IoT-based Wireless Access Point for Underground Safety Services

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***Abstract*— Recently, many researchers have focused on solving problems related to sinkholes, exploring both natural and artificial options. To address this problem, researchers need to work with land subsidence related to groundwater. In this paper, we consider outdoor environmental factors such as groundwater, water supply, and sewer and propose an Underground SAfety Hybrid (USAH) architecture. Specifically, the WAPUS (Wireless Access Point for Underground Safety services for Sinkhole detection) exploits a periodic monitoring and an aperiodic sensing. To increase the accuracy and reliability, we propose a hybrid architecture which merges these techniques. Furthermore, in our proposed architecture, the sensor nodes collect sensing data as part of periodic monitoring and our platform carefully examines it using aperiodic sensing. Our simulation results show that WAPUS enhances the reliability in the hybrid special condition.**

Keywords—sink hole; underwater detection; wireless sensing

I. INTRODUCTION

Recently, there has been an increasing interest in the processes going on under the ground in Korea. Humans can not see the natural sinkholes that form underground. Because of artificial water supply and sewer leaks, a subsidence of the ground occurs. This phenomenon has given rise to social issues [8] [9].

In particular, if water leaks occur underground, they are likely to cause sinkholes. For this reason, several sinkhole technologies have been proposed. Many proposals [4] dealt with how to connect the information gathered from the sensors of the central server. In general, smart meters using ZigBee method have wireless networks (900MHz, 2.4GHz ISM band). LoRaWAN is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things in regional, national or global network [2]. LoRa technology has over 1Km RF (Radio Frequency) range and the LoRa alliance wants to achieve reliable networks.

This paper explains that WAPUS has several networks simultaneously connected to the central server using several connecting methods, such as WiFi network, Ethernet, and Long Term Evolution (LTE) [6].

Secondly, WAPUS supports IEC/ISO 30128 specification to connect to the server and IEEE 802.15.4 standardization to link reliable RF connectivity.

Due to its support for standard interfaces, WAPUS has a merit of dynamic extensibility.

Periodic sensing has to use an existing technique via the various wireless sensor networks, which will be expanded into the Internet of Things applications. Further, these applications include a lot of aperiodic and non-destructive techniques.

The rest of this paper is structured as follows. In Section II, we present USAH architecture, which can be used for wireless sensing. Section III describes the application and the architectural benefits of WAPUS. In Section IV, we introduce a system design that takes into consideration the hybrid wireless sensing data. In Section V, we evaluate the WAPUS based on the simulation environment. Finally, in Section VI, we provide some concluding remarks along with directions for future research.

II. USAH AND WAPUS ARCHITECTURE

The architecture presented in this paper is a sensor network infrastructure that is used by the general wireless sensor network architecture [1]-[3]. Current legacy infrastructure provides a common standard interface and a core infrastructure of the sensor network [7].

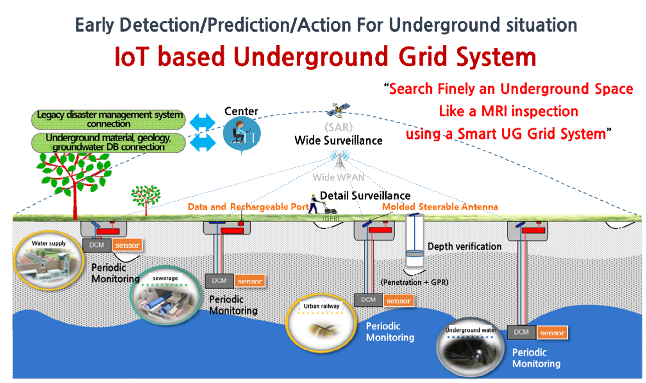

Figure 1. USAH system scenario [5].

The main idea provided in this paper is a method of collecting periodic and aperiodic sensing information at the same time. Periodic sensing has long break periods to achieve low power consumption. It performs aperiodic sensing if slightly suspicious information is reported from periodic sensing. By using this method, it is possible to perform hybrid sensing by utilizing low power consumption.

We propose a hybrid structure with the aperiodic sensing information and periodic sensing information serving at the same time (see Figure 1 [5]).

Our WAPUS has several features;

1. Multi network connections (LTE, WiFi, Ethernet, etc.)
2. Two RF modules with dynamic ranges
3. NXP Cortex-A7 dual processor with 1GHz DDR 3 memory
4. 4+ UART ports

A. *WAPUS Hardware Architecture*

First, WAPUS supports several interfaces to be able to have multi networks (LTE, WiFi, Ethernet, etc.). In Figure 2, our platform has 2 RF ports, WiFi port, and LTE port. Also, WAPUS supports dual RF modes to know dynamic situations simultaneously.

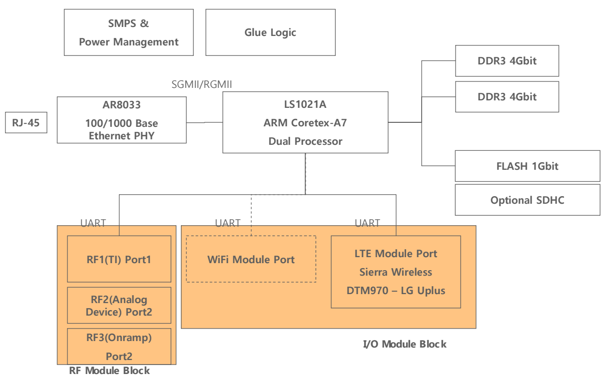

Figure 2. WAPUS Hardware Block Diagram.

B. *WAPUS Software Architecture*

The software architecture of WAPUS is as follows: WAPUS has multi-thread blocks and fundamental functions of logging, configuration, UART connection and network connections.

WAPUS has N2S (Node to Server) thread block that processes the messages transferred from PANC (PAN coordinator) through UART (Universal Asynchronous Receiver/Transmitter), and S2N (Server to Node) thread block that processes the messages transferred from the server through TCP (Transmission Control Protocol).

Also, WAPUS has a system initialization function and an AP (Access Point) main function (see Figure 3).

III. APPLICATION AND ARCHITECTURAL BENEFITS OF WAPUS

Our WAPUS proposal has several advantages, as follows. The WAPUS, unlike existing AP, has a structure that supports two or more RF devices. The AP with two or more RF components has an advantage in scalability. Another WAPUS advantage is the stability of the network. Furthermore, by supporting the ISO standard, WAPUS provides compatibility with other devices.

- ✓ WAPUS provides an aperiodic sensing function, periodic monitoring and a merged hybrid platform using these methods.
- ✓ WAPUS proposes a dual RX/TX queue architecture to remove a bottleneck of gateway.
- ✓ WAPUS provides extensibility with the ISO standard interface adaptation.
- ✓ WAPUS has several interfaces to allow aperiodic data sensing such as moving images.

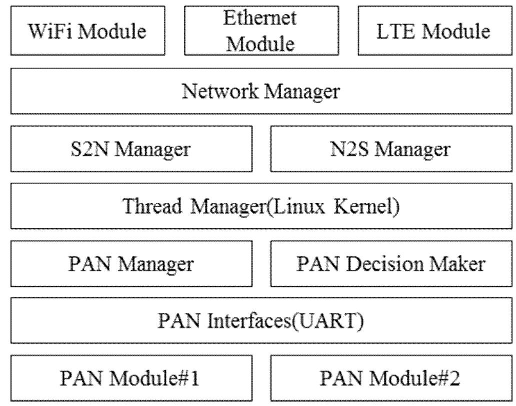

Figure 3. WAPUS Software Block Diagram.

A. *PAN Decision Maker Algorithm*

The proposed algorithm used in the PAN Decision Maker is as follows: The PAN Manager selects the better PAN module from the available networks, as shown in Figure 4.

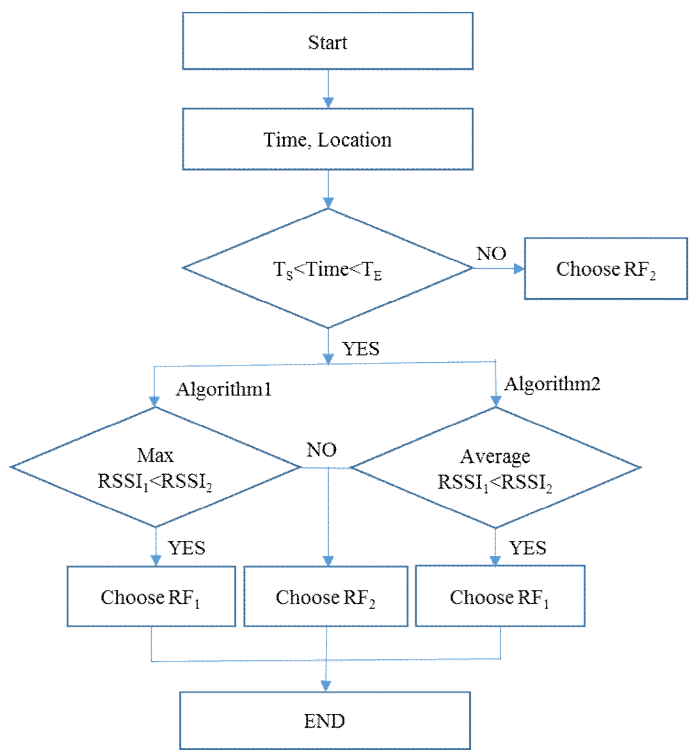

Figure 4. PAN Decision Maker Algorithm.

Referring to Figure 5, while managing two or more RF modules AP gateway corresponding to the spatial domain, WAPUS communicates with the sensor nodes using the RF1 module at point A and RF2 module for communication of the C point.

Basically, it will be responsible for different communication modules in Zone1 and Zone2.

Since the sensor node's RF characteristics vary at point B existing between the Zone1 and Zone2, the WAPUS selects the RF module according to the RSSI (Received Signal Strength Indicator) and RF characteristics.

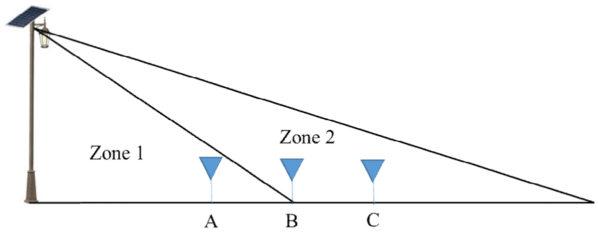

Figure 5. Sensor nodes spatial layout.

The method of RF selection is as follows. Firstly, we propose that average RSSI values are accumulated N times in selecting an RF module. We consider a method of selecting by using maximum and minimum values. If the difference between maximum value and minimum value is large, we will change to the better RF module. If the difference value is minimal, we keep the original RF module.

Also, we select the RF module depending on the determined angle, the obstacles and other settings between the sensor node and the WAPUS.

Normally, we have a choice of RF modules that gives a better RSSI value. We measure the average RF signal strength of at least N times, analyze the optimization characteristics of the communication, and choose to use the optimal RF module. We choose to collect N times or more RF signal strength, in consideration of the location and time change. This will select the RF module. Also, it will be determined in consideration of 2.4GHz method and 900MHz modulation scheme.

IV. EVALUATION

To evaluate our proposal, we used the Matlab toolkit. Simply, we propose a sensor accuracy model, as seen in Figure 6. We can calculate several parameters from equations (1)-(3).

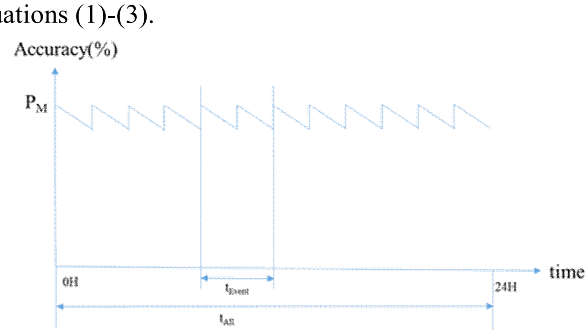

Figure 6. The sensor accuracy model with time interval.

$$R_{Event} = \frac{t_{Event}}{t_{All}} \quad (1)$$

$$P_{Accuracy} = P_M\left(1 - \delta(t - t_M)\right) \quad (2)$$

$$\delta = -5\%/hour \quad (3)$$

We show the average accuracy as a function of sensing rate (sensing counts/hour) in Figure 7 and the sensing cost versus aperiodic sensing over total sensing ratio in the simulation in Figure 8.

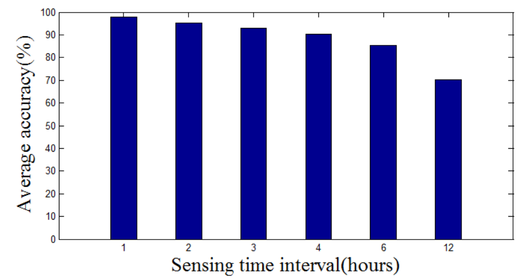

Figure 7. Average accuracy via sensing rate (sensing counts/hour).

As shown in Figure 7, the accuracy decreases in time after it is measured. When the measured value is corrected again, the system has high accuracy. Therefore, the average accuracy decreased when the sensing time interval increases, as shown in Figure 7 and Figure 8.

The sensing cost, as shown in Figure 8, also increases as aperiodic sensing over total sensing ratio also increases.

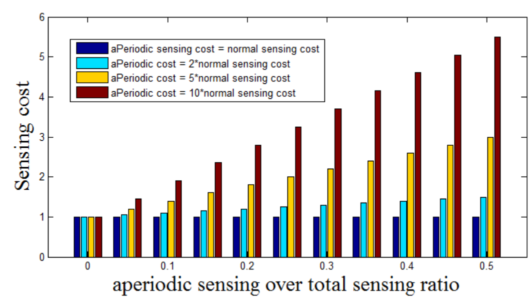

Figure 8. Sensing cost via R_{Event}.

For this reason, we do not select a large aperiodic sensing period. It is necessary to use the aperiodic sensing with the proper aperiodic sensing period.

V. CONCLUSION AND FUTURE WORK

This paper showed that WAPUS includes the sensing information to be acquired from various sensing devices in the underground facility management subsystem to transfer from the gateway to the upper platform. The sensing period of the gateway device dynamically varies according to the value of the sensing information.

Also, through a variety of RF modules in a long distance and a short distance, we dynamically select the better RF module.

In this paper, we introduced the WAPUS designed for sink hole detection applications. The WAPUS exploits its hybrid sensing characteristic to form a networked system that effectively increases the accuracy of the sensing measurement. We believe that this study is an effort to diversify our thoughts on IoT (Internet of Things) architectures and quantitatively notice that with new capabilities added on to the wireless sensor networks, a new perspective of network architecture design is required.

ACKNOWLEDGMENT

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