Smart Anti-Theft Water Metering System

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***Abstract*—This paper presents a new approach to the design and development of a specific context-based smart water meter system and implementation methodology based on water flow sensor technology, the Internet of Things (IoT) and cloud computing services. The main objective of this paper is to solve the lack of transparency problem in water meter readings and prevention of water theft. The proposed smart water meter system is an improved technology to facilitate remote water meter reading and transparency in billing with the capacity for immediate detection of water theft and leakages which can result in better control of water consumption. The water flow sensor was able to provide real-time monitoring of water consumption data which was sent to ThingSpeak, a Cloud server platform. The system was inexpensive because less expensive components such as NodeMCU, the water flow sensor and ThingSpeak were the major components used in recording, visualising and analysing the water flow patterns.**

***Index Terms*—Smart Water Meter, Internet of Things, Water Consumer, Water Distribution Company**

I. Introduction

Water is an essential resource used in human activities. In Ghana, the uses of water are vast and include; domestic uses (bathing, washing, cooking), industrial uses (for cooling machines), agricultural uses (irrigation) and others. The rural areas in the country usually rely on water obtained from wells, streams, rivers, among others. However, the Ghanaian population in cities and towns rely majorly on water provided by the Ghana Water Company Limited (GWCL), at a fee. Here, water is pumped from water sources such as rivers to processing plants for processing and forwarding to households through pipes. Water meters are installed on the inlet pipes to households for measuring the amount of water consumed by customers for billing purposes.

The main types of meters installed by the GWCL are the velocity water meters (specifically multi-jet water meters) and the ultrasonic water meters, of which velocity water meters form the majority. However, there are technical challenges regarding the use of these meters for consumption monitoring and measuring processes.

- Customers are unable to efficiently monitor water usage since they do not have access to real-time readings from the meters. Therefore, they lack the necessary information needed to optimise water usage.
- The Ghana Water Company Limited (GWCL) dispatch workers monthly to go and take readings from installed meters, where the dispatch records the meter reading and takes a picture of the meter for billing purposes. Also in some cases, customers are given estimated bills, which may not reflect the actual water consumed.
- Customers who have outside taps installed are vulnerable to water theft by neighbours, where neighbours fetch water from outside taps when they are away or asleep.

Considering these technical challenges, there is a need for a metering system for water consumption monitoring and billing that provides solutions for these challenges. This paper proposes a novel context-specific metering system with the following features:

- An application that provides real-time meter readings which can be accessed by customers remotely provided they have internet access.
- A subsystem that sends the total monthly water consumption by customers to GWCL at the end of the month.
- A subsystem system that enables customers to remotely close the inlet valve, preventing water theft.

The rest of this paper is organised as follows: Section II gives an overview of smart metering systems, section III summarises the methods tools and methodology used to develop the system, section IV discusses the results obtained from experimentation and finally, section V gives a conclusion from the work and its limitations.

II. Overview of Smart Water Meters

A. Smart Water Meter

A water meter is a measuring device that uses a particular type of technology to measure water consumption in residential, commercial, agricultural and industrial settings or to determine water flow at a specific portion of a water distribution system [1]. Water metering is the process or the practice of measuring the water flowing through a water

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distribution system to facilitate water management and proper billing [2].

A smart water meter performs the same functions as a non-smart water meter with the major difference resulting from the fact that the smart water meter has an embedded system or components that allows continuous electronic readings of water flow, storage, display and transmission of water consumption data to the water distribution company to facilitate water management and billing [2]. A smart water metering system could be equipped with a wide variety of electronic computing units, the Internet of things (IoT) technology and other related technologies that facilitate communication between the meter at the consumer's end and the water distribution company to ensure more accurate measurements and in some cases provide almost real-time readings of the water meter [3].

Many prototypes of smart water meters had been designed and developed by scientists without the integration of IoT-based technology or features of cloud computing technology into the operations of the smart water meter system. These earlier systems worked well but with difficulties maintaining them in large-scale implementation because they are prone to a single-point failure [4], [5].

In a study conducted by [6], the concept of the android-based smartphone application to visualise water consumption where the data was directly transmitted to a smartphone was discussed as a suitable design for a smart water meter system. An improved design based on a cloud computing platform and Raspberry Pi or Arduino UNO micro-controllers was also proposed in a study by [7], even though the system proved to be efficient it was relatively expensive as a result of the components used.

B. Benefits and Challenges of Smart Meters

A lot of potential benefits come with the adoption and implementation of a smart water metering system from the perspective of the water supplier and the user. Research conducted by [8] on household smart water metering in Spain with a remote meter reading scheme, it was established that the system could immediately detect water leakages in the water distribution network which resulted in an estimated increase of 0.5% in the water distribution network efficiency.

A study comprehensively conducted by [2] [9] on water utilities in Australia and New Zealand discovered that water wastage prevention, reducing the cost of water usage by customers, increasing revenue generation by the water companies and customer satisfaction are the major benefits of implementing a smart water meter system. In the research work of [2] using a total of 158 installed smart water meters, 21 of the smart water meters were able to detect water losses caused by internal pipework leaks and leaking taps or appliances connected to the water distribution network. This shows the effeteness of smart water meters application in urban areas to benefit both the customer and the supplier.

In a socio-technical study conducted by [10], they concluded that the adoption of smart water meters by water distribution companies is driven by socio-technical factors such as engineering and efficiency considerations such as occupational health and safety improvements from automated reading, reduction in the cost of reading meters, improved accuracy of measurements, reduction of non-revenue water which can result from inaccurate meter reading, leakages and theft, and early detection of leaks.

Many kinds of research had shown huge potential and benefits of the adoption and implementation of smart water meters but the initial cost of replacing the existing non-smart water meters with smart water meters is generally high nevertheless research had shown, that as the technology improves and with more options becoming available, the initial cost would gradually reduce as was established in a research conducted in the Caribbean region. The research found that the cost of smart water technologies significantly decreased as their developments progressed [2], [11]–[13].

III. Methods, Tools and Methodology

In this paper, we proposed a solution for monitoring water utilization and remote reading of water meters using a water flow sensor interfaced with NodeMCU microcontroller embedded with Arduino codes. Arduino Integrated Development Environment software was used for coding the logic and was uploaded to the microcontroller to determine the water flow rate. The calculated rate of water flow is then displayed on the LCD monitor locally and also the data is sent to the cloud which can be monitored by the customers on their mobile phones and also monitored by the water distribution company for billing and management activities. A block diagram of the proposed system is shown in Fig. 1.

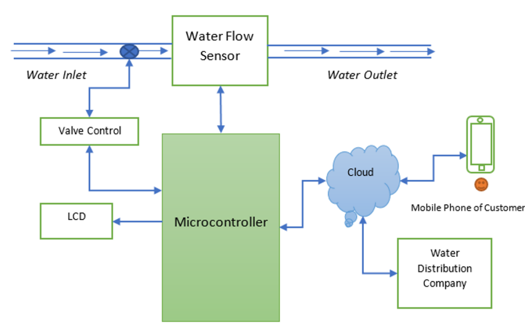

Fig. 1. Functional Block Diagram of The Proposed Smart Water Meter System

A. Hardware and Software Used in the Proposed System

1) NodeMCU Micro-controller (ESP8266-12E Board): The NodeMCU ESP8266-12E board is a well-known, widely used and inexpensive development board based on the ESP-12E Wi-Fi Module that combines elements of easy programming with Arduino IDE (C++) and Wi-Fi capability. It has an open-source Lua-based firmware and development board specially targeted for IoT-based Applications. The NodeMCU micro-controller was chosen because it is cost-effective, durable, and readily available on the Ghanaian market [14], [15].

2) Water Flow Sensor (YF-S201): The YF-S201 Hall effect water flow sensor consists of a plastic valve body, a water rotor and a hall-effect sensor used to measure how much water has moved through it. The Hall effect sensor generates an electrical pulse with every revolution. It works on the Hall effect principle and with a flow rate range of 1∼30L/min. The module has three pins: Power, Ground, and Analog output. YF-S201 consumes very little current and can work with a maximum pressure threshold of about 1.75MPa. The YF-S201 Hall effect water flow sensor was selected for the proposed system because it has been verified as an excellent device for water flow rate measurement [16].

3) LCD (Liquid Crystal Display (16×2): An LCD is an electronic display module that uses liquid crystals to produce a visible image. For the proposed system the 16×2 LCD was used because it is a basic module commonly used in circuits and it is inexpensive but durable to display all the information needed in our proposed system. The LCD 16×2 was selected for the proposed system because it is a cost-effective, durable and portable device that can display text without a flicker [17].

4) Breadboard: A breadboard sometimes called a plug block is a useful tool mainly used for building temporary circuits and it allows components to be removed and replaced easily. For our proposed system the half-size breadboard (5.5 cm x 8.5 cm) with a standard double-strip in the middle and two power rails on both sides was used because it is inexpensive and adequate to accommodate all circuits.

5) Connecting Wires(Jumper Wires): Connecting wires are used to allow an electrical current to travel from one point on a circuit to another. For our proposed system jumper wires were used to link power from one part of the breadboard to another.

6) Arduino IDE(Integrated Development Environment): The Arduino Integrated Development Environment is software that contains a text editor used for writing codes. It connects to the Arduino hardware to upload programs and communicate with them. For our proposed system the Arduino IDE was used to generate the codes and uploaded them to the microcontroller for implementation and testing of the smart water meter. The Arduino IDE was selected for the proposed system because it is easy to learn, and a strong platform for all researchers, programmers and other industry project development [18].

B. Experiment

The assembly of the hardware components in their operational mode of the proposed system is shown in Fig. 2. Per the operational methodology of the proposed system illustrated in Fig. 3, the water flow sensor senses the water flow and communicates its analog readings to the NodeMCU. The NodeMCU calculates the real-time water flow rate and the total monthly volume of water consumed and sends it to ThingSpeak via its inbuilt Wi-Fi module. In the ThingSpeak a chart for the water flow rate and the accumulated volume of water consumed is displayed in a chart as can be displayed in a chart. These readings can be accessed by the Ghana Water company Limited (GWCL) and the customers. From the readings, the GWCL can bill the customers without the need to physically go to the meters in their homes. Also, the valve can be remotely closed by the customer when water theft or leakage is detected. However, when a customer delays paying his/her bills, GWCL can remotely close the valve which can only be reopened by the GWCL. Lastly, GWCL and customers can physically take the readings from the LCD if they are unable to read from the cloud due to connectivity challenges.

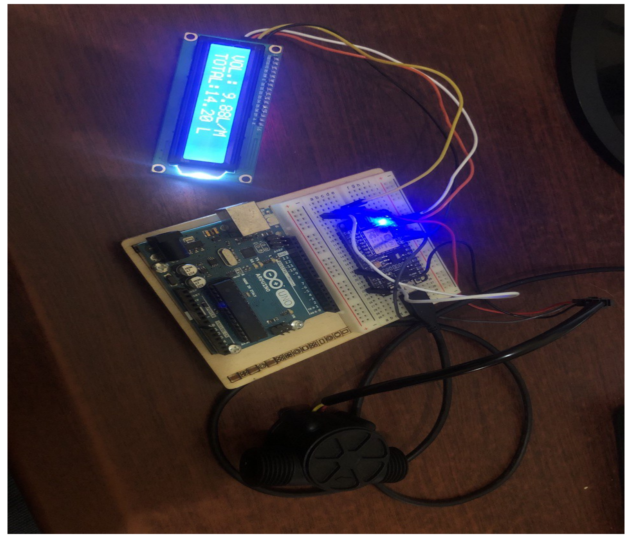

Fig. 2. Assembled Hardware Components of the Proposed System in their Operational Mode

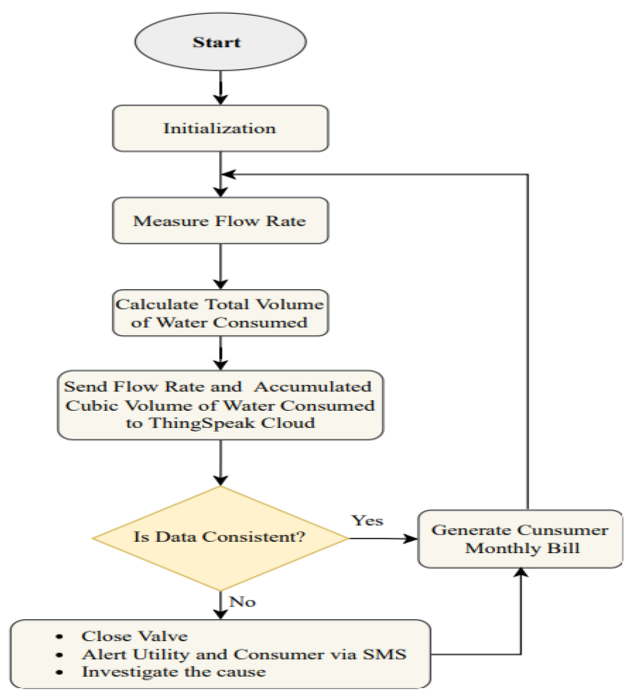

Fig. 3. Flowchart of Proposed System

1) Calculation of Water Flow Rate: The calculation for the water flow rate which was measured in litres per hour (L/hr) is estimated using the expressions in Equations 1 and 2.

$$Q = AV \tag{1}$$

where,

Q: is rate flow of water through the pipe,
V: is the average velocity of the flow Frequency(F) = 1/time
A: is the cross-sectional area of the pipe.

$$A = \pi r^2 \tag{2}$$

Hence flow rate is given as $Flowrate = Frequency/7.5$

IV. Results and Discussion

After several tests and experimentations with the developed prototype of our smart water meter system, the water flow sensor was able to effectively pick up accurate readings which were noted by the NodeMCU and transmitted in real-time to ThingSpeak once internet connectivity is available. Fig. 4 and Fig. 5 show the real-time transmission of the data collected from the flow sensor to ThingSpeak. The data obtained from the smart water meter was stored in the cloud platform which is accessible in real-time by both the water consumer and the water distribution company. This system would ensure transparency in the water billing systems and enhance the trust between the water distributor and the consumer. It will also minimize the operational cost of GWCL by eliminating printed hardcopy bills and reducing huge staff numbers who only go out for manual meter readings.

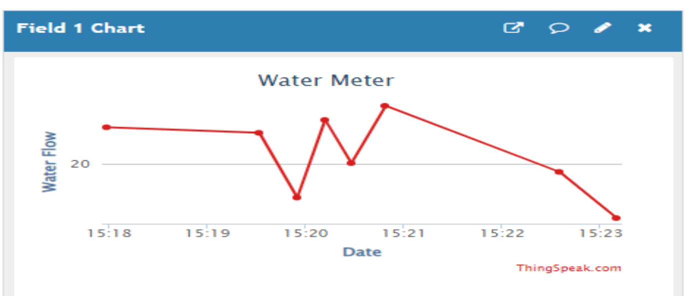

Fig. 4. Chart for Current Water Flow Rate

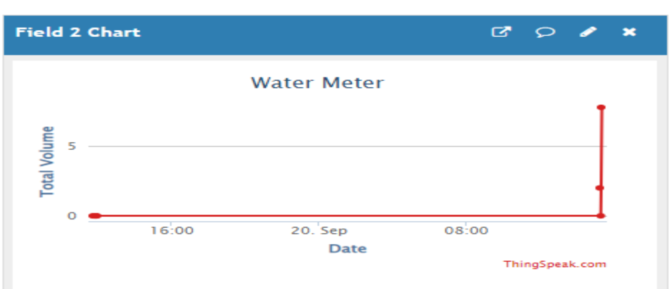

Fig. 5. Chart for Total Volume of Water Consumed

V. Conclusion and Limitations

The proposed smart water meter system was effective and inexpensive in terms of the infrastructural cost, because the key components used were the NodeMCU and the water flow sensor for recording, visualizing, and analysing the water flow patterns. For a large-scale implementation, it would include the cost of cloud computing services. We, therefore, propose a serverless architecture that would ensure the reliability of the data once recorded in the cloud. The proposed solution can also minimize the operational cost of GWCL by eliminating printed hardcopy bills and reducing huge staff numbers who only go out for manual meter readings.

References

[1] S. C. Hsia, S.-H. Wang, and S.-W. Hsu, "Smart water-meter wireless transmission system for smart cities," *IEEE Consumer Electronics Magazine*, vol. 10, no. 6, pp. 83–88, 2021.
[2] T. Randall and R. Koech, "Smart water metering technology for water management in urban areas analysing water consumption patterns to optimise water conservation," *Water e-Journal*, vol. 4, 02 2019.
[3] A. Ray and S. Goswami, "Iot and cloud computing based smart water metering system," 02 2020, pp. 308–313.
[4] A. Ray and H. Ray, "Ssiwm: Smart secured iot framework for integrated water resource management system," in *2020 IEEE Bangalore Humanitarian Technology Conference (B-HTC)*, 2020, pp. 1–6.
[5] M. Mudumbe and A. Abu-Mahfouz, "Smart water meter system for user-centric consumption measurement," 07 2015.
[6] M. Suresh, U. Muthukumar, and J. Chandapillai, "A novel smart water-meter based on iot and smartphone app for city distribution management," 07 2017, pp. 1–5.
[7] G. Tamilselvan, V. Ashishkumar, S. Prasath, and S. Yusuff, "Iot based automated water distribution system with water theft control and water purchasing system," *International Journal of Recent Technology and Engineering*, vol. 7, pp. 151–156, 01 2019.
[8] H. March, Morote, A. Amorós, and D. Saurí, "Household smart water metering in spain: Insights from the experience of remote meter reading in alicante," *Sustainability*, vol. 9, p. 582, 04 2017.
[9] C. Beal and J. Flynn, "The 2014 review of smart metering and intelligent water networks in australia new zealand," 11 2014.
[10] R. Koech, Y. Gyasi-Agyei, and T. Randall, "The evolution of urban water metering and conservation in australia," *Flow Measurement and Instrumentation*, vol. 62, pp. 19–26, 2018. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0955598617304235
[11] A. Overmars and S. Venkatraman, "Towards a secure and scalable iot infrastructure: A pilot deployment for a smart water monitoring system," *Technologies*, vol. 8, p. 50, 09 2020.
[12] A. Liu, D. Giurco, P. Mukheibir, S. Mohr, G. Watkins, and S. White, "Online water-use feedback: household user interest, savings and implications," *Urban Water Journal*, vol. 14, no. 9, pp. 900–907, 2017.
[13] E. F. Arniella and Y. Mellinger, "Evaluation of smart water infrastructure technologies," May 2017. [Online]. Available: https://publications.iadb.org/en/evaluation-smart-water-infrastructure-technologies-swit
[14] G. M. Madhu and C. Vyjayanthi, "Implementation of cost effective smart home controller with android application using node mcu and internet of things (iot)," in *2018 2nd International Conference on Power, Energy and Environment: Towards Smart Technology (ICEPE)*, 2018, pp. 1–5.
[15] R. N. Sardhara and N. R. Bhalani, "Nodemcu based electrical appliances control using internet of things and network of things," *International Journal of Computer Applications*, vol. 182, no. 50, pp. 29–32, Apr 2019. [Online]. Available: http://www.ijcaonline.org/archives/volume182/number50/30540-2019918757
[16] C. Rajurkar, S. R. S. Prabaharan, and S. Muthulakshmi, "Iot based water management," *2017 International Conference on Nextgen Electronic Technologies: Silicon to Software (ICNETS2)*, pp. 255–259, 2017.
[17] T. N. Ruckmongathan, "A successive approximation technique for displaying gray shades in liquid crystal displays (lcds)," *IEEE Transactions on Image Processing*, vol. 16, no. 2, pp. 554–561, 2007.

[18] M. Fezari and A. Al Dahoud, “Integrated development environment ”ide” for arduino,” 10 2018.