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Research Article

Development and Implementation of Smart Water Metering System based on Lora Technology

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ABSTRACT

The article presents an overview of traditional water meters in Vietnam, digitizing metrology technologies and wireless data transmission technology for data collection and user applications in smart water metering systems. After that, it is proposed to design a smart wireless water meter module. This paper focuses on designing and implementing a smart water meter to re-use traditional mechanical water meters by designing a smart water metering module attached to the existing meter. This way, it eliminates the costs of investing in flow water meter and influences the old water meter infrastructure system. The contribution of this paper is threefold: (i) Firstly, it proposes wireless data transmission and digitizing metrology technologies suitable for water metering systems in Viet Nam. (ii) Secondly, the proposed smart water meter module designs include hardware, firmwave, and plastic cover. There are two experimental prototypes of the module is introduced in this paper (iii) Lastly, The paper provides a water metering management software model for smart cities. And the overall systems of the proposed platform were built to verify the presented design. To reduce the amount of water leaking or users hacking from outside the meter in the measurement results, the article proposes to design features to alert about: abnormal flow, strong magnetic field influence, and equipment cover being removed. The experimental verification was designed with the Actaris water meter using Hall technology to digitize data and the Itron water meter with digitizing technology using the LC sensor. Besides, the Lora wireless network system is proposed and deployed to verify the water metering management with the advantages of low energy consumption, high security, and strict authentication process. Actual results for the laboratory environment and residential areas show that signal loss (RSSI) and signal noise (SNR) is within the allowable range. In addition, the packet loss rate <1% and average power consumption meter <50uA. Water metering management software is presented to verify the smart city service system.

Key words: Smart water metering, Lora network, Hall sensor, LC sensor, IoT platform

INTRODUCTION

Today with the strong development of industry 4.0, IoT products are increasingly being applied in most fields. In particular, Smart water meters are IoT devices that measure and communicate water usage from consumer to provider to facilitate water management and proper billing. Smart water meters are designed to deliver a completely new and revolutionary service to cities and towns around the world - the ultimate alternative to traditional water metering systems. Smart water meters not only provide water consumption data. It also helps control water consumption effectively and detect and warn unusual incidents [1]. Innovations in water metering technology, smart water metering systems have reduced labor costs, reduced losses due to leaks, and helped customers analyze and proactively use water [2]. That improved service time help improves customer experience [3]. In the article, we are focus on analyzing wireless data transmission technologies used for smart water measurement solutions, reviewing the traditional mechanical water meter popular in Vietnam with metrology digitization technology for it, and designing a smart water metering module. The smart water metering module is installed and integrated on old traditional mechanical meters that exist on the old water supply system. This helps reduce production costs and keep using the traditional mechanical water meters instead of using a new smart water meter. Therefore, the smart water metering research helps save labor costs, reduce leaks, improve the quality of water service, and support the smart city system [4].

To deploy a smart water metering system using smart water meters, the article analyzes the research and development of the following basic technologies [4,5]:

- Digital water meter technology: digitization technology selection sua ch as magnetic field or

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inductive sensor. That helps to detect the number of water meter revolutions and converts to the amount of water flow used.

- Technology to detect leaks, outside interference: develop abnormal warning technologies such as leaks, measurement fraud, and disassembled meters.
- Data transmission technology: designing data receiving and transmitting equipment and data transmission mechanism, IoT smart water metering system requires connectivity mainly at two levels: long-range low-power wide-area network (LPWAN) and short-range wireless local area network (WLAN). Long-range IoT radio solutions include NB-IoT, LTE-M, LoRa, Sigfox, and Ingenu. Short-range communication technology works in the industrial, scientific, and medical (ISM) bands and includes ZigBee, Z-Wave, Thread, Bluetooth Low Energy (BLE), Wi-Fi, and Li-Fi.
- IoT Platform: IoT Platform architecture includes network layers, transport layer, middleware, and application. The network layer is the transport layer that connects everything, handling IP addresses for IoT devices, and routing IP packets. The transport layer is designed to organize reliable delivery of data packets between addressable nodes and to provide security for applications and services built on top of TCP or UDP. The middleware layer is the processing layer that stores analyze, and processes the data coming from the transport layer. The application layer is where data is transformed into value, defining and providing different applications to control and monitor various aspects of the IoT system.

INTRODUCE TO SMART WATER SYSTEM TECHNOLOGIES

Most of the smart water metering systems mentioned in section 1 only solve some problems and are not suitable for the actual environment in Vietnam. Because the existing infrastructure is completely manual, it is more expensive to deploy from new water meters than to design technologies to digitize data from the old system. At the same time, the water meter is installed in a hidden location and the implementation cost makes it difficult to choose the data transmission technology. In this section, the article discusses the methods that can be applied to build a smart water metering system to reduce investment costs by using existing mechanical water meter digitization technology and data transmission technology suitable for long distances as well as low cost.

Radio communication technique

There are many wireless technologies suitable for smart water metering applications [6–8]. Figure 1 shows LoraWAN and NB-IoT stand out with their energy-saving capabilities and wide coverage. However, the NB-IoT network in Vietnam is still in the testing phase. Therefore, choosing the right Lora network for practical deployment in Vietnam with the advantage of not having to pay for a network subscription-like NB-IoT.

LoRaWAN™ data transmission technology is a low power and radio frequency wireless transmission technology that brings the Internet of Things concept closer to scale in terms of cost-effective and technical capabilities [10,11]. Its outstanding features: low-power, long-range, immunity to interference and spread spectrum are easily achieved by interoperability and design of security features. It provides seamless interoperability between smart devices without complicated installation and brings convenience to users, developers, and businesses, enabling the deployment of the Internet of Things [10].

The data authentication security model presented in Figure 2 is proposed by the Lorawan association to help secure the system against system intrusions from multiple layers.

The smart water metering system

Smart water metering system designed with automatic and remote data collection via a wireless network. The system consists of the water meter, data collector, wireless network system and management software. Depending on the technology selected system components can be deployed differently. For example, some systems deployed on: M-Bus [4,8], Wifi [1], RF [3]. In the article, a smart water metering system based on the Lora network is selected to build

The proposed smart water metering system uses a data collector designed to be integrated into a traditional mechanical meter (this combination make traditional mechanical can ability monitoring remotely and don't waste old mechanical meter)

The proposed smart water metering system with 3 stages as shown in Figure 3:

- 1st stage: smart water meter (include: Lora smart monitoring module and traditional mechanical water meter)
- 2nd stage: Lora wireless network
- 3rd stage: Control center – Management software

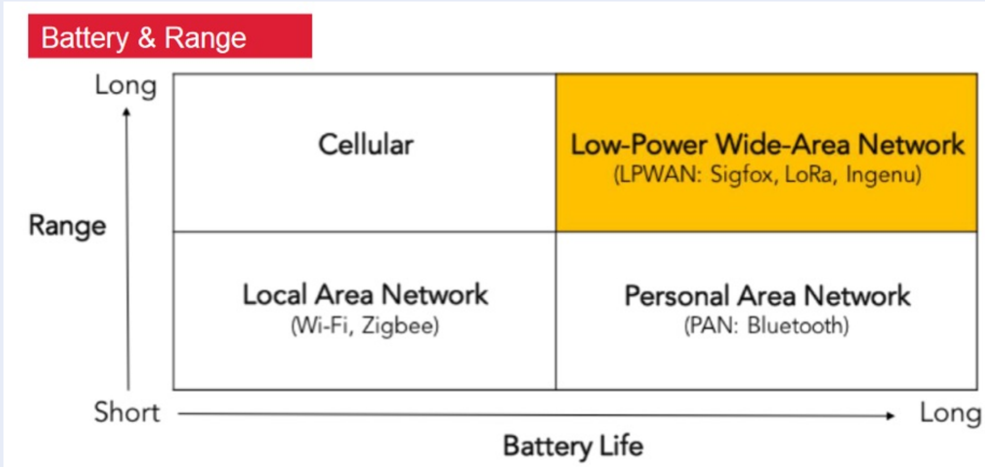


Figure 1: Compare wireless transmission technology [9]

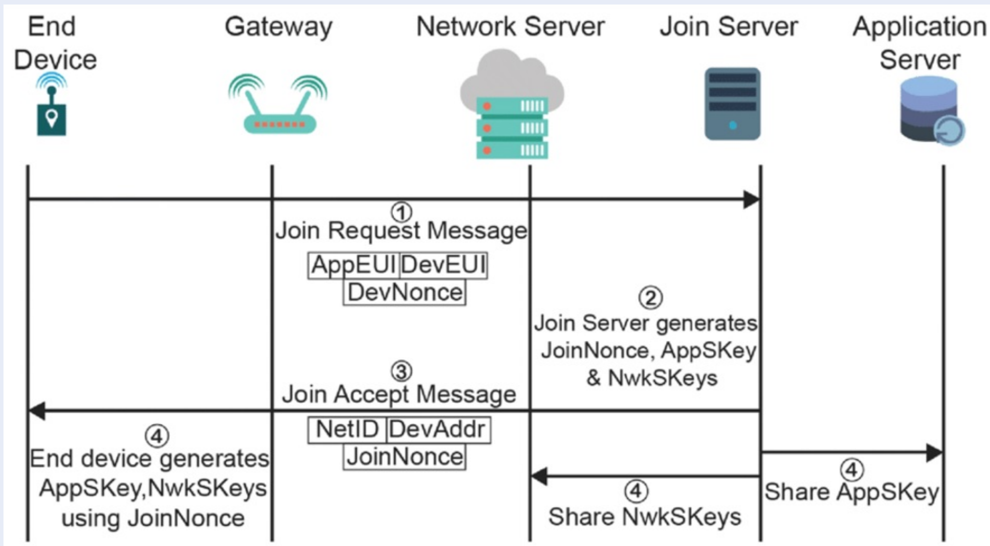


Figure 2: Authentication multi-layer data encryption model [12]

The system uses modern data transmission technologies that allow the connection, control, analysis of reporting data, and other functions such as geolocation. With main ingredients:

- Water meters: includes a smart water metering module attached to a traditional mechanical water meter.

- Smart water metering module: transmits data from the water meter to the Gateways via the Lora network.

- Gateways: collect data from all meters within a coverage radius. It will send information to cloudloud where the data is analyzed by a Server.

- Server: data management server.

- Application server: user interaction via the website, mobile application, alerts, reports, and other issues

Building a smart water meter system for the existing infrastructure of Ho Chi Minh City

Existing infrastructure mostly uses mechanical meters as shown in Figure 4. Replacing new water meters is costly. In the article, specific methods can be integrated into the controller to digitize water meter data to build a smart water metering system based on the existing system.

A smart water meter is a water meter with an additional network interface module to transmit data to a

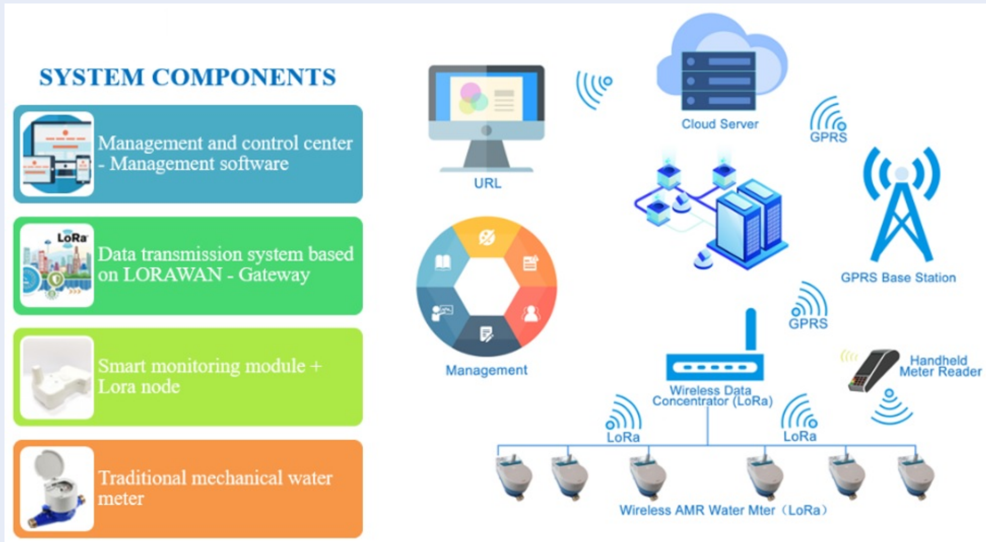


Figure 3: The stages of smart water metering system

local area network or a wide area network for remote monitoring and infrastructure maintenance through leak detection, monitoring, control, automated accounting, and customer management. Thus, a smart meter is a way to be expressed in a management solution compared to reading traditional meter numbers.

According to a report from the Ho Chi Minh City Water Supply Corporation SAWACO, currently, the entire terminal water supply system throughout the domestic water supply network for Ho Chi Minh City uses mainly 3 types of commercial water meters: KENT, Actaris, and Itron. This is a mechanical meter that has been tested to meet metrological standards for the water industry. In particular, the Itron meter is a recently used type with a product design for IoT devices to collect data in a smart water metering application.

In this paper, we focus on designing an integrated smart water metering module for the Actaris and Itron water meter.

When we want to upgrade the mechanical water meter to be able to collect data remotely, we need to convert the mechanical number on the meter into a digital signal through the sensors. The sensor technologies used in water meters in the solution to renovate smart water meters from mechanical water meters include[13]:

- Hall sensor: reads magnetic field from water meter needle magnet

- LC sensor: reads LC oscillation from metal water meter hands

- Optical sensor: reads light reflection from plastic water meter needle

Figure 5 shows the technology of digitizing data of water meter rotation, the core of the technology is to detect the rotation of the clock circle, thereby saving the data of the water meter over time.

The power consumption consumed by the sensor must be low (usually at the level of microamps). In Figure 6, The optical sensor uses LED for reflective readings to detect light reflection surfaces. In this way, the measurement accuracy is affected by surface cleanliness.

As shown in Figure 7, The current consumption refers to the experimental optical sensor solution TI Design[14]. It depends on the sampling frequency.

LC sensor solution with 2 options using external oscillator circuit and using direct oscillator from microcontroller[15]. The schematic diagram of the LC sensor is shown in Figure 8. The Extended Scan Interface (ESI) on the microcontroller to achieve ultra-low power consumption compared with the same detecting methodology using an external circuit. In water meter designs: coupled to 3 LC rotation detection sensors: the ESI is continuously detecting the rotation of the propeller while the rest of the microcontroller is in a low-power mode[16].

Power consumption level refers to 2 options LC sensor shown in Figure 9[17].

Compare the power consumption plan of LC sensor better than using electro-optical sensor

Figure 4: Popular types of water meters in use in Vietnam

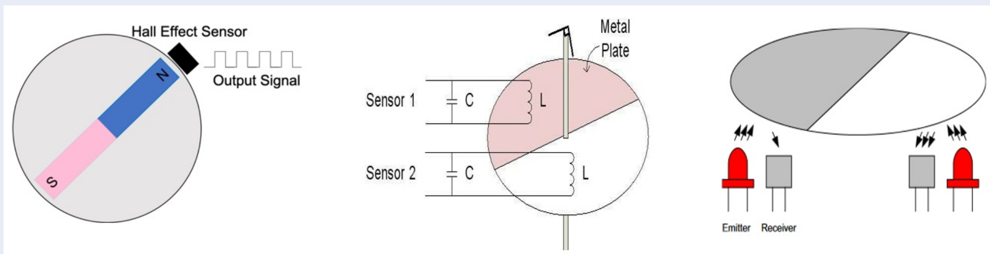


Figure 5: From left to right: Hall – LC – Electro-optical sensor

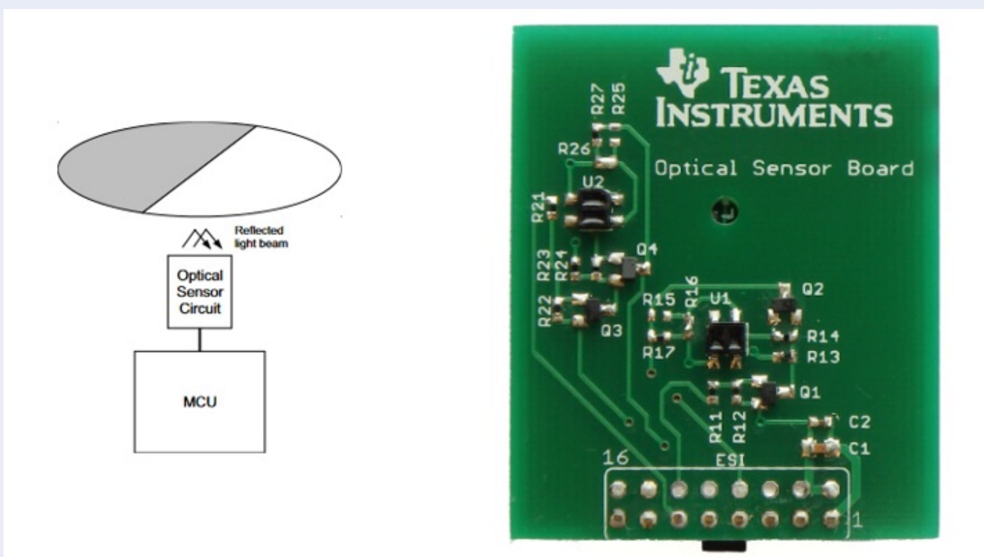


Figure 6: The solution to read the reflection of light on the surface of the rotating disc [14]

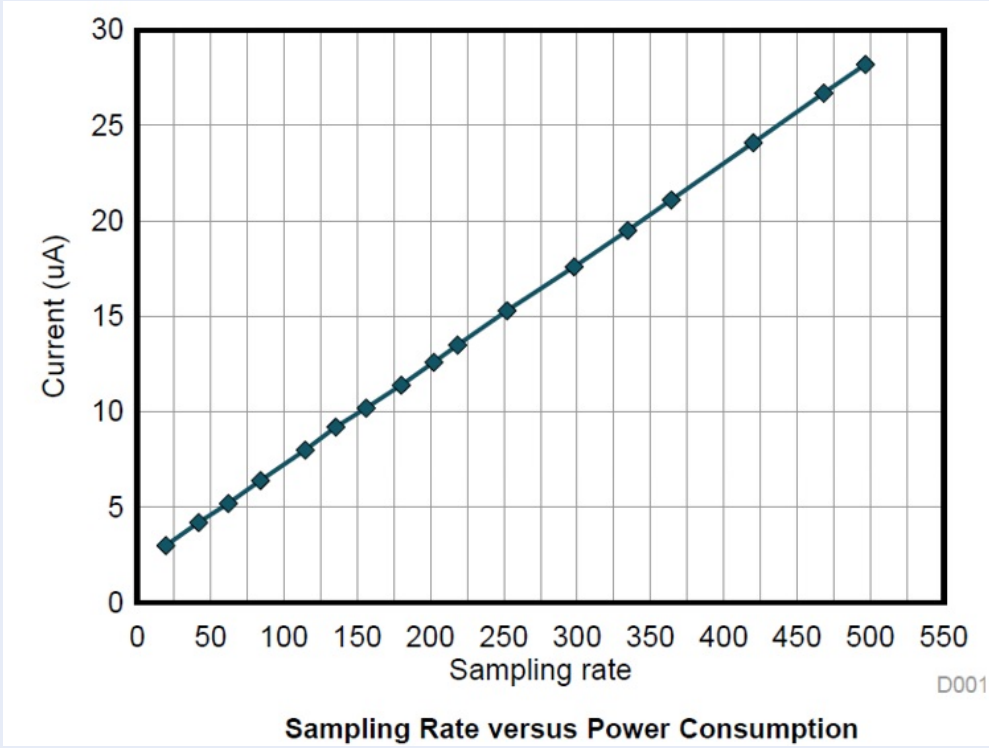


Figure 7: Optical sensor power consumption [14]

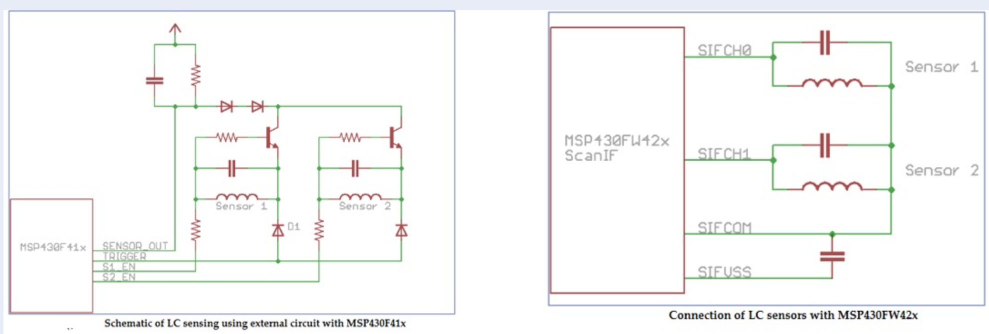


Figure 8: External and direct oscillator LC circuit [16]

The Hall sensor solution is the industry leader in ultra-low power consumption, with lower consumption even at 20Hz sampling rate 1.6uA (reference from ultra-low power Hall sensor solution) use sensor DRV5032

The DRV5032 is an ultra low power digital switch Hall effect sensor designed for the low power consumption application device. The sensor is offered in a variety of magnetic thresholds, sampling rates, output drivers, and packages to suit different applications. The applied flux density exceeds the BOP threshold, the device generates a low voltage. The output stays slow until the flux density drops below BRP, and then the output drives high voltage or becomes high impedance, depending on the device version. Figure 10 shows the schematic diagram of the rotary encoder sensor circuit using Hall sensor DRV5032.

By incorporating an internal oscillator, the device samples the magnetic field and updates the output rate to 20 Hz or 5 Hz for the lowest current consumption. Figure 11 shows the power consumption using the Hall sensor. The results when operating at 5Hz and

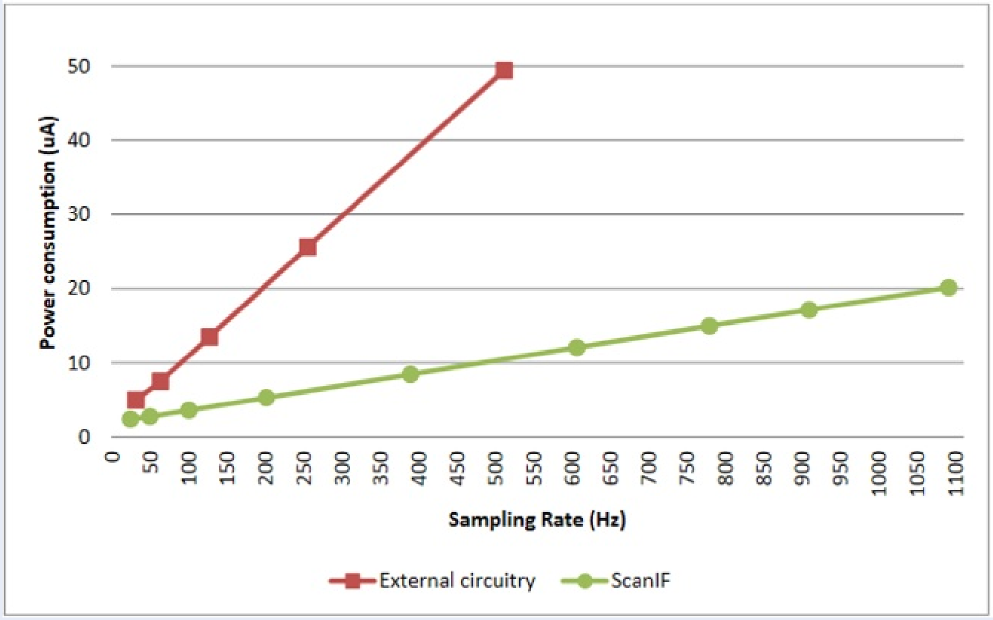


Figure 9: LC sensor power consumption [16]

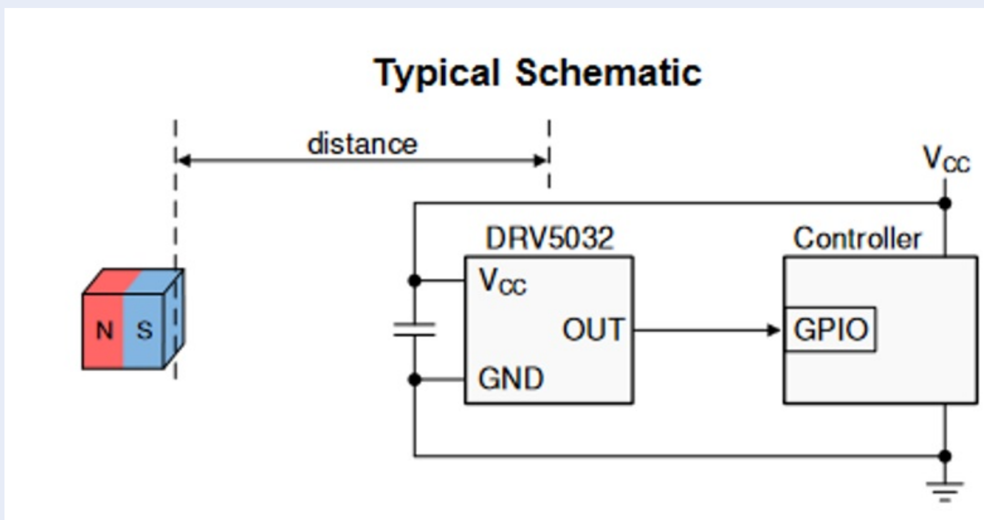


Figure 10: Hall sensor model using DRV5032 [18]

30^oC , the average sensor current consumption is about 0.7uA.

Through analysis of Hall technology and LC sensor results in low energy consumption. The article goes into the experimental design to evaluate between these two technologies

PROPOSED SMART WATER MEASUREMENT SYSTEM AND THE IMPLEMENTATION METHOD

In this paper, the proposed system aims to design an IoT platform-based smart water meter to monitor water consumption, alarms, battery capacity and wireless signal status. According to the analysis in section 2, Lora technology is selected to develop a data trans-

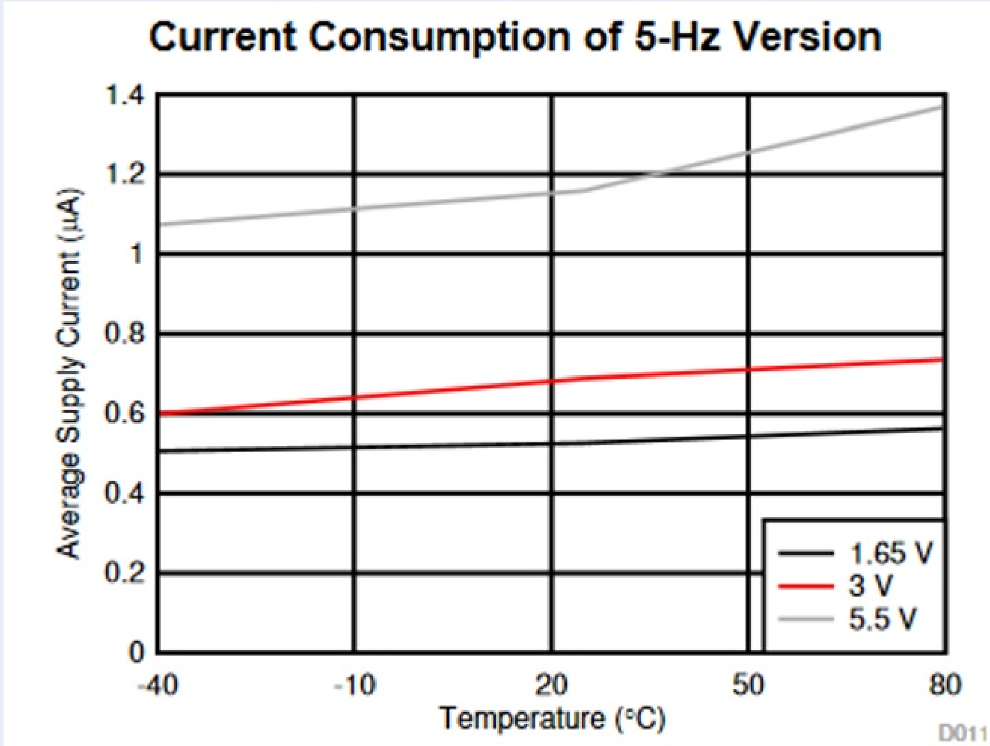


Figure 11: Hall sensor power consumption DRV5032 [18]

mission system. This section will propose the design of a data transmission frame for a smart water meter with the above characteristics. At the same time, in this section, it is also proposed to design a water meter data collection module for two popular water meters using Hall and LC sensor technology.

Data frame for Lora transmission

To perform the data transmission from the water meter, a radio transceiver (RF) is integrated to take care of this task. There are many wireless data transmission technologies used for this purpose today and are divided into 2 main groups: Group of close-range connections with representatives of Bluetooth Low Energy/BLE, ZigBee, Z-Wave, WLAN... and low power long-range connection group (LPWA). The LPWA group is further divided into 2 subgroups: Groups based on cellular technologies (such as LTE-M and NB-IoT) and groups based on non-mobile technologies (such as Weightless-P, LoRa, UNB).

In the article, wireless data transmission technology is selected because of many advantages that are suitable for smart water measurement systems such as [11,19]:

- Data transfer rates range from 300 bps to 5 kbps (In the 125 kHz band) and 11 kbps (In the 250 kHz band), low power ensures the best battery life and long battery life.

- The frequency hopping spread spectrum technology of LoRaWAN® protocol expands network capacity with new long-range shown in Figure 12.

- High data encryption two-way communication, anti-interference ability. Possibility to create a public or private network

- Wide coverage measured in kilometers. Operates on free frequencies, with no licensing costs to use the technology.

- The LoRa single gateway device is designed to handle thousands of end devices or nodes, providing easy network expansion.

- Adding gateway easily expands the ability to connect more terminals

- Low bandwidth makes it ideal for actual IoT deployments with fewer data and with intermittent data transmission.

- Low connection cost, wireless deployment, easy to set up, and fast.

- Security: One layer of security for the network and one layer for the application with AES encryption.

- Supported by CISCO, IBM, and 500 other LoRa Alliance member companies.

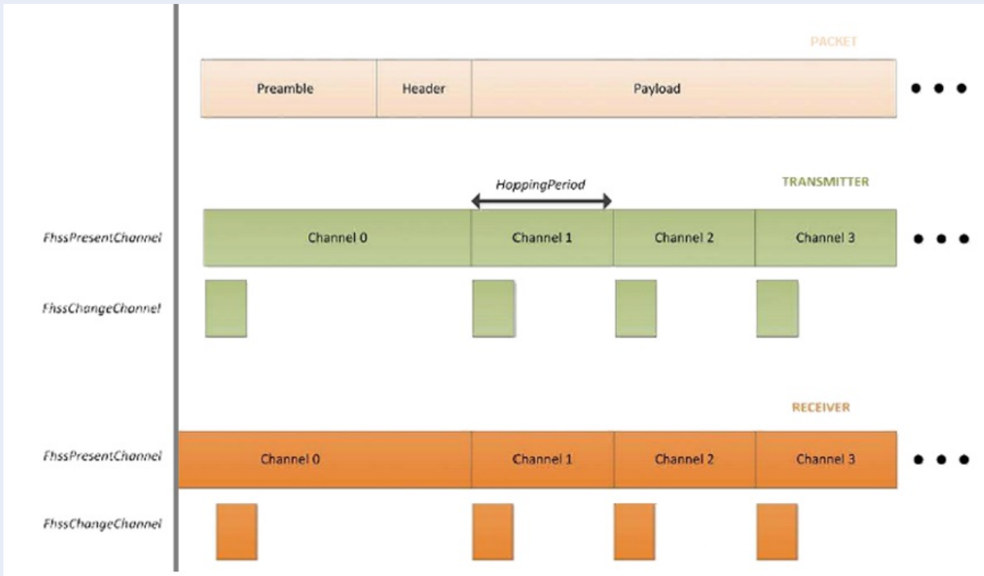


Figure 12: Transmission scheme and interrupts generated in case of channel hopping with LoRaWAN [20]

In a LoRaWan network, the network configuration used is a star of a star, which means that an end device connects directly to one or more gateways within range. Therefore, the LoraWan network speed in this case is the transmission speed between the gateway and the end device. Each channel's carrier is at least 25kHz or 20dB of hopping channel bandwidth, whichever is greater. The dwell time of each channel should not exceed 400mS with a transmission period of the 20s, the minimum number of channels is 50 for systems with a bandwidth of 20dB less than 250kHz. Thus, it can be seen that, with the guarantee of design requirements of less than 200mS, together with a small payload, it is possible to bypass channel hopping in the LoRaWAN network.

The LoRaWAN network itself is designed with variable speeds depending on signal strength to ensure optimal transmission. On the other hand, bandwidth and spreading factors also contribute to the transmission speed. All these parameters will be selected when knowing the payload needed to control devices in the network. An IoT sensor module control protocol designed by the research team for controlling and querying data from devices can be shown in Table 1.

In Table 1, the 1-byte service IDs represent that the commands required to access or control the terminal are water meters. These service IDs are followed by response data to the server. Depending on the requested data, more or less data is returned. In a smart water meter, packets used to send control commands will contain fewer parameters, and therefore will be more concise than return packets (which may contain information about the status of the consumed load) or power sources. This also makes control commands need to be kept as short as possible to increase network reliability and improve transmission speed.

Packets are limited to user payloads between 1 and 12 bytes. In the case of updating parameters from the device to the system. Thus, a payload of 12 bytes can be used as a parameter for calculating transmission parameters. Other parts of the LoRa packet structure will be automatically added to the physical layer of the device. And the CRC as analyzed in the previous LoRa network theories.

The carrier frequency of the LoRaWAN network can operate from 470 MHz to 928 MHz depending on the region. In Vietnam, currently the frequency regulation of LoRaWAN network frequency 923 MHz is selected by users to design for public IoT network to ensure transmission speed. The bandwidth of the LoRaWAN network is selected at 125 kHz, 250 kHz, or 500 kHz. The larger the BW, the faster the transmission and reception speed, the lower the distance. The data transmission frame is designed with 15 bytes for data exchange between the water meter and the data server shown in Table 2.

Sensor circuits to digitize the number of water meter revolutions

In this section. we analyze the technological features as well as how to digitize the water meter.

Table 1: Proposal table for control services and data query command firmware from water meters

Code	Name	Description
0x07	GET_FW_VERSION	Read the FW version
0x0a	Reset	Command used for restart the microcontroller that manages the device
0x14	SET_DATE_AND_TIME	Command used for setting date and time
0x15	GET_DATE_AND_TIME	Command used for reading data and time
0x16	SET_REVOLUTION_COUNTEI	Command used for setting the initial consumption of water meter
0x17	GET_REVOLUTION_COUNTE	Command used for reading the initial consumption of water meter
0x1A	SET_METER_PAR	Command used to set physical counter parameters
0x1B	GET_METER_PAR	Command used to read the physical parameters of the counter
0x26	SET_ALARM_PAR	Command used to set alarm detection parameters
0x27	GET_ALARM_PAR	Command used to read alarm detection parameters
0x28	GET_ALARM_DATA	Command used to read detected and stored alarm data
0x29	SET_ALARM_DATA	Command used to set the flags relating to the detected alarms

Hall-effect technology

Some of the common challenges associated with Hall effect sensors in industrial and automotive applications – are rotary encoders, robust signals, and in-plane magnetic sensors.

Challenge #1 - Can't get good orthogonal characteristic for a rotary sensor with Hall effect experiment

When trying to track speed and direction (clockwise or counterclockwise) in a rotary encoder application, it is common to use two Hall effect pins or a double pin. While there can be several reasons for a poor perpendicular signature, one of the most common is the position (and misalignment) between the device and the ring magnet poles.

When using two Hall-effect pins, a two-bit perpendicular output can be achieved mechanically by placing the Hall-effect sensors half the width apart from each pole plus any integer width. This is exactly shown in Figure 13, where sensor 2 is located at the North/South interface, while sensor 1 is placed the width of a full pole plus half the width of the far North pole sensor 2. For a double-latched Hall effect, you can use a device whose distance between its sensors is exactly half the width of the magnet pole. Of course, this is very limited because we have to match the distance with the ring magnet poles.

The figure above illustrates potential placement problems when using a two-sensor solution and shows how to overcome using two separate sensors or a single-chip solution, respectively.

Challenge #2 – EMI on sensor communication

If voltage output that has magnetic noise coupled to it. While your trace may be short, if there is a lot of electromagnetic interference (EMI) that it cannot account for, your analog signal may be coupling this noise directly into your measurement. There is a reliable link between the sensor and the microcontroller (MCU) that allows the MCU to know if the sensor is connected or disconnected. With a voltage output device, the output can be pulled to low voltage or disconnected altogether - and the MCU won't be able to detect the difference.

EMI is extremely difficult to remove. Shielding, careful wire re-routing, and other mitigation methods can add to the cost of your design. The proposed solution focuses on the sensor itself. Two-wire current output devices are inherently less sensitive to electrical interference, making them an excellent choice for mid-length cabling remote sensing applications. While sending a signal over a long wire causes voltage losses, for most industrial and automotive applications a two-wire current output sensor implementation should work fine.

Challenge #3 - Hall effect sensor is only sensitive to orthogonal magnetic fields

Figure 14 presented most single-axis Hall-effect sensors available today detect a magnetic field perpendicular to the face of the sensor. The choice is limited if you need a sensor that can monitor the magnetic field parallel to the side of the package.

To solve magnetic field detection problems. TI offers an extremely low power consumption Hall sensor

Table 2: Definition of payload command firmwave from smart water meter to Server

Byte	Defined	Value	Note
1	Application code	0x69	Water meter
2	Absolute value byte 1/4		Uint32 number, count up value byte 1 – unit is m3
3	Absolute value byte 2/4		Uint32 number, count up value byte 2
4	Absolute value byte 3/4		Uint32 number, count up value byte 3
5	Absolute value byte 4/4		Uint32 number, count up value byte 4
6	Reverse flow counter 1/2		Uint16, reverse value byte 1 – unit is m3
7	Reverse flow counter 2/2		Uint16 number, value byte 1
8	K index (1 BYTE)		Water meter multiplier
9	Alarm (1 byte)	Bit 0: Reverse flow Bit 1: Abnormal using Bit 2: High magnetic field Bit 3: Low bat Bit 4: Sensor fault Bit 5: Module fault Bit 6: xxx Bit 7: xxx	The alarm of the water meter 0: normal 1: alarm triggered
10	Battery voltage 1/2		Battery voltage - byte 1
11	Battery voltage 2/2		Battery voltage - byte 2
12	Timestamp byte 1/4		UNIX format
13	Timestamp byte 2/4		UNIX format
14	Timestamp byte 3/4		UNIX format
15	Timestamp byte 4/4		UNIX format

The data frame payload includes data such as: application code, revolution encoder value, rate and flow factor, alarms, battery voltage and data transfer time.

chip solution DRV5032 leading the way in Hall sensor choices for rotary encoders. The energy-saving advantage has been mentioned in the energy usage optimization presentation, low power sensor selection.

With low average power consumption, a very small sampling time, the average 3V consumption is 1.6uA with a 20Hz sampling period. Dual pole detection magnetic field with DU/FD current upper threshold active detection 2.5mT, lower threshold no detection 1.8mT

The detection distance is described as shown in Figure 15 and the schematic diagram of the designed circuit is shown in Figure 16.

The design results apply to the Actaris water meter with the old clock hand being replaced by a clock hand integrated with a permanent magnet. The 3D housing design model and sensor placement are shown in Figure 17.

Damped LC Oscillator Technology

The sensor is controlled by a GPIO pin that has both an output function and an ADC input function. First, the GPIO is set to the output function and pulses into the LC circuit. Immediately after that, the GPIO pin is set to Analog input mode and starts reading the damped oscillator signal. The signal will be compared with the reference voltage level and converted to a pulse signal level 0 -1. Figure 18 shows the damping oscillation waveform of the sensor circuit when a metal disc is detected below.

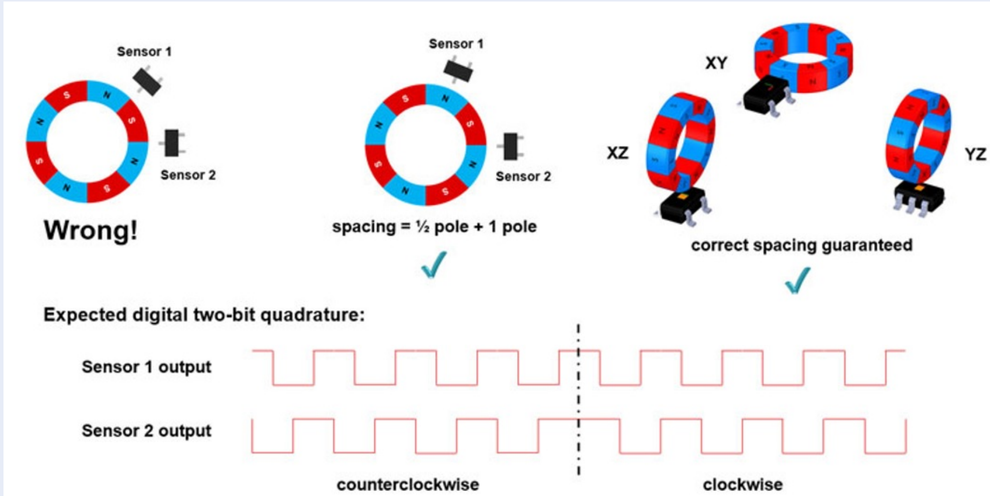


Figure 13: Illustrated selection of the installation location of the Hall sensor [21]

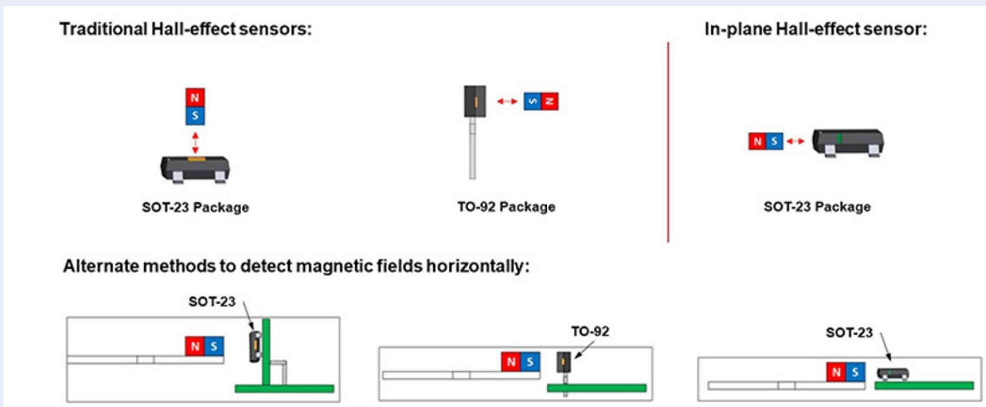


Figure 14: Hall sensor mounting techniques [21]

When the metal plate passes over the top of the LC sensor, some of the magnetic energy is consumed by the metal plate. As a result, the damping oscillation is turned off earlier and the count of pulses is also reduced. The software program is designed to count these pulses, thereby knowing the number of revolutions of the indicator needle (the number of times the metal piece passes through the LC sensor) [16,22].

As shown in Figure 19, The waveform of the sensor is in the absence of a metal pad (red) and with a metal pad (blue). In the case of a piece of metal, the energy is partially consumed so the damping amplitude decreases faster [22].

Figure 19 shows the operation of a sensor. In this case, the comparator threshold level is set to 2.3V (this value is experimentally adjusted during the design process). The yellow line shows the amplitude of the off-oil oscillation, the green line shows the pulse level after comparing it with the threshold. The number of pulses in each oscillation period will indicate whether or not a piece of metal is passing through the sensor. In the figure, the number of pulses to compare 24 pulses. If the actual number of pulses counted is more than 24 pulses, it means that there is no metal cross.

The sensor consists of a parallel LC circuit connected to a voltage generating circuit VDD/2. The reason to use voltage level VDD/2 is that like the waveform shown in the figures above, the self-oscillation phenomenon will cause amplitude much larger than the amplitude of the applied pulse voltage, the use of VDD/2 to ensure that the ADC and comparator of the MCU can still read the damped oscillation voltage within the threshold. The voltage source part VDD/2

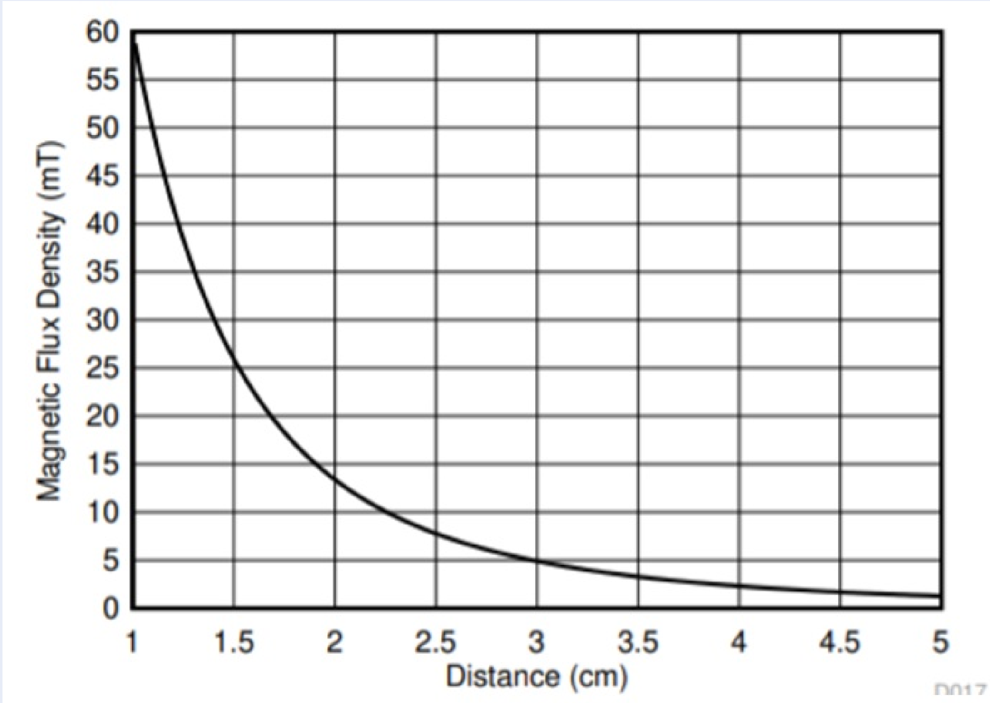


Figure 15: Detection distance with a corresponding active magnetic field [18]

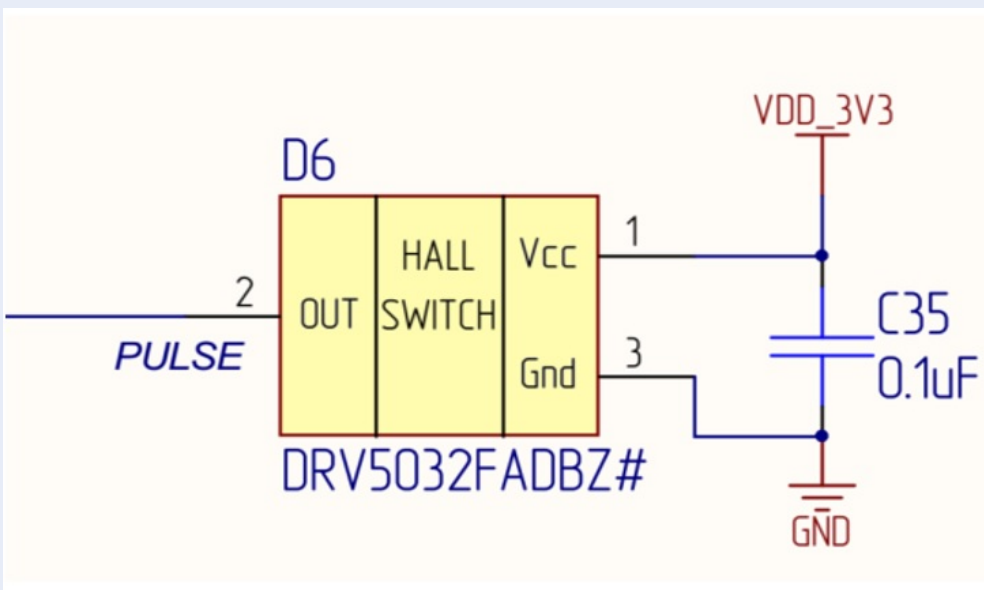


Figure 16: Diagram of the Hall sensor reading the number of clockwise revolutions

Figure 17: 3D model of Lora smart data transmission module integrated on Actaris water meter

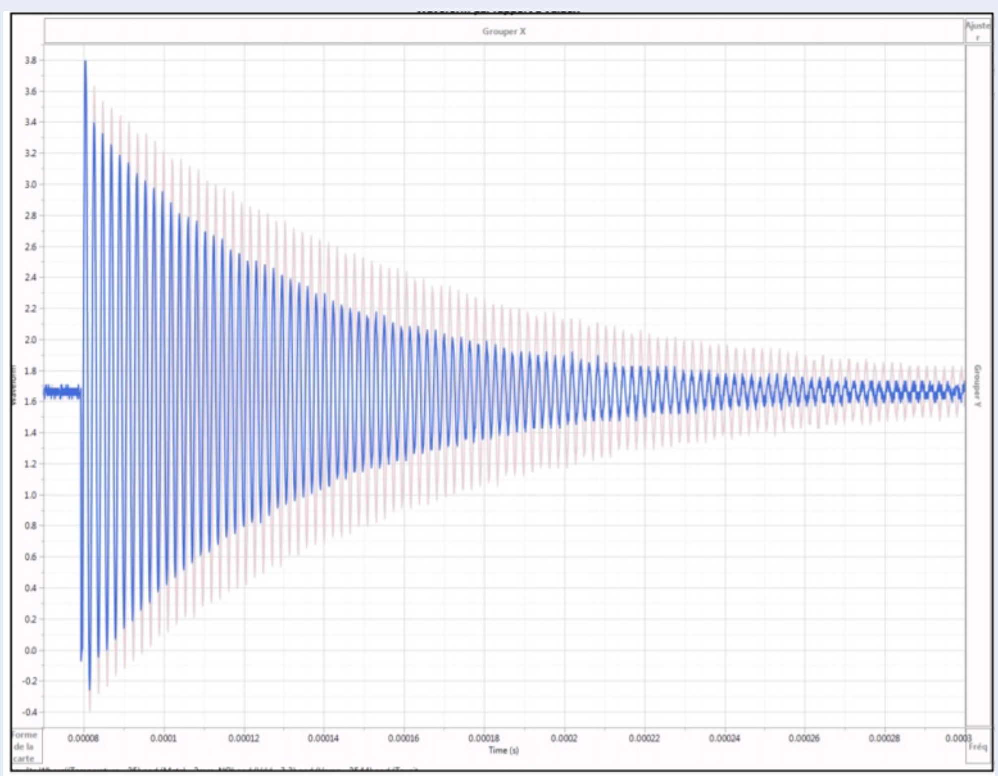


Figure 18: The voltage waveform of the sensor [22]

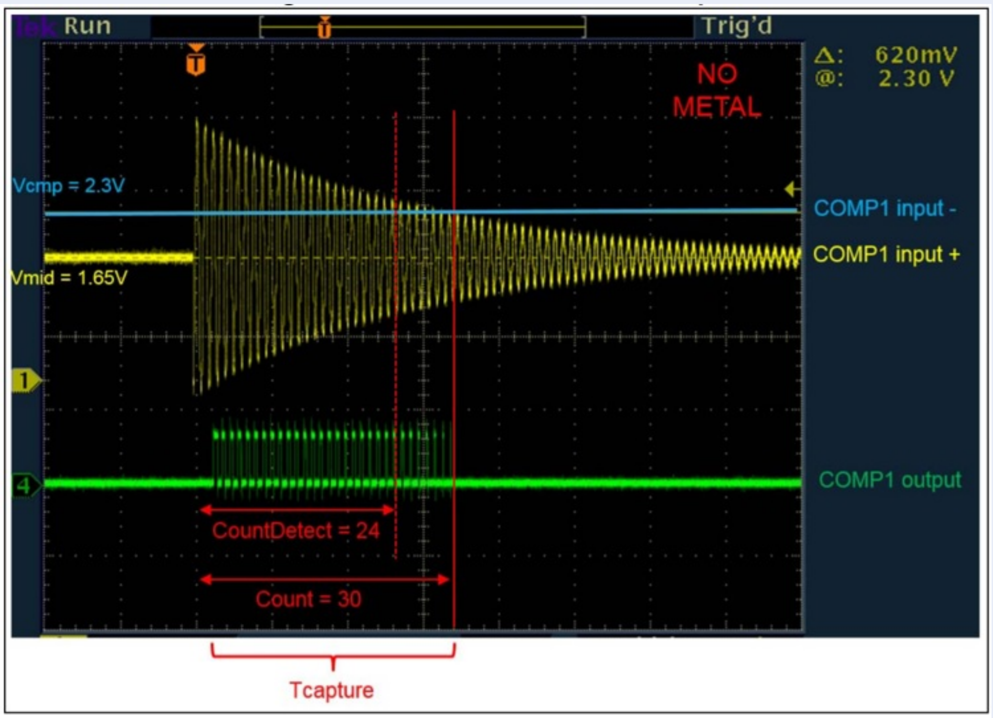


Figure 19: Description of LC sensor operation [22]

is controlled by the IO pin. The excitation signal of the LC circuit is controlled and read by the IO pin (which can perform the function of an output pin as well as an ADC input). The DAC output, compare blocks and an energy-saving timer (LP timer) are used to read and locate the metal piece passing by the sensor.

There are many ways to distribute LC sensors according to different purposes. Figure 20 shows 4 distributions corresponding to 1 to 4 sensors. To detect rotation direction at least 2 sensors are distributed.

For the case of 2 LC sensors described in Figure 21, the sensor can determine the forward and reverse rotation of the water meter.

For the case of 3 sets of LC sensors, in addition to determining the forward and reverse rotation of the water meter, it can also respond to warn when the sensor is compromised and warn when the module is separated from the mechanical water meter.

The schematic diagram and design board are shown in Figure 22 with 3 LC sensors distributed 120 degrees apart.

The design results apply to the Itron water meter with an integrated half metal ring are shown in Figure 23.

mart water meter module

The smart water meter design meets the energy standards and stores the warning by the actual requirements from the water supplier SAWACO. The technical specification requirements are presented in Table 3.

As shown in Figure 24, the circuit board includes: Power Supply and Sensor Voltage blocks, Internal MCU and EEPROM block, LORA block, Block Hall Sensor, UART block, LED Block, Header block connect LC sensor.

Power Supply Block

Figure 25 shows the schematic of the power block. It has 2.5V - 4.2V input voltage and 3.3V output voltage using TPS78233DDCR LDO IC specially designed for battery-powered applications with extremely low IQ static current (500nA)

Static current IQ is the small amount of current required to keep a microchip or other circuit working. Current flows even when the product may be in sleep mode or shutdown. IQ runs even when there is no load on the chip. Furthermore, this current cannot be eliminated or altered. That's why it is a major determinant of battery life.

The voltage divider R3 and R5 are used to read the voltage on the battery to warn Alarm 4 when the battery is low. Because when the voltage bridge is active, there will be a voltage drop on the voltage divider

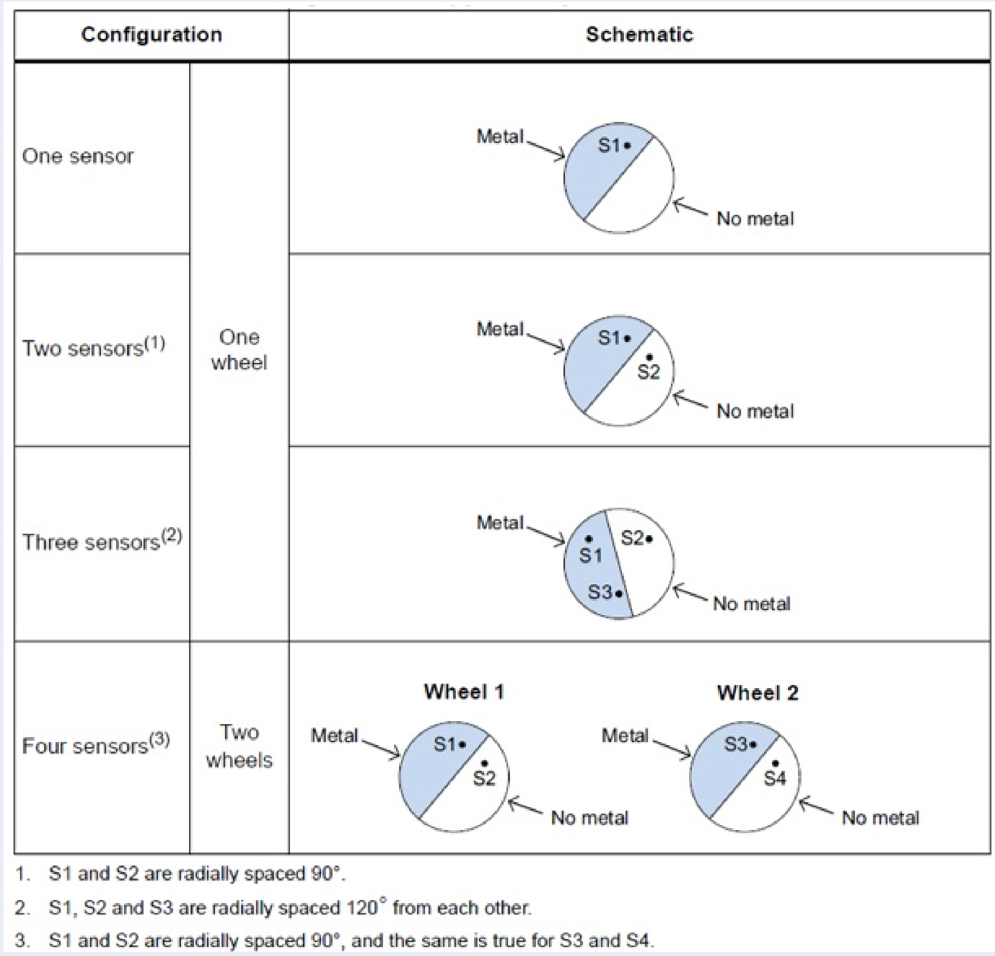


Figure 20: Sensor distribution technique on metal plates [22]

bridge, increasing power consumption, so Q1 is used to turn the voltage divider bridge on and off to reduce power consumption.

Block MCU and EEPROM Internal

IC STM32L081KZU6 with 192Kbytes Flash, 6Kbytes Data EEPROM is the popular energy-saving chip line, full functions and I/O to satisfy two water meter versions. It is enough internal memory to store data according to the set index. The schematic diagram in Figure 26.

LORA block

IC SX1272 is an IC that uses LoraWan network design. The SX1272 IC is connected in advance to the MCU so that it can be programmed to operate in different modes. The LORA block is designed to operate at 915MHz. The RF_PWN_ON pin LORA block is used to control the RF Switch 4529-63 IC to reduce power consumption when there is no need to transmit data to the Gateway. The schematic diagram of the Lora block in Figure 27.

Hall sensor block

Hall Sensor block uses DRV5053 Hall IC to warn Alarm 3. The schematic diagram of the hall sensor circuit is shown in Figure 28. The Q2 MOSFET is used to the ON/OFF Hall sensor block to reduce power consumption.

IoT Platform

From the above analysis, it can be said that LoRaWAN has many advantages and is suitable for smart water measurement applications. The model of a smart water metering system using a smart water meter and LoRaWAN data transmission technology is shown in Figure 29. In each water meter integrated data acquisition controller and LoRa Module. When

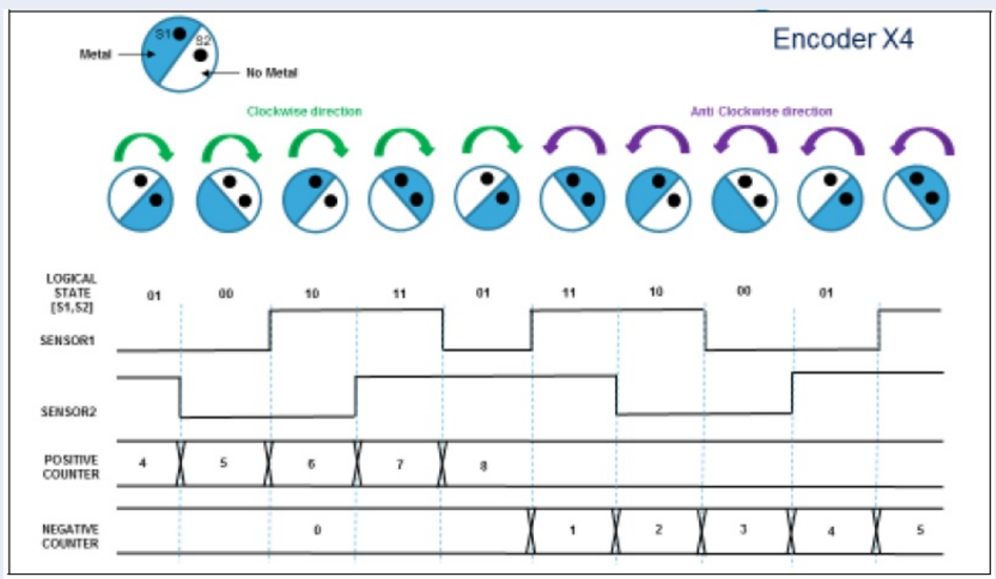


Figure 21: The case of 2 LC sensors [22]

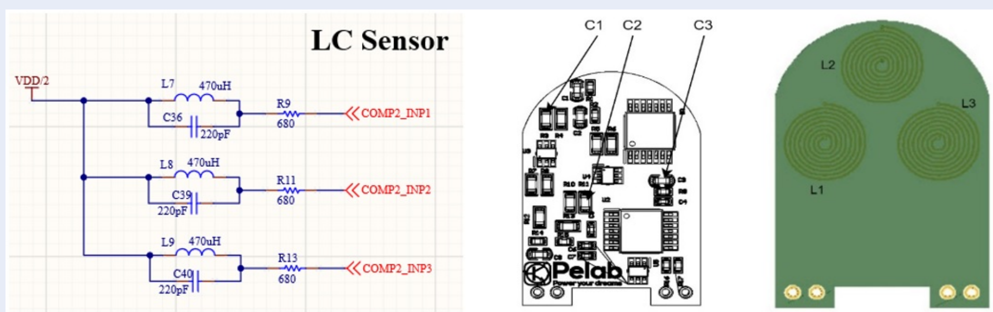


Figure 22: The schematic and printed circuit board of the LC sensor

the user sets the clock parameter. The command will appear from Web application- from Web service to Gateway- Gateway sends command down to LoRaWAN module- and module sends a command to data collection controller for execution Comeinand. This process is a two-way process when the user sends the command down, the command has to run again to get a response. The data from the controller will be transferred to the LoRaWAN module and the Gateway to send to the cloud, the network protocol is TCP. The system architecture consists of a central server, LoRa technology gateways (They are gateways, gateways, or hubs), and terminals (They are points, nodes). Each LoRaWAN module has a unique MAC ID, so that the gateway can distinguish data from which node is sending it. The data packets come from the endpoints to the ports, then to the next chain link, the central server, then they go to the application server and then only to the user.

In a LoRaWAN network, all base stations communicate with the terminals and are visible to the terminals as a network. The process of exchanging information is carried out under the control of a dedicated network server on which specialized software is deployed - the Network Platform.

The Network Platform monitors a device's connection to the network and manages their interaction at the physical and MAC layers according to the LoRaWAN protocol specified by the LoRa Alliance^{TM}.

- End Point
- Gateway (Base Station)
- Operator Server Platform (OSP)

Based on the LoRaWAN specification, the intelligent lighting data transmission system needs to meet the

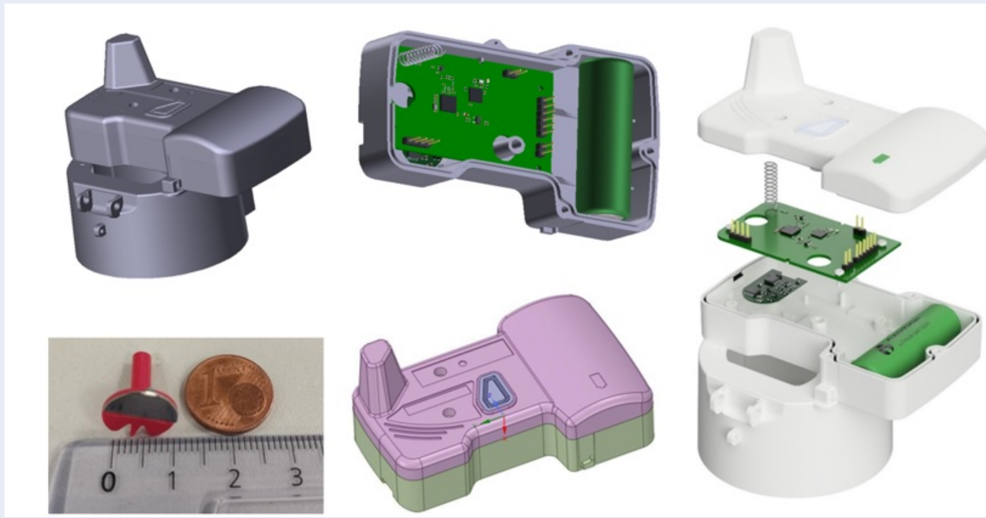


Figure 23: 3D model of smart water metering module integrated on Itron water meter

Table 3: The propose smart water meter specifications

The battery:	- Battery: 3.6V. lithium - Life cycle: 6 years - Normal working current < 20uA - Replaceable battery: separate glue dispenser.
Radio interface:	- Lorawan class A - 915 Mhz - OTA activation method
Data storage:	- The last 180 days - The last 100 months - MCU: STM32L081KZxx
Alert:	- Alarm 1: Warn when there is a phenomenon of pumping water back into the network - Alarm 2: Warn when there is an abnormal increase in water usage - Alarm 3: Warn when being penetrated by a magnetic field - Alarm 4: Alerts when the battery is low - Alarm 5: Warn when the sensor is compromised (using LC sensor). - Alarm 6: Warn when the module is separated from the mechanical water meter (using LC sensor).

following basic technical requirements:
- Sensitivity should be above -137dBm; RSSI value must be in the range (0; -137) dBm and SNR; data transmission time from end device to gateway must be less than 200ms.
- The power consumption of the system must be extremely low, meeting the LoRa specification; the ability to stabilize current and voltage must be <3%.
- Transmit, receive data on: clock revolutions, water consumption, power consumption, battery status, RSSI, SNR, alarms, sampling time, clockwise/clockwise rotation ratio/ liter…

IoT Platform was built with the services (Figure 30)
- LoraWAN Service: process upstream and downstream Lora package message.
- Public-API: provide for design application (web/mobile app).
- Platform core: build on a virtual machine with Kubernetes and Docker.
- Other IoT services: connect another smart system such as environment, lighting, security, home management, smart city…
- Monitoring: monitor server and service.

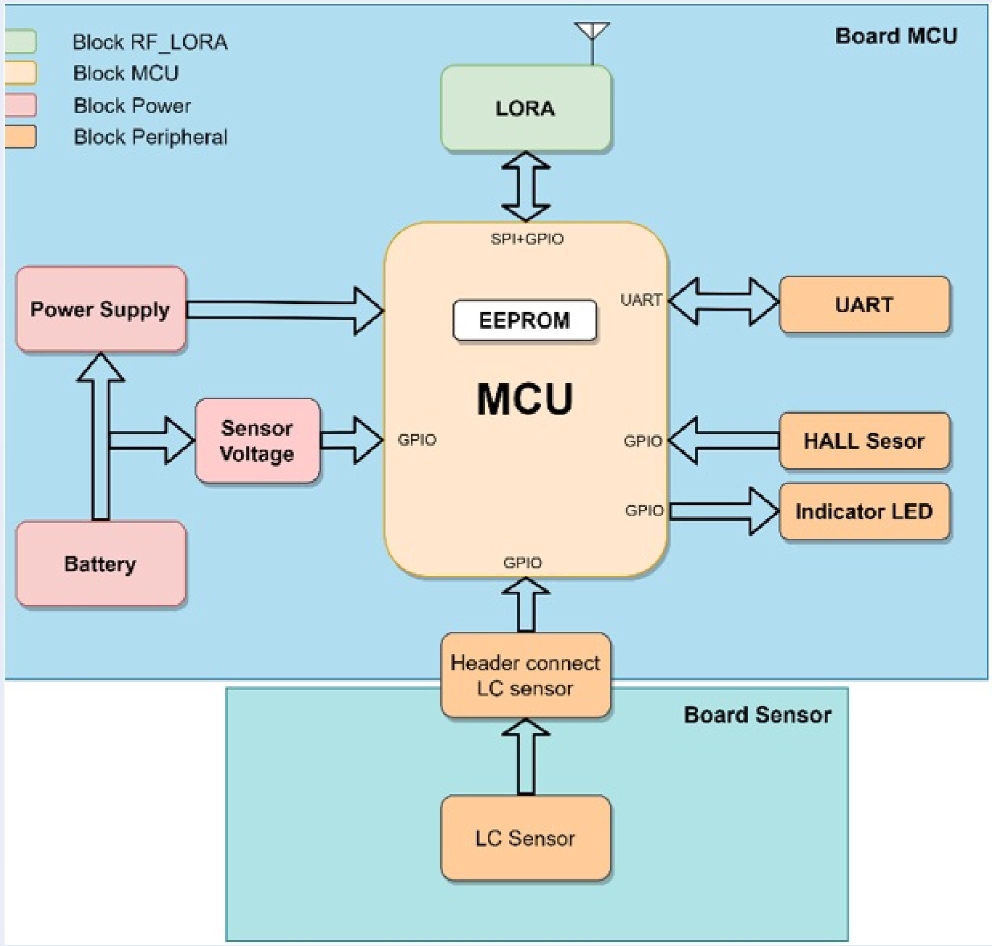


Figure 24: Smart water meter hardware block diagram

- UserSpace: dashboard for managing gateway and end device.
- Location-Based Service: manage location.
- Device Registry: manage the device.

EXPERIENCE RESULTS AND DISCUSSION

A smart flow water monitoring system was built to verify the design. These works included Lora gateway installation on the building, setting up the server, and testing the smart water meter in the laboratory. We aim to find a full solution with a smart water metering system that can be built in Viet Nam. Figure 31 shows the installed equipment for experimental evaluation of the deployed smart water metering system.

The signal loss results in the Lora network are shown in Figure 32 was provided by the manufacturer of the gateway. The required signal loss within a 1.2km radius allows for good data transmission and less packet loss (RSSI < -90dB).

Actaris water meter integrated smart water metering module is shown in Figure 33. The printed circuit board is designed with the circuits: Hall sensor, power supply, magnetic field alarm and lid opener, central control MCU and wireless Lora.

Itron water meter integrated smart water metering module is shown in Figure 34. The printed circuit board is designed with the circuits: LC sensor, power supply, central control MCU and wireless Lora.

The result for energy consumption was shown in Figure 35.

According to experimental data, the number of data transfers correlates with battery life. In Table 4 are the survey results with the number of data transmissions from 1 to 4 times in 1 day compared with the energy consumption of the water meter.

Energy consumption module in normal operating mode approximate 46uA and data transmission mode

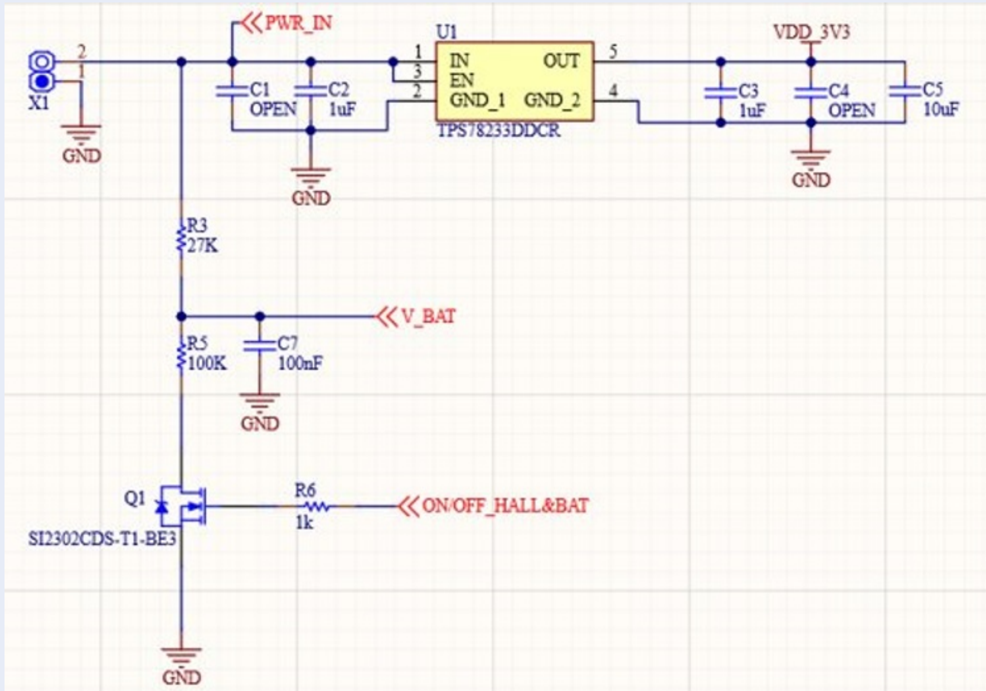


Figure 25: Schematic power supply

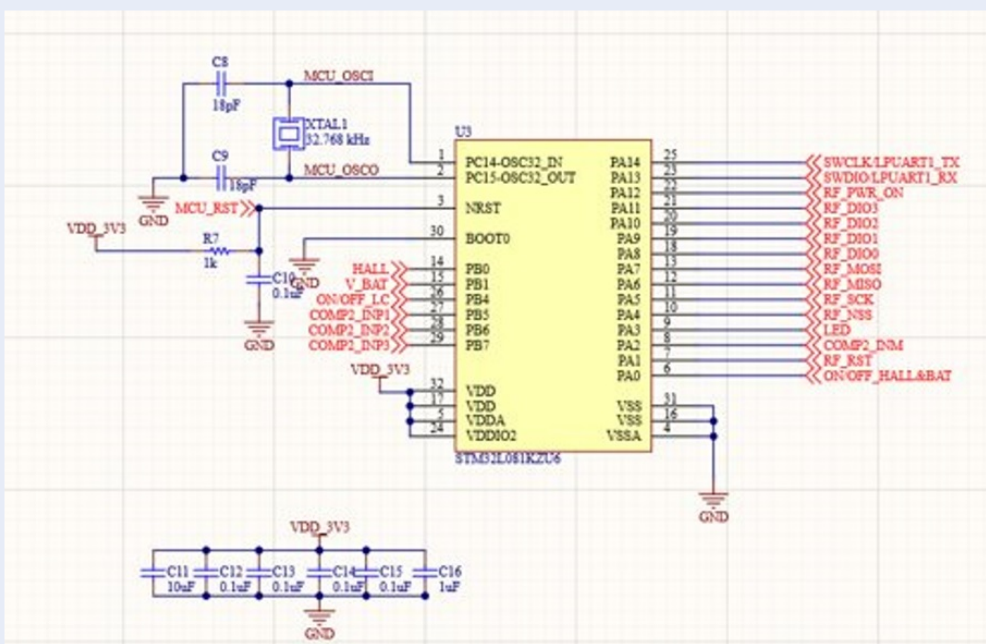


Figure 26: Schematic MCU STM32L081KZU6

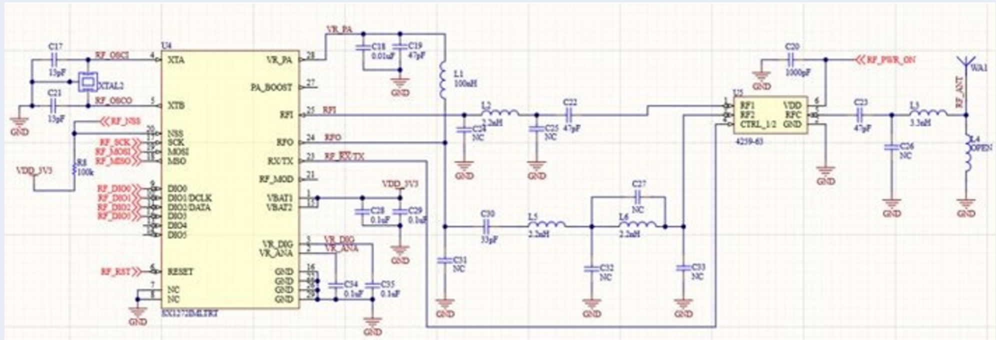


Figure 27: Schematic Lora circuit

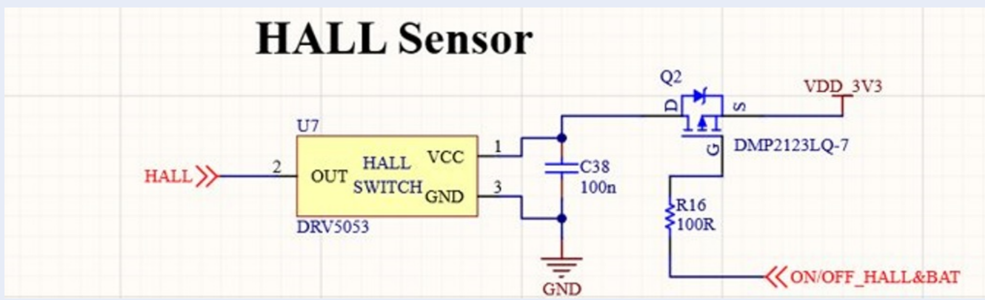


Figure 28: The schematic hall sensor circuit

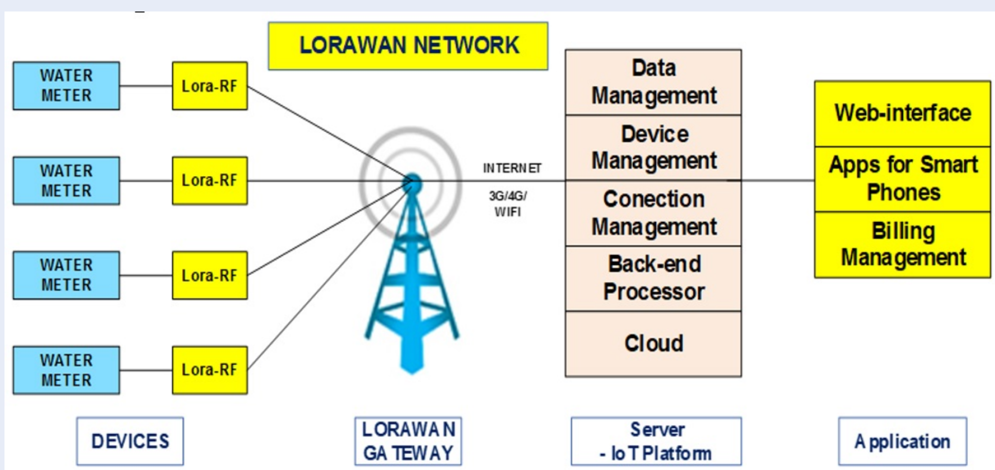


Figure 29: Structure model of wireless intelligent water metering system

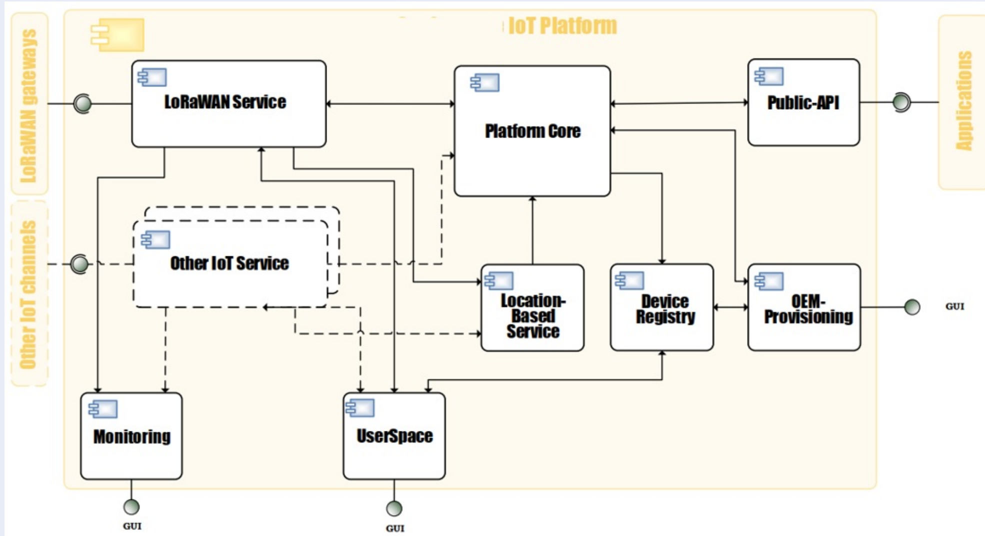


Figure 30: The structure of IoT Platform

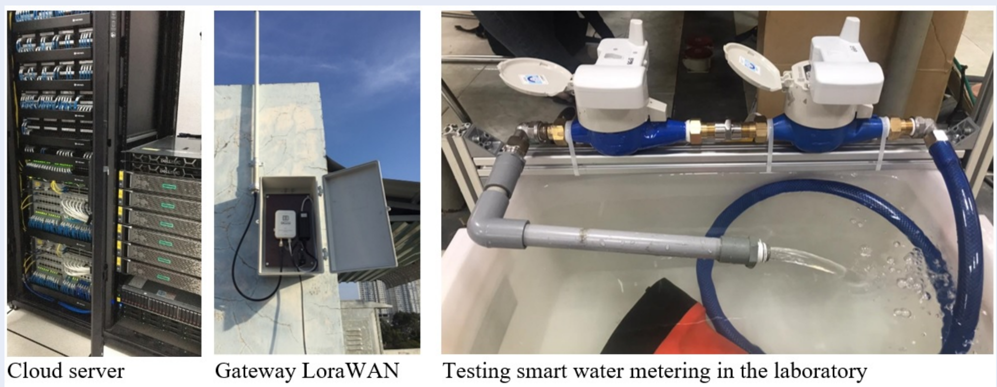


Figure 31: The whole smart water metering system (end device, network, and server)

Table 4: The comparison of life cycle and the number of data transmit every day

Battery capacity(mAh)	The number of data transmitted per day	Current at transmission (mA)	Current at normal operating (mA)	Current consumption per day (mAh)	uses	The number of years
3600	1	31.5	0.0464	1.2011	2997.25	8.21
3600	2	31.5	0.0464	1.2886	2793.73	7.65
3600	3	31.5	0.0464	1.3761	2616.09	7.17
3600	4	31.5	0.0464	1.4636	2459.69	6.74

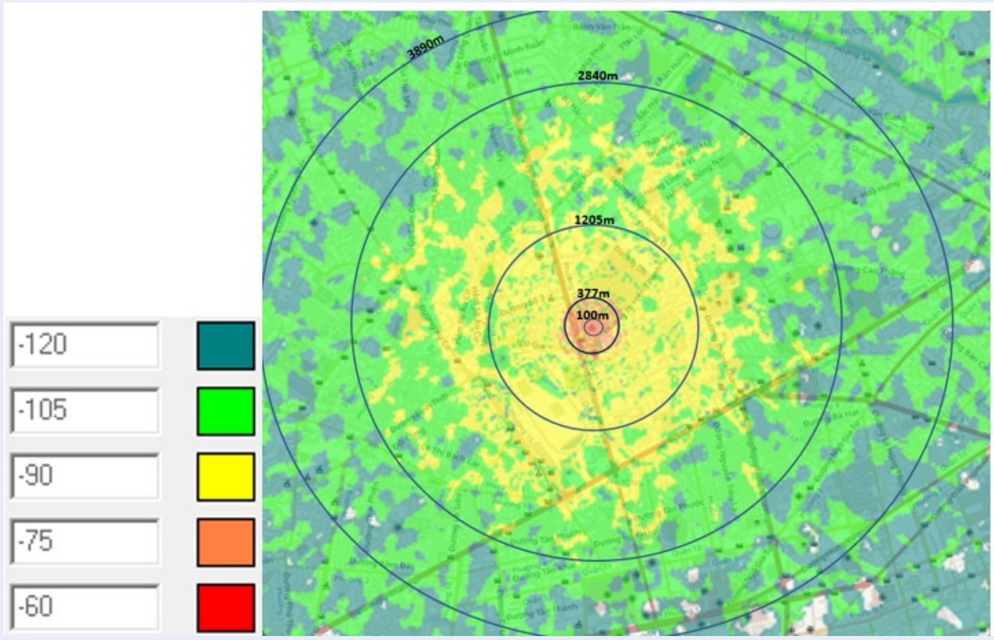


Figure 32: Received Signal Strength Indicator lorawan network vs distance

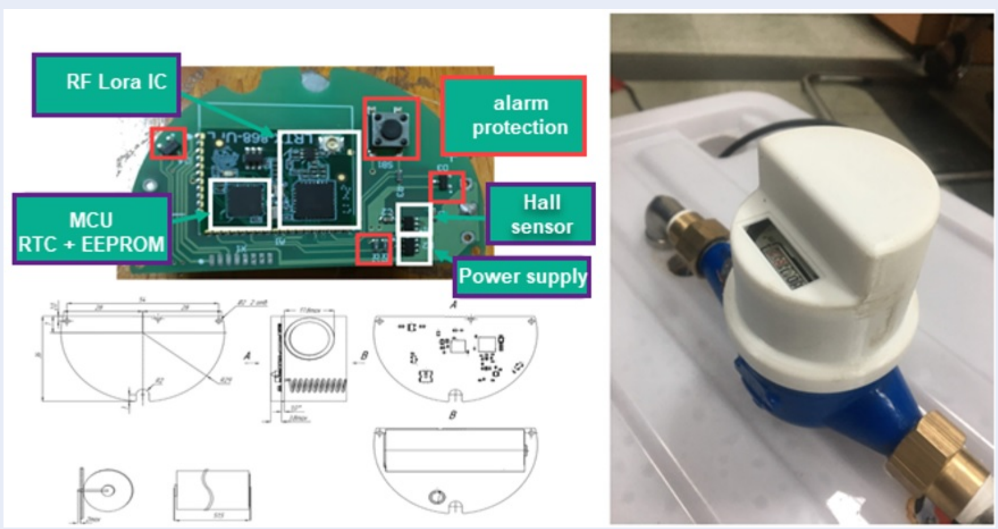


Figure 33: Smart water meter board for Actaris mechanical meter

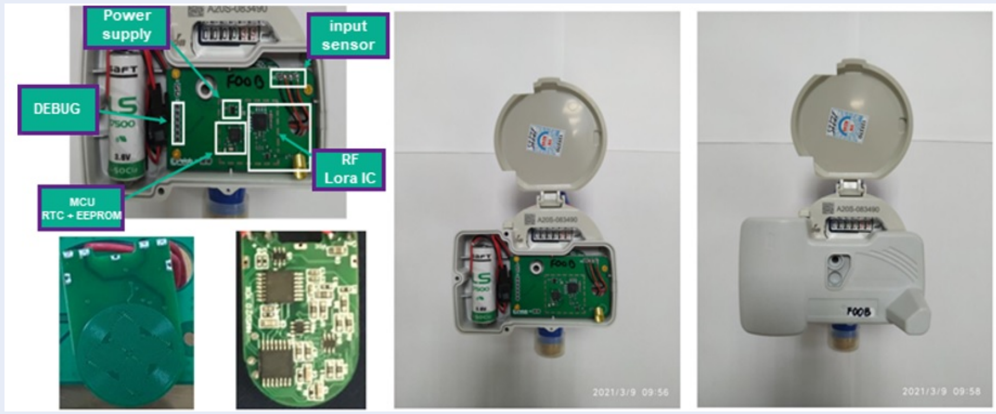
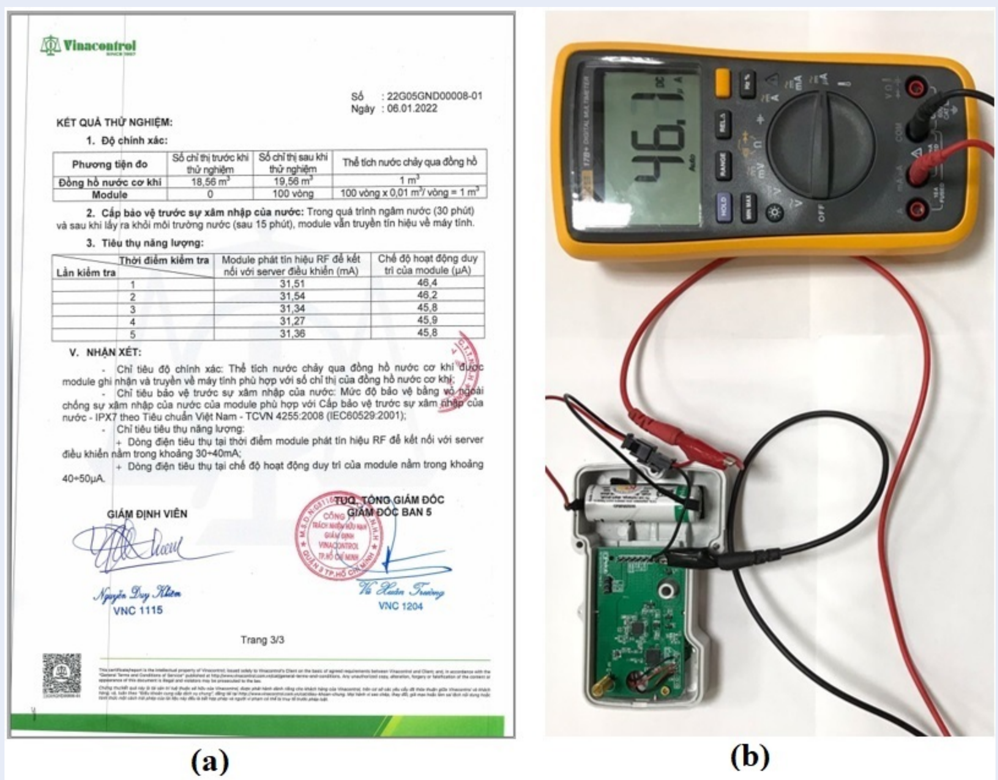


Figure 34: Smart water meter board for Itron mechanical meter



Vinacontrol

Số : 22G05GND00008-01
Ngày : 06.01.2022

KẾT QUẢ THỬ NGHIỆM:

1. Độ chính xác:

Phương tiện đo	Số chỉ thị trước khi thử nghiệm	Số chỉ thị sau khi thử nghiệm	Thể tích nước chảy qua đồng hồ
Đồng hồ nước cơ khí	18,56 m^3	19,56 m^3	1 m^3
Module	0	100 vòng	100 vòng x 0,01 m^3/ vòng = 1 m^3

2. Cấp bảo vệ trước sự xâm nhập của nước: Trong quá trình ngâm nước (30 phút) và sau khi lấy ra khỏi môi trường nước (sau 15 phút), module vẫn truyền tín hiệu về máy tính.

3. Tiêu thụ năng lượng:

Lần kiểm tra \ Thời điểm kiểm tra	Module phát tín hiệu RF để kết nối với server điều khiển (mA)	Chế độ hoạt động duy trì của module (µA)
1	31,51	46,4
2	31,54	46,2
3	31,34	45,8
4	31,27	45,9
5	31,36	45,8

V. NHẬN XÉT:

- Chỉ tiêu độ chính xác: Thể tích nước chảy qua đồng hồ nước cơ khí được module ghi nhận và truyền về máy tính phù hợp với số chỉ thị của đồng hồ nước cơ khí;
- Chỉ tiêu bảo vệ trước sự xâm nhập của nước: Mức độ bảo vệ bằng vỏ ngoài chống sự xâm nhập của nước của module phù hợp với Cấp bảo vệ trước sự xâm nhập của nước - IPX7 theo Tiêu chuẩn Việt Nam - TCVN 4255:2008 (IEC60529:2001);
- Chỉ tiêu tiêu thụ năng lượng:
  + Dòng điện tiêu thụ tại thời điểm module phát tín hiệu RF để kết nối với server điều khiển nằm trong khoảng 30÷40mA;
  + Dòng điện tiêu thụ tại chế độ hoạt động duy trì của module nằm trong khoảng 40÷50µA.

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Trang 3/3

(a) (b)

Figure 35: a. Certificate of energy consumption; b. Energyconsumption module innormal operating mode

approximate 31.5mA, with 3.7V/3600mA the life cycle time device more than 6 years with one data transmitted per day. It is suitable for the water meter replacement cycle.

System management software:

User hierarchy: includes administrator (super administrator), supervisor controller (admin), the user (user)

Administrator: has the right to create a new project page, create an admin account for the supervisor as well a user account.

Supervisory controller: has the right to install more and fewer areas and equipment, set operation mode, and monitor and monitor all activities on the management system. At the same time, it also has the right to create user accounts, add or remove information, and limit user rights.

User: only has the right to view, monitor, and monitor, but cannot install system control, the parameters to be viewed are specified by the supervisory controller.

Decentralized system management: including project-based management, each project manages many areas, each area manages many devices. The web interface of the login page is shown in Figure 36. Users can register an account as well as retrieve their password on this page.

Figure 37 is shown the system overview website. System overview monitoring interface can view system overview (number of zones, number of water meters, On/Off/Trouble/Warning/Lost operation status, and quantity comparison graphs consuming countries in the last 6 months).

The area management interface for installing water meters, selecting an area will list water meters in the area on the map and information for each customer. The actual installation position and signal strength are shown in Figure 38.

Figure 39 shows the device management page by region. On this page, users can view information about water meters by area.

Figure 40 shows the management page for each water meter. The management interface of water meters in the area, existing smart meters, including features such as information viewing, monitoring, alarm activity monitoring, and settings.

Figure 41 shows the management interface tab of the smart water meter. Thanks to leakage and abnormal detection warning, the user can save water usage by cutting down on water waste and quickly identifying issues in a water distribution network.

Figure 42 shows the system user account management page, the permissions of each account.

The test installation at the HCMUT helps detect leaks due to pipe damage as well as users forgetting to lock the water, saving money and timely handling. Moreover, abnormal flow detection and usage history monitoring help users adjust their water usage habits more economically. As shown in Figure 37, Actual measurement on software after having the smart water metering system reduces average water consumption by 23%.

CONCLUSION

The article presents an overview of technologies for building smart water metering systems, including designs: digital meter technology, wireless data transmission technology, smart water metering module. The new solution is to take advantage of the old water meter by designing a smart water metering module. This significantly reduces the cost of building the system. The device has many features to help manage water measurement more effectively. The smart water metering system is deployed on the Ho Chi Minh City University of Technology campus to verify the economic efficiency and obvious benefits of the system. The design system has solved the problem of remotely collecting statistics and detecting and adjusting unreasonable water usage, reducing consumption by up to 20%. The designed devices are quality tested by competent authorities and meet requirements according to set standards. The research smart water metering platform improves water-saving habits, pipe leak warning, and remote installation reduce operating costs promptly detect road damage, especially creating a premise for the development of the ”Smart City” system.

ACKNOWLEDGMENTS

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CONFLICT OF INTEREST

The authors have no conflict of interest on the subject

AUTHORS’ CONTRIBUTIONS

Le Minh Phuong researches design methods and writes articles, Nguyen Van Phuc designs hardware, Nguyen Hoai Phong and Nguyen Minh Huy writes control programs, runs experiments to measure and collect data. Le Minh Phuong consulted and supervised the process of writing and editing the article.

Figure 36: Login interface to the management and control system

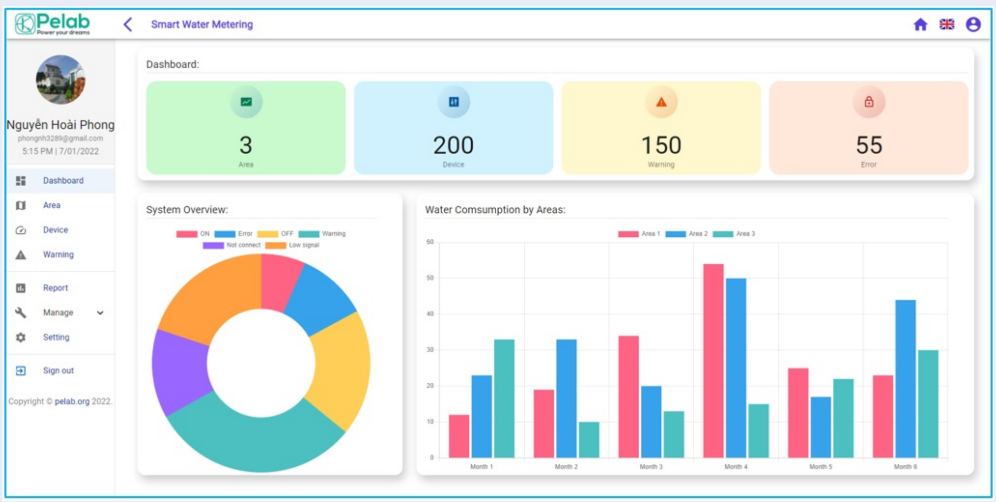

Figure 37: System overview interface

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Figure 38: The smart water metering system at HCMUT

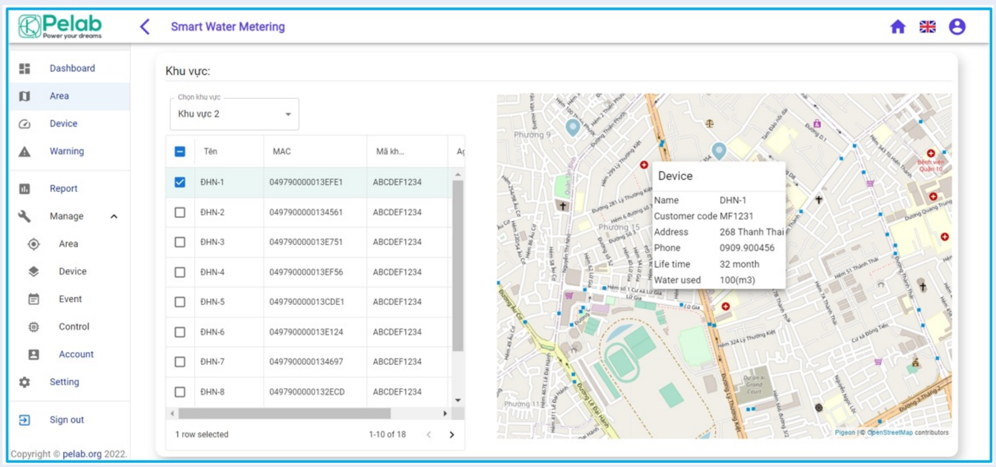

Figure 39: Area management interface

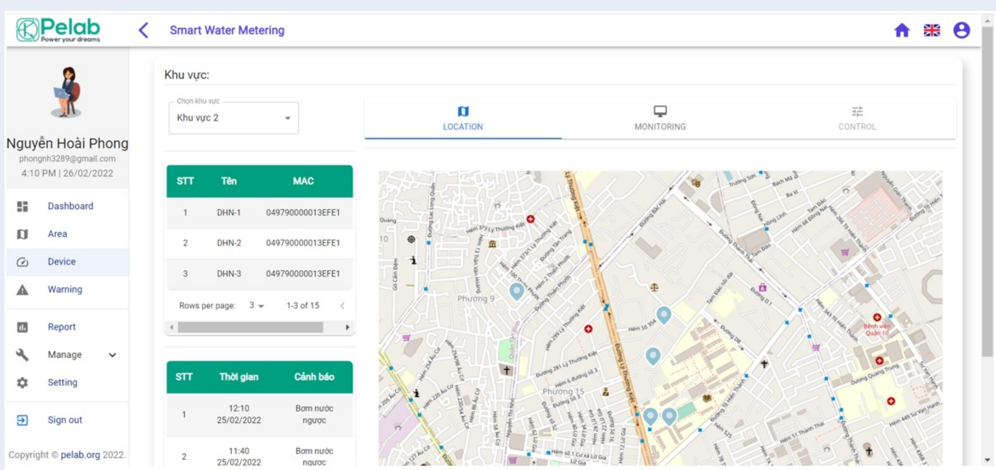

Figure 40: Device management interface

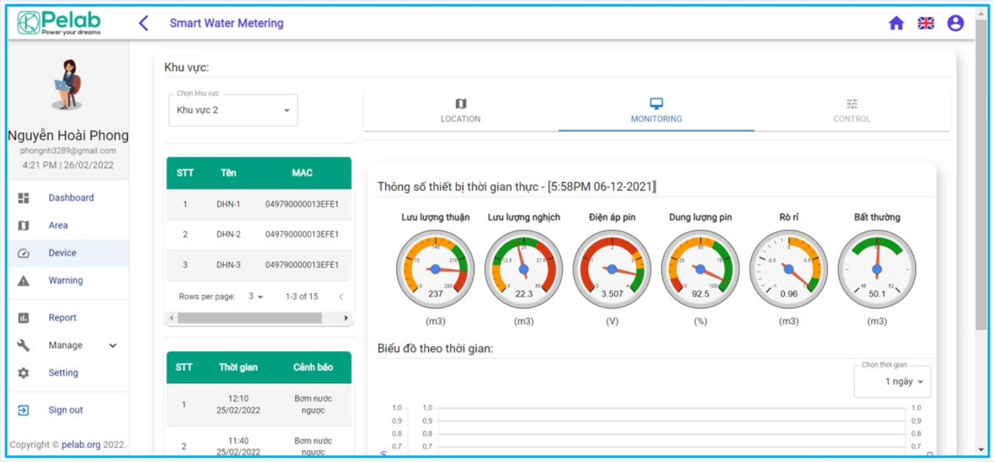

Figure 41: Smart water meter management interface

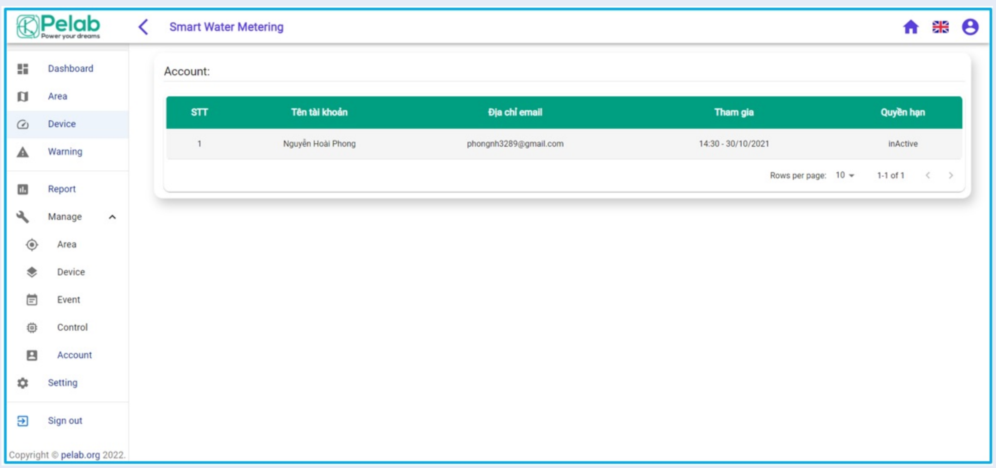

Figure 42: User account management interface

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Tạp chí Phát triển Khoa học và Công nghệ – Kĩ thuật và Công nghệ, 5(1):1342-1370

Open Access Full Text Article

Bài nghiên cứu

Phát triển và triển khai Hệ thống đo nước thông minh dựa trên Công nghệ Lora

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TÓM TẮT

Bài báo trình bày tổng quan về đồng hồ đo nước truyền thống ở Việt Nam, các công nghệ số hóa đo lường và công nghệ truyền dữ liệu không dây để thu thập dữ liệu và ứng dụng người dùng trong hệ thống đo nước thông minh. Sau đó, đề xuất thiết kế bộ điều khiển đồng hồ nước không dây thông minh. Bài báo này tập trung vào việc thiết kế và triển khai hệ thống đồng hồ nước thông minh nhằm tái sử dụng đồng hồ đo nước cơ truyền thống bằng cách thiết kế một bộ điều khiển đo nước thông minh gắn liền với đồng hồ hiện có. Bằng cách này, giúp loại bỏ các chi phí đầu tư vào đồng hồ đo lưu lượng và ảnh hưởng đến hệ thống hạ tầng đồng hồ đo nước cũ. Đóng góp của bài báo này gồm ba phần: (i) Thứ nhất, đề xuất các công nghệ đo lường số hóa và truyền dữ liệu không dây phù hợp với hệ thống đo lường nước ở Việt Nam. (ii) Thứ hai, các thiết kế bộ điều khiển đồng hồ nước thông minh được đề xuất bao gồm phần cứng, truyền dữ liệu không dây và vỏ nhựa. Có hai mẫu thử nghiệm của bộ điều khiển được giới thiệu trong bài báo này (iii) Cuối cùng, bài báo này cung cấp một mô hình phần mềm quản lý đo lường nước cho các thành phố thông minh. Hệ thống tổng thể của nền tảng được đề xuất đã được xây dựng thực tế để xác minh thiết kế được trình bày. Để giảm lượng nước rò rỉ hoặc người dùng gian lận từ bên ngoài đồng hồ vào kết quả đo, bài báo đề xuất thiết kế các tính năng cảnh báo về: dòng chảy bất thường, ảnh hưởng từ trường mạnh và vỏ thiết bị bị tháo. Thử nghiệm kiểm chứng được thiết kế với đồng hồ nước Actaris sử dụng công nghệ Hall để số hóa dữ liệu và đồng hồ nước Itron với công nghệ số hóa sử dụng cảm biến LC. Bên cạnh đó, hệ thống mạng không dây Lora được đề xuất và triển khai để xác minh quản lý đo lường nước với ưu điểm là tiêu thụ năng lượng thấp, bảo mật cao và quy trình xác thực nghiêm ngặt. Kết quả thực tế đối với môi trường phòng thí nghiệm và khu dân cư cho thấy suy hao tín hiệu (RSSI) và nhiễu tín hiệu (SNR) nằm trong phạm vi cho phép. Ngoài ra, tỷ lệ mất gói tin <1% và công suất tiêu thụ trung bình <50uA. Phần mềm quản lý đo nước được trình bày để kiểm chứng cho hệ thống dịch vụ thành phố thông minh.

Từ khoá: Đo lường nước thông minh, mạng Lora, cảm biến Hall, cảm biến LC, nền tảng IoT

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