Towards Gas Density Measurement: Design and Implementation of the Application-Oriented WSN

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Abstract

A design and implementation of WSN is introduced in this paper, which is applied to concentration measurement of hazardous gas. A hardware platform solution with compatibility and scalability is proposed in the paper. The customized communication protocol and applications-oriented software design ensure that the network could respond and refresh data rapidly. The WSN has been deployed in the field to monitor gas leakage for experimentation and performed well.

Keywords: *WSN; gas leakage; concentration measurement; design and realize*

1. Introduction

It is well known that the dangerous chemical gas is harm to health and even cause death. In actual scenarios, chemical gas leakage will not alert people until the density reach relative high level which often could be life threatening. Hence, in the zone where hazardous chemical gas is stored of releases, it is indeed necessary to supervise the hazardous gas concentration in real time to resolve incidents in the very beginning[1, 2]. Wireless sensor network (WSN) provides an effective real-time monitoring approach.

WSN is composed of small-size low-cost sensor nodes which are placed in some area and communicate with each other via wireless channel. Further, generally, there is one or more sink nodes as date centers in the WSN to collect sensing information. Once sensor nodes has been set up, a variety of sensing information such as geographical position, time, dangerous chemical gas density etc. could be associated with to represent the physical world accurately[3].

Before the introduction of WSN technology, gas monitoring was implemented in wired network[4]. The great advantage the wired network owns is that the powerful hardware platform can be as an ordinary sensor node without considering the power limitation. But it still has obvious disadvantages: requiring long time to deploy, spending lots of money on maintaining and being constrained by cables[5]. Applying WSN can solve the above-mentioned problem.

This paper utilizes WSN to measure the gas concentration. Easy-to-upgrade hardware structure, application-oriented software design and the customized communication protocol make it function well in the interested area.

The organization of this paper is as follows: the overall of the system will be introduced concisely in Section 2. The hardware design will be represented in Section 3. In Section 4, we will describe the application-oriented software. The communication protocol will be depicted in Section 5. The experimentations and the system application will be shown in Section 6. We draw conclusion in Section 7.

2. System Overview

The WSN is comprised of sensor nodes and one sink node. As shown in Fig. 1, sensor nodes are front-end nodes which usually are exposed in chemical gas directly and they will integrate the measured value, package them in the format of protocol and send to the sink node. The sink node is in the back-end and it is responsible to manage the WSN status, collect data from sensor nodes, encapsulate data in IP packets and send to the data server.

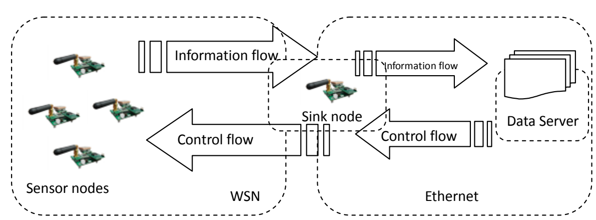

Fig. 1 System Diagram

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3. Hardware Design

The hardware of sensor nodes and the sink node are different. Considering versatility and expansibility of the nodes, the design of the hardware separated the core processing module and other expansion modules. Along this thought, corresponding modules can be plugged in to achieve specific function according to the concrete requirements.

The core processing module is made up of MCU, EEPROM(some configuration information could be stored in EEPROM), battery volume supervision unit, power management circuit and some other interfaces. MSP430 series MCU is adopted for its low-power property.

3.1 Sensor node

As illustrated in Fig. 2(a), sensor nodes can be equipped various chemical gas sensors. The interface 1 and interface 2 are pure digital interfaces, which are capable of running as UART, I2C and SPI by appropriate command. And the interface 3 is a mixed interface, they can play both UART and 4-20mA industrial signal.

3.2 Sink node

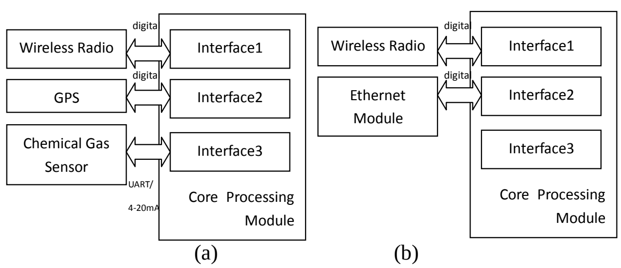

Fig. 2 Nodes: (a) Sensor node; (b) Sink node

Sink node is shown in Fig. 2(b) with wireless radio and Ethernet module. Ethernet Module is in charge of transfer UART to RJ-45.

4. Software Design

The main idea of sensor node software design is to combine traditional general software and gas measurement application as shown in Fig. 3. Application-oriented libraries are added on the increasingly mature event-driven operating system. For example, the feature library contains common dangerous gases (the lower explosion limit bounds, standard concentration of toxic gas, etc.). The application data in communication process is encapsulated and parsed in Protocol Encapsulation library. The application such as gas density alert, gas measurement and sensor configuration and management are all run on the libraries.

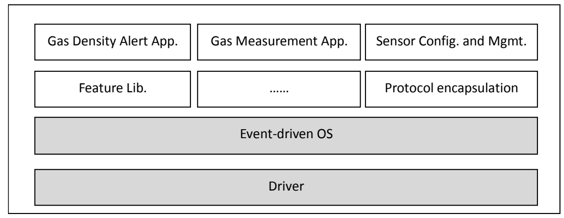

Fig. 3 Application-oriented software design

5. Communication Protocol

The communication protocol is divided into media access control (MAC) layer, network layer, and application layer. CSMA/CA is run at the MAC layer, and the dynamic mesh is accomplished in network layer. And application layer run a customized, variable length and light weighted protocol, which not only has the function of data transmission but also integrates the network configuration management function, e.g. sleeping, shutdown, restart and logical address allocation, etc.

6. Experiments and Applications

6.1 Experiments

There is 1 sink node and 29 sensor nodes which are placed in the test field for experiments as depicted in Fig. 4. The red cycle represents the sensor node and the blue square stands for the sink node. The sink node collects sensing data, put them into IP packet and send to the data server. The refresh period is 2 seconds. After the experiments, the time all the nodes in the network (with 30 nodes) refreshes spend equals less than 10 seconds. The refresh time of the node whose measured value changes frequently can reach 1 second.

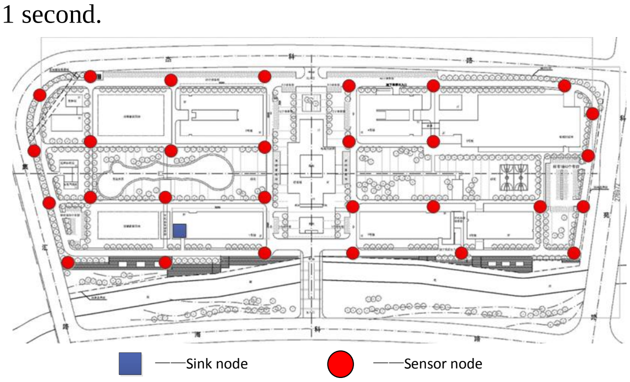

Fig. 4 Field test deployment diagram

6.2 Applications

These sensing data can be used to simulate the gas diffusion when the WSN completing placing. The gas diffusion is calculated in Algorithm Server and the sensing data is obtained from Data Server as shown in Fig. 5.

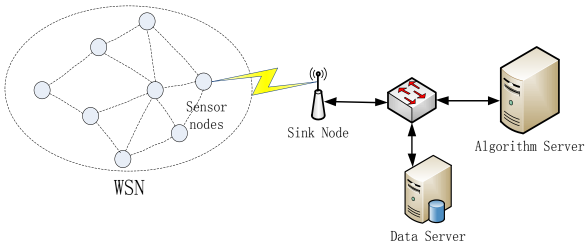

Fig. 5 Application Framework

The test scenario parameter table is as Table 1:

Table 1: Initial Parameter of the model

Scenario Model	Tank rupture
Gas Type	Alkanes
Tank Size	Diameter: 10 m; Height: 8 m
Pipeline Size	Diameter: 6 cm; Height (above the ground): 1 m
Volume	0 degree Celsius; pressure: 30 ps
Pool	20 m2
Environment	20 degree Celsius; atmos: 1013 mpa

And the gas flow model is as follows:

$$\frac{dm}{dt} = C_d AF[2(P_{TANK} - P_{ATM})dv]^{1/2} \quad (1)$$

$$F = (1 - B^4)^{-1/2}[1 - (\frac{1 - \frac{P_{ATM}}{P_{TANK}}}{K})(0.41 + 0.35B^4)] \quad (2)$$

C_d is deliver factor, A is the leakage area, P_{ATM} stands for pressure atmosphere, P_{TANK} is the tank pressure, v represents the gas density and B is the diameter rate(leakage area / tank diameter).

On the basis of the deployment, the gas diffusion can be simulated and predicted according to the sensing data as shown in Fig. 6.

Fig. 6 Gas diffusion simulation based on WSN

7. Conclusions

With the development of wireless sensor network technology, it has been applied to more and more aspects. The solution proposed in this paper has versatility and expansibility. Validation experiments and applications show that the WSN performed well.

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