Research Paper Engineering

Research on The Wireless Meter Reading Technology Applied in Ultrasonic Water Meter Based on Zigbee

Zhao Hong	School of Computer and Communication, Lanzhou University of Technology, No.287 Langongping Road Qilihe District, Lanzhou City, Gansu, P.R.China, 13909489418
Guo Li-lu	School of Computer and Communication, Lanzhou University of Technology, No.287 Langongping Road Qilihe District, Lanzhou City, Gansu, P.R.China, 18189546800
Wang Wen-jing	School of Computer and Communication, Lanzhou University of Technology, No.287 Langongping Road Qilihe District, Lanzhou City, Gansu, P.R.China, 18652950108

ABSTRACT

In view of the traditional cable meter reading way of household water meter existing many disadvantages, one kind of remote wireless meter reading method based on Zigbee communication technology has been proposed. Firstly, analyze the measuring principle and communication parameters of ultrasonic water meter, and then modify the code which involves serial port baud rate, parity and message transmission in protocol stack on the basis of the Z-stack data transparent transmission project. In addition, the paper also gives the design of the overall framework of wireless meter reading system and instructions on the usage of the upper machine. Experimental tests show that the system can effectively replace traditional cable reading way and has a certain application value.

KEYWORDS: wireless meter reading system, ultrasonic water meter, Zigbee wireless communication, protocol

INTRODUCTION

Ultrasonic water meter is one kind of measuring equipment which is widely used in modern industry. It measures flow in a non-contact way, which is an important supplement of traditional mechanical measurement. Ultrasonic water meter is a fully electronic water meter which uses the ultrasonic propagation time difference principle and is manufactured by industrial electronic components. Compared with the mechanical water meter, it has many advantages, such as high precision, good reliability, broad range ratio, long service life, no moving parts, at any angle installing, etc. It provides an effective solution especially for large diameter pipeline and strong corrosive, radioactive and other harmful medium measurement.

With the development of the Internet of things technology, the research and development of wireless meter reading system applied in ultrasonic water meter also gradually get the attention of people[1,2]. Traditional cable meter reading way exists many disadvantages, such as the in-home trouble, the high cost of wiring, lines including a safety hazard and so on, which leads people to be badly in need of an effective wireless alternative[3]. Zigbee as a new two-way communication protocol based on the IEEE 802.15.4 standard wireless local area network (LAN), has the characteristics of short distance, low power consumption, low cost, low complexity, self-organization[4], is suitable for wireless sensor networks, remote control, intelligent household and many other areas[5,6]. Therefore, using Zigbee technology is undoubtedly the ideal solution for wireless meter reading system.

This article focuses on how to use the Zigbee wireless technology to improve the existing ultrasonic water meter on the market, so as to design a set of complete wireless meter reading scheme. Using Jiangsu Maxtor corporation's MTW-9 type ultrasonic water meter as an example, the adaptation process between the intrinsic characteristics of water meter and Z-Stack data transparent transmission project are discussed in detail, such as baud rate, parity and RS485 interface, which mainly include CJ/T 188-2004 protocol analysis, the study of serial port communication protocol and the key code changing of Z-Stack, etc. Finally, we use an upper computer program to test the whole system. The results show that the improved ultrasonic water meter can realize reliable wireless meter reading function, meeting the demand of industry in the meter reading and replace the traditional cable meter reading perfectly.

MEASURING PRINCIPLE OF ULTRASONIC WATER METER

Ultrasonic water meter realizes the flow measurement by using the ultrasonic propagation characteristics in the liquid. When the ultrasonic wave travels in a liquid, it will carry on the fluid velocity information, such as the velocity in direct flow or reverse flow, which will change due to the superposition of the liquid velocity. So the ultrasonic transducers are respectively installed in upstream and downstream of the water meter measuring channel used on transmitting or receiving ultrasonic signal, the flow velocity of measured liquid can be detected by calculation of ultrasonic propagation time difference. In the case of known cross-sectional area of water meter's measuring channel and known fixed parameters of ultrasonic transducers, the flow rate of liquid can be calculated out by using water meter's built-in chip. The measurement principle is shown in figure 1.

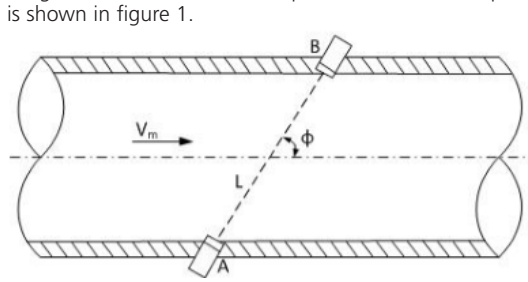

Figure 1 The measurement principle of water meter

The formula of ultrasonic wave propagation in the direct flow is easy to obtain from Figure 1, as shown in Equation 1.

$$(v + v_m \cos\varphi)t_d = L \qquad (1)$$

Similarly, the formula of ultrasonic wave propagation in the reverse flow is shown in Equation 2.

$$(v - v_m \cos\varphi)t_u = L \qquad (2)$$

After the merger of the two equations 1 and 2, the formula of liquid's flow velocity can be obtained, as shown in Equation 3.

$$v_m = \frac{L}{2\cos\varphi}\left(\frac{1}{t_d} - \frac{1}{t_u}\right) \qquad (3)$$

In the above formulas, v is the ultrasonic wave's travel velocity in measured liquid, v_m is the liquid average velocity along the axial line direction, t_d is the travel time of ultrasonic wave in reverse flow, t_u is the travel time of ultrasonic wave in direct flow, L is the length of water meter measuring channel, and φ is the channel angle.

Then, the flow rate of liquid can be calculated by the following Equation 4.

$$Q = \int K V_m S dt \qquad (4)$$

Wherein, Q is the measured flow rate of liquid, K is the velocity distribution factor, V_m is the liquid average velocity, and S is the cross-sectional area of water meter's measuring channel.

COMMUNICATION PARAMETERS OF ULTRASONIC WATER METER

Maxtor MTW-9 type ultrasonic water meter has wide application in engineering. It uses two-way protocol to communicate with upper machine using RS485 bus, and the communication protocol follows the CJ/T 188-188 industry standard, which is used in meters data transmission. This standard specifies the basic principles in the process of data transmission, including interface types, physical characteristics, data identification, data format, data security and other related requirements, is mainly suitable for the electronic instrument of centralized meter reading system, in which master station can exchange the data with multiple slave station. The protocol adopts the half duplex communication mode; a single direction of data transmission is for a data frame, the frame format is shown in table 1.

Table 1 CJ/T 188-2004 data frame format

Field name	Value	Description	Length
Frame start code	68H	Fixed value	1 Byte
Meter types	T	Water meter is 10H	1 Byte
Address field	A0-A6	The unique address in network	7 Byte
Control code	C	Fixed value	4 Byte
Data field	DATA	Measured data	Indefinite
Checksum	CS	The low byte of accumulation	1 Byte
Frame end code	16H	Fixed value	1 Byte

MTW-9 type ultrasonic water meter's meter reading instruction frame length is 16 bytes, and the number of water meter under test is given in the meter reading instruction's address domain. Water meter upload frame length of 40 bytes of data, the data field contains measuring indicators of water meter, the specific format example is shown in figure 2.

a. Water meter reading instruction frame

68	10	54270982001111	0103901F	00	53	16
Frame start code	Meter types	Address field	Control code	Data field	Checksum	Frame end code

b. Water meter upload data frame

68	10	54270982001111	8118901F	85	57020000	29
Frame start code	Meter types	Address field	Control code	Voltage	Positive cumulative flow	Unit

03000000	29	00000000	32	18381026071520	04	00	46	16
Negative cumulative flow	Unit	Transient flow	Unit	Meter reading time	Status	Fault code	Checksum	Frame end code

Figure 2 The data frame of MTW-9 water meter

The calculation of checksum in data frames is to accumulate from the start code of frame to the former one of the checksum, and then take the low bytes of the accumulation. The calculation of water meter voltage is to take the corresponding value of voltage code in data frames, and then be divided by 50, its unit is volt. In addition, the measured value of the data field also include positive cumulative flow, negative cumulative flow, transient flow and its measurement unit, water supply status, meter reading time and information related to communication failure.

The default serial port configuration parameters of MTW-9 type ultrasonic water meter inside are as follows: baud rate to 2400 bps, even parity check, data bits for 8 bits, stop bit for 1 bit, the start bit level to low level, and stop bit level to high level. Among them, the start bit, parity and stop bits will be automatically added by the hardware when data was sent and the low data bits will be firstly sent and then high data bits. The specific format example is shown in figure 3, in which D0 is the lowest bit and D7 is the highest bit of data bits.

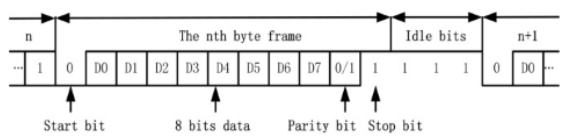

Figure 3 Serial port byte format of MTW-9 water meter

CODE MODIFICATION IN PROTOCOL STACK

The design of Zigbee protocol stack in wireless meter reading system is modified based on the existing Z-Stack data transparent transfer project. Data transparent transmission refers to the exchange of information between the upper computer and the lower computer, without adding instruction prefix, terminator and other additional packet information. Once the upper computer serial port data output, the module will encode the data and send in a wireless manner, upon receiving module receives the wireless signal, the signal will be decoded and be sent in accordance with the format sent from the upper computer to serial output, that is, the module is open and transparent to user. Thus, we can use this data transparent transmission way to instead of cable transmission in meter reading system. It works shown in Figure 4.

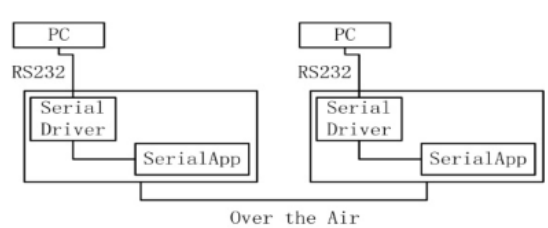

Figure 4 The principle of data transparent transmission

In the process of modifying the Z-Stack data transparent transmission project, there are three key problems need to be solved: the first is the protocol Stack of baud rate setting, the second is the protocol stack of parity modification, the third is to realize many-to-one message transmission in communications network.

CC2530 chip of Ti Company is used in this system; the baud

rate is decided jointly by two special function register, namely UxGCR and UxBAUD. Its calculation formula is given in formula 5.

$$B = \frac{(256 + BAUD\_M) * 2^{BAUD\_E}}{2^{28}} * F \qquad (5)$$

Wherein, B is the calculated baud rate, $BAUD\_M$ is the value of register UxBAUD, $BAUD\_E$ is the values of D0-D4 in register UxGCR, F is the System clock frequency. The common baud rate Settings provided by the chip manual are shown in table 2.

Table 2 The common baud rate settings (System clock frequency is 32MHZ)

Baud rate	UxBAUD	UxGCR	Baud rate	UxBAUD	UxGCR
2400	6	59	28800	9	216
4800	7	59	38400	10	59
9600	8	59	57600	10	216
14400	8	216	76800	11	59
19200	9	59	115200	11	216

Protocol Stack of baud rate setting in Z-Stack need to make the following modification in code:

a. To add definition in the file of Hal_uart.h, which is in the Hal layer of protocol stack: #define HAL_UART_BR_2400 0x05;
b. To modify the file of SerialApp.c in the App layer of protocol stack, modify this line: #define SERIAL_APP_BAUD HAL_UART_BR_38400 to #define SERIAL_APP_BAUD HAL_UART_BR_2400;
c. To modify the file of _hal_uart_dma.c in the Hal layer of protocol stack, add related configuration about HAL_UART_BR_2400 in the DMA mode of serial port configuration function HalUARTOpenDMA. Specific code is as follows:

```
static void HalUARTOpenDMA(halUARTCfg_t *config)
{dmaCfg.uartCB = config->callBackFunc;
HAL_UART_ASSERT((config->baudRate== HAL_UARBR_2400)||
    (config->baudRate == HAL_UART_BR_9600) ||
(config->baudRate == HAL_UART_BR_19200) ||
(config->baudRate == HAL_UART_BR_38400) ||
(config->baudRate == HAL_UART_BR_57600) ||
    (config->baudRate == HAL_UART_BR_115200));
if (config->baudRate == HAL_UART_BR_57600 ||
config->baudRate == HAL_UART_BR_115200)
{ UxBAUD = 216;}
else{UxBAUD = 59;}
switch (config->baudRate)
{case HAL_UART_BR_2400:
UxGCR = 6;
break;
case HAL_UART_BR_9600:
UxGCR = 8;
dmaCfg.txTick = 35;
break;
……}
```

CC2530 chip's parity check function is determined by the special function register UxUCR, when BIT9 and the parity bit of register are set to 1, parity check goes to work. At this point, when a serial port is sending data, the hardware automatically calculates data parity, and sends it as ninth bit. When a serial port is receiving, the hardware automatically calculates the parity of received data, and comparing it with the ninth bit of the data. If the parity is error, then automatically set UxCSR. ERR to 1. Its specific definitions are shown in table 3.

Table 3 The definitions of register UxUCR

Bits	Name	Default	R/W	Description
7	FLUSH	0	R/W	Clear function
6	FLOW	0	R/W	Hardware flow Control 0,disable; 1,enable
5	D9	0	R/W	Parity 0,odd; 1,even
4	BIT9	0	R/W	Data length 0,8 bits; 1,9 bits
3	PARITY	0	R/W	Parity enable 0,disable; 1,enable
2	SPB	0	R/W	Stop bit number 0,1 bit; 1,2 bits
1	STOP	0	R/W	Stop bit level 0,low level; 1,high level
0	START	0	R/W	Start bit level 0,low level; 1,high level

The table 3 shows that register's configuration of 0x3A can meet the communication requirements of MTW-9 type ultrasonic water meter, and the parity check function can be realized by modifying the HalUARTOpenDMA function in the file of _hal_uart_dma.c in the Hal layer of protocol stack. Specific code is as follows:

```
if (config->flowControl)
{UxUCR = UCR_FLOW | UCR_STOP|
UCR_PARITY | UCR_D9 | UCR_BIT9;
PxSEL |= HAL_UART_Px_CTS;
PxOUT &= ~HAL_UART_Px_RTS;
PxDIR |= HAL_UART_Px_RTS;}
else{UxUCR |= 0x3A;}
```

The modified protocol stack has already had parity function in theory, but the start bit, parity and stop bits information can't be checked directly in serial debugging assistants. To verify the effect, this paper uses the oscilloscope by observing the serial level output so as to achieve the purpose of the analysis of the data bits. The first three characters of meter reading instructions are respectively 0x68, 0x10 and 0x54, which is shown in figure 5. The waveform shows that the modified protocol stack has been conform to the requirements of the communication of water meter.

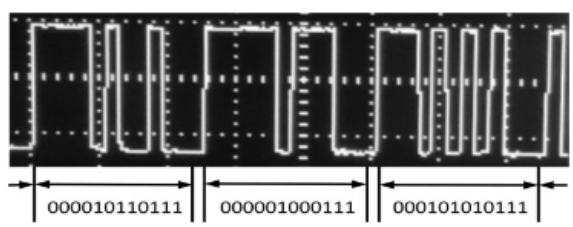

Figure 5 Serial level output in the oscilloscope

Many-to-one message transmission in the communication network of Zigbee is the key to the implementation of wireless meter reading system. In this network, it requires that all water meters which connected to the Zigbee terminal enable to receive the meter reading instruction from upper machine, and the upload data of the water meter is only to send to the upper machine alone. Therefore, broadcast message is used when sending meter reading instruction and unicast message is used when uploading water meter data in protocol stack. The message transmission model is shown in figure 6.

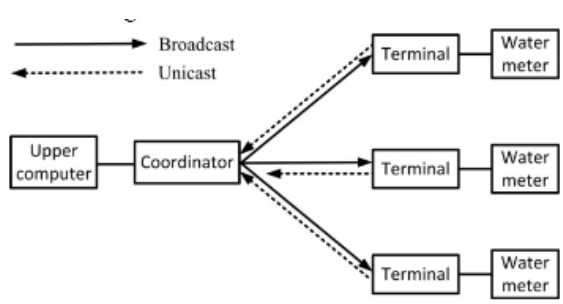

Figure 6 Many-to-one message transmission model

In order to realize many-to-one message transmission in the communication network of Zigbee, the SerialApp_Send function in the file of SerialApp.c in the App layer of protocol stack need to be added some codes. Specific code is as follows:

```
if (SerialApp_TxLen) {
afAddrType_t SerialApp_TxAddr;
if(SampleApp_NwkState == DEV_ZB_COORD) {
SerialApp_TxAddr.addrMode = (afAddrMode_t)AddrBroadcast;
SerialApp_TxAddr.endPoint = SERIALAPP_ENDPOINT;
SerialApp_TxAddr.addr.shortAddr = 0xFFFF; }else{
SerialApp_TxAddr.addrMode = (afAddrMode_t)Addr16Bit;
SerialApp_TxAddr.endPoint = SERIALAPP_ENDPOINT;
SerialApp_TxAddr.addr.shortAddr = 0x0000; }
if (afStatus_SUCCESS != AF_DataRequest(&SerialApp_TxAddr,
    (endPointDesc_t*)&SerialApp_epDesc,SERIALAPP_CLUS-
    TERID1,
SerialApp_TxLen+1, SerialApp_TxBuf, &SerialApp_MsgID, 0,
    AF_DEFAULT_RADIUS)) {
osal_set_event(SerialApp_TaskID, SERIALAPP_SEND_EVT); }}
```

MEASURING PRINCIPLE OF ULTRASONIC WATER METER

Wireless meter reading system includes the following three types of equipment: the upper machine equipment of meter control center, the gateway equipment used to organize local wireless network and terminal device connected to the water meter. Among them, the PC can be used as the upper machine equipment of meter reading and control center, Zigbee coordinator can serve as a gateway device, and Zigbee terminal equipment can be used to directly connect to the water meter. In the system, PC and gateway communicate through the RS485 bus, the gateway and the terminal equipments communicate through wireless network. In addition, by setting up different PANID on local gateway between adjacent network to avoid network interference, and a single local network can connect as many as 65000 devices theoretically. At the same time the system can still extend the same amount of local network, so on the aspect of number of nodes can completely meet the need. System overall framework is shown in figure 7.

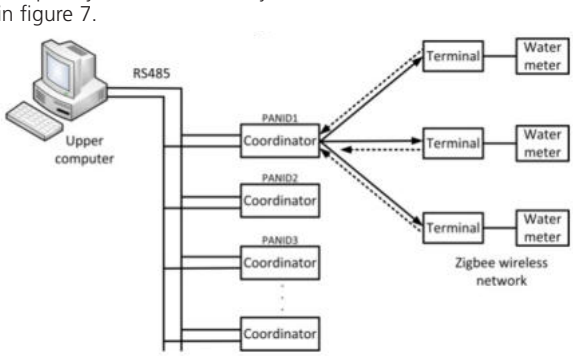

Figure 7 The system overall framework

The CC2530 chip of Zigbee terminal equipment communicate with water meter via a serial port IO pin P0_2 and P0_3, and its output is 3.3 v TTL level. Therefore, the system needs to use TTL to RS485 module to realize the conversion between different levels. Physical connection is shown in figure 8.

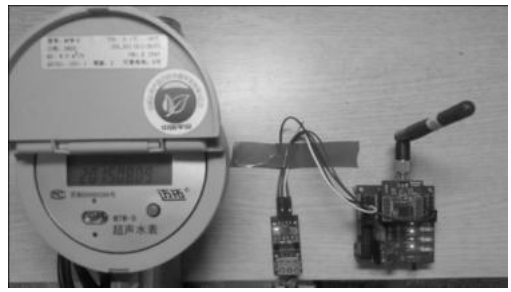

Figure 8 The physical connection of Zigbee terminal

System upper machine programs are developed with the MFC framework of VC + +, and the communication protocol follows the CJ/T 188-2004 industry standard for data transmission. In the process of using, the upper machine will automatically sent meter reading instruction according the number of user input. When receiving upload data of the water meter, it will be automatically resolved as a measurement parameter. In addition, the upper machine also has the following functions: automatic identification to serial port, batch reading meter and report generation. Meter reading test using upper machine is shown in figure 9

Figure 9 The meter reading test using upper machine

CONCLUSIONS

Combining Zigbee wireless communication technology, this paper implements a set of complete remote wireless meter reading system on the basis of the Z-Stack data transparent transmission project. Compared with the traditional cable meter reading way, the system is superior to it on the aspects of construction difficulty, cost of installation and use safety. In addition, this paper has done a lot of analysis on ultrasonic water meter's measuring principle and communication parameters, detailed introduced the modification of code about serial port baud rate, parity, and the message transmission in protocol stack, which has reference value for the development of the wireless meter reading system.

ACKNOWLEDGEMENTS

This work is supported by the Natural Science Foundation of China under Grant No. 61262016, the University Foundation of Gansu Province under Grant No. 04-056001, the Natural Science Foundation of Gansu under Grant No. 1208RJZA239, and the Technology Project of Lanzhou under Grant No. 2012-2-64.

REFERENCES

[1]Patel Parita, Samina Zafar, Pavan Shrivastav, Jimish K "V2V Technology Broadcasting Applications In Vehicular Mobile Wimax Wireless Ad-Hoc Networks" Paripex - Indian Journal Of Research, Vol: 1, Issue: 7 July 2012. | [2]M. Janardhana Raju Dr. P. Subbaiah Optimized Routing Protocol for Mobile AD-HOC Network Paripex - Indian Journal Of Research, Vol: 3, Issue: 4 May 2013. | [3]Cao L, Jiang W, Zhang Z. Networked wireless meter reading system based on ZigBee technology[C]//Control and Decision Conference, 2008. CCDC 2008. Chinese. IEEE, 2008: 3455-3460. | [4]Li G, Han J. Application of the medical care system based on ZigBee technology[C]//Electrical & Electronics Engineering (EEESYM), 2012 IEEE Symposium on. IEEE, 2012: 301-303. | [5]Gong H, Qu Y G. Wireless Centralized Meter Reading System Based on Short Distance Wireless Communication and 3G[J]. Computer Engineering, 2011, 2: 103. | [6]Xin Z, Li H, Hu L. The research on CC2530 nodes communicating with each other based on wireless[J]. TELKOMNIKA Indonesian Journal of Electrical Engineering, 2013, 11(1): 430-435.