The results were seen in the serial monitor of the Arduino Integrated Development Environment (IDE). Such IDE established the connection between the Wi-Fi Module and web application. In this validation procedure, 30 connectivity trials were made.

2.9 SMS Time Delay Test

The purpose of this test was to determine the transmission delays of the SMS from the time of transmission to the time of reception. This was done to identify the best network pair to be used in the system. This was performed by transmitting a “hello” message from location 1 (M.J. Cuenco Avenue) to location 2 (Eduardo Aboitiz Street). The transmission and the reception time was recorded using synchronized and calibrated timers. The difference in the transmission and reception times served as the transmission delays. This process was repeated for 30 times using different cellular networks. The available cellular networks were Globe, Sun, and Smart.

2.10 Internet Speed Test

This test was to identify the internet speeds of the two available internet service providers in the area namely, Globe and Smart. It was crucial to identify the internet speed to properly select the network that could provide higher speeds in data transmission from the IoT module. The test was performed by recording the upload and download bit rates in terms of megabit per second (Mbps) of the two networks at location 1. The data of the internet speeds of the networks were recorded at the same time (7 PM).

2.11 Garbage Level Test

The data obtained in the garbage level test originated from the ultrasonic sensors. The ultrasonic sensor automatically emitted a signal in the kilohertz range. This triggered the transmission of a high-level signal of at least 10 microseconds in duration. As the signal hits the garbage or water, the signal is reflected in the ultrasonic sensor. The propagation time of the signal from its transmission until the reception of the ultrasonic sensor was computed. Such time information was used to determine the depth or level of the garbage or water using Equation 1.

$$D_t = \frac{(T_{high\ level})(S_{sound})}{2} \tag{1}$$

where:

D_t = test distance, m
$T_{high\ level}$ = high level time, s
S_{sound} = speed of sound (343 m/s)

The computed distance was used to determine the extent of the garbage level. The greater the computed distance, the farther is the level of the garbage and water from the ultrasonic sensor. This indicates that the status of garbage or water is not that critical. Conversely, the shorter the computed distance, the closer the distance of the water and/or garbage to the ultrasonic sensor. Such status is very critical that needs immediate action from the concerned user.

3. Results and Discussion

3.1 Validation of the System Connection

In the validation, the study conducted 30 trials of connectivity. In these trials, the system was able to send all the data without failure. Figure 8 shows the serial monitor of the Arduino IDE wherein the validations were made. The establishment of a connection between the IoT module (ESP8266) and the web application was made possible through the Attention (AT) commands. At line 0, AT command printed OK means that the ESP8266 was ready to establish a connection to the Wi-Fi. Line 1, AT+CWMODE =1 printed OK means that the ESP8266 was looking for internet access being programmed. Line 2, AT+CWJAP=" Anime", "qwerty123" printed OK implies that the ESP8266 had found the programmed network where it established its connection in sending the data. Printed "Connected" signals that the ESP8266 had a connection with the network. The "garbage Ping: 28 cm" and the "water sonar Ping: 28 cm" indicate that the data were gathered by the sensors and were successfully transmitted to the web application. Also, at line 3, AT+CIPMUX=1 suggests that there were multiple data to be sent. Also, at line 4, AT+CIPSTART =0, "TCP","128.199.168.148", 80 printed OK means that there was a sending of the data to the TCP-Internet Protocol (IP) with an address of 128.199.168.148 in port 80. Moreover, at line 5, AT+CIPSEND=0 printed OK means that the data were already sent to the TCP-IP. Lastly, AT+CIPCLOSE=0 printed OK implies that the ESP8266 was going to temporarily cut-off its connection to the WiFi and be prepared for the next transmission of data.

```
garbage Ping: 0cm
waterSonar Ping: 0cm
garbage Ping: 0cm
waterSonar Ping: 28cm
0. at command => AT OK
1. at command => AT+CWMODE=1 OK
Connecting to wifi...
2. at command => AT+CWJAP="Anime","qwerty123" OK
Connected!
garbage Ping: 28cm
waterSonar Ping: 28cm
3. at command => AT+CIPMUX=1 OK
4. at command => AT+CIPSTART=0,"TCP","128.199.168.148",80 OK
5. at command => AT+CIPSEND=0,73 OK
7. at command => AT+CIPCLOSE=0 OK
```

Figure 8. A display in the serial monitor of the Arduino IDE showing the establishment of the connection to the web application

3.2 SMS Time Delay Tests

Table 3 is the summary of the SMS time delays of the three cellular network providers. As noted, the average time delays of the three networks had minimal differences. Moreover, in terms of standard deviation, the three networks had also very slight differences. These differences can be considered negligible for the reason that it was roughly one second. Hence, any of the network pairs can be used in the system. Figure 9 shows the time series ploy of the three network's time delays.

Table 3. Comparison of the three networks considering SMS time delays (seconds [s])

	Globe	Sun	Smart
Average SMS Time Delay (s)	9.78	8.58	10.04
Standard Deviation (s)	1.05	0.69	1.05

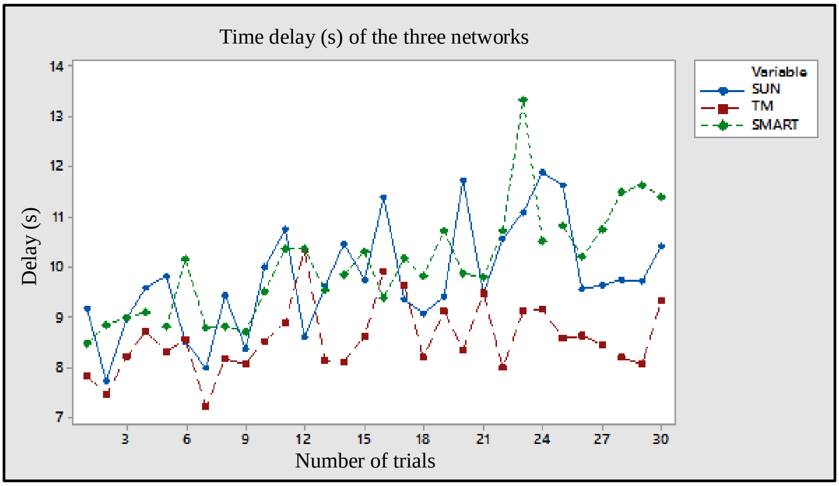

Figure 9. The time series plot of the SMS time delays of the three networks

Internet speed tests were conducted to assess the reliability of the network speeds in terms of upload and download bit rates. This was to ensure that the IoT module can effectively transfer data to the cloud server. Table 4 shows the comparative matrix of the average upload and download speeds of the networks used in the deployment. As observed, there were significant differences between the upload and download speeds of the two network locations as reflected in Figure 10. These significant differences can be primarily attributed to several factors like the proximity distance of the respective cellular sites within the test areas, network traffic, time of the day, and among others. Thus, the choice of the internet network to be used in the system is left to the decision of the users. The users should also reflect on factors like costs and customer services in the final choice of the internet service provider.

Table 4. The upload and download bit rates of internet providers in Cebu City

	Globe		Smart	
	Upload	Download	Upload	Download
Average Speeds (Mbps)	11.62	7.11	0.87	0.46
Standard Deviation (Mbps)	3.52	2.40	0.60	0.39

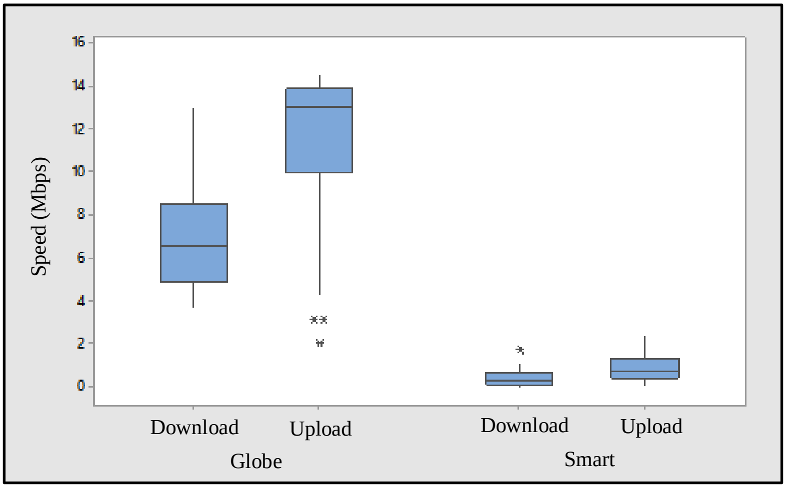

Figure 10. Box plot of the internet speed test considering bit rates of the networks

3.3 Garbage Level Tests

Figure 11 shows the series plot of the garbage level in the drainage when the system was deployed at M.J. Cuenco Avenue. As noticed, the garbage level has changed over time considering 100 data samples. The primary reason for these variations was the random changes in the water level in the drainage and the actual quantity of garbage in it.

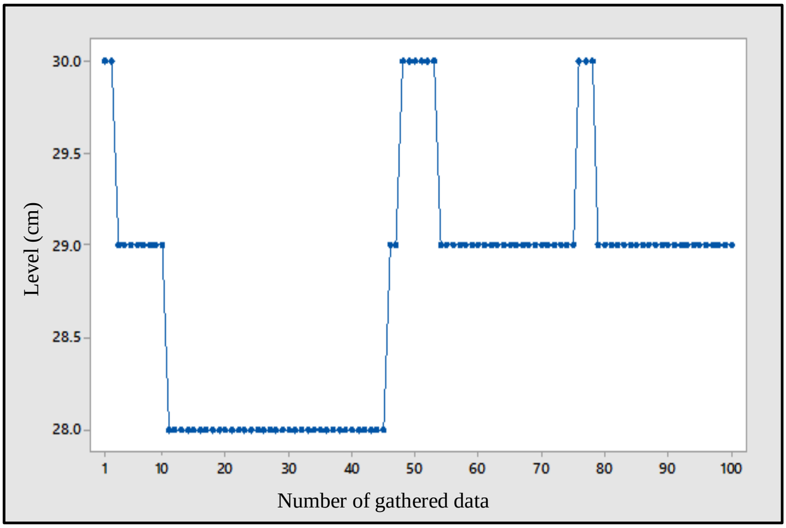

Figure 11. The series plot of the garbage level in the drainage at M.J. Cuenco Avenue

Figure 12 shows the garbage levels relative to the water levels for 100 samples. As noted, the distance of the garbage levels concerning the ultrasonic sensors was lower as compared to the distance of the water levels to the same sensors. Such results were true as expected since the garbage was usually on top of the actual water levels.

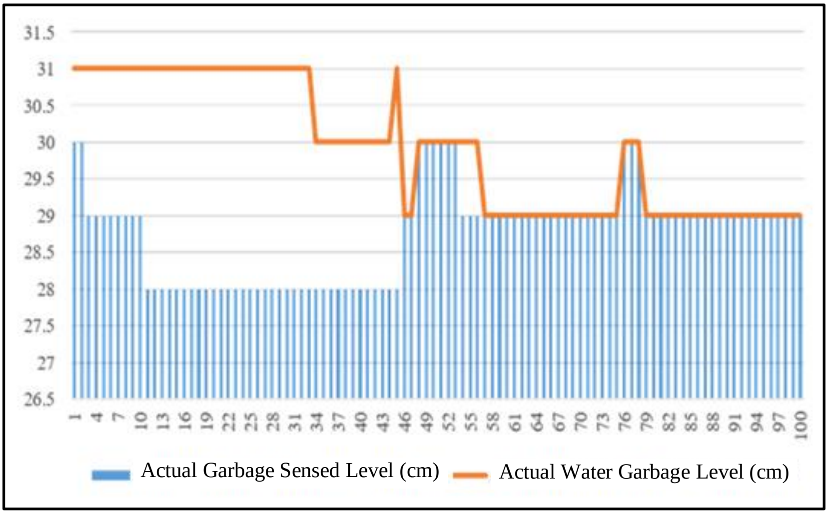

Figure 12. Cluster-column line graph of the actual levels of the garbage and the water in the drainage at M.J. Cuenco Avenue

Figure 13 shows the series plot of the garbage level in the drainage when the system was deployed at Eduardo Aboitiz. As noticed, the garbage level has changed over time considering 100 data samples. It is also shown in Figure 14 that the levels of water and garbage were equal all the time. It indicated that the garbage and water level in this area were constant during the conduct of the experiments. The sensed garbage level was a water level only for there were no changes in the level in the side of the garbage. Another observation in this area was that the level sensed changed at no constant time. It implied that the location of the drainage has a sub-pipe connected to that manhole that threw water wastes from the inner households in the area. Hence, the changes in the level of the garbage and water were affected by the location of the manhole being experimented.

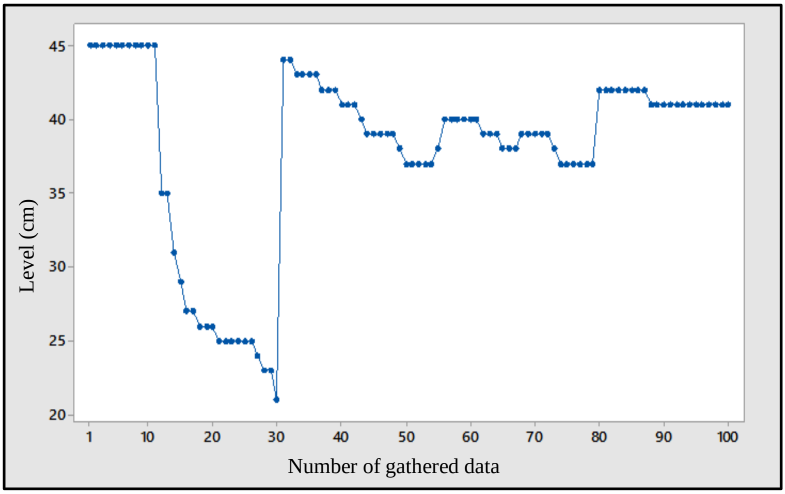

Figure 13. The series plot of the actual garbage levels in the drainage at Eduardo Aboitiz Street

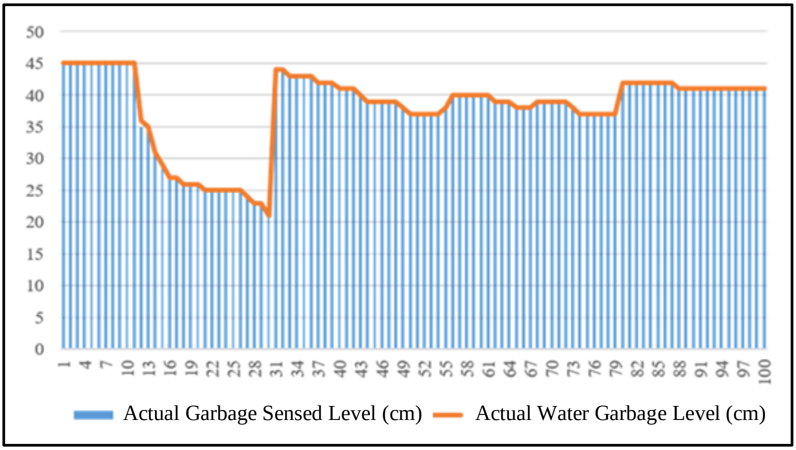

Figure 14. Cluster-column line graph of the actual levels of the garbage and the water in the drainage at Eduardo Aboitiz Street

Figure 15 shows the series plot of the garbage level in the drainage when the system was deployed at Bonifacio Street. As noticed, the garbage level changed over time considering 100 data samples. The primary reason for these variations was the random changes in the water level in the drainage and the actual quantity of garbage in it.

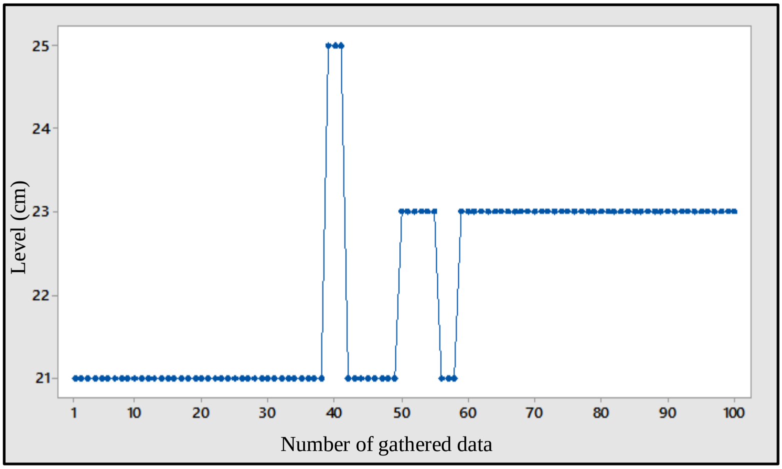

Figure 15. The series plot of the actual garbage levels in the drainage at Bonifacio Street

Figure 16 shows the garbage levels relative to the water levels for 100 samples. As noted, the distance of the garbage levels concerning the ultrasonic sensors was lower as compared to the distance of the water levels to the same sensors. Such results were true, as expected, since the garbage was usually on top of the actual water levels. The graph further shows that when the garbage level changed, the detected level stayed at the level in multiple minutes before it changed. The water level of the drainage affected the change of the gathered data from the drainage.

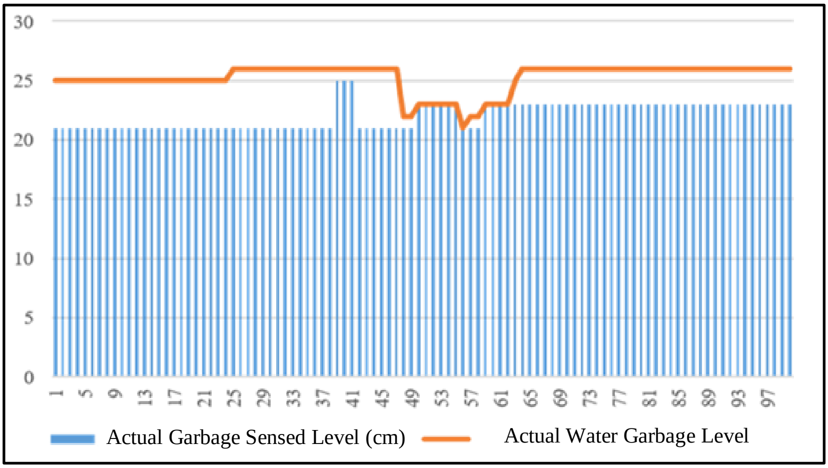

Figure 16. Cluster-column line graph of the actual levels of the garbage and the water in the drainage at Bonifacio Street

4. Conclusion and Recommendation

In the Philippines, the accumulated garbage in the drainages is one of the primary causes of floods in urban areas. In these areas, a bold step to countermeasure this perennial problem is to use a garbage level monitoring system. Hence, a garbage level monitoring system using IoT was developed in this paper. This system, particularly the system cabinet, is considered low-cost since it is made from recycled and disposable materials. Based on experiment results, the developed system was effective in performing its desired functions. Specifically, the system provided the user with the status of the garbage level in particular drainage in real-time. This was achieved by integrating the different elements and technologies such as ultrasonic sensors, IoT module, web application, GSM module, and among others. These were systematically interconnected to the cloud in such a way the user could monitor the real-time status of the garbage level in the drainages. The appropriate authority could then collect the garbage from the monitored drainages. With the integration of the different components to establish an effective garbage level monitoring system in drainages, the novelty of the developed system from previously developed ones is evident.

Though the system offers significant contributions in the aspect of monitoring the garbage levels in urban drainages in Cebu City, Philippines, several system limitations were pinpointed for future research. First is to integrate a robotic mechanism to collect the garbage in the drainage once the garbage level reaches the critical level. Another suggestion is to further enhance the system's smart features, particularly in determining the exact garbage level and in distinguishing garbage and water levels. Moreover, the system's power supply should be non-disruptive. Hence, it is proposed to use solar energy as the primary power source to operate the system. As experienced by most Filipinos, internet connectivity in the Philippines is fluctuating at different times of the day with the present 4G technology. Thus, it is advised that the developed system should be deployed using 5G technology since it is mainly dependent on internet connectivity.

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