A Cognitive Data Gathering Scheme for Gas Monitoring Employing Mobile Phone based Wireless Sensor Networks

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1. Introduction

With the progressing of industrialization and urbanization, the leakage of gas or other chemicals has been a serious threat to the safety of humans. In the recent years, with the development of electronic and communication technology, wireless sensor network has been widely utilized for gas monitoring [1]-[2].

In the paper, mobile phone based wireless sensor networks are proposed for gas monitoring. In the network, each mobile terminal is equipped with a sensor, which senses gas data from surrounding environment. Using such mobile devices as sensors, significant advantages can be achieved over unattended wireless sensor networks. First, mobile phones can provide coverage where static sensors are hard to deploy and maintain. Second, mobile phones and cellular networks have already existed around the world, providing the physical sensing infrastructure. Third, each mobile phone is associated with a human user, whose assistance can sometimes be used to enhance application functionality.

However, cellular networks have been overloaded in some parts of world. To avoid congestion of the cellular networks, new data gathering schemes have to be proposed. In our past research [3], a data gathering scheme based on location update has been proposed. In the proposal, sensor employed mobile phones send data to base station within location update information. This proposal could gather data without utilizing data channel, but because location update just happens at the boundaries of the location registration areas, only the gas data in a large area can be monitored. In order to monitor gas data in every area or every intended time, a cognitive data gathering scheme is proposed in this paper.

The organization of the rest of this paper is as follows: in section 2, we present the network model; in section 3, we propose the cognitive data gathering scheme; in section 4, we present computer simulation; in section 5, we conclude this paper.

2. System Model

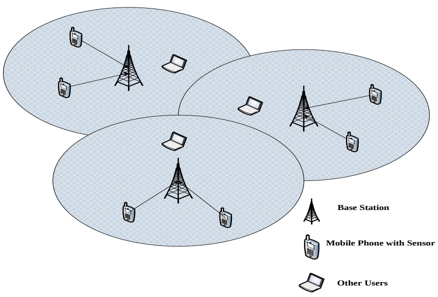

Fig.1. System Model

In the network, each mobile terminal is equipped with a sensor, which senses data from surrounding environment. Sensor employed mobile phones send data to base stations, so that the base stations not only support cellular network, but also perform as sink nodes. Besides that, the sensor employed mobile phones are supposed secondary users, and send data just when the spectrum is not utilized by primary users.

3. Data Gathering by Cognitive Radio

3.1 General Model for Spectrum Sensing

In the proposal, energy detection is utilized for spectrum sensing. Fig. 2 shows the frame structure designed for our proposal with periodic spectrum sensing. Each frame consists of one sensing slot and one data transmission slot. Suppose the sensing duration is *ts* and the frame duration is *T*. If *N* is the number of detection samples, then we assume $N=ts \cdot fs$

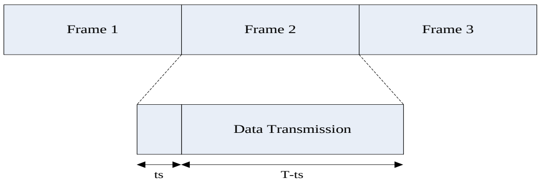

Fig.2. Frame Structure for Spectrum Sensing

Suppose the variance of noise is σ_n^2, the signal to noise ratio of primary users is SNR_p. If the primary users' signal is complex PSK, and the noise is circularly symmetric complex valued, the false alarm probability is [4]:

$$p_f = Q\left(\frac{\varepsilon-\sigma_n^4}{\sqrt{\sigma_n^4/N}}\right) = Q\left(\left(\frac{\varepsilon}{\sigma_n^2}-1\right)\sqrt{N}\right)$$

The probability of detection is:

$$p_d = Q\left(\left(\frac{\varepsilon}{\sigma_n^2}-SNR_P-1\right)\sqrt{\frac{N}{2SNR_P+1}}\right)$$

Therefore,

$$P_d = Q\left(\frac{1}{\sqrt{2SNR+1}}\left(Q^{-1}\left(P_f\right)-\sqrt{N}SNR\right)\right)$$

3.2 Sensing Duration and Energy Consumption

Error control protocol is supposed to be utilized, so that if the base station can't receive the data from a mobile phone correctly, the mobile phone will send this data once more. For cognitive radio, if the detection is missed, the signals of primary users and mobile phone will be mixed together, and the data can't be received by base station. Therefore, the mobile phone will transmit the data once more. In our proposed system, the probability that the data is transmitted by a mobile phone is:

$$A = P\left(H_0\right)\left(1-P_f\right)+P\left(H_1\right)\left(1-P_d\right)$$

The probability that the data is not transmitted by a mobile phone can be expressed as:

$$B = P\left(H_1\right)P_d + P\left(H_0\right)P_f$$

For one frame, we define P_s as the power consumption of spectrum sensing, then as the energy consumption of spectrum sensing:

$$E_s = P_s \cdot ts$$

Suppose E_t as the energy consumption of data transmission, the average energy consumption of one transmission can be expressed as:

$$\sum_{n=1}^{\infty} B^{n-1} A\left(nE_s + E_t\right)$$

However, if the detection is missed, the mobile phone has to transmit the data again, so that the average energy consumption for the transmission of one data can be expressed as:

$$\sum_{n=1}^{\infty} B^{n-1} A\left(nE_s + E_t\right) + P\left(H_1\right)\left(1 - P_d\right) \sum_{n=1}^{\infty} B^{n-1} A\left(nE_s + E_t\right)$$

For a given frame duration *T*, the longer the sensing time *ts*, the more energy is consumed on spectrum sensing. On the other hand, for a given false alarm probability, the longer the sensing time *ts*, the lower the probability of miss detection, and the less energy is consumed on data retransmission. In the following simulation, we will show the optimal sensing time *ts* so that the energy consumption can be minimized.

4. Simulation

The simulation parameters:

Table 1. Simulation Parameters

T	100ms
P_f	0.9
f_s	1
$P(H_0)$	0.8
P_s	1mW

Figure3 shows the relationship between sensing time and energy consumption for different signal noise ratio of the primary users when signals of primary users' are complex PSK.

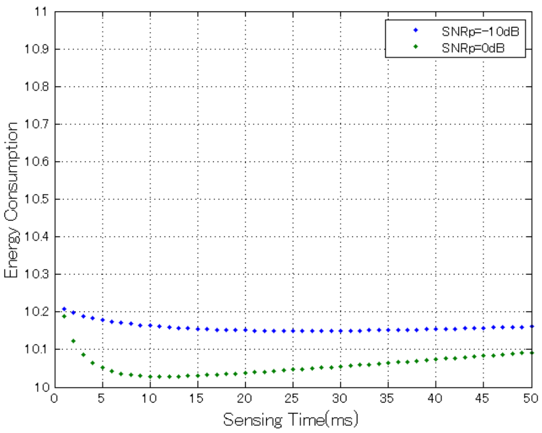

Fig.3. Relationship between Sensing Time with Energy Consumption

From this result, we can see that there is an optimal sensing time that the energy consumption can achieve minimum. For the signal to noise ratio of primary users equals 0dB, the optimal sensing time that energy consumption can achieve minimum is 12ms. Besides that, the optimal sensing time increases as the signal to noise ratio of the primary users decreases.

5. Conclusion

A cognitive data gathering scheme for gas monitoring employing mobile phone based wireless sensor networks is proposed in this paper. In the network, each mobile phone is equipped with a sensor, so that this sensor employed mobile phone can sense data from surrounding environment. The sensor employed mobile phone send gas data to base station by cognitive radio, and energy detection is utilized for spectrum sensing. The relationship between sensing duration and energy consumption is studied, and there exists an optimal sensing duration that the minimum energy consumption can be achieved.

6. References

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