A Smart Delivery System Using Internet of Things

Van-Lan Dao and Van-Phuc Hoang
Le Quy Don Technical University, 236 Hoang Quoc Viet Str., Hanoi, Vietnam
E-mail: landv@mta.edu.vn; phuchv@mta.edu.vn

Abstract— **Real time parameter monitoring for the products in the smart delivery system is an extremely necessary task but there are many challenges due to great quantities and the movement of products. In this paper, a smart delivery system based on Internet of Things (IoT) is presented. The system allows managers and customers to monitor all real time parameters of the products during the delivery process using Massage Queuing Telemetry Transport (MQTT) protocol. In addition, the proposed system employs compact, low power consumption sensor nodes as well as optimal control algorithms so that the lifetimes of fixed node and mobile node are appropriately 286 days and 40 days, respectively.**

I. INTRODUCTION

In recent years, IoT is the key word that there are a large number of people looking for and it is a part of the fourth industrial revolution. Many researchs [1-5] related to this subject have been performed with many different areas, such as healthcare, transportation, smart infrastructure, smart city, etc. Howerver, most of these applications have different extreme requires, operate in different environments, so all equipment of each application have to be designed the most optimal to achieve the highest effectiveness. Especially, one of these applications is smart delivery system based on IoT that it is being concerned by most of customers who need to send something for someone or organization. There are a wide range of goods, requiring strictly storage conditions when they are transported by any vehicle, such as vaccine, freeze categories. If the conditions of storeges or vehicles do not ensure these conditions, they can be easy to fail in short-time. Hence, the design of smart delivery system allows that it can monitor all necessary parameters of goods on vehicles or storages. Therefore, it can provide a warning when storage conditions are not ensured by these vehicles or storages is significantly important to deal with these incidents on time.

This paper presents the implementation results of a smart delivery system with the optimized power consumption of each sensor node. Section II introduces related work and MQTT protocol, then section III presents the hardware architecture and software algorithms, followed by section IV with the implementation results. Finally, section V provides the conclusions and future research plan.

II. RELATED WORKS AND MQTT PROTOCOL

In the past few decades, there have been a large number of researchers focus on applications related to Wireless Sensor Networks (WSN), Wireless Body Area Networks (WBAN), IoT with a variety of different platforms. Table I compares the difference of different designs for various applications [6-25]. In these designs, microcontrollers (MCU) which are often ultra-low power chips were chosen to reduce the system power consumption and MSP430 family from Texas Instrument (TI) is a good choice [8-10, 13]. Moreover, some transceivers were used in these works, including Wi-Fi module, bluetooth module, Radio Frequency (RF) module with many different protocols. Especially, authors in [10] presented the comparison of different wireless transmission modules to give the best choice for a detailed application. In addition, in recent years, smart cities have concerning in many countries, so Wi-Fi will cover most of place in the future.

Therefore, using Wi-Fi modules as transceiver should be used in applications related to WSN, WBAN, IoT. With each application which has different functions, sensors will chosen to ensure the lowest power consumption and the highest accuracy.

As mentioned above, many communicative modules with different protocols are used for various applications, however, MQTT protocol is more popular than others [26-32] since it has many advantages as presented in [30-31]. Therefore, MQTT protocol should be considerred to use in applications related to IoT using a Wi-Fi module.

III. HARDWARE DESIGN AND SOFTWARE ALGORITHMS FOR THE SMART DELIVERY SYSTEM

From the comparisons and analytics in section 2, this work propose the general model of smart delivery system as Fig. 1 rely on MQTT protocol. This model requires two hardware designs for fixed node and mobile node (version 1.0) that will be mounted on delivered goods in storages and vehicles, respectively. All components used in this work are all energy saving ones. MCU of mobile node is MSP430F5529 from TI which is an ultra-low-power MCU as shown Table II. Sensors include the temperature and humidity HDC1080 of TI, GPS module using L70 module of Quectel, SIM module using SIM800L which enables to save energy by sleep scheduling and to achive high accuracy with its parameters as Table III. Power supply unit is lithium FR9888 of Fitipower with the size of 4800mAh, having ability recharge.

With the fixed node, we chose MCU Wi-Fi ESP8266 designed on low-power technology which integrated WiFi module with 802.11 b/g/n standard as given Table IV. Moreover, this MCU support many protocols such as i2c, spi, sdio, i2s that enable MCU connect to sensors with different protocols. In this design,the function of “smart config” is used to configure for MCU ESP8266 operating as a client. The block diagrams of mobile node and fixed node is designed as Figures 2, 3 respectively.

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TABLE I. THE COMPARISON OF SENSOR NODE FOR DIFFERENT DESIGNS.

Design	Application	MCU type	Operating voltages	Transceiver
[6]	Monitor of oil wells	Atmega128	4.5 ÷ 5.5V	SIM300 module
[7]	Example	Atmega128	4.5 ÷ 5.5V	CC1100 or CC2420
[8]	Magagement system for parking IoT	MSP430f123 and MSP430F2012	1.8 ÷ 3.6V	nRF24L01
[9]	Data acquisition for oil drilling	MSP430F123	1.8 ÷ 3.6V	nRF24L01
[10]	Example	MSP430F149	1.8 ÷ 3.6V	nRF24L01 or CC1100 or WIFI module
[11]	Monitoring gas facilities	ARM Cortex M3 or Arduino UNO	6 ÷ 20V	Bluetooth or WIFI module
[12]	Combustible gas leakage monitoring	AtXmega32A4	1.6 ÷ 3.6V	ETRX3 (Zigbee) module
[13]	Air quality crowdsensing	MSP430BT5190	1.8 ÷ 3.6V	CC2560 (Bluetooth) module
[14]	Remote stress monitoring system	CC2531	2 ÷ 3.6V	CC2591 and GPRS module
[15]	Water environment monitoring	SAM300, AGPRS1090	2.7 ÷ 5.5V	C51RF-CC2530-PK
[16]	Greenhouse environment monitoring	NRF51822	1.8 ÷ 3.6V	NRF51822 module
[17]	Example	CC2530	2 ÷ 3.6V	ESP8266 module
[18]	Example	LPC2103FBD48	1.8 ÷ 3.6V	nRF24L01 module
[19]	Example	PIC18LF6720	2 ÷ 5.5V	CC1000 module
[20]	Aquaculture monitoring	CC2530	2 ÷ 3.6V	CC2591 module
[21]	Intelligent parking	Arduino board	-	Ethernet cable (RJ45)
[22]	Monitoring environmental quality in agriculture and pisciculture	PIC32F32KA302	2 ÷ 3.6V	SIM808 module
[23]	Tracking solar-powered panel for Paddy field environment	STM32F103VE	2 ÷ 3.6V	SIM900A module
[24]	Room temperature control and fire alarm/suppression	Arduino	-	Wifi module
[25]	Monitoring radioactivity	MSP430FR5969	1.8 ÷ 3.6V	CC110L module

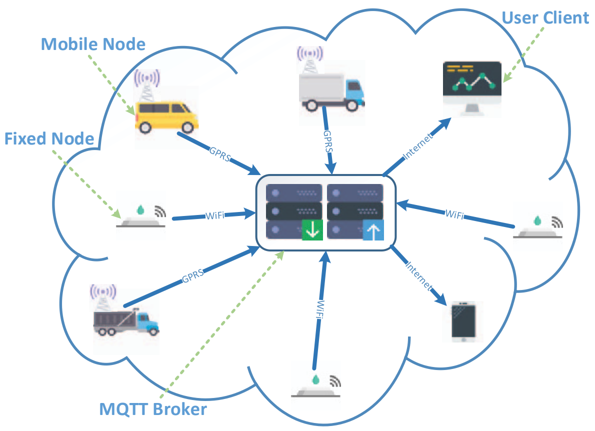

Fig. 1. The general model of proposed smart delivery system.

To achieve the high energy efficiency, we proposed the control algorithms for mobile node and fixed node as Figure 4. According to this diagram, sensor nodes will acquire all parameters and then these data will sent to MQTT broker, this process take time is T_1. After that, these sensor nodes will fall into sleep mode to save energy and they will self wake up after the time of T_2. MQTT broker use CloudMQTT [33] with package named "Cute Cat" for our experiment. This package support the maximum of ten connections with the highest speed is 10Kbps.

In addition, in this work, a website was designed to help managers and customers can monitor parameters of their products (http://modulesimtracking.esy.es). It connects to MQTT Broker as a client to indicate all parameters for each product and to show the position of product on google map integrated in this website. The algorithm of this webite is shown in Figure 5.

TABLE II. PARAMETERS OF MCU MSP430F5529.

Voltage range (V)			1.8÷3.6
Power consumption	Active mode (µA/MHz)	Flash program execution	290
		RAM program execution	150
	Low-power mode (µA)	Sleep	2.1
		Deep sleep	1.1
		Shutdown	0.18
Wakeup time (µs)			3.5

TABLE III. PARAMETERS OF SIM800L.

Voltage range (V)			3.4÷4.4
Power consumption	Sleep mode (mA)	Mode 0	0.796
		Mode 1	1.02
		Mode 4	0.892
	Transmit burst (A)		2

TABLE IV. PARAMETERS OF ESP8266 MODULE.

Voltage range (V)		3÷3.6
Power consumption (mA)	TX, out = 17dBm	170
	Modem sleep	15
	Light sleep	0.9
	Deep sleep	0.01
	Power off	0.0005
Wakeup and transmit packets (ms)		< 2

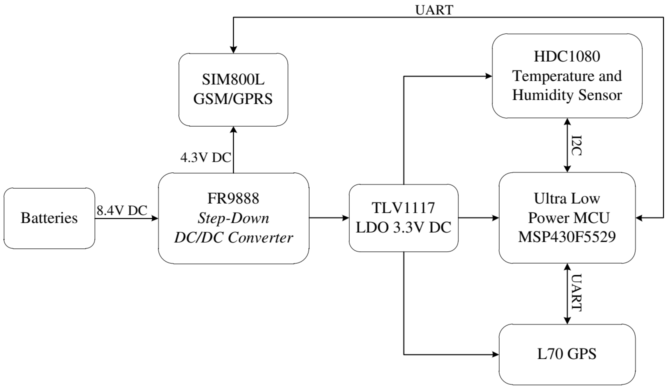

Fig. 2. Block diagram of a mobile node.

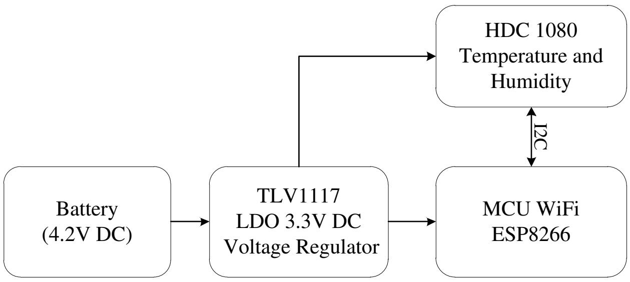

Fig. 3. Block diagram of a fixed node.

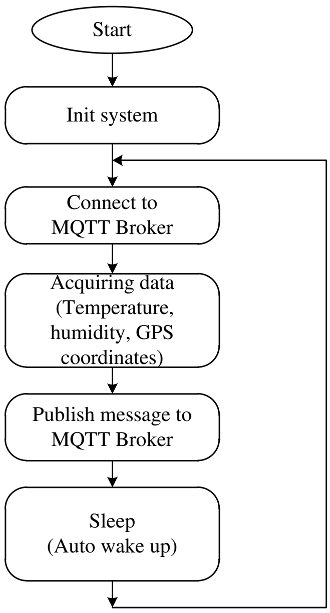

Fig. 4. The control algorithm for mobile node and fixed node.

IV. IMPLEMENTATION RESULTS

A prototype of smart delivery system were designed in this work which tested in real conditions. The prototype of proposed smart delivery system is shown in Fig. 6-7. In addition, this work was carefully evaluated in real conditions to calculate lifetime for each sensor node as described in the following part.

A. *The lifetime of the mobile node*

In fact, the time that a mobile node acquires all parameters and sends successfully message to MQTT broker is T_1 = 15s and average electrical current consumption is 90mA. In this design, each mobile node will be sleep in T_2 = 120s with average electrical current consumption is 9mA. So, average electrical current consumption of each mobile node in a cycle of 135s is calculated in (1).

$$I_0 = \frac{90*15+9*120}{15+120} = 18\ (mA) \quad (1)$$

Each mobile node includes two parallel lithium batteries (FR9888) with the capacity of 4800×2 mAh, so the lifetime of each mobile node is identified in (2).

$$T_{mobile\_node} = \frac{4800*2}{18} = 533(hours) = 22.2(days) \quad (2)$$

B. *The lifetime of the fixed node*

With fixed node, the time of T_1 and T_2 is 6s and 600s, respectively. By measuring in real conditions, average electrical current consumption in T1 and T2 intervals are 73mA and 5mA respectively. A lithium FR9888 is used for the fixed node, so the lifetime identified in (3), (4).

$$I_1 = \frac{73*6+5*600}{6+600} = 5.7\ (mA) \quad (3)$$

$$T_{fixed\_node} = \frac{4800}{5.7} = 842.1(hours) = 35.1(days) \quad (4)$$

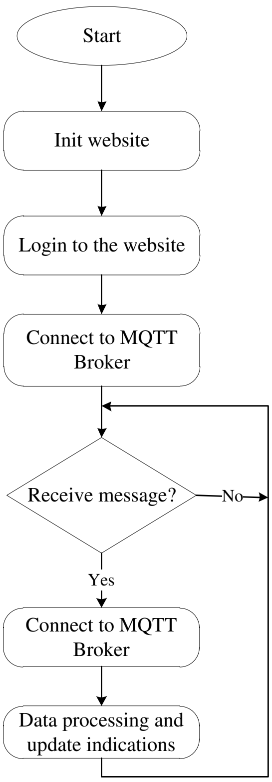

Fig. 5. The diagram algorithm of website.

(a)

(b)

Fig. 6. Mobile node (a) and fixed node (b) in the proposed smart delivery system.

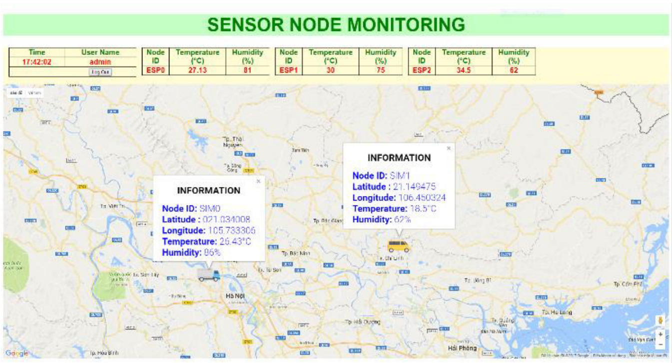

Fig. 7. The website interface in the proposed smart delivery system.

On the other hand, this work proposed new design for mobile node and fixed node (version 2.0) as Figures 8-9 which enable to improve the lifetime of each node by using chip Nano Timer TPL5111 [16] to control T_1, T_2 intervals. This chip will turn off power of system in T_2 interval with average electrical current consumption is very low, at 35nA in both intervals. With this new proposed solution, the lifetime of mobile node and fixed node will be calculated again in (5), (6) and (7), (8) respectively.

$$I_0 = \frac{90*15+35*10^{-6}*120}{15+120} \approx 10\ (mA) \quad (5)$$

$$T_{mobile\_node} = \frac{4800*2}{10} = 960(hours) = 40(days) \quad (6)$$

$$I_1 = \frac{73*6+35*10^{-6}*600}{6+600} \approx 0.7\ (mA) \quad (7)$$

$$T_{fixed\_node} = \frac{4800}{0.7} = 6857.1(hours) = 285.7(days) \quad (8)$$

Moreover, new algorithms are proposed for both new sensor nodes as shown in Fig.10 with very small power consumption of 35nA. From these results as Table V and Fig.11, it is clear that while there is 1.8X increase in the lifetime of mobile node, there is dramatically 8.1X improvement in the lifetime of fixed node.

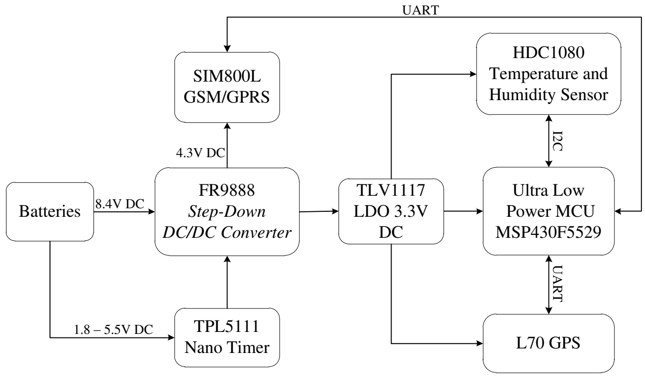

Fig. 8. The new proposed diagram for mobile node.

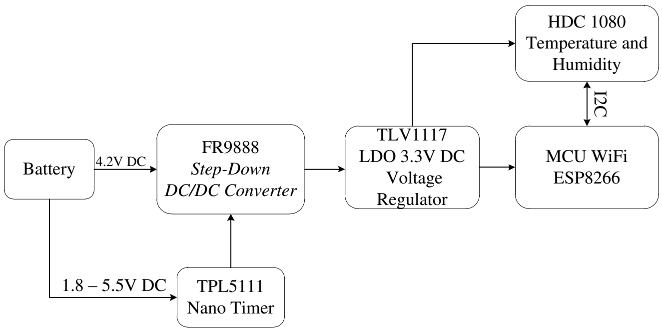

Fig. 9. The new proposed diagram for fixed node.

TABLE V. THE LIFETIME OF SENSOR NODES.

Architecture	Version 1.0	Version 2.0
Fixed node (days)	35.1	285.7
Mobile node (days)	22.2	40

V. CONCLUSION

In this paper, we have presented a prototype of smart delivery system based on IoT by utilizing power efficient algorithm and devices which allows the sensor node can operate in a long period when using battery supply. This design is suitable for applications in many areas mentioned in section 1 above. Using only low-end battery power supply, the mobile node and fixed node can operate in 40 days and 285.7 days, respectively. In the future, we will expand system for other applications towards a smart society by employing new types of sensors such as Beat sensors [34]-[36].

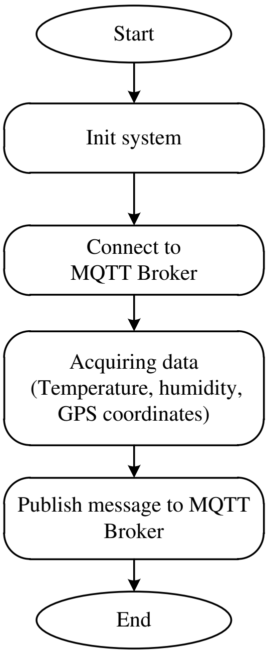

Fig. 10. The new algorithm for both sensor nodes.

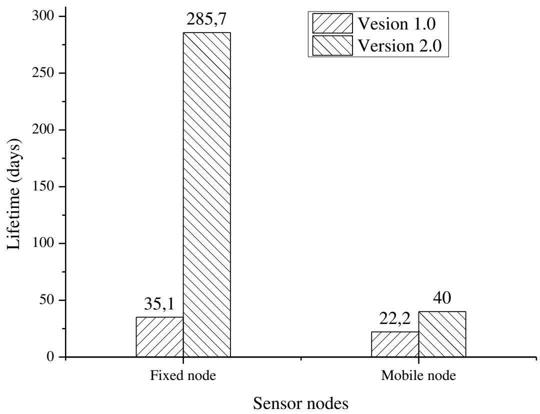

Fig. 11. Lifetime results of sensor nodes.

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