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System on chip (SOC) wi-fi microcontroller for multi-station measurement of water surface level using ultrasonic sensor

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Abstract.– Experimental results of data acquisition and transmission of water surface level from the field using System on Chip (SOC) Wi-Fi microcontroller are described here. System on Chip (SOC) Wi-Fi microcontroller is useful in dealing with limitations of in situ measurement by people. It is expected to address the problem of field instrumentation such as complexities in electronic circuit, power supply, efficiency, and automation of digital data acquisition. The system developed here employs five (5) nodes consisting of ultrasonic water surface level sensor using (SOC) Wi-Fi microcontroller. The five nodes are connected to a Wi-Fi router as the gateway to send multi-station data to a computer host. Measurement of water surface level using SOC Wi-Fi microcontroller manages conduct multi-station communication via database service programming that is capable of inputting every data sent to the database record according to the identity of data sent. The system here has a measurement error of 0.65 cm, while in terms of range, communication between data node to gateway varies in distance from 25 m to 45 m. Communication has been successfully conducted from one Wi-Fi gateway to the other that further improvement for its multi-station range is a certain possibility.

Keywords: *water surface level, node, gateway, multi-station, database*

1. Introduction

Water surface level is a physical unit that is important for environmental monitoring and production processes throughout the world. Water surface level sensor has been developed using all sorts of techniques by making use of the physical effect of ultrasonic wave time-flight, the capacitive property of parallel plates, the buoyant force model, and even optical diffraction. There are many methods available to measure water surface level [1]. Generally, the object of water surface level measurement is located in the field barely accessible for in situ measurement. Therefore, a remote measurement technique is needed.

In order to manage water surface level potential, an instrument capable of continuous, real-time measurement covering wide area and including massive data, as well as interpreting them is needed. The use of telemetry for measurement of water surface level is proven to be able to store data in a data base of a dedicated server. These stored data can be processed and integrated into a decision making system in a network [2].

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Nowadays, the technology of wireless communication has greatly advanced. This also provides good opportunity for modernizing techniques in water surface level measurement. Application of this technology is advantageous in that it is quick and has reliable quality [3]. The use of wireless sensor has been proven to be cost efficient and easy to install in the field [4]. Integration of measurement instrument into a data network allows data analysis using cloud computing on the internet [5].

Technology for measurement and monitoring of water surface level has advanced greatly. This is only reasonable as such technologies are used on a daily basis. Generally, such technologies are sophisticated and costly in nature. One good example of sophisticated water surface level monitoring is the use of satellite technology [6]. Water surface level measurement using ultrasonic wave has been developed and is advantageous for measurement in rivers. This type of non-contact measurement is very effective as it comes with better precision than that of the buoyant model [7]. Nonetheless, non-contact measurement system still needs to be developed using the wireless model to improve on its effectiveness and efficiency. Microcontroller application has proven to increase cost efficiency by up to 50%. Better still, integration of microcontroller and Wi-Fi greatly contributes to data acquisition. This integrated system is even more advantageous as it is practical in the field and is low cost [8].

2. Methods

This research made use of system on chip microcontroller featuring short range Wi-Fi to acquire data from water surface level sensor using ultrasonic wave. The block diagram of instrument connection system is shown in Figure 1. Multi-station Remote Terminal Unit (RTU) was used for this research. It consists of sensor-nodes accessible by one computer serving as the Control Monitoring System (CMS). Some other similar systems are connected to a wireless router and a 2.4 GHz High Power Wireless Outdoor Wi-Fi network, which enables it to transmit data up to tens of kilometre away. On the other hand, the CMS consists of an outdoor radio Wi-Fi and a computer to receive and store data from measurement.

Measurement of water surface level in this research utilized waterproof ultrasonic range sensor with ultimate performance. This sensor is capable of quick response measurement. It is also portable and highly mobile. It is small in dimension, and has a range of 4.5 m. This ultrasonic sensor works in the acoustic wave spectrum and is able to measure physical quantity. This sensor was placed perpendicularly on the water surface. SOC Wi-Fi microcontroller was used to trigger bursts of ultrasonic wave pulses. These burst is from pin D.0, as written in the program. In no time, these pulses are received by pin D.1 of SOC Wi-Fi microcontroller. The sensor node circuit of this system is depicted in Figure 2. Time-of-flight of the wave is then counted by the SOC Wi-Fi microcontroller and converted into the following wave equation :

$$s = \left(\frac{t_{of}.c.\cos\theta}{2} \right) \tag{1}$$

Where s is water surface level, $t_{of}$is the time-of-flight, and θ the angle of ultrasonic wave bursts transmitted and received, and c ultrasonic wave velocity in the air. That equation indicates water surface level s, which a function of $t_{of.}$.Therefore, calculation for s can be done for SOCWi-Fi microcontroller from counting of $t_{of.}$

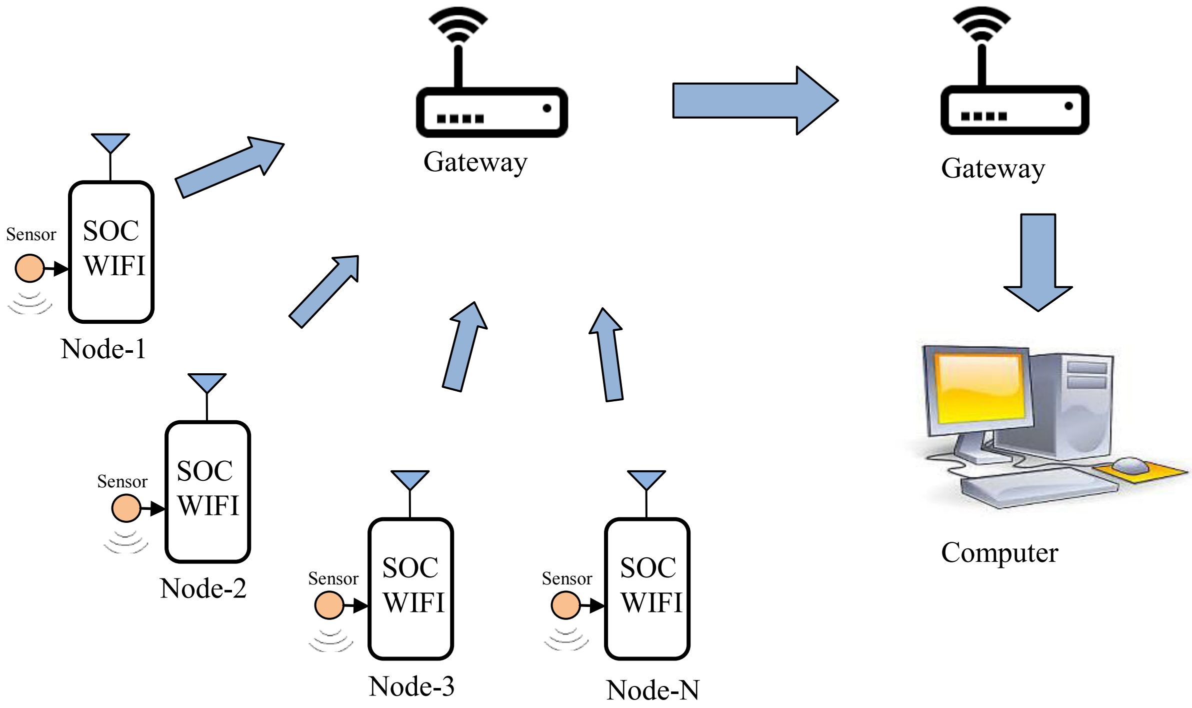

Figure 1. System diagram of Wi-Fi microcontroller for water surface level measurement using ultrasonic sensor.

This research applies System on Chip (SOC) Wi-Fi microcontroller of type ESP8266. It is a member of 32 bit microcontroller family with Wi-Fi feature and is very cheap, even though it is already capable of IP networking via Wi-Fi and the internet. This chip is programmable using high programming language such as C, Python, Lua, and Basic. This chip is equipped with 32 bit TensilicaXtensa LX106 80 MHz CPU, with 64 KB instruction RAM, and 96 KB data RAM. It comes with port I/O (GPIO, SPI, I2C, I2S), and an ADC. Wi-Fi microcontroller chip type ESP8266 is programmed using C that has the following routines: ultrasonic burst generation, time-of-flight counting, calculation for velocity, and data transmission via Wi-Fi.

The microcontroller used in this research has two main functions of acquiring water surface level data and serving as an interface to send data to the host server via Wi-Fi. System communication via Wi-Fi was at 11680BPS using TCP/IP protocol. Wi-Fimicrocontroller chip was set to use software instruction with different IP and Port addresses for each node. Other than that, all network IPs used in the system communication were made in one class IP. Configuration setting for TCP/IP on Wi-Fi microcontroller chip is shown in Table 1.

The host computer in this research functions to read data acquired by each node and keep them in the database. Each node has its own service table that differs in one database. Each table stores data of node number, time, and acquired water surface level. In order to send data from the System on Chip Wi-Fi microcontroller to the host computer, a software is made for each device. For the SOC Wi-Fi microcontroller, a program to connect to gateway Wi-Fi router network was made. This program sets port for the database, and sets the IP address of the host computer. Once data of water surface level is acquired, they are sent to the host computer. An ESP service software was developed to receive data sent from the Wi-Fi microcontroller. Program script is written in the database service of the database software used. This written program is aimed at matching the data sent via Wi-Fi microcontroller with the database table according to the identity sent by Wi-Fi microcontroller.

Table 1. Configuration of board serial to TCP/IP converter.

Station	IP Address	Subnet
Node1	192.168.1.1	255.255.255.1
Node2	192.168.1.2	255.255.255.1
Node3	192.168.1.3	255.255.255.1
Node4	192.168.1.4	255.255.255.1
Node5	192.168.1.5	255.255.255.1
Wi-Fi Router	192.168.1.6	255.255.255.1
Host Computer	192.168.1.6	255.255.255.1

3. Result and Discussion

This research has successfully implemented a system of data acquisition, data communication, and database programming between SOC Wi-Fi microcontroller and a host computer to measure water surface level using ultrasonic ranger sensor. Results of measurements are readable in the database of the host computer. Recorded data can be directly viewed from database with a viewer, which has also been developed. Results ofdata base viewer of water surface level on the host computer are shown in Figure 2.

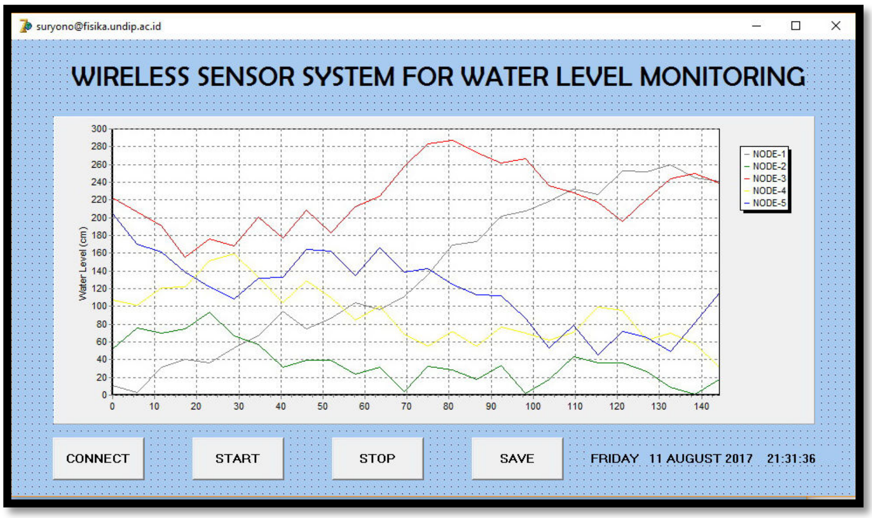

Figure 2. Database viewer on the host computer.

The graph shown above is a result of water surface level measurements sent from each sensor. It shows level values in line with changes detected by every sensor on each node installed. System validation was carried out by comparing measurement results shown on the host computer with results of measurement using a standard meter. Efficacy of the system developed is reflected on the error gained. Results of calculation for errors are presented in Table2.

Calculation results indicate that the average error of the system is 0.65 cm. This value is very small compared to the range the sensor manages to reach, at 4.5 m. Testing for range of the wireless sensor system was carried out by varying the distance of each node to gateway 1. Results of this measurement are seen on the value recorded in the data base of the host computer. Testing was conducted in open air without any antennae with varied distances of 10 m, 15 m, 20 m, 25 m, 30 m, 35 m, 40 m, 45 m and 50 m. All results of this testing are given in Table 3.

Table 2. Error value for each node.

Station	Error (cm)
Node1	0.82
Node2	0.76
Node3	0.97
Node4	0.62
Node5	0.48
Average	0.65

It can be seen from testing results that SOC Wi-Fi microcontroller has varied communication range. Node 1 and Node 4 have the shortest range (25 m – 30 m). At distances ≥ 30 m they can no longer communicate data that record on the database is empty. Node 5 comes with the longest range (45 m – 50 m). These differences in communication range are affected by some factors, among others are Wi-Fi radio power, use of antenna, and node elevation. These problems can be tackled by placing gateway 1 closer to the RTU and increasing Wi-Fi router power on gateway 1 and gateway 2. In theory, using long distance antenna for both gateways can improve the range of the wireless sensor system. Some outdoor Wi-Fi radio with rotating antenna can increase communication range by ten to hundreds of kilometres.

Table 3. Results of testing for SOC Wi-Fi microcontroller range (no antenna).

Station	Testing distance from node to gateway (meter)								
	10	15	20	25	30	35	40	45	50
Node 1	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
Node 2	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
Node 3	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
Node 4	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
Node 5	ON	ON	ON	ON	ON	ON	ON	ON	OFF

Note: ON = connected data, OFF = disconnected data

4. Conclusion

System on Chip (SOC) Wi-Fi microcontroller can be used for water surface level data acquisition system using ultrasonic sensor. Using SOC Wi-Fi microcontroller ensures more effective measurement. The system developed here is simple that it does not need complicated circuiting and consumes less power. Water surface level measurement using Wi-Fi microcontroller has been shown to be capable of multi-station communication with the help of database service programming. This programming allows input of data sent to the host computer according to the identity sent. The system in this research has a low average error of 0.65 cm. In addition, communication range from the node to gateway is varied, from 25 m to 45 m.

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