OPEN-SOURCE IMPLEMENTATION OF SMART HOME GATEWAY FOR Z-WAVE PROTOCOL

Jan Krejci
Doctoral Degree Programme (2), FEEC BUT
E-mail: xkrejc57@stud.feec.vutbr.cz

Supervised by: Jiri Hosek
E-mail: hosek@feec.vutbr.cz

Abstract: Z-Wave protocol is one of the most popular wireless protocols for home automation or smart home. However, in recent years there have been only few studies on practical measurements of this protocol. There are several manufacturers on the market, implying a vast array of devices, as well as deploying a commercial solution to the home is expensive and mostly focused on a single manufacturer's portfolio. In this article, we designed and implemented our own Z-Wave home gateway for a smart home system based on open source software. We verified the feasibility of the proposed gate using the prototype and evaluated its performance according to the execution time of the command. We also discussed the limitations of the Z-Wave protocol based on our experience.

Keywords: Home Automation, Smart Home, Z-Wave, Remote Reading, Wireless Communication, Sigma Designs, Open-Z-Wave

1 INTRODUCTION

In recent years, wireless sensor and actuator networks have gained high momentum, receiving significant attention from academia, industry, and standards development organizations. One of the primary application domains of this technology is home automation. WHANs (Wireless Home Automation Networks) enable monitoring and for home user comfort and efficient home management. Smart home wireless protocols are used to provide facilitate and to enable the transfer of commands between devices within the home, there are many wireless protocols for smart homes such as ZigBee, Z-Wave, Insteon, EnOcean or Wavenis. In this paper, we will focus on the Z-Wave wireless protocol. Several organizations and companies have developed WHAN solutions according to different architectures and principles. This article aims to the open source implementation of Z-Wave to covers universally most of WHAN solutions based on Z-Wave protocol. Paper is organized as follows: Section I introduces the Z-Wave protocol and Section II shows a scenario of home gateway implementation.

1.1 Z-WAVE

Z-Wave is a wireless protocol architecture developed by ZenSys (now a division of Sigma Designs) and promoted by the Z-Wave Alliance for automation in residential and light commercial environments. The main purpose of Z-Wave is to allow reliable transmission of short messages from a control unit to one or more nodes in the network. Z-Wave is a low-power wireless protocol that is only targeted for home automation systems. The Z-Wave protocol has been developed specifically for the needs of home appliances such as thermostats, sensors, lighting, air conditioning, air conditioning, audio and video control, which transfers only small amounts of data. Z-Wave devices have minimal power consumption while maintaining the instant response.

2 PROTOTYPING AN INDUSTRIAL IOT SCENARION

To demonstrate the functionality of the created solution, we have completed a full-scale open-source implementation of Z-Wave home gateway.

2.1 SELECTED HW DEVICES

We have selected Sigma Designs module ZM5304 (see Fig. 1) as receiver module for Z-Wave protocol, Raspberry Pi 3 as main board and the Aeotec MultiSensor ZW100 (see Fig. 2) as a transmitting device. The connection of Raspberry Pi and the mentioned shield is realized via the 26 pin board. The UART (Universal Synchronous / Asynchronous Receiver and Transmitter) bus is escorted via cabled to the Z-Wave communication module.

Figure 1: Z-Wave module Sigma ZM5304

The ZM5304 module is a fully functional stand-alone module with a built-in antenna and complete FCC (Federal Communications Commission) approval and CE (Conformité Européene) pre-approval. It is designed to be as easy as possible integrated into devices such as television, set-top boxes, and gates. The device has well documented Z-Wave Serial API (Application Programming Interface) via either USB (Universal Serial Bus) or UART using the device can be easily used and updated. The module is low powered, only 2 A in sleep mode. Module support hardware AES (Advanced Encryption Standard) 128bits security engine.

Figure 2: Z-Wave multisensor Aeotec Multisensor ZW100

Multisensor is a Z-Wave 5th generation Z-Wave Plus device. It is powered via mini USB cable or using a pair of CR123A batteries. When using batteries it lasts to work for up to 2 years. The Sensor is based on Sigma module ZM5101 which is an older and smaller version of the mentioned ZM5304 module. The sensor can transmit motion, temperature, light, moisture, vibration, and UV (ultraviolet) radiation. The sensor acts as a slave and can add a maximum of 5 associated nodes. When the sensor is detected, it sends a basic set to all associated nodes and after a preconfigured time, sends a periodical report about all remaining values.

2.2 IMPLEMENTED SW FRAMEWORK

First of all, using the USB to UART converter to download from the PC to the current Z-Wave firmware for 868 MHz, meeting the EU (European Union) regulations. Next step was the installation of Open-ZWave library [1] to operation system deployed on RaspberryPi. After downloading and installing the library, it was necessary to install and compile a graphical user interface for the mentioned library called Open-ZWave-control-panel [2]. Installation of the last package runs a local web server on

[1] https://github.com/OpenZWave/open-zwave.git
[2] https://github.com/OpenZWave/open-zwave-control-panel.git

port 8888 with installed GUI. It will appear when you start the web browser at the local computer at the address and port 8888 the graphical interface where you need to enter the module address first and initialize it. It should be mounted as /dev/ttyAMA0, as in our scenario. If the module is instructed, individual commands can be entered and read data from connected sensors. At first, we needed to pair Multisensor with our module. After succesful pairing, in the control panel, we add a line between paired devices. In the case of Multisensor 6 offers sensor off / on, rows with temperature, radiation, humidity, ultraviolet radiation, alarm type and level, source node ID, burglary and charge levels. Now, the actual values can be requested or interval for auto refresh can be set.

2.3 CONSTRUCTED SCENARIO

For the purpose of our trial, we concentrated on communication distance between two devices transmitting data indoor: (i) Z-Wave Aeotec ZW100 sensor acting as a periodical data generator, and (ii) developed home gateway z in the role of the receiver.

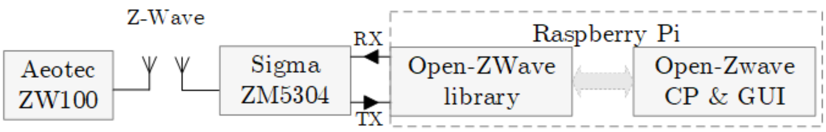

Figure 3: Considered constructed scenario

The realized scenario is shown in Fig. 4 where locations for all measuring points are displayed. The green circle represents the location of developed home gateway. Going further, the red circles stand for the positions where we placed the multisensor act as a data generating device and tested one-by-one the parameters of the communication link.

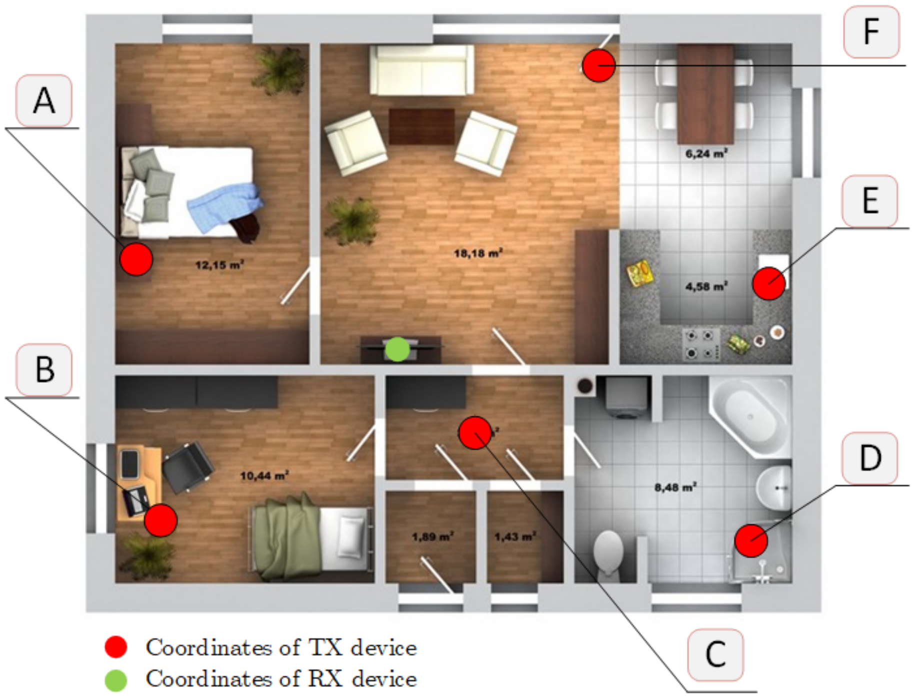

Figure 4: Element placement scheme in Z-Wave realized scenario

The locations of the red point are in Fig. 4 depicted only for the first floor, with the same position being selected on the second floor in the transmitter positions. The topology of the rooms on the second floor was the same, but with the difference that it was only residential rooms with minimal variation in the materials used. At each location (Location A, B, C, D, E, and F) all values of all quantities were transmitted. The data transmission consisted of sending 15 telegrams in a row with the time interval set to 15 s.

2.4 Measurement Results

We made practical measurements during our development in all of the above-mentioned locations, as shown in Fig. 4 and the obtained data are shown in Fig. 5.

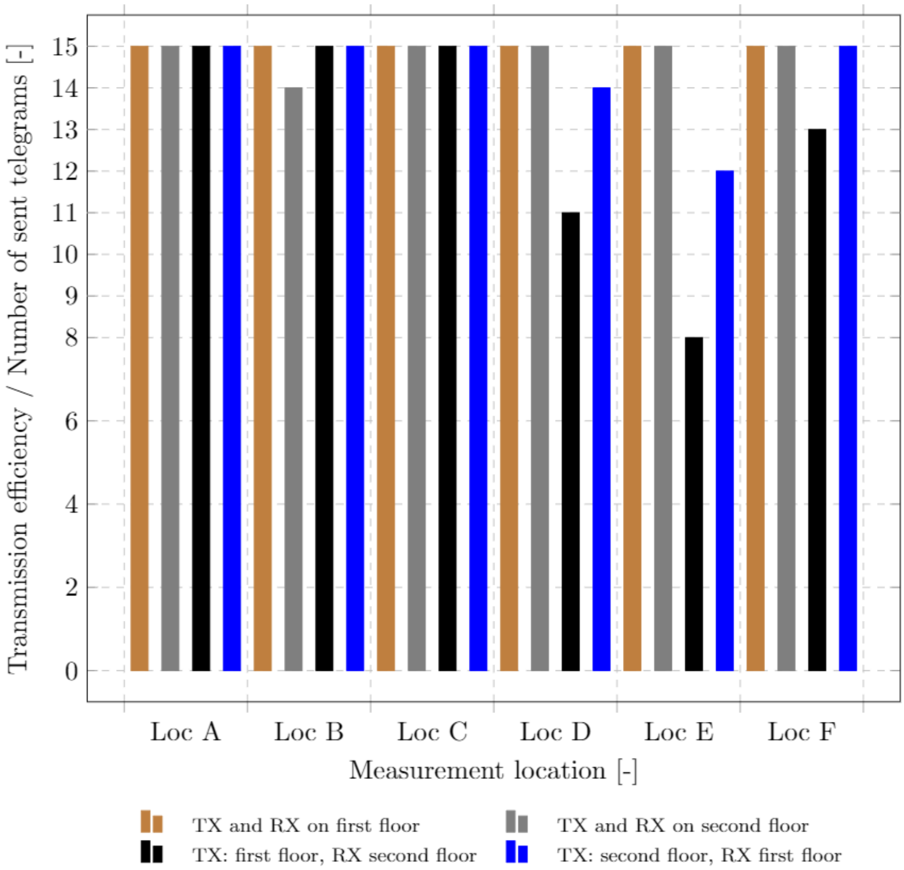

Figure 5: Transmission efficiency – dependence on RX and TX location.

One can clearly see the results in case of some location combinations do not follow the theoretical expectations. This behavior has two possible explanations: (i) the measurements were conducted with EMI (Electromagnetic Interference) with kitchen machines, televisions or computers. On the other hand, those results stand for the real conditions expected to be met in case of remote metering e.g., housing estate; (ii) the utilized frequency band is free to use which together with the unique rooms acting as obstacles causes unexpected signal propagation while sending the data at 868 MHz. As the measurements took place indoor, types of used materials play the key role with respect to the signal propagation. Owing to the possibility to use information from the drawing documentation of the building, the following materials are used: (i) reinforced concrete, (ii) clay block masonry, (iii) oriented strand board, (iv) gypsum boards and (v) thermal insulation.

3 CONLUSION

During the development and implementation phases of our work, we have solved a number of challenges: (i) Z-Wave communication module is distributed without internal code, furthermore, it was necessary solve firmware upload to module ZM5304 without very expensive original board; (ii) Raspberry Pi 3 uses different access to the serial interface, for connecting the module via UART it was necessary to disconnect the Raspberry Bluetooth module; (iii) full z-wave docs and codes are only z-wave alliance members, it was a suitable library the OpenZWave library and the GUI of the Control Panel, whose code was needed download and translate especially for Raspberry.

As mentioned before, this paper was intended as a proof-of-concept hardware implementation that significantly reduces the cost of Z-wave home automation platform. In our future work, we are planning to expand the functionality of our platform by adding support for more smart-meter vendors.

ACKNOWLEDGEMENT

The work of BUT was partially supported by the National Sustainability Program under grant LO1401, and infrastructure of the SIX Center was used.

REFERENCES

[1] Z-WAVE ALIANCE About [online] [cit. 2019-03-15]. Available from: https://z-wavealliance.org/z-wave-alliance-overview/.

[2] Z-Wave Alliance MultiSensor 6 - Z-Wave Protocol Implementation Conformance Statement [cit. 2019-03-15]. Available from: https://products.z-wavealliance.org/products/2511/pics

[3] Silicon Labs ZM5304 Module [online] [cit. 2019-03-15]. Available from: https://www.silabs.com/products/wireless/mesh-networking/ z-wave/modules/zm5304-module

[4] P. Amaro, R. Cortesão, J. Landeck and P. Santos, "Implementing an Advanced Meter Reading infrastructure using a Z-Wave compliant Wireless Sensor Network," Proceedings of the 2011 3rd International Youth Conference on Energetics (IYCE), Leiria, 2011, pp. 1-6.

[5] ROBLES, Rosslin John a Kim TAI-HOON Applications, Systems and Methods in Smart Home Technology. International Journal of Advanced Science and Technology. 2010(15), 39. ISSN 2005-4238.

[6] BADENHOP, Christopher W., Scott R. GRAHAM, Benjamin W. RAMSEY, Barry E. MULLINS a Logan O. MAILLOUX. The Z-Wave routing protocol and its security implications. Computers Security. 2017, 68(68), 112-129. DOI: 10.1016/j.cose.2017.04.004

[7] C. Gomez and J. Paradells, "Wireless home automation networks: A survey of architectures and technologies," in IEEE Communications Magazine, vol. 48, no. 6, pp. 92-101, June 2010.DOI: 10.1109/MCOM.2010.5473869