A Temperature Sensor System in the 4G-Based Internet of Things

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Abstract. In order to manage real-time ambient temperature values at all times and places, this paper realizes a 4G-based temperature sensor system for the internet of things. Sensor platform gets the temperature values from wireless terminal nodes through the ZigBee coordinator, and upload it to the remote MySQL database server via 4G. In addition, an application is developed on mobile phone for users to obtain real-time temperature values, and a website for PC users is set up to realize the temperature values searching and displaying in real time.

**Keywords:** Temperature sensor · ZigBee · 4G · Internet of Things

1 Introduction

Since the concept of the Internet of Things (IoT) was first presented by Kevin Ashton, IoT has become one of the significant concepts that transform our surroundings more and more intelligent. During the past decades, we have witnessed IoT emerging into smart homes, healthcare system, transportation system, and other enterprises. This paper realizes a kind of temperature sensor system in IoT involving 4G telecommunications. Sensor platform gets the temperature values from wireless terminal nodes through the ZigBee coordinator, and upload it to the remote MySQL database server via 4G. In addition, an application is developed on mobile phone for users to obtain real-time temperature values, and a website for PC users is set up to realize the temperature values searching and displaying in time.

2 Description of the System

2.1 Framework

The system could be represented with four layers. Each neighboring layer interacts with each other, and they form a whole service system [1]. Figure 1 shows the framework of the system.
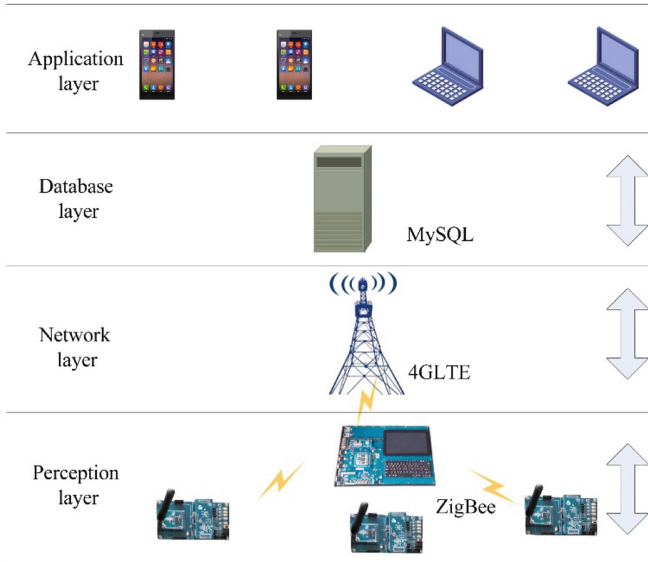
Fig. 1. Framework of the temperature sensor system

Perception Layer. ZigBee technology is used to transmit the temperature values adopted from the sensor nodes to ZigBee coordinator on this layer. ZigBee based on IEEE802.15.4 is a typical LAN protocol. It is also featured by its low-power consumption [2] and short distance of communication.

Network Layer. The data transmission between ZigBee coordinator and remote data storage units is realized by 4GLTE technology, which is widely applied by the communication operator in China. Featured by its IP routing technology, the upload rate reaches 50 Mbit/s, and the download rate is about 100 Mbit/s. The transmission demand of the system will be fully satisfied.

Database Layer. It is based on a remote MySQL database server, which is a small open-source database management system. It is widely used in small websites because of its high R/W speed and low cost. It is compatible with different operating system, such as Windows and Linux.

Application Layer. There are two types of terminal devices, personal computer and mobile terminal. Personal computer, which is based on B/S structure, obtains the temperature values from MySQL database. The mobile terminal uses the popular Android operating system and Java language to develop special temperature values gathering Android Package (APK) on the Eclipse development platform, which enables Android smart phones to obtain ambient temperature values at anytime and anyplace.

2.2 Work Flow

As shown in Fig. 1, the ZigBee nodes collect the environmental temperature values, and upload it to the ZigBee coordinator through the ZigBee network; the coordinator

transmits data to the remote MySQL database via 4G mobile network; after that, the terminal computer could check the temperature values through the B/S architecture, while the mobile terminal could check it through the special APK.

3   Application of the System

According to the description above, the temperature sensor system is mainly composed of three modules: temperature sensor module, data storage module and displaying module.

3.1   Temperature Sensor Module

This module is responsible for temperature values collection and transmission based on ZigBee technology [3]. There are three node types in structure of ZigBee, coordinator, routing node and terminal node. This system uses zxbee-s4412xe temperature values gathering platform as coordinator node and CC2530 of TI Company as terminal node [4]. The main system of zxbee-s4412xe platform adopts Android operating system and provides quad-core CPU with a core of ARM9. Meanwhile, it is equipped with ZigBee wireless module, which can be used as ZigBee coordinator node to obtain data from terminal node through special APK. CC2530 is a new generation of ZigBee SOC chip, which supports IEEE802.15.4 standard [5]. DHT11 digital temperature and humidity sensor is inserted into CC2530, which is used to collect the temperature and humidity values and convert it into digital signal to transmit. The transmission distance is more than 20 m.

When network is being established, coordinators and terminal nodes use PAN_ID to identify whether they are in the same network, and the two types of nodes need to be set to the same value, otherwise the two nodes cannot communicate with each other normally.

Zxbee-s4412xe starts the special APK and searches for the node devices which have the same PAN_ID. After successful networking, the temperature and humidity value of the node could be checked. It is shown in Figs. 2 and 3.

In order to upload the values to the remote server database, network transmission function in the special APK is needed. In the original project, MyThread.java is added by the Eclipse development tools, and mysql-connector-java-5.0.88-bin.jar is added to the libs. Then asynchronous HTTP requests are executed and the MySQL database is connected by correct configuration of user name/password through the designated port of 3306.

3.2   Data Storage Module

This module is located on the remote computer server which is equipped with MySQL database. In the system construction, MySQL is built with XAMPP software. XAMPP software is a powerful integration software package, including Apache, MySQL, PHP, FileZilla, Tomcat, and so on. It can be installed under Windows, Linux and other operating systems. Navicat for MySQL software is used to operate the database. It provides a visual interface and convenient operating mode.
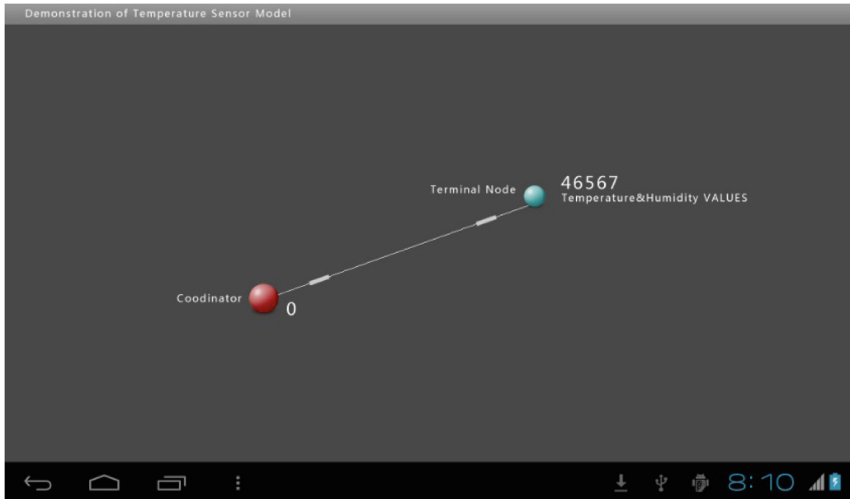
Fig. 2. Zxbee-s4412xe successfully connects to the DHT11 terminal node
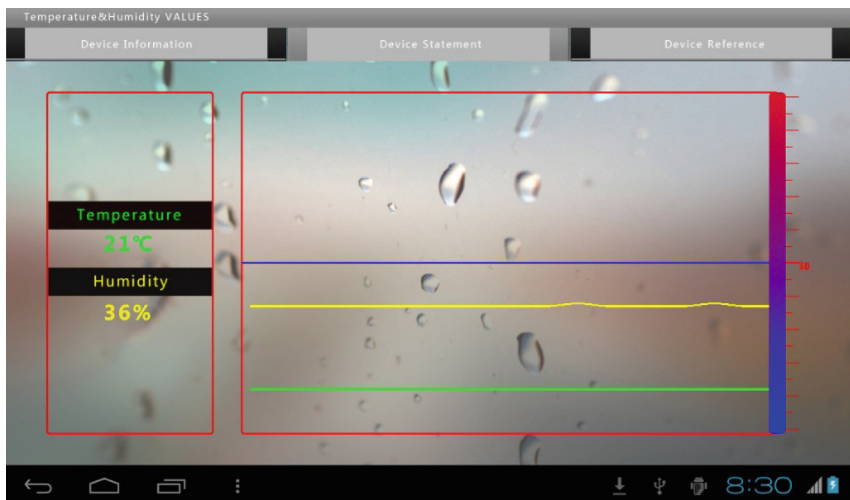
Fig. 3. Zxbee-s4412xe obtains the temperature values from DHT11 terminal node

A database (named as temptest) is created in MySQL, and two tables (named as temp and user) are created which are used to store temperature values and access user's authentication.

DROP TABLE IF EXISTS 'temp';
CREATE TABLE 'temp' (
'id' int(11) NOT NULL AUTO_INCREMENT,
'temp_l' float(10,2) NOT NULL DEFAULT '0.00',

'temp_h' float(10,2) NOT NULL DEFAULT '0.00',
'eq' varchar(50) NOT NULL,
PRIMARY KEY ('id')
) ENGINE=InnoDB AUTO_INCREMENT=10 DEFAULT CHARSET=utf8;

As the temp table shows, id represents the number of devices, temp_l means the minimum temperature, temp_h means the maximum temperature, and eq represents the device. When the coordinator has data updates, it updates the corresponding contents of the temp table in the temptest database. At the same time, MySQL is needed to be set up to allow external connection access, and the specified host is allowed to connect to the server's MySQL database via legal username/password.

3.3 Displaying Module

This module includes two parts: Android terminal and PC terminal, presenting the temperature values in different ways.

In the aspect of Android terminal, Eclipse development tools are used to develop a special APK, including data searching function for MySQL database. In the process of programming, network access is configured in Androidmanifest.xml, and the MySQL connection package is added to libs; while in the process of interface designing, Fragment is used to set the bottom of the interface with option buttons, so different operations are conducted on MySQL through different options. Figure 4 shows the details.
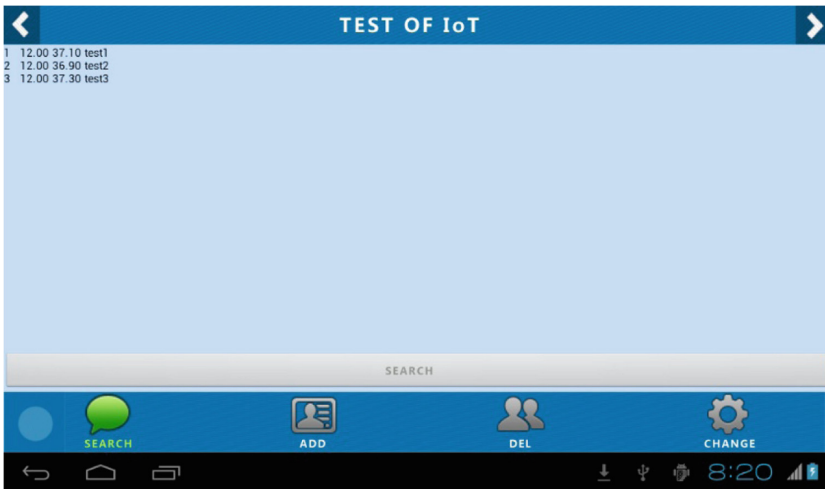
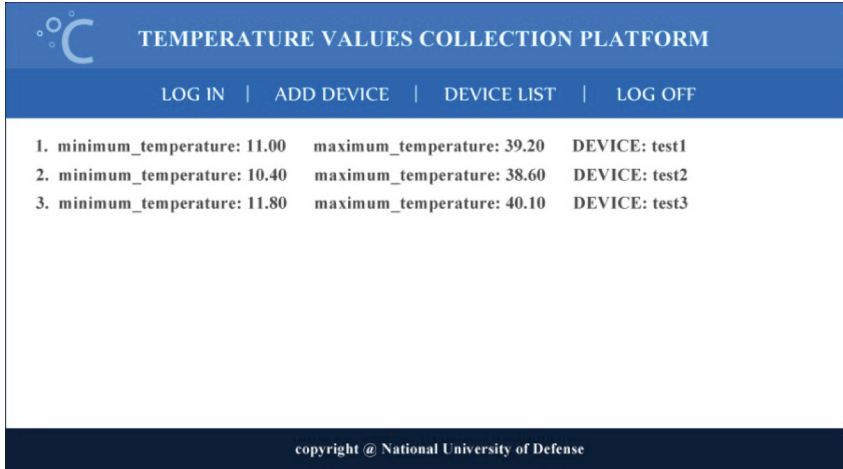

Fig. 4. Interface of the android terminal

In order to display on the PC terminal, a website is deployed on the database server. The system selects Apache to provide network access, and uses PHP language to develop the website. Other terminals (PC, mobile phones) can access the website through 4G network. As the following programming shows, data processing on the MySQL database could be performed.

```
$link_id=mysql_connect($DBHOST,$DBUSER,$DBPWD);
mysql_select_db($DBNAME);
$str="select * from temp ORDER BY id;";
$result=mysql_query($str, $link_id);
```

Figure 5 shows the interface of the website. The contents of temp table is able to be obtained from temptest database, and be sorted according to id. It presents the lowest temperature, the highest temperature and the collection device.

Fig. 5. The interface of the temperature values collection platform

4   Conclusion

For managing ambient temperature values at all times and places, this paper realizes a temperature sensor system involving IoT and 4G telecommunications. The system is composed of four layers. In particular, sensor platform gets the temperature values from ZigBee terminal nodes through the ZigBee coordinator, and upload it to the remote MySQL database server by 4G. In addition, an application is developed on mobile phone for users to obtain real-time temperature values, and a website for PC users is set up to realize the temperature values collecting and displaying in real time. This realization of system could be applied to other similar occasions such as environmental monitoring system or smart home system design.

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