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Digital centralized water meter using 433 MHz LoRa

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ABSTRACT

The local water supply corporation in Indonesia only uses analog water meter so that the monitoring of water usage information was conducted by officers manually. Officers must physically monitor the value in the customer's water meter that can lead to unreliable reading and ineffectiveness of process. Smart meter is one of the smart city metrics which could overcome this problem. This research uses the flow sensor to design and incorporate automated water meters. The measured value is then passed via the 433 MHz LoRa, a low-power wide-area network protocol, to the local hub, then forwarded to the server via the internet based cellular network. Results show that our proposed system's accuracy hit 97.31% at an ideal distance of 200 meters from customer to the local hub. The customer's water usage could be tracked in real time with our proposed system. Furthermore, the original water meter need not to be replaced which may minimize capital costs for this system.

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1. INTRODUCTION

Smart city main concept is the integration of infrastructures technologies to address urban challenges, mainly in the use of natural resources and public infrastructures [1]. In smart city, where many houses are considered, water is essential. Water usage is varying in each house, depends on the season, number of people in the house [2]. However, in average, number of water usage is high, proven from the reading of water meter in customers' house. The reading of the existing customer's water meter is still done conventionally by the officers visiting customer's home to record or photograph water usage shown in the meter then input the data into a computer to be processed as a reference for making the billing form [3]. The process of recording water meters was too risky, as errors resulted in customer complaints about the number of charges that needed to be paid. However, the most significant impact is that customers are frequently disadvantaged solely due to officers' mistakes in recording conventional water meters due to outdated analog water meter equipment [4]. Local water supply companies withstand a significant amount of responsibility for finding solutions to problems like this, particularly those involving officers' frequent human error in reading meters and manually entering data into the system [3], [5].

Smart meter, one of the indicators in smart city, could be used to solve this problem. A smart meter not only helps the consumer understand the load consumption but also serve as a platform for load control, thus significantly improving energy conservation [6]. By replacing existing analog water meter devices with digital-based system one, all processes can be carried out automatically by the machine, by including application software for centralized reading of water usage on the server [7]. The development of automation, telemetering and telecontroling technology is more than enough to support the digitalization and automation of conventional water meter devices [3], [8], [9].

Previously conducted researchs proposed many methods for digitizing water meter. W. Zheng, Z. Yang, L. Feng *et al.* [4] meter value is captured using camera and transmitted via 3G wireless network to the server. Short message service is used in [7] to enquire automatic water meter reading. Y. Li, X. Yan, L. Zeng *et al.* [10] develops multi level relay and concentrator to lower the power consumption although more complicated. Both using wireless sensor networks, [3] proposed image to text conversion of meter value, while [11] implemented remote valve controller based on user' water quota.

This study provides new approach on digitizing analogue water meter. The water usage data detected by this digital meter is automatically transmitted using 433 MHz wireless transceiver to the concentrator which acts as a coordinator that handles several digital water meters with a maximum capacity of 500 meters. Since node do not need to transmit a large number of data each time, and it is electrically supplied by batteries, it needs transmision system that has low power consumption. LoRa is suitable for this system due to its low-power and long-range characteristics [12]. LoRa has proven to have better effect on maximizing the battery life span compared to other technology [13]. It also has the advantages of a very large distance transmission with extreme low bandwidth [14]. On the other hand, since higher bandwidth is required, cellular networks is used to transmit data from all concentrators to the server. The following is a summary of the paper: The first chapter is an introduction, outlining the context of this study and previous studies. In section 2, the methods used in this paper are described. The testing results and discussion are explained in section 3, and the conclusion is given in section 4.

2. METHOD

In this study we implement wireless sensor network (WSN) architecture to conduct our research. WSN is used due to its wireless structure, infrastructure simplicity, and lower battery consumption. Although WSN has low speed communication, limited memory, and narrow bandwidth [15], this method works perfectly for our system since we do not transmit high amount of data from each sensor. The common WSN network consists of two major parts, namely the node and the base station. A node, usually in the forms of sensor, is responsible for measuring, processing, and transmitting parameters. A base station is responsible for collecting data from each node and acting as gateway to allow remote access of the data [16].

Here we named node as node, and base station as concentrator that supervise several nodes. Our study is designing, constructing, and implementing centralized digital water meter using 433 MHz wireless transceiver network following the steps of data collection and transfer in WSN. There stages of implementation are as; a) design and manufacture node devices for water usage volume measurement and send its results to the server through a concentrator by using a 433 MHz wireless transceiver, b) design and manufacture concentrator devices, which serve to collect data received from several number of nodes, c) design and develop data processing and interfacing application. Programs created by using PHP language with a MySQL database.

Figure 1 shows the block diagram of our proposed system. This system consists of three main parts; 1) node, a piece of equipment that is installed at customer section for measuring, digitizing, and recording user's water consumption and transmitting the results to the concentrator by using 433 MHz wireless transceiver, 2) concentrator, acts as hub of digitized data sent from several nodes in its vicinity before being sent to server, and 3) servers, consists of databases and web-based software as interface, is the monitoring center for data being sent from concentrator. These data are then processed for customer billing and recorded for company report.

Central part of node is water flow sensor that is used to measure the volume of water flow through the pipes from water company to customer's house. This sensor consists of several parts; valves, water rotors, and hall effect sensors. When water flows through the sensor, it will rotates the motor. The rotor movement is then converted to the water volume in litres as shown as Figure 2 [17].

In detailed, the flowing water will pass through the valve and make the magnetic rotor rotate at a certain speed in according to the flow rate. The magnetic field was contained in the rotor will give effect to the hall effect sensor and it will produce a pulse signal in the form of a voltage (pulse width modulator) [18]. Different techniques, such as a change in velocity or kinetic energy, can infer flow rate inferentially. The change in water velocity was used to calculate the flow rate. The pressure that forces the through pipelines determines the velocity. Because the pipe's cross-sectional area is known and constant, the average velocity is a good indicator of the flow rate. In such cases, the basic relationship for determining the liquid's flow rate is [19]:

$$Q = V \times A \tag{1}$$

Where Q is the flow rate or total flow of water through the pipe, V is the average velocity of the flow, and A is the pipe's cross-sectional area (viscosity, density, and friction of the liquid in contact with the pipe also affect the water flow rate) [19].

$$\text{Pulse frequency (Hz)} = 7.5 \times Q, \left(\text{Q in} \frac{\text{Litres}}{\text{minutes}}\right) \tag{2}$$

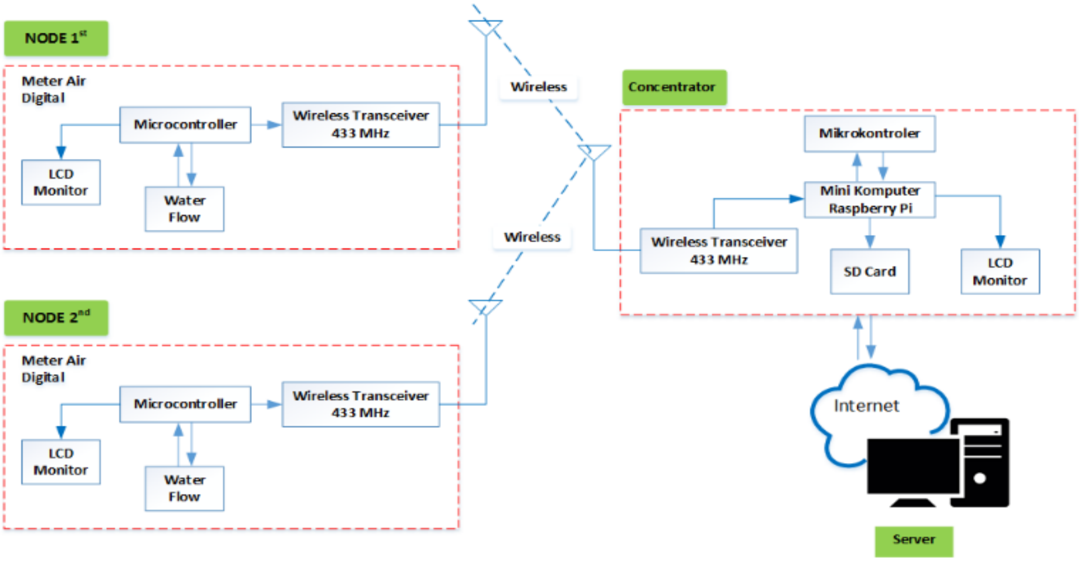


Figure 1. Digital water meter system

This pulse signal is captured by microcontroller which in this case uses Arduino Uno and is processed as flow rate data. These data are displayed in LCD embedded in each node. Water volume data for each customer was sent to the server through a concentrator. The task of this concentrator was to request, collecting and recording data which were received from a number of nodes around it with a distance radius was determined based on the range of the 433 MHz wireless transmission system. The main device that controls the work of this concentrator is a microcontroller which in this case using the Raspberry Pi 3 B+.

Mesh topology that is effective for communication [20] was used between these nodes and concentrators. This communication network architecture as shown in Figure 3 consists of three main components. End nodes are devices that connected to the concentrator as a gateway. Concentrator was a two-way relay or protocol converter that forwards data to server. Server was responsible for monitoring and processing data centers related to the customers' water usage, including monitoring the leakage and maintenance system.

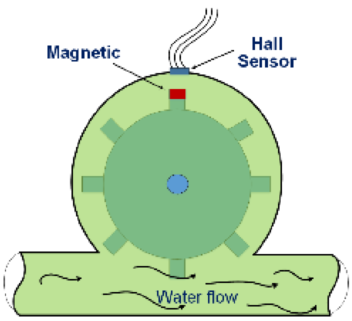


Figure 2. Water flow sensor

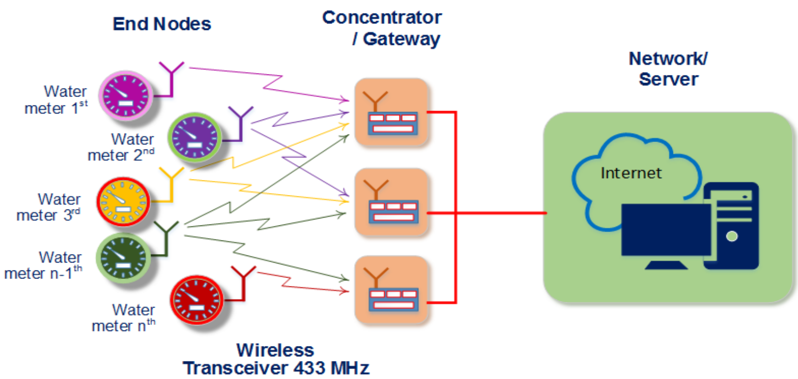


Figure 3. Communication network architecture

2.1. Device specifications

Four main components of our proposed system are:

a. Water flow sensor

The water flow sensor used was DIGITEN G-3/4 inch type, FL-068, which consists of several parts, namely; plastic valve body, rotor, and hall effect sensor, which are designed to detect changes in position or movement of magnetic objects [21]. The specifications of this water flow sensor of FL-068 type in detail can be shown as Table 1.

b. Arduino Uno microcontroller

The Arduino Uno microcontroller is based on the ATmega328P microcontroller, which has 14 digital input/output pins (6 of which can be used as PWM outputs), six analog inputs, and a 16 MHz crystal oscillator [22]. In detail can be show as Table 2.

Table 1. Water flow sensor specifications

No.	Parameters	Specification
1.	Voltage	5V- 24V DC
2.	Maximum Current	15 mA
3.	Sensor Weight	43 gr
4.	Diameter	20 mm
5.	Water discharge	1-80 Liter/minute
6.	Operating Temperature	0˚C-80˚C
7.	Pressure	< 1,75 MPa
8.	Humidity	35% -90% RH
9.	Cross-sectional area	½ inch

Table 2. Arduino uni microcontroller specification

No	Parameters	Specification
1	Microcontroller	ATmega 328P
2	Operating Voltage	DC 5 V
3	Input Voltage	5-9 V
4	Digital I/O Pin	14 (6 of which provide PWM Output)
5	Analog Input Pin	6
6	DC Current per I/O Pin	40 mA
7	Flash Memory	Bootloader
8	SRAM	2 KB
9	EEPROM	1 KB
10	Clock Speed	16 MHZ

c. Raspberry Pi

The Raspberry Pi 3 B+ model was used, a 64-bit quadcore processor running at 1.4 GHz, dual-band 2.4 GHz and 5 GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a different HAT PoE [23]. The detailed specifications of the Raspberry Pi 3 B + single board computer used in this study are as in Table 3.

Table 3. Raspberry Pi 3 B+ specifications

No.	Parameters	Specification
1.	Processor	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz
2.	Internal Memory	1GB LPDDR2 SDRAM
3.	Connectivity	2.4 GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE Gigabit Ethernet over USB 2.0 (the maximum throughput 300Mbps) 4 × USB 2.0 ports
4.	Input/ Output Access	Extended 40-pin GPIO header
5.	Video & sound	1 × full size HDMI MIPI DSI display port MIPI CSI camera port 4 pole stereo output and composite video port
6.	Multimedia	H.264, MPEG-4 decode (1080p30); H.264 encode (1080p30); OpenGL ES 1.1, 2.0 graphics
7.	SD card support	Micro SD for running operating system and data storage
8.	Input power	5V/2.5A DC via micro USB connector 5V DC via GPIO header Power over Ethernet (PoE)-enabled (requires separate PoE HAT)

d. 433 MHz wireless transceiver

The wireless tranceiver used was Lora SX1278 that operates at 433 MHz frequency. Semtech SX1278 has patented the modulation technique, which can achieve a sensitivity of -148dBm. [10]. The specifications details of these wireless transceiver type were shown in Table 4.

Table 4. Lora sx1278 module specifications

No.	Parameters	Specification
1.	Operating voltage	DC voltage 1.8 V – 3.7 V
2.	Frequency Range	137 - 525 MHz
3.	Radio Frequency Input Level	+10 dBm
4.	Modulation	FSK/OOK/LoRa^{TM}/ GMSK/MSK
5.	Bandwidth	7.8 – 500 kHz
6.	Effective bit rate	0.018 - 31.5 kbps
7.	Receiver sensitivity	-111 dBm to -148 dBm
8.	Operating temperature	-40 °C to +85 °C
9.	Radio Frequency Output Power	+20 dBm
10.	Range distance	3 – 5 Km
11.	Dimension	20.5 x 15.5 x 2.0 mm

2.2. System design

The design of 3 sub parts of our system is explained as:

a. Node device; Figure 4 shows the design of node.

The water flow detected by the sensor will be processed in the Arduino Uno and resulted in flow rate and water meter usage volume. The supply voltage needed for the sensor is taken from 5 volt V_{cc} pin of Arduino Uno and data communication connection established by connecting SIG pin on the water flow to the input pin 2 on the Arduino Uno. Henceforth, water usage volume data will be transmitted to the concentrator using LoRa SX1278 transceiver module. Data transmission is done periodically and automatically; adjusted to customer/water company needs. Schematic diagram of node is shown in Figure 5.

Based on Figure 5, wiring diagram of Arduino Uno module to 433 MHz transceiver explained as follows. Concentrator; the concentrator was designed as a trigger for each node to send its data. Besides relaying data from nodes to the server, it also temporarily store those data in micro-SD memory card. The temporarily stored data is used as redundancy data for maintenance purpose, that could be manually retrieved by officers, although only most recent data are stored. More details for the Arduino wiring diagram to the 433 Mhz transceiver are shown in Table 5. Whenever nodes send their data to concentrator, previously stored data will be replaced with the new one. Figure 6 (a) and (b) respectively shows the block diagram and schematic circuit of concentrator.

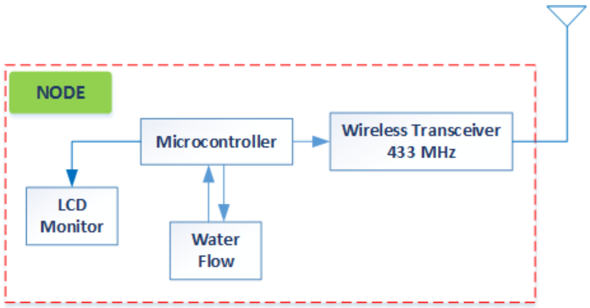


Figure 4. Diagram block of node

Table 5. Wiring diagram Arduino to 433 Mhz transceiver

Arduino Uno Microcontroller Pin	433 MHz Transceiver Pin
D5	RESET
D6	DIO0
D11	MOSI
D12	MISO
D7	DIO1
D10	NSS
Vcc : +3.3 volt	Vcc

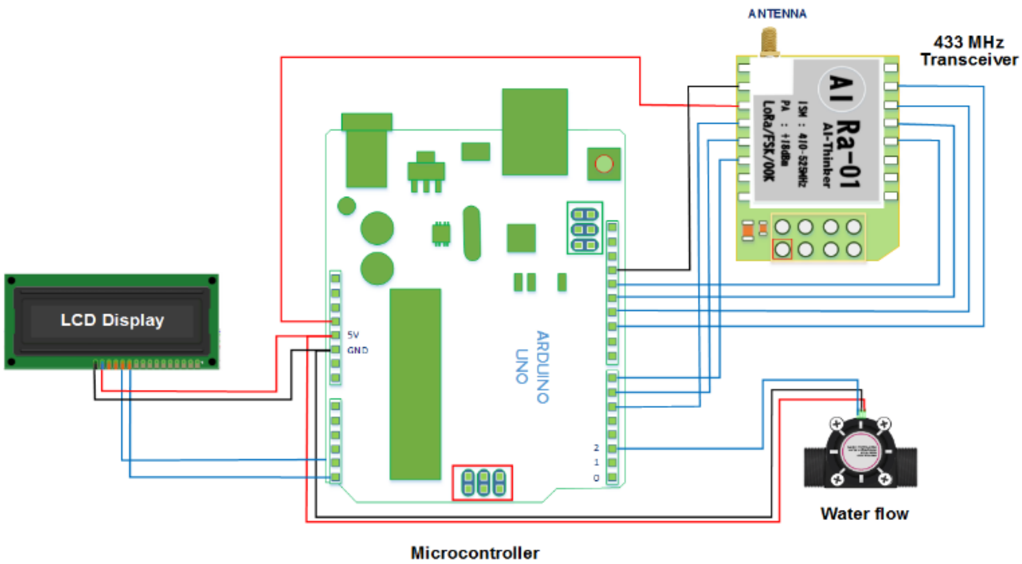


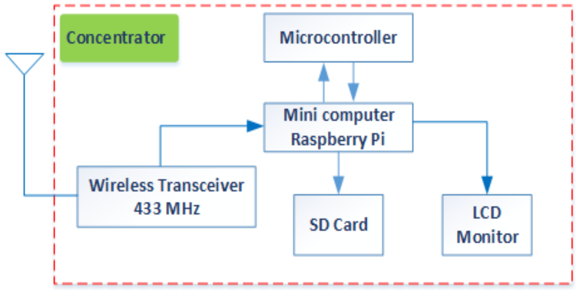
Figure 5. The schematic circuit of node

Data transmission system between the node and the concentrator was carried out using a 433 MHz Transceiver of LoRa SX1278 type. Single-hop routing method is used due to its higher energy efficiency compared to multi-hop [24]. The sequence of data transmission process listed as:

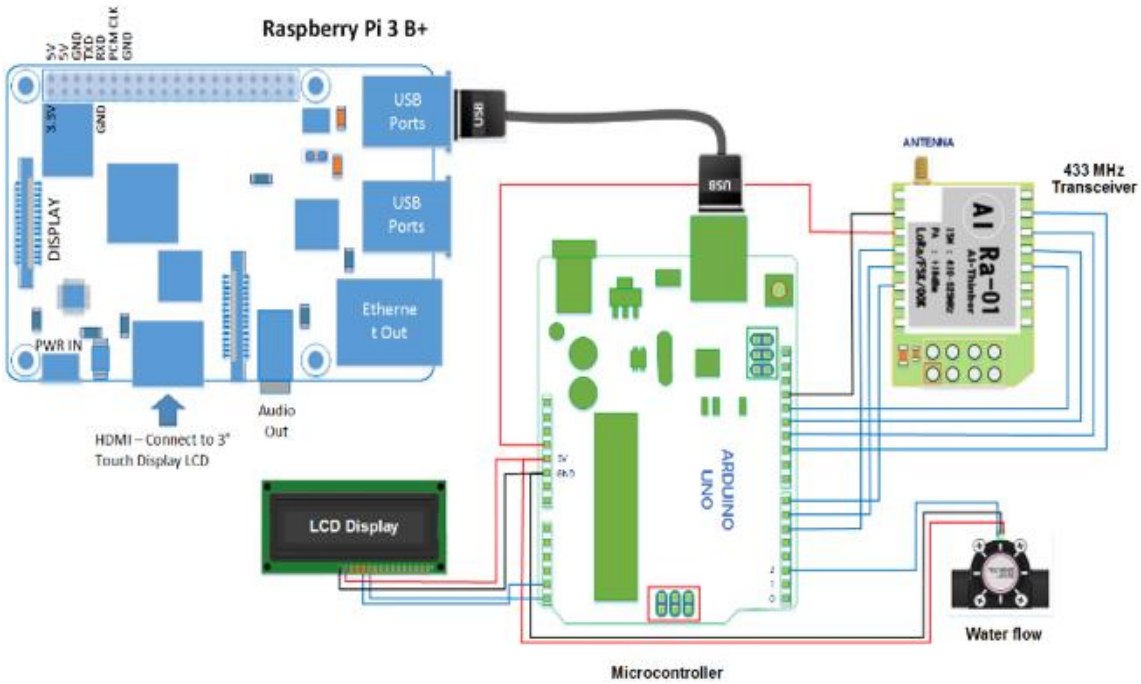
a. Concentrator sends code bits contain command for nodes to retrieve water usage data.
b. Node placed in customer’s side will digitized water usage value and automatically sent to concentrator

c. Concentrator temporarily save water usage data including customer's meter ID and sent them to the server.
d. Concentrator will inquire other nodes using the same command to transmit water usage data.

MySQL is used as database management system in the server. Processed data will be displayed through a web based application using pHp programming language. Users could enquire data in the form of customer billing, water company report, or other forms of public information.



(a)



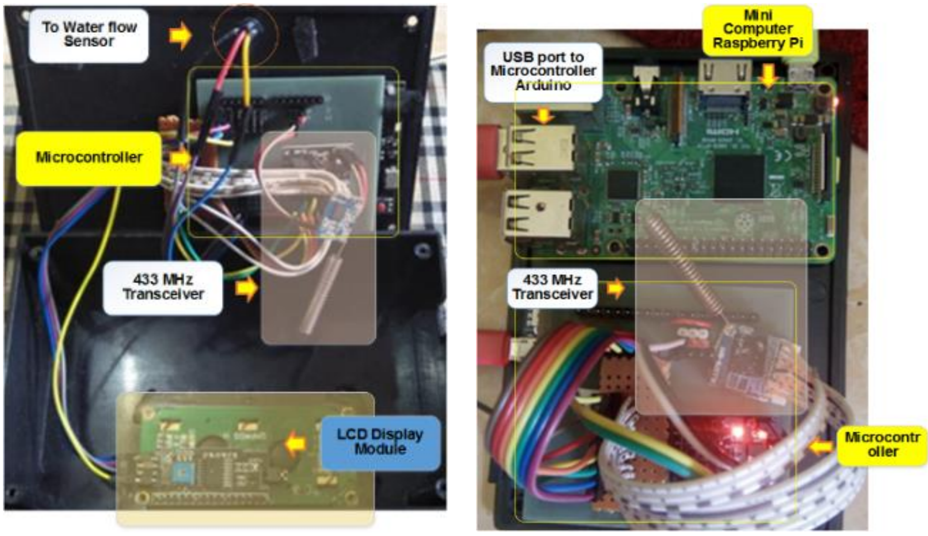
(b)

Figure 6. Of concentrator, (a) diagram block, (b) schematic circuit

3. RESULTS AND DISCUSSION

3.1. Digital water meter design results

Figure 7 shows the result of our digital water meter system. In Figure 7 (a), the node has three-inch touch display LCD. It is embedded in node device so that customer could monitor the water usage value not only by website. Two 3.6V lithium batteries are used to supply each of the node devices. The control device used for node and Lora SX1278 is supplied by Li-SOCl2 sort ER24615 with 19,000 mAh. Concentrator is supplied by the nearby electrical utility for a reliable supply of power as shown as Figure 7 (b). The data obtained by the concentrator from a variety of nodes will be stored as a file data logger, which can be retrieved manually. At the same time, data transmission from concentrator to the cloud server is done in real time using an internet-based GSM communication network.



(a) (b)

Figure 7. Digital water meter system, (a) node, (b) concentrator

3.2. Calibration of digital water meter systems

Water flow sensor reading value is the main function that need to be tested in our proposed system. Step by step on calibrating and testing of our system is carried out as:

a. Prepare the node device and use the LCD display as a display of the meter reading results.
b. Prepare a standard liquid measuring vessel as a comparison to the measurement of water volume (in this research was used a standard 20 liters MDR liquid measuring vessel, type AD-SS-2015) [25].
c. The test was carried out by flowing water into the node where the water meter output was accommodated to a standard liquid measuring vessel.
d. Record node reading value and compare them to the value of water volume in liquid measuring vessel.
e. Repeat the process and calculate the difference between each measurement
f. Simulateously, set the calibration factor in Arduino for reading accuracy.
g. Fill in calibration factor with a certain constant value, so that the difference between the meter reading result and the liquid measuring vessel capacity was closest to zero.
h. Calibration factor used is the one that made smallest difference between meter value and vessel capacity.

Table 6 shows the results of water meter reading testing. Smallest error is 3.14% with calibration factor of 3.

Table 6. Result of digital water meter calibration

No.	Calibration factor	Reading value on (liters)		Error (%)
		Digital water meter	*Standard measuring vessel*	
1	7.4	13,713	20.01	31.47
2	7	14,417	20.03	28.02
3	6	24,036	20.02	20.02
4	3	19,202	20.01	4.04
5	3.5	20,644	20.02	3.14
6	3	19,202	20.00	3.99
7	6	24,036	20.00	20.18
8	7	14,417	20.00	27.92
9	7.4	13,713	20.00	31.44

3.3. Digital water meter reading test

This test was carried out to get the tolerance value of the reading result of a calibrated digital water meter. Reading procedure here is the same with the one in calibration procedure, however the calibration factor is fixed to 3.5. Error calculated from difference between meter reading value and standard liquid measuring vessel is shown in Figure 8. From 20 experiments, the average error of our proposed meter is 2.69% with the highest error is 3.3%.

Our proposed system has higher accuracy than proposed meter in [26], [3], and [9]. Compared to [27] and [28], our proposed meter has slightly larger error by 1%. However, the system used in [27] requires high precision in plum blossom needle positioning which is rather complicated in practice. Also, Zigbee is used in

[28] as the communication system that is smaller in coverage area compared to LoRa. In implementing digital water meter to support smart city, the transmission coverage needs to be as wide as possible.

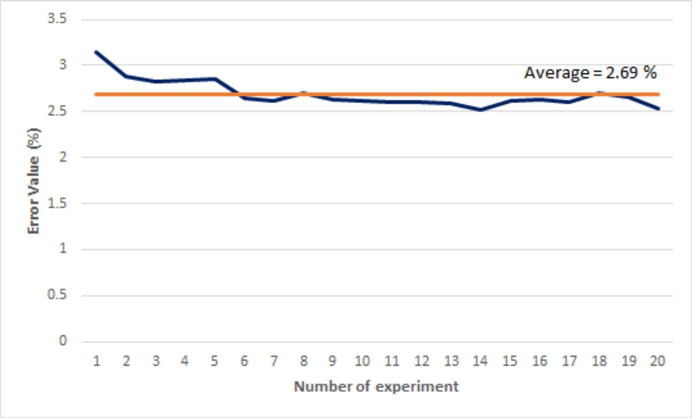
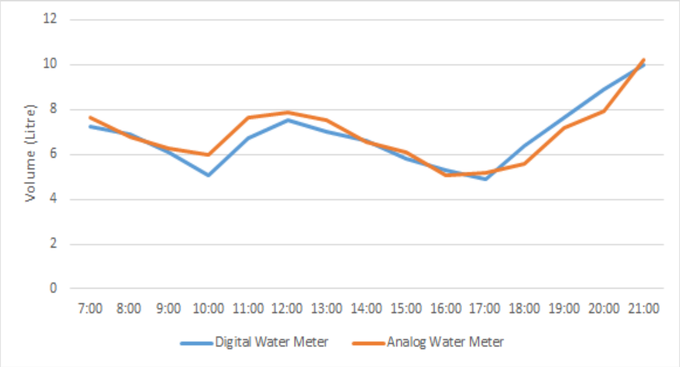


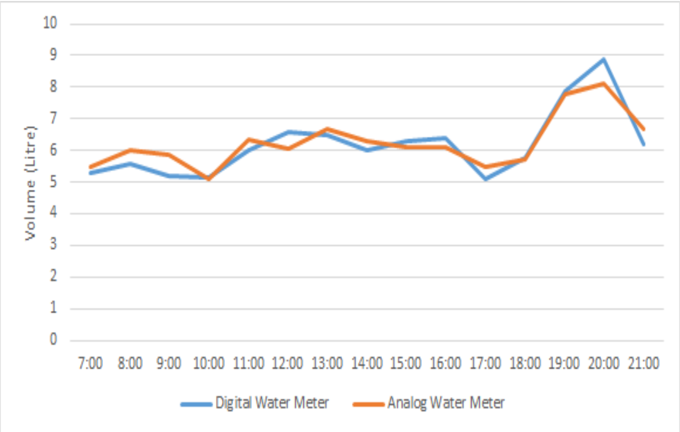
Figure 8. Error percentage value of digital water meter

3.4. Digital water meter periodical reading test

In periodical reading test, we implement our proposed digital water meter and record the water usage every hour and compare the reading value with the existing analogue meter, in this case, meter with serial number 15029504 is used. Both meter has been calibrated with the same method. Test was conducted from 07.00 a.m. until 09.00 p.m (GMT +7) for two consecutive days. Figure 9 shows the recorded reading of our proposed meter.



(a)



(b)

Figure 9. Test results of digital water meter periodical reading, (a) day 1, (b) day 2

3.5. Communication coverage between nodes and concentrators test

To find out optimum distance between node and concentrator, signal quality in the form of received signal strength indicator (RSSI) value is evaluated. RSSI is measured by varying the distance between node and concentrator with transmit power is set to 17 dBm. It was discovered that with 200 meters' distance between the two, RSSI value of our proposed system reaches -105 dBm, far above the minimum receiver sensitivity in -148 dBm, proving that our proposed system could work properly even in longer distance between node and concentrator. This is show at Figure 10.

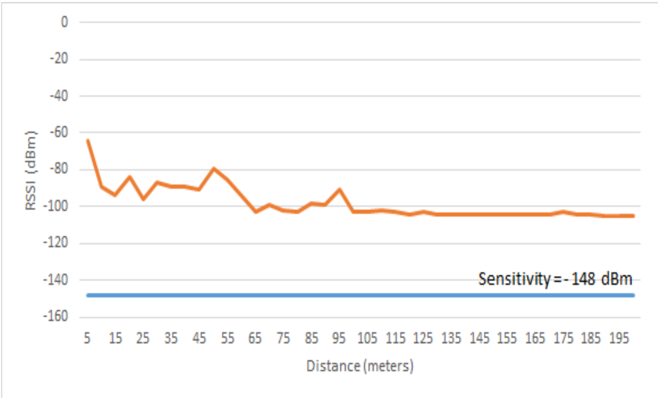


Figure 10. The testing results of the communication range of the 433 MHz transmission system

4. CONCLUSION

Our proposed centralized water meter system is found to have high accuracy with less than 3% error that meets the drinking water meter criterion standard based on SNI 2547: 2008. Communication coverage reaches 200 meters with signal quality -105 dBm, far above the minum standard of -148 dBm. Thus, it could be concluded that our proposed meter can be used as a substitute for the existing analogue water meter. The implementation of this digital water meter system device will be more efficient because this device was designed to be able to real time monitor customers' water usage and could process those data into other valuable form, like billing and management report.

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REFERENCES

[1] S. P. Caird, S. H. Hallett, "Towards evaluation design for smart city development," *Journal Urban Design*, vol. 24, no. 2, pp. 1-22, 2019, doi: 10.1080/13574809.2018.1469402.
[2] R. Priya, G. P. Rameshkumar, "A Novel Method to Smart City's Water Management System With Sensor Devices and Arduino," *International Journal of Computer Intelligence Research*, vol. 13, no. 10, pp. 2391-2406, 2017.
[3] H. Hudiono, M. Taufik, R. H. Y. Perdana, W. R. Rohmah, "Design and implementation of centralized reading system on analog postpaid water meter," *IOP Conferences Series Materials Sciences and Engineering*, vol. 732, no. 1, pp. 1-12, 2020, doi: 10.1088/1757-899X/732/1/012102.
[4] W. Zheng, Z. Yang, L. Feng, P. Fu, "Remote automatic meter reading system," *International Journal and Biomedical Engineering Ijoe*, vol. 13, no. 10, pp. 48-62, 2017, doi: 10.3991/ijoe.v13i10.6751.
[5] X. J. Li, P. H. J. Chong, "Design and implementation of a self-powered smart water meter," *Sensors (Switzerland)*, vol. 19, no. 19, pp. 1-17, 2019, doi: 10.3390/s19194177.
[6] A. E. Ibhaze, M. U. Akpabio, A. A. A. Atayero, "Smart meter solution for developing and emerging economies," *International Journal of Automation and Smart Technology*, vol. 8, no. 3, pp. 119-126, 2018, doi: 10.5875/ausmt.v8i3.1529.
[7] G. A. Mills, "Photo Encoding of Analog Water Meter for User Access and Payment System," *International Journal of Engineering Science and Technology IJEST*, vol. 4, no. 7, pp. 3500-3508, 2012.
[8] I. Monks, R. A. Stewart, O. Sahin, R. Keller, "Revealing unreported benefits of digital water metering: Literature review and expert opinions," *Water (Switzerland)*, vol. 11, no. 4, pp. 1–32, 2019, doi: 10.3390/w11040838.
[9] G. Jin, K. Bai, Y. Zhang, H. He, "A smart water metering system based on image recognition and narrowband

internet of things," *International Information and Engineering Technology Association*, vol. 33, no. 4, pp. 293-298, 2019, doi: 10.18280/ria.330405.
[10] Y. Li, X. Yan, L. Zeng, H. Wu, "Research on water meter reading system based on LoRa communication," *IEEE International Conference on Smart Grid and Smart Cities (ICSGSC)*, 2017, pp. 248-251, doi: 10.1109/ICSGSC.2017.8038585.
[11] A. E. Rakhmania, M. Taufik, M. Sa'adah, "Centralized Post Paid Water Meter Controller Using Wireless Sensor Network," *International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA)*, 2019, pp. 302-305, doi: 10.1109/ICAMIMIA47173.2019.9223421.
[12] A. Augustin, J. Yi, T. Clausen, W. M. Townsley, "A study of Lora: Long range & low power networks for the internet of things," *Sensors (Switzerland)*, vol. 16, no. 9, pp. 1-18, 2016, doi: 10.3390/s16091466.
[13] M. Bor, J. Vidler, U. Roedig, "LoRa for the Internet of Things," in *2016 International Conference on Embedded Wireless Systems and Networks*, 2016, pp. 361-366.
[14] A. Lavric, V. Popa, "Internet of Things and LoRa™ Low-Power Wide-Area Networks: A survey," *International Symposium on Signals, Circuits and Systems ISSCS*, 2017, pp. 1-5, doi: 10.1109/ISSCS.2017.8034915.
[15] M. Kocakulak, I. Butun, "An overview of Wireless Sensor Networks towards internet of things," *IEEE 7th Annual Computing and Communication Workshop and Conference CCWC*, 2017, pp. 1-6, doi: 10.1109/CCWC.2017.7868374.
[16] M. Pule, A. Yahya, J. Chuma, "Wireless sensor networks: A survey on monitoring water quality," *Journal of applied research and technology*, vol. 15, no. 6, pp. 562-570, 2017, doi: 10.1016/j.jart.2017.07.004.
[17] S. I. Abdullahi, M. H. Habaebi, N. A. Malik, "Design, simulation and practical experimentation of miniaturized turbine flow sensor for flow meter assessment," *Bulletin of Electrical Engineering and Informatics*, vol. 8, no. 3, pp. 777-788, 2019, doi: 10.11591/eei.v8i3.1501.
[18] V. C. Sharath, S. Suhas, B. N. Sachin Jain, S. B. Vinay Kumar, C. P. Kumar, "Smart aqua meter," *International Conference on Advances in Electronics Computers and Communications*, 2014, pp. 1-5, doi: 10.1109/ICAECC.2014.7002440.
[19] F. Properties, "An Introduction to Flow Measurement & Fluid Properties How Can You Quantify Flow Rate ?," *AZO Materials*, pp. 1-5, 2018.
[20] A. Abdrabou, "A Wireless Communication Architecture for Smart Grid Distribution Networks," in *IEEE Systems Journal*, vol. 10, no. 1, pp. 251-261, March 2016, doi: 10.1109/JSYST.2014.2304291.
[21] R. Sood, M. Kaur, H. Lenka, "Design and Development of Automatic Water Flowmeter," *International Journal of Computer Science, Engineering and Applications IJCSEA*, vol. 3, no. 3, pp. 49-59, 2013, doi: 10.5121/ijcsea.2013.3306.
[22] R. W. Fransiska, E. M. P. Septia, W. K. Vessabhu, W. Frans, W. Abednego, Hendro, "Electrical power measurement using Arduino Uno microcontroller and LabVIEW," *International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering ICICI-BME*, pp. 226-229, 2013, doi: 10.1109/ICICI-BME.2013.6698497.
[23] M. Sałuch et al., "Raspberry PI 3B + microcomputer as a central control unit in intelligent building automation management systems," MATEC Web Conferences, vol. 196, 2018, doi: 10.1051/matecconf/201819604032.
[24] R. H. Y. Perdana, H. Hudiono and A. F. N. Luqmani, "Water Leak Detection and Shut-Off System on Water Distribution Pipe Network Using Wireless Sensor Network," *2019 International Conference on Advanced Mechatronics, Intelligent Manufacture and Industrial Automation (ICAMIMIA)*, 2019, pp. 297-301, doi: 10.1109/ICAMIMIA47173.2019.9223386.
[25] E. I. Ionete, D. Schitea, B. Monea and A. Salceanu, "Aspects regarding the liquid level measurement for a cryogenic pump," *2012 International Conference and Exposition on Electrical and Power Engineering*, 2012, pp. 151-153, doi: 10.1109/ICEPE.2012.6463934.
[26] K. A. Mohamed, M. G. Munier, P. P. William, S. A. Nagar, A. M. A. Ibrahim, "Enhanced Smart Water Meter Efficiency Based on Mounting Position Selection and Extended Battery Life Time," *International Conference on Computer Control Electrical and Electronics Engineering ICCCEEE*, pp. 1-6, 2018, doi: 10.1109/ICCCEEE.2018.8515854.
[27] G. Yan, J. Sun, T. Lu, "Research on Monocular Vision Positioning Technology Used in Water Meter Verification," *3rd International Conference on Mechanical, Control and Computer Engineering ICMCCE*, 2018, pp. 60-64, doi: 10.1109/ICMCCE.2018.00020.
[28] X. Junhua, W. Tingling, Y. Chao, "The Design of Tiered Pricing Meter Based on ZigBee Wireless Meter Reading System," *2011 Third International Conference on Measuring Technology and Mechatronics Automation*, 2011, pp. 761-764, doi: 10.1109/ICMTMA.2011.763.