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

ISBN978-88-95608- 60-0; **ISSN** 2283-9216
DOI: 10.3303/CET1762132

Smart Logistics Monitoring System for Hazardous Chemicals Based on Wireless Sensor Technology

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To meet the monitoring demand of larger range, stronger stability and higher safety performance in nuclear power plant and on the basis of the current use of wireless sensor technology in nuclear power plant and the current research of domestic and foreign scientific research institutions, this paper puts forward a three-dimensional monitoring method and builds model of system for radiation field of nuclear power plant based on wireless sensor technology. A decision-making model for hazardous chemicals logistics considering time window and route set is researched. Targeting smallest social risk and transport expense, transport capacity of road, storage capability of nodes, transport route and time window are overall considered. Considering features of the model, ant colony algorithm with elite strategy is designed to solve the model. At last, living example is used to verify the model and algorithm. It proves that the application based on RFID and WSN wireless sensor technology achieves smart monitoring on the logistics of hazardous chemicals. This has guiding significance for making scientific method and theory of hazardous chemicals logistics informatization.

1. Introduction

In the latest years, industrialization process accelerates in our country. The logistics of hazardous chemicals rapidly increases in large amount. In 2010 report of hazardous articles storage branch of China Association of Warehouses and Storage (Erdelj et al., 2013), the output of hazardous chemicals has reached 1400 million tons in our country (Joshi et al., 2013). The weight is large around the world. The total number of practitioner units reaches 310 thousand, including 11071 storage units and 9700 transport units. The safety in the logistic process of hazardous chemicals attracts the attention of government (Abbasi et al., 2014), safety authority and relevant enterprises (Song et al., 2014). Even so, serious accident in the field of hazardous chemicals logistics happens frequently, which brings monstrous menace to the safety of economic society and people's life. Relying on RFID and WSN wireless sensor technology (Bottero et al., 2013), this paper starts from the framework of hazardous chemicals logistics monitoring system, integrates decision-making support system (Rawat et al., 2014), considers the support of hazardous chemicals logistics decision and optimization to smart decision making and the stimulus of hazardous chemicals storage & transport process modelling and optimization to framework of system (Güngör and Hancke, 2013), and forms a set of method and theory with the significance of guidance to hazardous chemicals logistics informatization. This is to monitor the market of hazardous chemicals logistics, normalize the market of hazardous chemicals logistics, improve the ability of hazardous chemicals logistics increasing social benefit and resisting social risks (Joshi et al., 2013), help enterprises to effectively prevent and decrease the risks of hazardous chemicals logistics and enhance management and operation level of enterprises (Mejjaouli and Babiceanu, 2015).

2. The current use of RFID and WSN technology in logistics field and the analysis on it

Based on the technical features of RFID and WSN, they can be divided to be RFID & WSN sensing technology which is responsible for information acquisition and recognition and WSN network transmission technology which is responsible for information transmission and networking (Mejjaouli and Babiceanu, 2014). RFID and WSN sensing technology are jointly called information sensing technology of Internet of Things. WSN sensing technology includes satellite navigation terminal, video identification, sensor technology and

Please cite this article as: Chunjun Luo, Qimin Fu, 2017, Smart logistics monitoring system for hazardous chemicals based on wireless sensor technology, Chemical Engineering Transactions, 62, 787-792 DOI:10.3303/CET1762132

others. WSN network transmission technology includes wireless network transmission, mobile communication network and cable carrying network. The logical partitioning is shown in Figure 1.

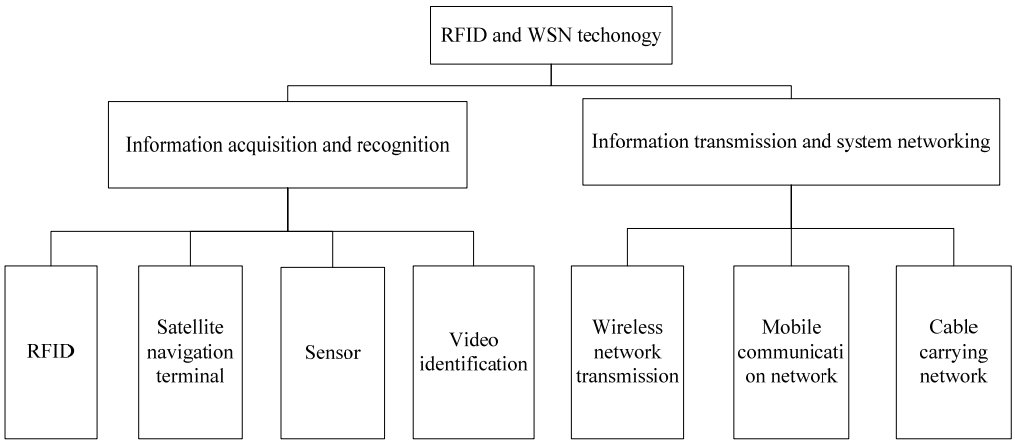

Figure 1: Logical partitioning diagram of RFID and WSN technology

2.1 RFID and WSN technology

RFID is Radio Frequency Identification. In details, radio signal is used to recognize specific targets and read relevant data; the coupling or transmission of electromagnetic wave is used to communicate for the purpose of automatically recognizing and getting relevant information of objects. At present, it has been widely used in industrial automation, business automation, transportation control and management. RFID is mainly comprised of electronic tag, reader and application software. Electronic tag is comprised of chips and antenna. Every tag has the sole electronic code. The basic structure is shown in Figure 2.

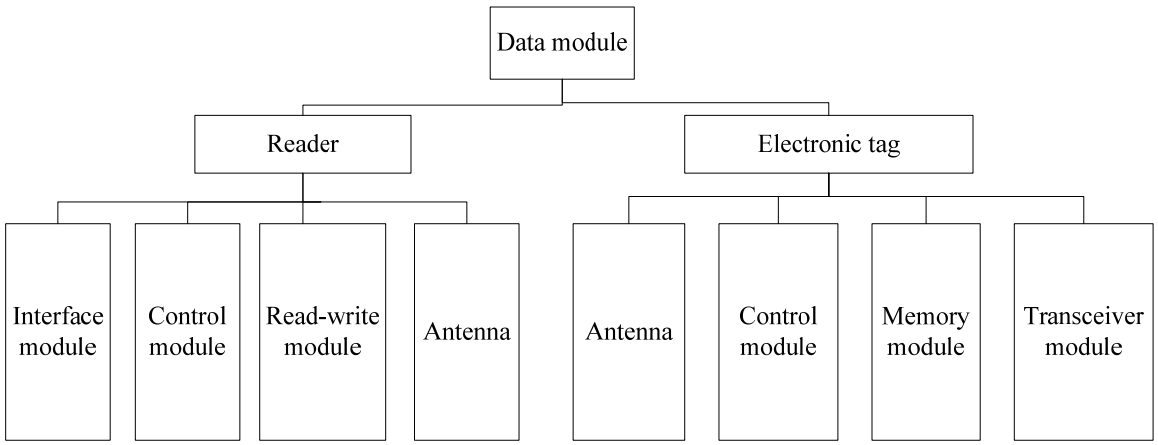

Figure 2: RFID system structure

In accordance with the universality of logistics application, the application of RFID tags and smart handheld RFID terminal products are widest. The secondary is GPS/GIS technology. Logistics information system uses GPS/GIS sensing technology to find, trace, monitor and manage the vehicles and substances in transport and distribution link. The technology universally focuses on the link of transport. Video and image sensing technology is usually used to monitor logistics for its safety and prevention of burglary. The technology is in its monitoring stage at present. Manual work is needed to analyse images and there is no function of automatic sensing and recognition. At present, sensor is also applied with RFID and satellite navigation to recognize the goods and environment of hazardous chemicals logistics system, grain logistics system and cold chain logistics system. Sensor technology enriches the sensing means in the system of Internet of Things. It will be widely used in cold chain logistics of food and hazardous chemicals logistics. Some other sensing technologies, including scanning, infrared ray, laser and bluetooth, are also applied in the field of logistics. The application of technologies of RFID and WSN in logistics industry is shown in Figure 3.

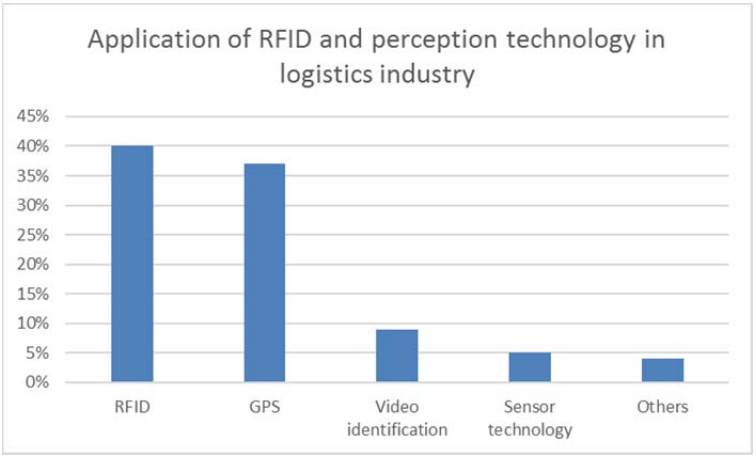

Figure 3: Application of RFID and perception technology in logistics industry

2.2 WSN network transmission technology

WSN is comprised of 4 parts: sensing module (sensor node), control module (convergence node), transmission medium (wireless transmission technology or cable carrying network technology) and control terminal. Sensor node is front-end basic equipment in wireless sensing network system. It is comprised of 4 parts: data collection, data transmission, data processing and power supply. The structure of sensor node is shown in Figure 4.

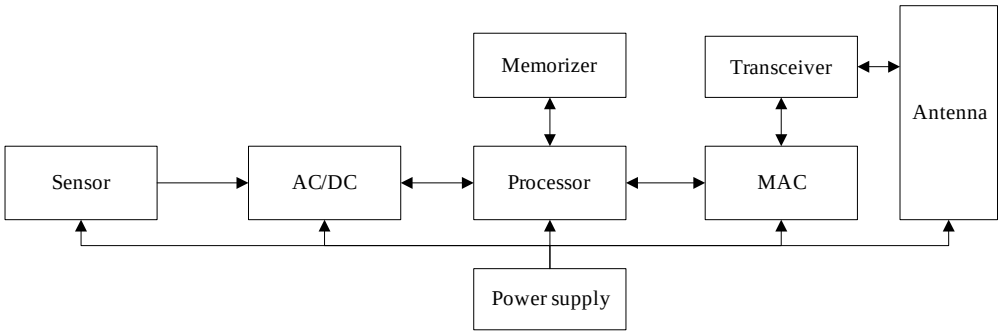

Figure 4: Structure of sensor node

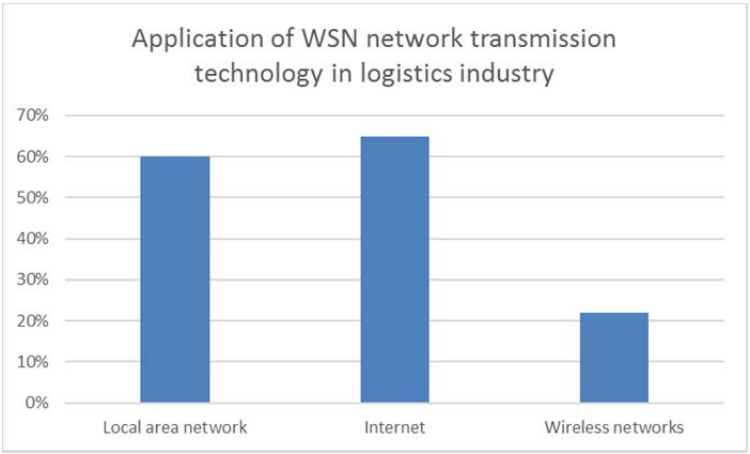

Figure 5: Application of network layer technology in logistics industry

The internal information system of logistic enterprises is an independent network system constructed with the main body of internal Local Area Network. When nodes of goods logistics are scattered and goods are moved in real time and large range, logistics information system is usually combined with Local Area Network of enterprise. Some enterprises only use the technology of Local Area Network. In logistics center or logistic nodes, logistic network is usually based on the technology of Local Area Network. Wired Local Area Network or Wireless Local Area Network is used to build logistic information system. In data communication, wireless communication is usually combined with wired communication. Advanced 3G communication technology is also widely used. The application of WSN network transmission technology in logistics industry is shown in Figure 5.

3. The structure of smart hazardous chemicals logistics monitoring system and analysis on key problems

RFID and WSN complement each other's advantages and complete information transmission and processing. The research on smart hazardous chemicals logistics monitoring system based on RFID and WSN needs considering the practical support of RFID and WSN technology. At the same time, smart decision-making module is introduced to analyse the core problems of smart decision-making on hazardous chemicals logistics, form complete information system structure, analyse and put forward the key problems involving smart monitoring and application of hazardous chemicals logistics, clearly state the framework of smart hazardous chemicals logistics monitoring system and the modelling of hazardous chemicals logistics process, and analyse the mutual relation among the problems about decision making for hazardous chemicals logistics.

3.1 Classification of hazardous chemicals

In accordance with GB 13690 Classification and Marking of Common Hazardous Chemicals, hazardous chemicals can be divided into 8 classes: explosives, compressed gases and liquefied gases, flammable liquid, inflammable solid, self-inflammable articles and wet inflammable goods, oxidizing substances and organic peroxides, poisonous substance and corrosive substance. There are 1074 listed common chemicals. The classification of hazardous chemicals is shown in Figure 6.

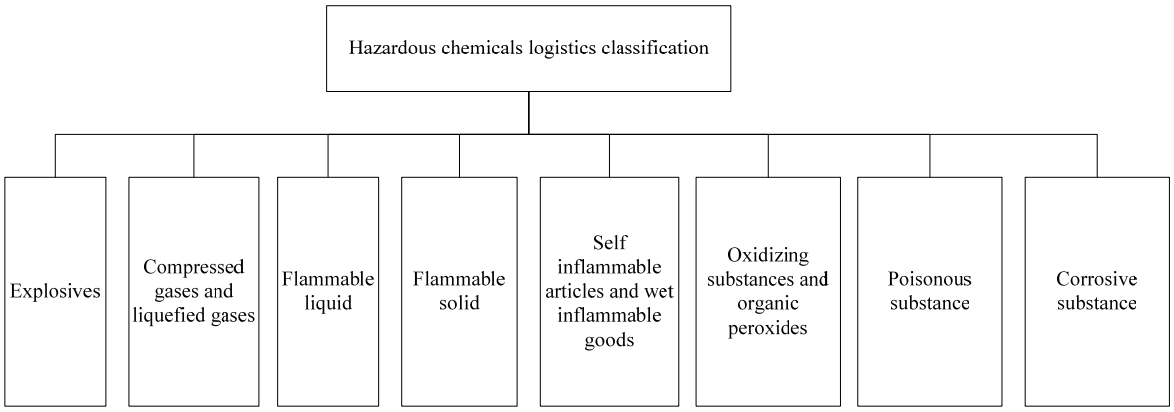

Figure 6: Sketch map of hazardous chemicals classification

3.2 Logistic form of hazardous chemicals

Hazardous chemicals have different physical and chemical properties. In logistics of hazardous chemicals, different type of hazardous chemicals has different logistic form. Objects of information collection are different in different storage and transport forms. The storage environment and form of hazardous chemicals classification is shown in Table 1. Analysis on smart hazardous chemicals monitoring scheme based on RFID and WSN

In the field of hazardous chemicals logistics, the introduction of RFID and WSN technology can enhance management quality and service level, save the time of business and operation treatment in logistics link, improve the accuracy and timeliness of information transmission and strengthen the safety of hazardous chemicals logistics. The system of hazardous chemicals logistics based on RFID and WSN shall be built on the basis of information technology to stimulate the innovation of logistics management and mechanism of hazardous chemicals and contribute to standard implementation and modern management. The following is concrete monitoring work of wireless sensor technology:

Safety status monitoring & early warning and equipment control. In storage and transport link, front-end monitoring terminal can get real-time information of hazardous chemicals in logistic process, including temperature, pressure, moisture and density. Front-end monitoring terminal can automatically record the information. The system adjusts air fan and temperature & moisture controller according to actual status. When abnormal status or emergency happens, the system will give an alarm and start emergency facilities.
Automatic goods recognition. RFID technology is used to confirm the status of operators in storage and transport link. The workers with corresponding operation qualification can operate logistics. Operators use automatic scan terminal to scan the information label of hazardous chemicals and check whether safety information of hazardous chemicals and basic information of goods are complete.

Table 1: Storage environment and form of hazardous chemicals classification

Classification standard	Type	Storage environment	Storage form
I	Explosives	Storage Room	Normal, case package
II	Compressed gases and liquefied gases	Storage Room Yard	Bottle filling Tank container
III	Flammable liquid	Storage Room Yard	Tank container Tank container
IV	Flammable solid Spontaneous combustion material Inflammable goods exposed to dampness	Storage Room	Barrels; boxes; bags; basket
V	Oxidant Organic peroxide	Storage Room	Barrels; boxes; bags
VI	Toxic substance	Storage Room Yard	Barrels; boxes Tank container
VII	Radioactive material	Storage Room	Special container
VIII	Corrosive substance	Storage Room Yard	Barrels; boxes; Tank container

Transport means positioning and navigation. In the logistic transport of hazardous chemicals, transport means use the terminal of satellite navigation system to receive position information. The terminal of satellite navigation system uses its own communication technology or other communication technologies to communicate with front-end monitoring platform. In transport process, transport operators can communicate with monitoring terminal with voice and words. The workers or organizations relevant to logistic transport of hazardous chemicals can inquire the information of transport on the internet.

3.3 Analysis on the process of hazardous chemicals logistics

In modeling process, overall performance indexes of the system can be got after weighing sub-performance of system. Through improving different task links and changing structure, the bottleneck that limits the optimization of the whole logistic process in normal status and mode can be found to improve the whole logistic process.

Table 2: A sub performance mean table for the main business processes of hazardous chemicals logistics

Weight \ Changes	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}
λ_{i1}	0.2	0.0	0.2	0.6	0.2	0.0	0.0	0.3	0.2	0.8	0.2	0.0	0.0	
λ_{i2}	0.6	0.0	0.4	0.5	0.5	0.0	0.0	0.4	0.5	0.6	0.3	0.0	0.0	

Taking the process of logistics of hazardous chemicals for example, two performance indexes considered in the whole logistic process are firstly defined: hazard degree (normalization) and time. The weight of the two indexes of each task migration are α_{i1} and α_{i2}. To simplify the overall performance measurement in the process of logistics, the same weight of α_1 and α_2 is used for performance index of each task. α_1=0.7 and α_2=0.3. Corresponding empirical values are got by expert scoring method. Through integrating relevant historical data corresponding to hazardous chemicals logistics items, the mean of sub-performance of each task λ_{i1}, λ_{i2} can be got in Table 2.

4. Conclusions

The logistics of hazardous chemicals has internal particularity. It is logistics of special commodities and a special part of logistics industry. Comparing with common logistics, logistics of hazardous chemicals has more dangers and more serious consequence. Informatization is a necessary measure and means for enhancing the level of hazardous chemicals logistics management. Therefore, it is urgent to build and improve logistics information system for hazardous chemicals using high-tech means. It can effectively push forward the normalized management to the informatization system of hazardous chemicals logistics and even drive improvement of informatization theory system of the whole logistics industry. Based on the analysis on the features of RFID and WSN technology, the paper considers the special reality of hazardous chemicals logistics and confirms the framework of smart hazardous chemicals logistics system. The system changes the mode of information collection and transmission in the process of hazardous chemicals logistics. This contributes to timely getting the dynamic information about hazardous chemicals logistics and monitoring, knowing the real-time status of hazardous chemicals in logistics, increasing the response speed for emergency rescue, effectively strengthening the safety management of hazardous chemicals logistics and decreasing the accidents happening in logistic process.

Acknowledgement

This paper is supported by Research project of Yangtze Normal University: 2017KYQD16.

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