CHEMICAL ENGINEERING TRANSACTIONS

VOL. 62, 2017

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

Guest Editors: Fei Song,Haibo Wang, Fang He

ISBN 978-88-95608- 60-0; **ISSN** 2283-9216

DOI: 10.3303/CET1762140

Personnel Location Software in Chemical Production Area Based on Wireless Sensor Network

Weiwen Shen, Yaqiong Zhu

Wuhan Technical College of Communications, Wuhan 430065, China
Henan Institute of Finance & Banking, Zhengzhou 451416, China
whsww@163.com

This paper proposes a Zigbee network-based real-time indoor personnel location system based on wireless sensor network through research and comparison of existing location solutions and according to the chemical plant personnel location requirements, so as to master the distribution of plant personnel at any time and improve the efficiency of accident rescue at the time of disaster and daily production management, which solves the problems such as complex, high cost and poor real-time performance in the existing location system. The functions of gateway, reference node and blind nodes of the personnel location system were implemented and verified experimentally. The experimental results show that the expected results have been achieved for the nodes in terms of communication distance, ranging precision, low power consumption and small size, meeting the requirements of real-time location tracking of indoor personnel.

1. Introduction

Various risks exist in the development of chemical industry in recent years due to inadequate safety management experience, imperfect safety monitoring equipment etc., leading to frequent accidents, threatening the safety of personnel in the production area and chemical manufacturing safety (Abraham et al., 2013).Subject to the complex environment of the chemical plant, the system shall be flexible, easy to set up the network and the nodes can work for long time (Kulba et al., 2017).The personnel information management system is performed to record attendance, leaving posts and other information automatically for intelligent management (Reina et al., 2013).In case of emergency, the personnel are identified by the surveillance system for rescue in time (Moridi et al., 2015).The real-time personnel location system is important for intelligent information management in chemical enterprises. Zigbee is an emerging wireless network technology with low power consumption, low data rate, low complexity, low cost and high reliability (Zhen, 2014), meeting the requirements of personnel location applications in chemical plants, and has been widely studied and used in recent years.

2. Design of system

2.1 Structure

Large workshops, small offices and narrow routes in the chemical plant constitute all areas for personnel activity (Sushabhan et al., 2015). The structure of the location system shall be flexible. The location network consists of four parts: reference point, blind point, gateway and location engine (Farihah et al., 2015). Each separate location area requires a gateway to establish the network, which is wired to the location engine (Ze et al., 2015). The reference points are located at the edge of the area to and cover the signals in the area; the blind points are attached to the surface of the location object like a hat or top of a device (Batista et al., 2014). Figure 1 shows the structure of network-based personnel location system. The blind nodes automatically access the network after entering the signal coverage; the location engine server and the monitoring terminal are connected via Ethernet (Kunho et al., 2015).
This system is a network-based location system. The blind node sleeps most of the time after joining the network, and then performs the single-hop broadcast task regularly. This blind node is simple with low power

Please cite this article as: Weiwen Shen, Yaqiong Zhu, 2017, Personnel location software in chemical production area based on wireless sensor network, Chemical Engineering Transactions, 62, 835-840 DOI:10.3303/CET1762140

consumption, suitable for wearing by persons for long time (Batista et al., 2014). The reference node is responsible for route selection and distance measurement. Take RSSI method for measuring of distance between nodes. The reference node converts RSSI values broadcast by blind nodes into the distance information, and finally forwarded to the gateway with the address 0x0000 (Chia et al., 2016). In each network, the address of gateway must be 0x0000. After establishing the network, it collects and uploads the information of reference nodes to the location engine server. Subject to limited bandwidth of 485 bus, change 485 with Ethernet before data aggregation at the gateway (Mohammad et al., 2014). The location engine server is a PC in general. The software in the PC will calculate the coordinates of blind nodes using the location algorithm and combining the obtained distance, and display on the monitoring terminal (Mohamed et al., 2015). This paper realizes the function of nodes in the location system. In this paper, the location engine server for implementation of the algorithm and the monitoring terminal for interaction with users are called as the monitoring center.

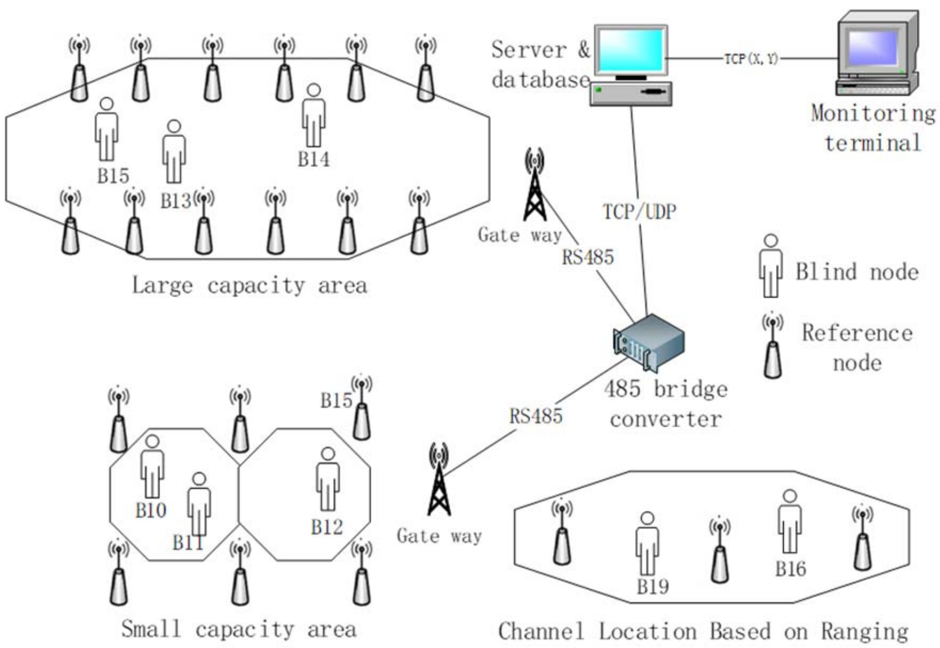

Figure 1: The overall structure of the system

2.2 Modules of system

Blind nodes in the location system are worn by persons. Lithium battery is designed for the blind nodes. A PCB antenna is used for portability. Gateway nodes and reference nodes are full-function FFDs. Blind nodes are simplified RFDs requiring field configuration and debugging. Expansion boards are set for site interoperability (Bernabe et al., 2017).

(1) CC2530 RF modules are selected, featuring high integration, only a few peripheral circuits are required. IFA omni-directional antenna is used for RF antenna.

(2) Blind nodes needs mobile power supply and long working hours. Blind nodes work indoor, so the photovoltaic cell is not available. The lithium ion battery features compact, light, low self-discharge and no memory effect compared with ordinary nickel-cadmium nickel-metal hydride batteries (Yong et al., 2017), widely used in many new mobile devices. In this design, high cost-effective rechargeable lithium-ion battery is selected.

(3) The expansion module has interfaces for manual configuration of FFD by developers and users. Figure 2 shows the structure of the expansion board, comprising the display circuit, joystick, buttons and serial circuit. The expansion module has 16-pin LCD display interface (Janja et al., 2014). 128 * 64 LM6059 LCD module is used for the display. The LCD module occupies the UART1 port of the CC2530.

2.3 Software design

The node software is written using Zstack2007/pro. The Zstack is a stack file system with hierarchical structure in compliance with Zigbee standard. Zstack is composed of files such as App, HAL, MAC, MT, NWK,

OSAL, Profile, Security, Service, ZDO, ZMain (Junming et al., 2014). The Z-Stack stack runs on TI's OSAL. OSAL runs on a polled list of tasks and is responsible for scheduling, time management and messaging.
The system enters the ZDO layer after the node starts up to determine the type of device. If the device in the node configuration file is coordinator, establishment of the network is initiated; If the device configured by nodes is router or enddevice, network discovery and joining are performed to ensure that the nodes are properly networked (Kimio et al., 2014).
The network allocates a short address to each node dynamically. Each node in the location system is assigned a unique node ID for identification (Zheng, et al., 2016). Cross-area cross-network tracking of blind nodes is realized using node IDs (Baldiviez et at., 2017). The gateway node shall allocate a unique area number for the network area that it starts up, so that the monitoring center can master the area topography and the node configuration according to the area number. The monitoring center can locate the blind nodes in the network in real time combining the ranging information of the nodes. Figure 3 shows the work sequence of nodes in the network (Dong et at., 2017).

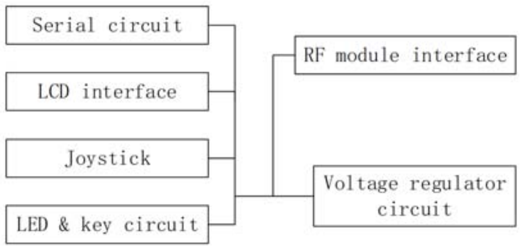

Figure 2: Expansion board structure

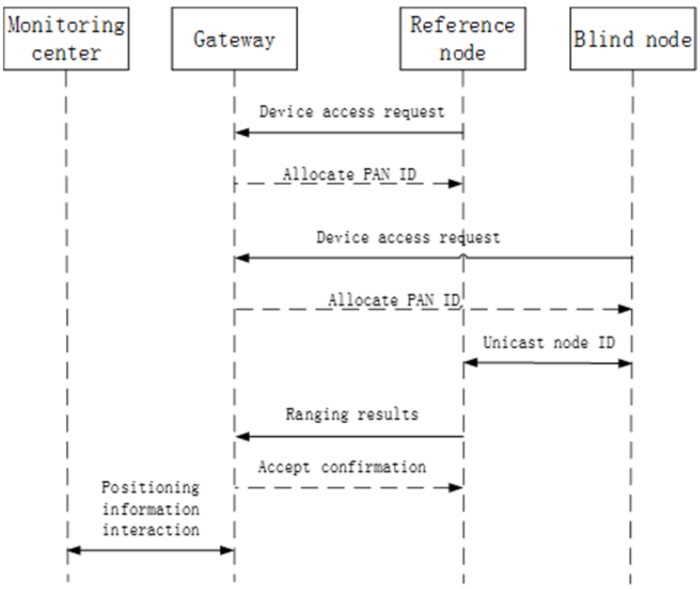

Figure 3: Sequence diagram of network work

3. Test and analysis

3.1 RSSI ranging algorithm

When the two nodes are visible to each other, the strength of the received signal can be predicted using a free space propagation model. For a certain distance between the receiver antenna and the transmitter antenna, the power received by the receiver is determined by the by Friis free space equation 1:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} \tag{1}$$

Where Pt is the transmit power; Pr(d) is the received power and also a function of the distance d between transmitter and receiver; Gt is the transmitter antenna gain; Gr is the receiver antenna gain; d is the distance between transmitter and receiver in m; λ is the wavelength in m. The parameters of expression (1) are not convenient for calibration, so a simplified estimation expression (2) is used in practice:

$$RSSI = A - 10n\lg(d) \tag{2}$$

where RSSI is the received signal strength in dbm; A can be deemed as the received signal strength within the transmission distance; n is the propagation factor, and the value depends on the wireless signal propagation environment; d is the distance between transmitter and receiver in m. The above two parameters can be obtained by measuring the nodes in a specific environment (Kim et at., 2017).

3.2 Test and analysis

During the experiment, the node power is set to 0db. Outdoor blind nodes can be joined in the network as far as 80m, and the farthest communication distance is about 100m. The reason for this difference is that the receiving sensitivity of blind nodes is -97dbm. According to the Zigbee regulation, the minimum signal strength of the network is -85dbm. Therefore, the communication distance between nodes is slightly longer than the network access distance.

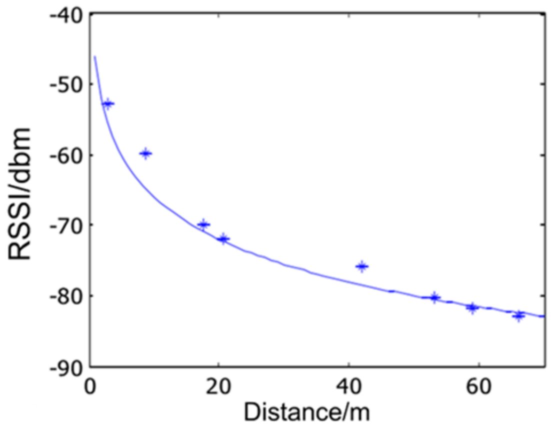

Figure 4: Measurement curve of parameter data

To obtain the calibration value A: Fix the coordinator 1.5m from the ground. Keep enddevice 1m away horizontal. To avoid the measurement error caused by the antenna direction, place the coordinator at the center to receive data. Choose 4 enddevice distributed evenly. Each enddevice sends more than 100 frames.
Fitting of n value of the parameter: select different node distances for communication. Table 1 shows the RSSI measurement for different communication distances. Get the value of the propagation factor n for the obtained data using formula 2 and the fitting curve. Figure 4 shows the obtained fitting curve as A takes -46 and n takes 2.

Table 1: Communication results for different communication distances

Distances（M）	Number of data frames	Mean of each RSSI group(dBm)
2.9500	100	-52.9100
8.8500	133	-59.8947
17.7000	107	-69.9813
20.6500	106	-71.8019
42.0000	123	-75.9187
53.1000	131	-80.1985
59.0000	105	-81.8286
66.0000	110	-82.9273

With the RSSI estimation equation for the distance obtained above, a static ranging experiment with fixed distance between nodes was conducted. Take the measuring point r=[1.84.810.816.844.35763](m) for communication between nodes. Figure 5 shows the absolute error between the estimated distance and the actual distance.
The static ranging results show that the accuracy of the distance measurement decreases as the communication distance increases. To obtain high location accuracy, the distance between the nodes shall be controlled within 40m.

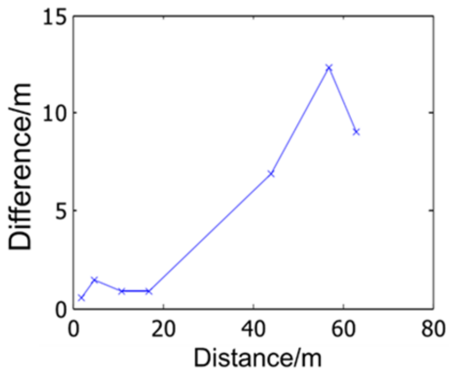

Figure 5: Difference of estimation and actual distance

4. Conclusion

This paper presents a real-time location system for indoor personnel based on Zigbee technology and analysis and comparison of existing location technologies and schemes, combined with the needs of personnel location in high-risk production areas. CC2530 radio frequency microcontroller is used to design and implement the hardware circuits comprising blind nodes, reference nodes and gateways. The RSSI method is adopted for measuring of distance between nodes. The function of the node software is realized based on TI Zstack stack. Experimental results verify the feasibility of the location scheme. The node communication distance and ranging accuracy meet the requirements of the location system.

Acknowledgement

This paper is supported by the follow projects:
(1)Scientific research projects of the Inner Mongolia Autonomous Region higher education institutions(NJZY17058);
(2) Research foundation of basic subject of Inner Mongolia Agricultural University (JC2015009);
(3) Research on the Key Technologies for visible image based forage identification (61562067).

Reference

Abraham M.C., Jon C., 2013, Evaluating opportunistic networks in disaster scenarios, Journal of Network and Computer Applications, 36(2), 870-880, DOI:10.1016/j.jnca.2012.11.001
Baldiviez L.M., Keim N.L., Laugero K.D., Hwang D.H., Huang L., Woodhouse L.R., Burnett D.J., Zerofsky M.S., Bonnel E.L., 2017, Design and implementation of a cross-sectional nutritional phenotyping study in healthy US adults, BMC Nutrition, 3(1), DOI: 10.1186/s40795-017-0197-4
Batista N.C., Melícioab R., Mendes V.M.F., 2014, Layered Smart Grid architecture approach and field tests by ZigBee technology, Energy Conversion and Management, 88, 49-59, DOI: 10.1016/j.enconman.2014.08.020
Batista N.C., Melícioab R., Mendes V.M.F., 2014, Wireless Monitoring of Urban Wind Turbines by ZigBee Protocol: Support Application Software and Sensor Modules, Procedia Technology, 17, 461-470, DOI: 10.1016/j.protcy.2014.10.182
Bernabe A.D., Martinez J.R., Ollero A., 2017, Efficient integration of RSSI for tracking using Wireless Camera Networks, Information Fusion, 36, 296-312, DOI: 10.1016/j.inffus.2016.11.001
Chia H., Chung C.H., 2016, Implementation of multi-channel technology in ZigBee wireless sensor networks, Computers & Electrical Engineering, 56, 498-508, DOI: 10.1016/j.compeleceng.2015.10.002

Dong S.H., Zhang H.W., Zhang L.B., Zhou L.J., Guo L., 2017, Use of community mobile phone big location data to recognize unusual patterns close to a pipeline which may indicate unauthorized activities and possible risk of damage, Petroleum Science, 14, 395, DOI: 10.1007/s12182-017-0160-7

Farihah S., Nasrudin A.R., Hew W.P., 2015, Zigbee-based data acquisition system for online monitoring of grid-connected photovoltaic system, Expert Systems with Applications, 42(3), 1730-1742, DOI: 10.1016/j.eswa.2014.10.007

Janja S., Marko M., Dušan G., 2014, Distance estimation using RSSI and particle filter, ISA Transactions, 55, 275-285, DOI: 10.1016/j.isatra.2014.10.003

Kim Y.J., Kim C.Y., Shin Y.J., 2017, The effects of ubiquitous healthcare service on the south Korean Economy: using input-output analysis, Information Systems Frontiers, 19, 1149, DOI: 10.1007/s10796-016-9640-3

Kulba V., Bakhtadze N., Zaikinb O., 2017, Scenario analysis of management processes in the prevention and the elimination of consequences of man-made disasters, Procedia Computer Science, 112, 2066-2075, DOI:10.1016/j.procs.2017.08.247

Kunho H., SuKyoung L., Kyoungwoo L., 2015, Performance improvement in ZigBee-based home networks with coexisting WLANs, Pervasive and Mobile Computing, 19, 156-166, DOI: 10.1016/j.pmcj.2014.03.002

Mohamed H., MahamatH., Ali M.,Hassan M.M., 2015, Development of Physical Intrusion Detection System Using Wi-Fi/ZigBee RF Signals, Procedia Computer Science, 76, 547-552, DOI: 10.1016/j.procs.2015.12.342

Mohammad A., Youhei M., MostafaK.S., 2014, An investigation of underground monitoring and communication system based on radio waves attenuation using ZigBee, Tunnelling and Underground Space Technology, 43, 362-3 DOI: 10.1016/j.tust.2014.05.011

Moridi M.A., Kawamura Y., Sharifzadeh M., 2015, Development of underground mine monitoring and communication system integrated ZigBee and GIS, International Journal of Mining Science and Technology, 25(5), 811-818, DOI: 10.1016/j.ijmst.2015.07.017

Reina D.G., Toral S.L., Bessisb N., 2013, An evolutionary computation approach for optimizing connectivity in disaster response scenarios.Applied Soft Computing, 13(2), 833-845, DOI: 10.1016/j.asoc.2012.10.024

Sushabhan C., Piyush K., Rajesh S., 2015, ZigBee and Bluetooth Network based Sensory Data Acquisition System.Procedia Computer Science, 48, 367-372, DOI: 10.1016/j.procs.2015.04.195

Yong I.R., Flora D.S., Martin T., 2017, D-Log: A WiFi Log-based differential scheme for enhanced indoor localization with single RSSI source and infrequent, Pervasive and Mobile Computing, 37, 94-114, DOI: 10.1016/j.pmcj.2016.09.018

ZeF.Y., Hui H., Zhao D., 2015, ZigBee Technology Application in Wireless Communication Mesh Network of Ice Disaster, Procedia Computer Science, 52, 1206-1211, DOI: 10.1016/j.procs.2015.05.159

Zhen L., 2014, Hardware Design of Smart Home System based on zigBee Wireless Sensor Network, AASRI Procedia, 8, 75-81, DOI: 10.1016/j.aasri.2014.08.013