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Wireless sensor network for real-time perishable food supply chain management

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ABSTRACT

Environment monitoring is essential to the perishable food supply chain management, since it provides important information to estimate the food quality and to predict its shelf life. In this work, a real-time perishable food supply chain monitoring system is developed based on ZigBee-standard wireless sensor network (WSN). Some important improvements including a configurable architecture for comprehensive sensors and an improved network switching scheme are designed to meet the application requirements. A tree-topology WSN system with 192 EndDevices and a star-topology WSN system with 80 EndDevices are implemented and evaluated in terms of both functions and performance. Test results show that the success rate of data communication is over 99%. Both theoretical analysis and realistic measurement results show that the EndDevices have a lifetime long enough for the application of supply chain monitoring.

1. Introduction

Real-time supply chain management is critical for the safety and quality of perishable food. For example, a temperature mismanagement during the transportation of perishable food may result in quality decay, and the loss of products can reach as much as 35% (Zöller et al., 2013). The vibration of the trucks will cause mechanical damage to fruit and vegetables (Zhoua et al., 2007). Monitoring environmental parameters during the supply chain of perishable food has significant economic value. In 2011, the European Parliament and the Council of the European Union put into force the EU 1169 regulation about food management (Regulation (EU) No 1169/2011). According to the regulation, the influence of food on consumers' health and the safe use of food should be provided to the consumers by December 2014. The durability and transportation/storage conditions are important factors for the safety and quality of perishable food. Therefore, it is meaningful to develop a real-time monitoring system to obtain the environment information of perishable food during the whole supply chain.

In traditional cold chain management systems, thermometers and humidity sensors are installed in vehicles and warehouses (Seco et al., 2011; Dolha, 2011). This method has some obvious defeats. It can only display and record environment information locally but fails to the share the real-time data with remote users; it monitors only the macroscopic environment in the warehouse or vehicle, not the microcosmic environment in boxes containing perishable food; it cannot record the environment condition during truck loading, vehicle switching or temporary storage, etc. Therefore, such systems cannot provide real-time and continuous environment information about perishable food.

Wireless sensor network (WSN) is a promising technology for perishable food supply chain management since it can provide real time environmental information of the perishable food with good performance and affordable cost; the sensor nodes can be made small enough to be installed in the boxes containing perishable food and go through the whole supply chain. Because of the progress of microelectronics technology, the cost and power consumption of WSN nodes have dropped substantially during the past few years. With appropriate configuration, WSN nodes can be used to detect different kinds of environment parameters related to food safety and quality, such as the temperature, humidity, carbon dioxide, ethylene, and vibration.

WSN has been applied in monitoring systems in various fields such as precise agriculture (Aqeel-ur-Rehman et al., 2014), remote healthcare (Pang et al., 2014) and animal behavior detection (Nadimia et al., 2008). Cold chain management is also an important application field of WSN (Yuan et al., 2009; Lil et al., 2012; Lang

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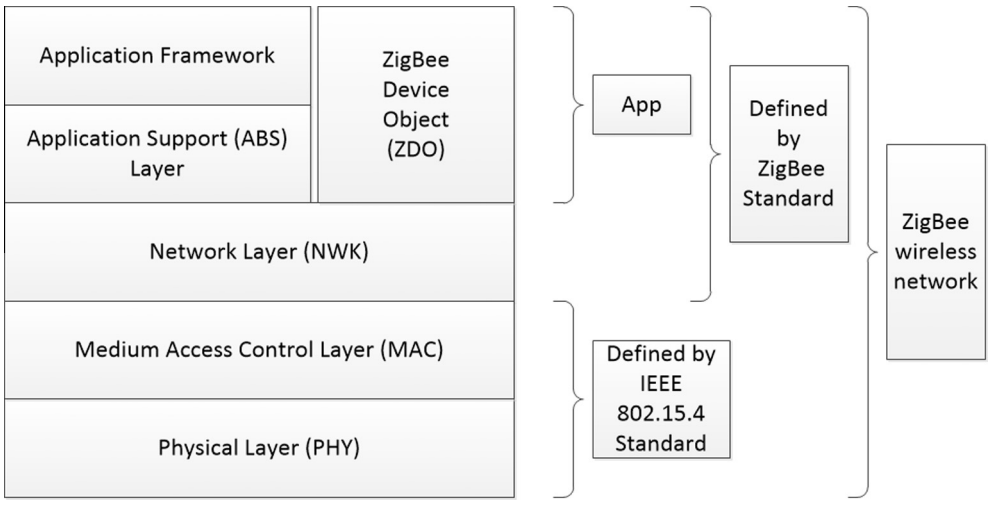

Fig. 1. ZigBee protocol stack architecture.

Table 1
Comparison between different topologies.

	Complexity	Power	Communication stability when food is of much water	Cost
Star topology	Low	Low	Low	Low
Tree topology	Medium	Medium	High	Medium
Mesh topology	High	High	High	High

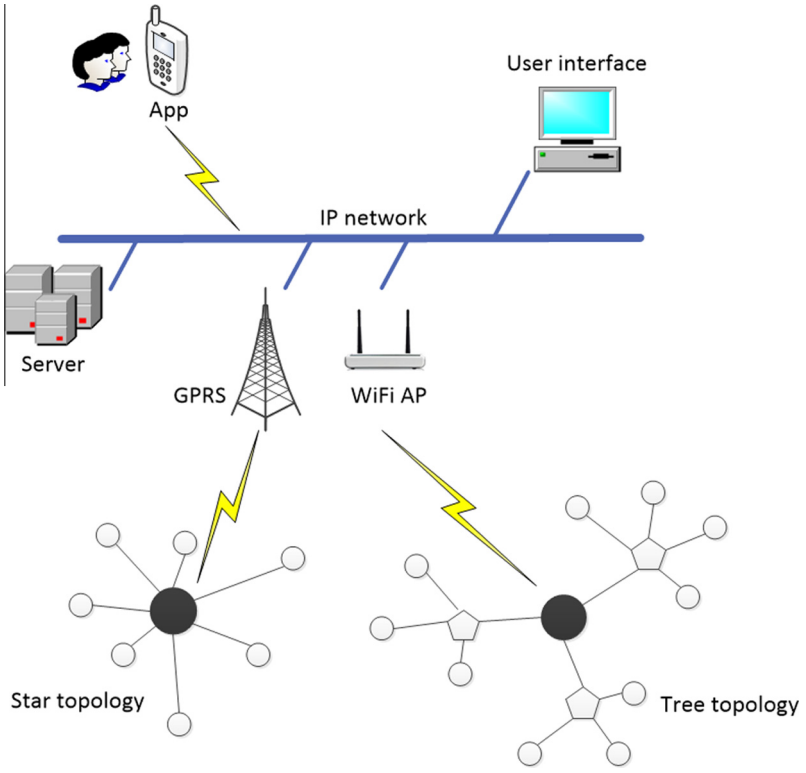

Fig. 2. System architecture.

et al., 2011; Ruiz-Garcia et al., 2010; Pang et al., 2009; Junxiang and Jingtao, 2011). Detection of different kinds of environmental parameters is realized (Lil et al., 2012; Pang et al., 2009; Junxiang and Jingtao, 2011). Researches and experiments on the data communication of WSN are conducted (Yuan et al., 2009; Ruiz-Garcia et al., 2010). Intelligent analyzing system is adopted to help the decision-making (Lang et al., 2011). However, most previous works cannot be used for perishable food supply chain management directly because of the following reasons: (1) Most of previous works only collect typical environmental parameters such as