CHEMICAL ENGINEERING TRANSACTIONS

VOL. 68, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; **ISSN** 2283-9216

DOI: 10.3303/CET1868017

Environmental Hazardous Odour Source Monitoring Method Based on WSN

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The purpose of the hazardous odour source monitoring method in WSN mode is to effectively monitor environmentally hazardous odour sources and provide early warning of pollution sources. The experimental results show that the WSN-based environmental hazard odour monitoring method can effectively monitor the hazardous odours in real time, and provide decision support basis for toxic and harmful leakage source monitoring, pollution control and pollution source tracking, and early detection and early warning of fire sources.

1. Introduction

Following the continuous advancement and development of communication, embedded, automatic control and network technologies, the monitoring system has experienced different stages such as centralized control, distributed control and fieldbus measurement and control (Chiwewe and Hancke, 2012; Liang et al., 2016; Zlatkova and Lyubenova, 2017; Guo et al., 2014). Now the distributed network monitoring system is widely used. At present, sudden air pollution incidents often occur in China (Badiav et al., 2008; Farrell et al., 2005; Hayes et al., 2002; Wang and Yang, 2011; Smolau and Beaubrun, 2011), such as the leakage of tank trucks with toxic chemicals on highways. The traditional automatic monitoring system obviously cannot meet this demand. If the environmental staff is asked to extract the sampled substances on site for monitoring, on the one hand, it may cause damage to their body; on the other hand, the on-site air quality parameters cannot be obtained in a timely and accurate manner, and scientific judgment cannot be made quickly, which is difficult to satisfy the need for timely treatment in air pollution. In response to the application limitations of traditional automated air quality monitoring equipment, the environmentally hazardous odour monitoring method based on wireless sensor networks (WSN) have emerged (Lu et al., 2013; Xia et al., 2008; Arpan and Debashish, 2018; Zhang and Wang, 2010; Younis et al., 2013; Mahessar et al., 2015; Dong et al., 2017), which can be applied to areas that cannot be monitored by traditional automated air quality monitoring equipment. In the event of the above-mentioned sudden hazardous odour pollution incident, the environmental staff only needs to properly deploy the sensor nodes in a specific area. These sensor nodes can sense the concentration of the surrounding odour. Thus, the staff can implement remote real-time monitoring, providing a scientific basis for related departments to make timely, reasonable and correct decisions.

2. Network structure

For the WSN-based environmental hazard odour source monitoring method proposed in this paper, it’s necessary to collect, process, send and receive and store multiple air environmental parameters (Rickenbach et al., 2009; Barba et al., 2014; Peleg and Roditty, 2008). The sensor nodes arranged in the monitoring area transmit the data about the environmental hazardous odour quality to the gateway node through the multi-hop ad hoc network, and the gateway node transmits the collected data to the monitoring centre through the Internet network for real-time monitoring, as shown in Figure 1.
In view of WSN node characteristics, its design is required to ensure lower node hardware cost, lower energy consumption (Abu-Affash et al., 2011), and supporting the multi-hop routing protocol. The Zig Bee protocol

Please cite this article as: Zhu L., Li J., 2018, Environmental hazardous odour source monitoring method based on wsn, Chemical Engineering Transactions, 68, 97-102 DOI: 10.3303/CET1868017

should address the application needs of WSN. Figure 2 shows the overall architecture of the wireless sensor device.

The application layer of WSN device contains three tasks, that is, the modules starting with the word “Task”. The three tasks at application layer are the “Main”, the “sensor data”, and the “Ledcontrol”. The interactive relationship between these tasks and the protocol stack is shown in the Figure 3 below.

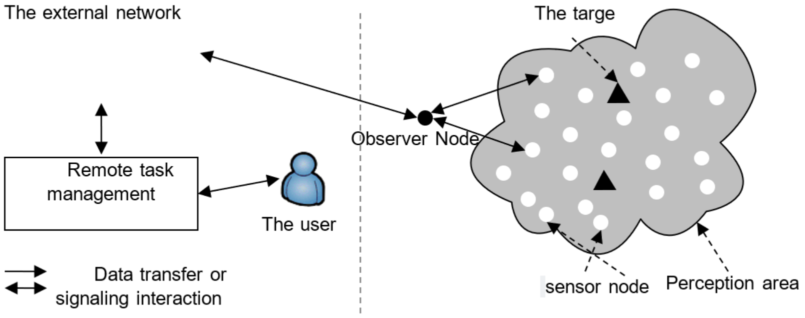

Figure 1: Wireless Sensor Networks System

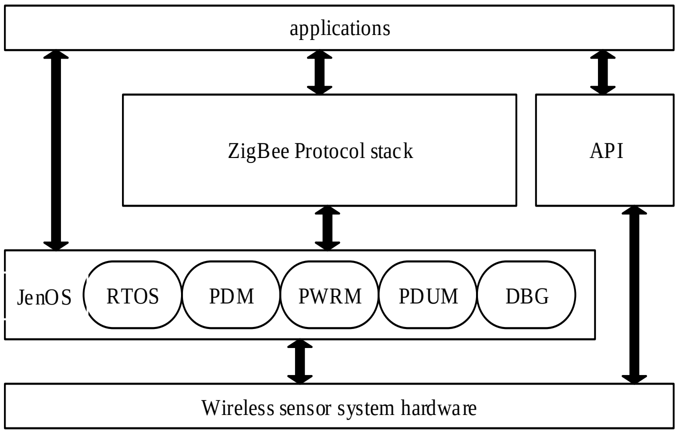

Figure 2: Overall architecture of wireless sensor device

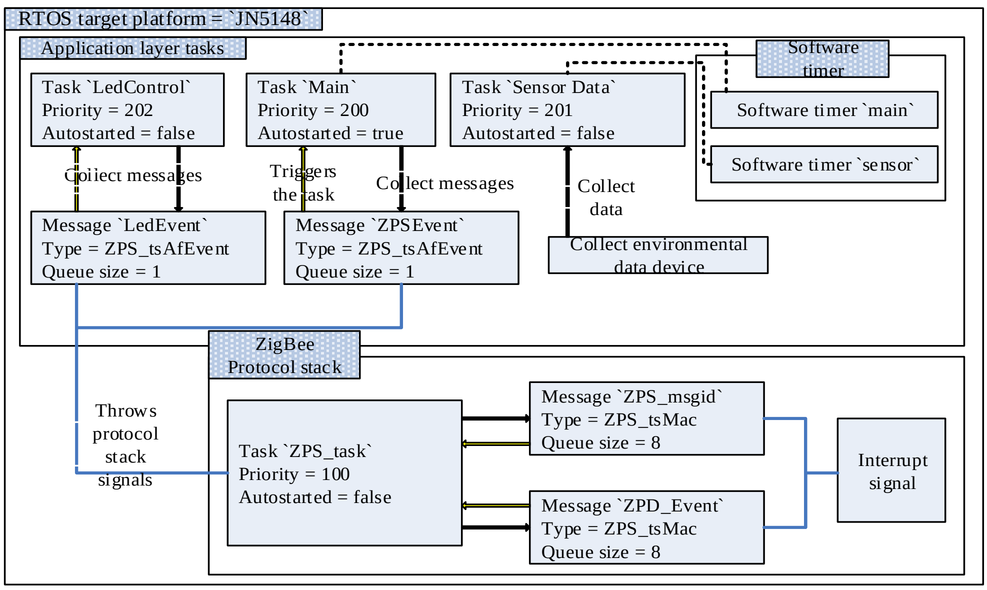

Figure 3: The application layer of WSN device

3. Methods

For the WSN-based air quality monitoring system, because of its large number of nodes, wide distribution, and complicated working environment, each sensor node collects a large amount of data, which will be transmitted to the gateway node or the adjacent sensor node. In such a distributed wireless sensor network, the power consumption of data transmission is very large, and it is obviously unrealistic to replace the battery of the node. Thus, it has become an urgent problem to be solved about how to process such a signal, reduce the amount of data transmission, reduce power consumption, and extend the node's service life. The WSN-based environmental hazardous odour monitoring method proposed in this paper uses many sensor nodes distributed in different monitoring areas to measure the concentration information of the location environment for the node itself. The fusion of the concentration information measured by these sensor nodes can realize the real-time monitoring, classification and judgment, thereby effectively transmitting information such as dangerous odour areas and improving people's quick response ability to emergencies.

The WSN node is mainly connected to the emergency monitoring device through its own data acquisition interface, thereby constructing a wireless local area network, which is responsible for collecting and transmitting data in the hazardous odour polluted area; the environmental monitoring device mainly realizes transmitting the data collected by the WSN node to the monitoring management platform which can achieve the functions of storing, analysing and displaying the on-site data, and share this information through the web. This shall provide basis for emergency decision-making and emergency command, and provide guarantee for emergency linkage.

Each sensor node in WSN performs system initialization. After starting the protocol stack, joining the wireless sensor network, and initializing the peripheral, the application layer task invokes the environment acquisition function to collect the environmental data (Cardoso et al., 2018), and then calls the corresponding function in the PDUM module in the operating system to package and send environmental data. If this device is required to have network data forwarding function, the routing table should be maintained to obtain data transmitted by other sensor nodes and send the data to the control node. And, the router table can be dynamically modified according to changes in the wireless network node.

Considering that the WSN nodes have certain differences at different time, combined with the node topology balance function, these nodes have a topologically adaptive reconstruction mechanism, and the nodes perform spontaneous topology reconstruction according to the relationship between node degrees and neighbouring key nodes. Taking any node Si in the network the neighbour node information in its communication range is obtained, wherein the node degree of the node Si is used to find the neighbour node with the node degree not less than the neighbour node. Then, the neighbour node subset S{Si....Sn} is established, where in Smin is the node with the minimum node degree, and Smax is the maximum node in the node degree. For the initialization of the sub-network, k nodes and their node degrees of k nodes are selected, and the node weight factors in the network is initialized. According to the changes of the WSN node's attributes itself, the weight value of the topology edge is dynamically adjusted, and the topology edge is also dynamically adjusted according to the value.

It's assumed that the nodes in the network all have unique ID identifiers, the transmit power of all sensor nodes is continuously adjustable, and the maximum transmit power can be inconsistent. In the case of unchanged environment between nodes in the network, the communication between nodes can satisfy the bidirectionality; the node can determine the connectivity of the network topology through the control information. If the node u communicates directly with any node γ in the region $R_{u \to v}$, the energy consumed by the node u is greater than that by the node u through v transferred to γ. Then the region u→v is the indirect control range of the node u about the node v, and:

$$R_{u \to v} = \{\gamma : C(u, v, \gamma) \le C(u, \gamma)\} \tag{1}$$

Let NF be the set of all nodes in region F, then:

$$NF = \{v \in V : Loc(v) \in F\} \tag{2}$$

If F=F(u,p), the direct control range of node u is expressed as RF(u), then:

$$RF(u) = \bigcap \{F(u, p_{max}) - R_u \to v\} \tag{3}$$

It can be seen from the above equation that the energy consumed by the direct communication between the node u and any node of the RF(u) regions is the minimum, and if the node u is to communicate with one node x outside the region RF(u), then the node y must be found in the region RF(u); the node u can communicate with the node x after being transferred by the node y, and consumes less energy than that consumed by the direct communication between the node u and the node x. The shaded part in the figure below is the direct control range RF(u) of the node u at a given node u and its neighbours v, m, and t.

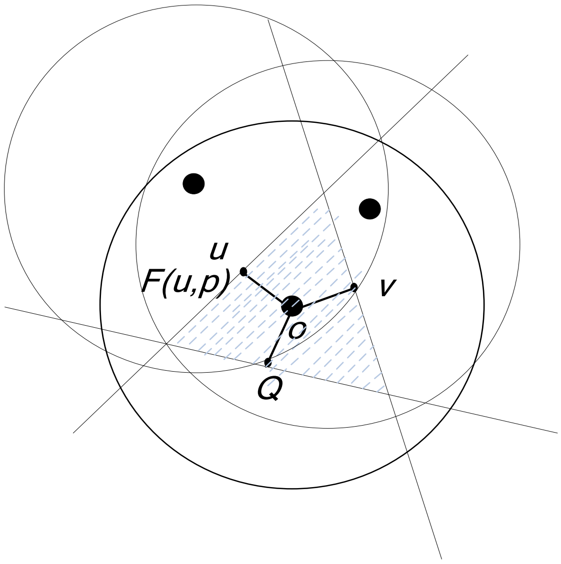

Figure 4: Node control range

In the initial stage of network operation, the cluster-head node in the network is firstly awakened, and initialized and then transferred to the network monitoring state. The common network node wakes up synchronously according to the time indicated by the scheduling configuration, completes data collection and upload in the time slice allocated by itself, and acquires new scheduling configuration information. Under the scheduling of the cluster head, all common nodes realize data collection under virtual synchronization based on self-scheduling configuration information. If there is no node transfer information in the current cluster head, they'll fall into sleep state in this time period. Then all the cluster heads establish the connection between the cluster heads according to the plane diffusion method, and collect data from the farthest end. The collected paths are selected according to the rule of minimum number of forwarding times. In the same case, the cluster head nodes with fewer nodes in the cluster are selected as the data relay node. Finally, the cluster head completing the data collection enters the sleep mode, and the current collection cycle ends.

4. Performance analysis

In view of the problems existing in the data transmission process for the traffic environment dangerous odour monitoring, the network performance parameters were tested through simulation experiments. The undirected graphs that randomly generate connectivity were used as the basis of the wireless network topology, and each node has a random connection with its neighbouring nodes. In the experiment, each node was randomly assigned with capability value, which represents the connectivity that it can afford. To simulate a highly dynamic network environment, the nodes in the network could fail continuously; after every T time, the performance analysis was made for the monitoring network.

The network performance under node random deployment (RAMD) is compared with that under network control method in this paper (NTCM). For the same initial network, the random nodes were first invalidated one by one, and the number of failed nodes was recorded before the overlay network was divided; then the key nodes in the network were invalidated one by one, and the number of key failed points was recorded before the overlay network was divided. The average value was taken from the multiple experiments, which shows that for the same overlay network, if you want to divide it, the number of failed nodes is much less than the number of random nodes that are invalid. From the perspective of the network coverage, it can be seen from Figure 5 that under the condition that the network coverage is relatively close, NTCM method has certain advantages in network lifetime.

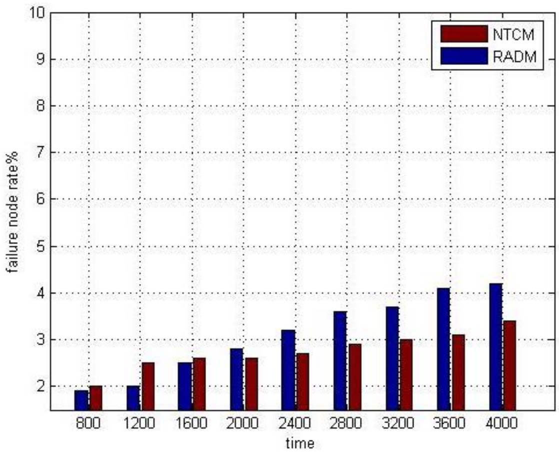

Figure 5: Network lifetime

Figure 6 shows that under different path and power control conditions, the network path loss parameters and node power are changed according to network node performance parameters at different times as the network connectivity changes continuously. That is, when the node power decreases gradually, work nodes are more evenly distributed, which proves that the environmental monitoring network has better fault tolerance.

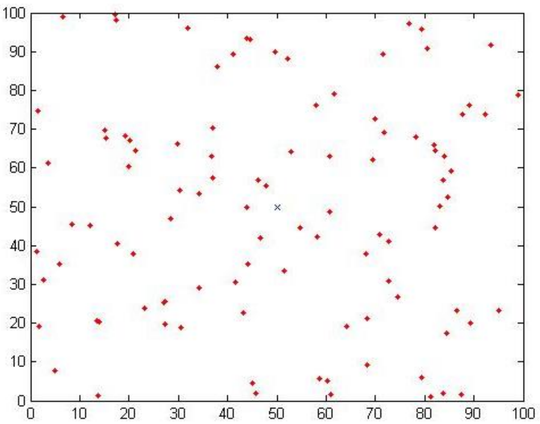

Figure 6: Work nodes distribution

5. Conclusions

In this study, the WSN-related technology was used to track the environmental hazardous odour monitoring information, wherein, the key issue is how to save the energy of WSN monitoring node. By adjusting the node power, optimizing the network performance and reducing the energy consumption (Sayed Kushairi et al., 2018) of the node, the survival time of the network can be prolonged. Meanwhile, the simulation results show that this algorithm has obvious energy-saving characteristics and high network connectivity. It can realize intelligent monitoring of hazardous odours in environmental pollution, which has certain use value.

Acknowledgements

This work was supported by key special project of National Key Research and Development Program (2017YFC0803900).

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