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Measurement data acquisition system with mobile server

Abstract

The paper describes an idea and the realization of a remote reading water meters system with wireless pictures transmission to the mobile server. The system consists of various water meters with installed electronic devices for measurement capturing. The measurements are read by taking a picture of the analog number indicators from the front panel. The pictures are send wirelessly to the mobile server which stores them until the acknowledgement from the main server is received. The mobile server is constructed of the microcomputer Raspberry Pi 3 connected with the XBee-PRO through adapter. The pictures transmission from the mobile server to the main server is realized by the Internet connection. The main server application allows recognizing the numbers from received pictures. The measurement data is available as digital numbers in a data base of the main server. The designed system is dedicated to the work in a low population density area.

Keywords: metrology, wireless sensor network, radio transmission, water meter.

1. Introduction

Nowadays the problem with reading analog meters still occurs very often. A situation with water meters system can be given as an example. Every one-two months a water meter has to be read. In the modern urban areas it does not present any problem. The payment system is fully automatized and equipped with digital wireless water meters. However, in a low population density area the situation is more complicated. A small village can be considered as an example. The distance between the houses is frequently bigger than 200 m. In each house the water meter is hidden usually in a basement, where the access for the collector of payment is restricted by the landlord's permission. This can bring up the problem because the collector has fixed working hours and the landlord has to be at home at the same time. A solution for this problem is reading water meter remotely. To enable this process the digital water meter has to be installed. However, nobody will enthusiastically make an investment to replace working and validated meter for a new one. The only solution is an installation of a digital universal extension on a water meter. It avoids rebuilding existing water installation.

Digital universal reading device is an extension not only for water meters. It can be used also for any analog indicators due to using a digital camera. Microcontroller's technology is developing very fast. It provides a huge computing power which allows pictures processing in single small chip. Taken picture can be cut, resized, rescaled and even used for a text recognition. So we can use a small digital camera to read any analog indicator which cannot be replaced by the digital one.

The described system consists of the meters extensions, the mobile server and the main server. The mobile server is an application running on the microcomputer Raspberry Pi 3. Thanks to small sizes this microcomputer can be installed on a drone or any vehicle. This solution enables reading water meters at any time with range up to 500 m inside buildings enabled by using XBee-Pro radio module [1]. Very important issue is the data privacy. There are two possible scenarios of protecting data. One of them relies on using Xbee-PRO built-in encryption [2]. Solution is very easy to implement but not as safe as a second approach. The chosen solution encrypts data sent to XBee by UART (Universal Asynchronous Receiver and Transmitter).

2. Comparison to existing solutions

Among available commercial solutions the two was chosen. First one is offered by Polish company Apator, the second one by German Techem.

Apator offers extension for water meter which uses WMBUS (Wireless M-Bus). Water flow is recorded using reflecting optocoupler. It is necessary to configure extension to work properly. Water meter's serial number and initial state have to be set. There are two scenarios of reading: stationary or by a payment collector. The payment collector is equipped with PDA (Personal Digital Assistant) computer with radio module. Stationary system uses additional devices which receive data from extensions and send them to the main server using GPRS (General Packet Radio Service) connection.

Techem offers not only water meters but also dedicated extensions. The water meter is a stand-alone mechanism with a place where the radio module can be connected. Water flow is recorded by counting impulses from special plate. Half of the plate is metal, the second half is plastic. The water meter and the extension are paired in the extension's software. The initial state and the serial number of the meter have to be set. In the memory 25 measurements are stored: 12 from the beginning and 12 from the middle of each month from previous year. 25th measurement is made every day at midnight. Moreover the device sends data periodically. Periods can be set for every time of each day. The system detects water dropping and rear flow. Information about this incident is also included in sent data. Techem offers also a possibility of stationary and mobile reading. Stationary solution uses an additional device equipped with GSM modem. In the mobile approach there is a person handling device dedicated for Techem's radio modules.

3. Microcomputers

The proposed solution uses a microcomputer as a mobile server. The selection was made among three models of microcomputers available in the market: Banana Pi M3, BeagleBone Green Wireless and Raspberry Pi 3. Each of them has GPIO (General Purpose Input/Output) ports and Wi-Fi interfaces. The price, power consumption and computing power was taken into account. In fact only UART port is required for communication with XBee-PRO throught adapter. This adapter is an extension for microcomputer which allows connecting radio module XBee-PRO and protects IO (Input/Output) ports with three state buffer. Size and power consumption are very important with reference to computing power what makes a microcomputer the best choice.

Due to the fact that Banana Pi M3 is very expensive, only BeagleBone Green Wireless and Raspberry Pi 3 were tested. Picture processing time, Wi-Fi range and battery operating time was compared.

Raspberry Pi is produced by Raspberry Pi Foundation. They developed following generations: A, B, B+, B2, Zero, B3 so far. In the described project the newest B3 version was used. In comparison to previous B2, version B3 is equipped with built-in Bluetooth and Wi-Fi interfaces. The CPU is distinguished by 64-bit data bus length.

Tab. 1. Specification of Raspberry Pi mod. B3 [3]

CPU	1.2 GHz quad-core ARM Cortex-A53 (64-bit)
RAM	1 GB LPDDR2 900 MHz (shared with GPU)
Network	10/100 Ethernet (RJ45), Wi-Fi (2.4 GHz 802.11n), Bluetooth 4.1
USB	4× USB 2.0
Additional ports	40 × GPIO

BeagleBone Green Wireless is based on BeagleBone Green. The only difference between these models is that in the wireless version on-board HDMI and Ethernet were removed to make space for wireless features and Grove connectors. Built-in 4 GB on-board flash memory is a huge advantage which allows the operation without memory card. This solution avoids problems with very small number of writing memory card cycles which makes the system more reliable.

Tab. 2. Specification of BeagleBone Green Wireless [4]

CPU	AM335x 1 GHz ARM® Cortex-A8
RAM	512MB DDR3 RAM
Network	WiFi 802.11 b/g/n 2.4GHz; Bluetooth 4.1 with BLE
USB	USB client for power & communications USB host with 4-port hub
Additional ports	2× 46 pin headers 2× Grove connectors (I2C and UART)

Memory card is the main storage medium for operating system in both microcomputers. The class of memory card is a critical parameter having an impact in performance.

Both microcomputers are powered with 5 V MicroUSB. Due to this fact they can be supplied from power bank used for charging smartphones. It makes microcomputers fully mobile. During picture processing by Raspberry Pi 3 measured supply current is averagely equal 300 mA. BeagleBone Green Wireless power consumption in idle mode is significantly lower than in Raspberry Pi 3. The measured current during image processing does not exceed 350 mA.

Range of the wireless network adapter is determined by the antenna. In Raspberry Pi 3 there is built-in board antenna. BeagleBone Green Wireless is endowed with connector for external antennas. Using the external antenna increases range from few meters up to several dozen meters depending on antenna gain.

4. Signal detector

The most critical parameter for whole system reliability is the power consumption of the camera module. It is very hard to achieve long battery operation time with the device containing radio module. The designed device can send measurements periodically or on demand. Solution with periodically sending measurements was discarded because of lengthening data capturing process. The receiving device (mobile server) needs to wait up to few minutes for data packet near each household. Approach with sending data on demand was chosen. This solution requires permanent listening if the mobile server tries to establish communication. Obviously transmitting requires a lot of power. Unexpectedly receiving mode also requires a significant amount of power. Xbee-PRO in idle needs current in range 65 mA.

It was essential to design a carriage detecting mechanism to reduce the power consumption in listening mode. This allows switching radio module and microcontroller into a sleep mode and wake them up easily. An external interruption from detector is necessary to wake up the microcontroller. Detector consists of microchip LTC5507 which responds to signal in the 868 MHz band, RF (Radio Frequency) switch and operating amplifier. The signal is received by antenna shared with radio module and detector. Sharing antenna requires signal switching between modules because impedance compatibility has to be provided. Moreover strong signal from XBee-PRO would destroy sensitive signal input of LTC5507. Signal switch is realized with PIN diodes BAP64-02. When a diode is polarized with DC current it is transparent for RF signal. If there is no DC current or current is too small, the diode fully blocks signal. Circuit is constructed to alternately switch signal between XBee-PRO and detector to antenna. Signal and DC current is filtered from each other by combination of capacitors and coils dedicated for 868 MHz band. Signal transduction was investigated in one channel of PIN switch in both directions. Results are presented in the Fig. 1.

It can be assumed that used PIN diodes transduction is the same in conducting direction as well as in barrier direction.

Used detector LTC5507 is very low power chip which converts power of input signal to output voltage. Figure 2 presents characteristic of detector. The detector responses significantly for signal stronger than −10dBm.

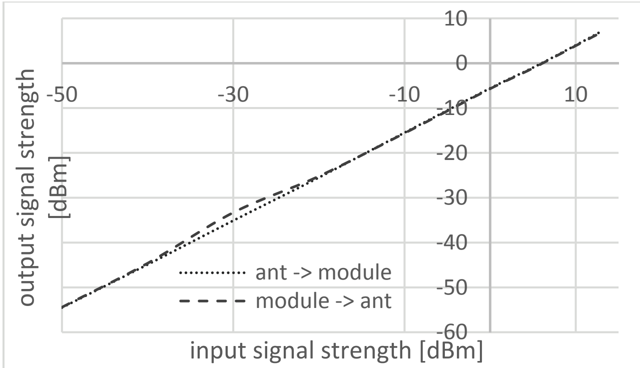

Fig. 1. Signal transduction in PIN switch

The output of the detector is connected with an input of operational amplifier configured as non-inverting comparator.

Threshold is set for 400 mV. When input voltage is lower than 400 mV on the output there is 0 V. Otherwise on the output is 3.3 V which corresponds to logic 1 for used STM32 microcontroller. This 3.3 V signal on input of microcontroller executes interruption which wakes up the whole chip.

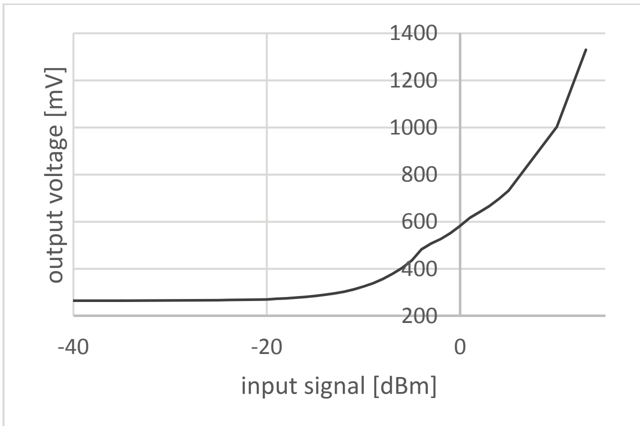

Fig. 2. Characteristic of signal detector LTC5507

5. System construction

The presented system consists of traditional analog water meters with installed camera module on each, the mobile server and the main server. Information flow between these devices is presented in the Fig. 3.

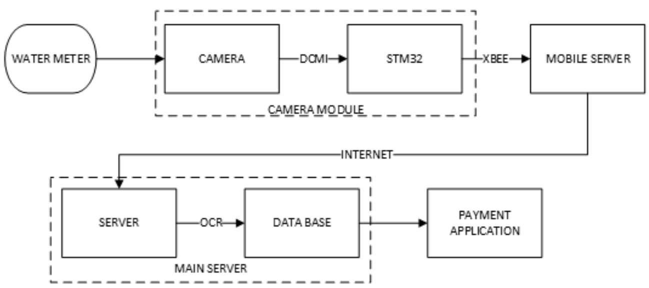

Fig. 3. Block diagram of presented system

The camera module is a small low power electronic device with a digital camera. Layout of extension is designed in a way to allow reading numbers by camera and also by human. The device is battery powered. All computations are made in the STM32 F4 microcontroller. This family was chosen because it supports DCMI interface where camera OV2640 is connected. To save the energy the signal detector was implemented. Communication with the mobile server is realized wirelessly using XBee-PRO 868 MHz radio module. Pictures of a water meter can be taken periodically and also on demand coming from mobile server. The camera module is equipped only with one antenna where two independent modules are connected. To save each of them and provide proper impedance, the signal switch with PIN diodes was designed.

The mobile server is an application running on microcomputer Raspberry Pi 3 with connected XBee adapter. The camera module sends encrypted data to the server on demand. The server saves pictures and stores them until an acknowledgement from the main server is received. When microcomputer is in authorized Wi-Fi network range, the connection with the main server is established and pictures are sent. After the main server receives pictures, it sends an acknowledgement for each of them to delete and release storage space. Saved pictures are used for OCR operation which allows recognizing numbers from image. Recognized numbers are stored with other settlement data in the data base.

In the Fig. 4 there are three screenshots. First from the bottom is a part of the original picture with squares drawn in the software around possible numbers. Second screenshot is the result of binaryzation of the first picture.

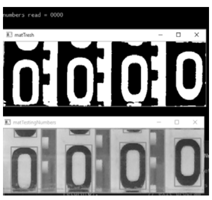

Fig. 4. Screenshots presenting result of OCR operations

Binaryzation is a process which converts each pixel of image into white or black color depending on value of luminance component. After binaryzation image is processed with OCR algorithms which returns a numbers. The result of this operation is presented in the top picture.

In the presented system pictures contain confidential billing data. This is the reason why transmission has to be encrypted and resistant to “man in the middle” attack. To satisfy this requirements encryption system with public key was chosen. The designed system is based on RSA. In RSA there are public and corresponding private keys. Both keys are generated according to RSA algorithm. If device B wants to send a message to device A it has to know the A’s public key. In the presented system B is the mobile server. Information about public key of each camera module are stored in mobile server’s memory. The camera module decrypts message using its own private key.

6. Conclusions

The proposed system is a good example of microcontroller, microcomputer and Internet cooperation. It is possible to read not only water meter but also any analog meter due to the fact that the digital camera is used. Even traditional thermometer or clock can be read because proper software is able to detect changing position of any object in the picture. Implementing artificial neurons gives a possibility to recognize shapes for example numbers and letters. They can be implemented in microcontroller but this kind of operations need high energy consumption. This solution reduces significantly the amount of transmitted data and also decreases battery operational time.

The used microcomputer can be installed in a building to offer stationary reading approach or can be moved by any mean of transport like a car or a drone which offers mobile reading. The camera module can also be equipped with GSM modem. Then third solution without mobile server can be provided.

The system was tested among various environment - a city and a village. It works perfectly everywhere and provides correct measurements of water meters.

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7. References

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