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Research Paper

A wireless sensor network-based monitoring system for freshwater fishpond aquaculture

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Cabled intelligent systems bring with them the complexities of structures, the complications of data measurements and transmission, and a limited scale of application. A wireless sensor network is used to eliminate these disadvantages, however reliability of data transmission and energy saving in a wireless sensor network are two challenges that still need to be addressed. The design information on three types of nodes in a wireless sensor network is described in detail. Tree topology for WSN is adopted to decrease the packet loss rate and improve reliability of data transmission. Allowing sensor nodes to sleep and reorganising the data frames are the two approaches used to achieve energy-saving. The experimental results demonstrate the usefulness of these approaches in solving the challenges.

1. Introduction

In 2016, the national total output of aquatic products in China was 69 Mt, of which 32 Mt (46%) were freshwater aquatic products. The freshwater aquaculture area was 6.18×10^5 ha, of which 2.76×10^5 ha (44.71%) were freshwater fishponds. There is a huge increase in demand for freshwater aquatic products in China. However, the total aquaculture area is rapidly diminishing because of industry's need for land. For example, the annual national decrease in total aquaculture area was 0.9% in 2015 and 1.4% in 2016 (Wang et al., 2017).

To alleviate the situation, some intelligent systems which can contribute to increased production and reduced costs are being applied in freshwater aquaculture to monitor important water environmental variables in real time, such as dissolved oxygen (DO) concentration in water, water temperature, pH etc. (Simbeye & Yang, 2014; Simbeye, Zhao, & Yang, 2014).

Siemens Corporation developed a system for monitoring 5 to 12 online water parameters in 2011 (Jawad, Nordin, Gharghan, Jawad, & Ismail, 2017). The American YSI Corporation also developed the YSI5200 aquaculture monitoring system for monitoring six kinds of water quality parameters in 2008. Researchers from the Chinese Academy of Fishery Sciences developed a multi-point online water quality testing

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system which can simultaneously monitor six water parameters in 2010. Scientists from Jiangsu University in China, developed a distribution monitoring system to determine a variety of key water parameters in real time, and the system had capacity for wireless data transmission in 2011 (Huan, Liu, & Chong, 2014; Huang et al., 2013). However, most of these existing monitoring systems, utilised in freshwater fishpond aquaculture, exchange information between the remote intelligent unit and monitoring computer through cable transmission. Cable communication systems carry many wires which results in a complex system and complications of data measurements and transmission. Moreover, such systems, once deployed, are inconvenient to expand to cover more targets. Further development of the freshwater fishpond aquaculture industry based on a cable communication system is limited, as cable communication systems are more suitable for a simple and small-scale scenario.

A wireless sensor network (WSN) is a kind of wireless network working on the IEEE 802.15.4 technical standard which consists of sensor nodes, routing nodes and a gateway node. The data generated in the networks are transmitted by means of one-hop or multi-hop to a gateway node. A WSN is often used to monitor situations in a region, such as environmental protection, traffic administration, even military surveillance. Some research projects on WSN have been launched in the US and Europe, and the technology of WSN has been applied in environmental monitoring in agriculture. In 2002, the Intel Corporation took the lead to create the first wireless vineyard in the State of Oregon (Duy, Tu, Son, & Khanh, 2015; Ma, Zhao, Wang, Chen, & Li, 2015). An animal farming centre in Australia deployed wireless sensor nodes on the animals to monitor physiological states, such as pulse, blood pressure, etc. (Adu-Manu, Tapparello, Heinzelman, Katsriku, & Abdulai, 2017; Ndzi et al., 2014). Researchers in Brazil developed a remote-control system based on WSN to monitor 1500 ha of farmland irrigation (Jiang et al., 2014; Rashvand, Abedi, Alcaraz-Calero, Mitchell, & Mukhopadhyay, 2014). Chandanapalli, Reddy, and Lakshmi (2014) designed an aqua monitoring system using WSN and IAR-Kick. Most research in the area of WSN in China focuses on fine detail management of field farming.

In this study, we introduce a WSN system for freshwater fishpond aquaculture to monitor DO concentration and water temperature in a freshwater fishpond. A feasible topology for the WSN system is confirmed and two energy-saving strategies are adopted after taking into account the reliability of data transmission and WSN node survival.

2. System overview and work principle

Figure 1 shows the architecture of the system. It consists of three elements: the WSN unit, the monitoring centre, and the remote clients.

The WSN unit is the fundamental element for the system, and is responsible for measuring some important environmental variables such as DO concentration and temperature in the fishpond water. The WSN unit consists of a number of WSN sensor nodes, some routing nodes and one gateway node. The gateway node automatically creates the wireless network and administrates it according to default or manual configurations. The gateway node is responsible for not only accepting data from sensor nodes, but also transmitting them to the monitoring computer in the monitoring centre for further processing using the GPRS module. Meanwhile, the sensor nodes are connected to different kinds of sensors through sockets, and are responsible for measuring variables in the water of targeted fishponds in real time. The collected data are transmitted to the gateway node by one-hop or multi-hop according to the topology of the WSN. The routing nodes work as route planners to find the best route to the gateway node for the data that originate far from the gateway and only reach the gateway node by multi-hop. Finally, the gateway node, the sensor nodes and the routing nodes all work together to achieve the tasks of measurement and transmission.

The monitoring centre has three essential pieces of equipment which are the monitoring computer, the database server and the web server. The monitoring computer works as a communication server, it accepts data transmitted by the remote gateway node and then uploads these data to the database server in the monitoring centre. All these transmissions are achieved via internet. In addition to the processes mentioned above, the monitoring computer also aggregates data and displays them in graphical user interface. The database server, running on Microsoft SQL Server 2013,

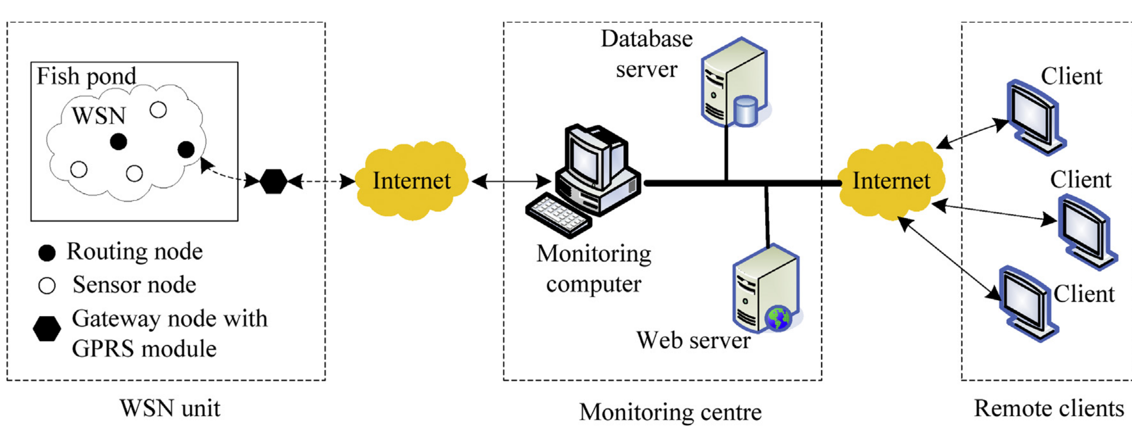

Fig. 1 – Architecture of the system.