Home Automation with IQRF Wireless Communication Platform: A Case Study

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***Abstract*— This paper describes a new wireless communication platform IQRF. In the paper is description of main features of the platform, available communication modules, gateways to other wired and wireless communication system, and development tools. The paper also describes a case study focused on IQRF Smart house concept. IQRF platform was designed and developed especially for home automation and telemetry projects.**

Keywords- Home Automation; IQRF; IQMESH; Wireless communication; Networking.

I. INTRODUCTION

Smart House is a building, equipped with electronic system enabling occupants to control, program or use variety of electronic devices by entering a simple command. For example, a homeowner on vacation can remotely monitor, arm or disarm security system or switch on heating system when he is returning from his vacation earlier. Devices can also communicate to each other. Remote thermometer located in the place of comfort can provide data to Heating Ventilating Air Conditioning (HVAC) system in different rooms and actuators can interpret variety of different commands sent by Control Unit or by other devices in distributed control systems.

Such electronic systems are making buildings smarter. They consist usually from electronic devices providing data (sensors), devices interpreting control data (actuators), control devices (central units) and from devices providing communication interface to the system (gateways). All of these devices are usually located at different places of the building, therefore there is a need to enable simple, usually low data rate, communication between devices.

In new buildings connectivity would be easily realized by structured wiring during building process, on the other hand in existing buildings it would be a problem to make new wirings, especially when the building has not been prepared for that. Also, from the point of the installation costs additional installation of structured wiring in existing buildings is highly expensive. Cost of wire installation for simple electronic devices, like light switches, is 20 or 30 times higher than the cost of the switch. In this case wireless communication would be an ideal solution. Prices of Radio Frequency (RF) modules are dramatically falling down, enabling widely penetrate the market. The main idea of a house with remotely controlled equipment is shown in Fig. 1.

More complex or larger buildings bring new challenges for wireless communication to cover all devices by the signal which guarantee sufficient QoS (Quality of Service) parameters. Simpler wireless network topologies such as star would be efficiently used for smaller buildings; increase of the transmit power and/or sensitivity of the receivers would help to cover less accessible places, but this approach increases also RF radiation, interferences and it would not be even possible in some cases to cover the whole building due to the obstacles or walls construction. Higher bands (2.4GHz or higher) would face such problems with signal propagation more often than sub GHz bands. Wireless Mesh Network therefore seems to be an ideal communication topology to make buildings smarter.

There are available different wireless communication solutions from different vendors on the market place. These solutions support different network topologies. Many of them are based on 802.15.4 [1] standard defining Physical Layer (PHY) and Media Access Layer (MAC) for Low Rate Wireless Personal Area Networks (LR-WPAN). In most cases they work on non-licensed wireless communication bands. Non-licensed bands are different in a lot of countries. In European Union, there are 433 MHz, 868 MHz, 2.5 GHz and other bands. In the United States of America, there are especially 916 MHz and several others.

One such standardized protocol that works on non-licensed bands is, for example, Zigbee. It involves a solution based on the IEEE 802.15.4 standard [1] prepared by Zigbee Alliance [2]. This standard was developed by consortium of industrial companies especially for building automation [3,4]. There are also special applications for industrial control [5,6,7,8,9,10,11]. Among the proprietary solutions, reference can be made to the technology of MiWi launched by Microchip Technology Inc. [12]. MiWi is based on the aforementioned standard but simpler than Zigbee from the implementation point of view. This technology does not support direct cooperation with Zigbee devices [13,14]. From other solutions available on the market, mention would be made, for example, of the solution promoted by Z-wave alliance [15,16].

These solutions have disadvantage in attempt on being a universal solution targeting every kind of applications. It brings heavier protocols, more difficult and more expensive implementations.

Implementation of solutions such as Zigbee or MiWi consists of software solution stack and hardware solution used for communication. Software solution stack is developed by a microcontroller manufacturer for defined microcontroller or by a producer that wants to supply his products for communication modules designed for the area of domestic automation. The software stack is a package of

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program routines, functional components and program subsystems (hereinafter Stack) permitting the basic operation of the communication module according to the chosen solution for wireless communication. The manufacturer of the end device uses the modules for selected communication solution, and then creates a further application extension to implement the actual application functionality of the end device [17,18,19,20].

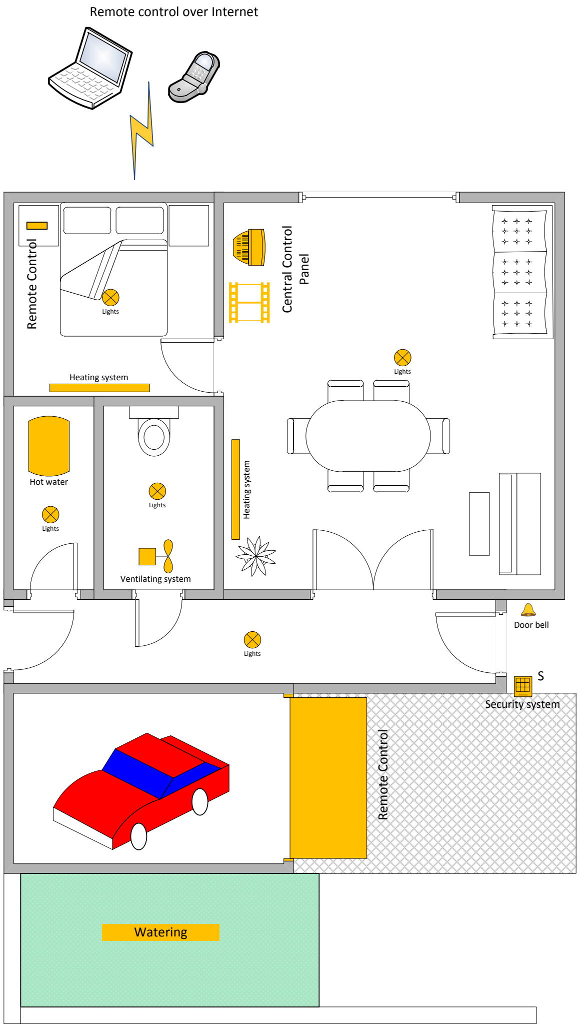

Fig. 1. The main idea of Smart House

There are also other proprietary solutions with wireless functionality. In the most cases they allow simple direct communication link without any other network functionality and they usually use master/slave communication model.

The paper is focused on description of IQRF wireless communication platform and its possible application in the smart house concept. At the beginning of the paper is short description of the smart house concept. Following section describes wireless communication platform IQRF, communication modules, IQRF operating system that allows rapid application development, available gateways to other wireless and wired systems, and description of development tools for fast design and development. At the end of the paper future work and conclusion are summarized.

II. IQRF Smart House Concept

The main idea of IQRF Smart House concept is shown in Fig. 1. The idea is to allow control almost all electrical equipment through wireless communication. The main parts are lights, heating system, ventilating system and hot water systems.

Smart house concept also contains security system that controls the main entrance doors, windows and when it is needed also contains motion sensors.

The concept also contains global garden watering system and control of garage door and car entrance.

III. Wireless Communication Platform IQRF

To address requirements from home automation and telemetry systems a new wireless communication platform IQRF was designed. The name IQRF is an acronym Intelligent Radio Frequency. At the beginning the platform was used especially to control electrical heating systems in a hotel or other commercial buildings where centralized control is needed. Now IQRF is designed to control whole set of devices used in a home automation process. The platform was developed by Microrisc company [21]. The main parts of the platform are covered by Czech and US patents [22,23,24,25]. These patents cover a method of creating a generic network communication platform, special signal coding scheme, and direct peripheral addressing in wireless network.

IQRF is using its own concept of the communication module structure. Wireless part is based on short-range radio components produced by RFM Company, which work in non-licensed communication bands. IQRF communication modules are available for 868 MHz and 916 MHz frequencies.

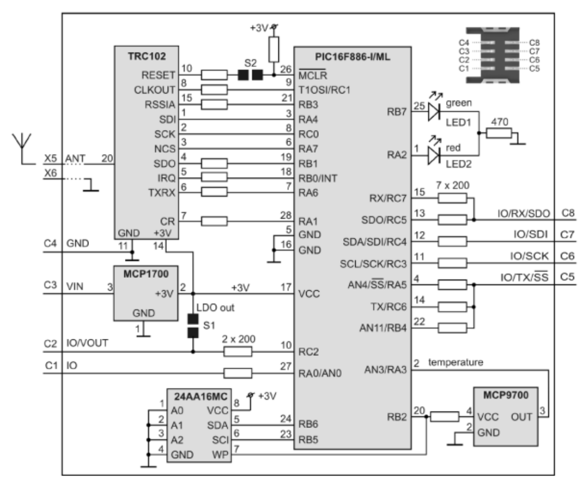

Fig. 2. The block structure of the IQRF communication module

A. *Transceiver Module*

Whole platform is based on transceivers modules. Basic block structure of a module is shown in Fig. 2.

Transceiver module is a tiny intelligent electronic board with complete circuitry needed for realization of wireless RF connectivity. Microcontroller with an inbuilt operating system, providing debug functionality, integrated LDO regulator and temperature sensor dramatically reduce time of application development. Low power consumption predetermines these modules for use in battery powered applications.

Depends on module version different microcontrollers are used. The newest version is using microcontroller Microchip PIC 16F886. Modules without integrated antenna are the same size like SIM card and they are using the same connector. Modules with integrated antenna are bigger by antenna but still with the same connector for assembling/plugging these modules to a superior systems. Therefore it is possible replacing each other according to the application needs.

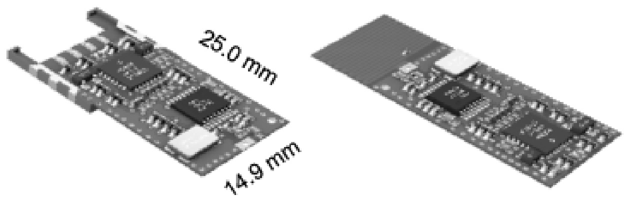

Fig. 3. IQRF communication modules with and without integrated antenna

Basically, the IQRF communication module has three standard input/output interfaces, one analogue input, an SPI interface, and digital ports. Each module contains integrated analogue temperature sensor, LED and 3 V linear regulators, which supplies communication module and moreover can be used for supplying user application. In Fig. 3 is shown the latest version of the IQRF communication modules TR-52 with and without integrated antenna. These modules are using FSK modulation and they have more digital input/outputs.

B. Operating system

Every IQRF Transceiver module is equipped by operating system (IQRF OS) implementing its basic functionality. IQRF OS is buffer oriented. Block scheme is shown in Fig. 4.

IQRF OS dramatically simplifies design phase, programmer of application can focus on application only, detailed study of RFIC and data processing before TX or after RX is not needed. Besides basic functionality IQRF OS provides also mechanism for application upload when the application is compiled. Programmer will set IQRF module to the programming mode, then, via SPI interface application code is uploaded to the module.

Whole system offers about 40 functions. A function block diagram is shown in Fig. 4. The main functions of OS are:

- RF functions for transmitting, receiving, bonding and setting up,
- IIC and SPI communication functions,
- EEPROM access functions,
- three buffers for RF, COM and INFO are available,
- other auxiliary functions for LED, OS information, delays and sleep mode functions are available too.

Up to 64 bytes is possible to send in one packet. The packet size is variable and should be set before packet is sent by a transmit function.

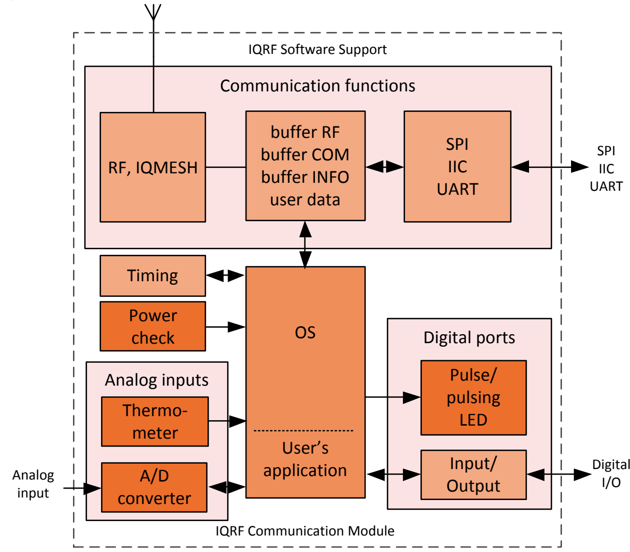

Fig. 4. Basic functionality block diagram of IQRF Operating system

IQRF operating system is implemented to the program memory of the microcontroller. Program memory is divided to two main parts. The first part is used by IQRF operating system and the second is available for user's application. When user's application needs to call some OS function, it calls function address defined in the definition file of the selected OS version. Programmers of the application can use whole set of the microcontroller instruction. Some restrictions for direct program memory access are applied. Because direct program memory access instructions are not allowed in the user's code, IQRF has implemented functions to store and read data from the on chip integrated EEPROM memory.

IQRF is wireless communication platform, therefore IQRF OS supports functions to create network, with different topology. When IQRF networking functionality is used, there have to be one coordinator in the network. Each communication module can work as a coordinator. Each module is possible to connect to two different networks. This functionality allows interconnection of the separated network without any gateway. Network possibilities and MASH functions are described in detail in the next chapter.

To support wireless and network functionality three data buffers are available. The OS also offers functions to copy data between buffers. Buffer called RF contains wirelessly received data or data to be transmitted. COM buffer is used to send and receive data via SPI, IIC and UART interface. INFO buffer is used by system for block operations.

A special signal coding scheme brings higher data throughput due to real time data compression and also higher reliability and noise immunity due to perfect DC balance of the coded signal [24].

OS also offers functions for timing, power control, reset and integrated LED control. Detailed description of all IQRF OS function is in [21].

C. Gateways and Development tools

Various gateways to common standards such as Bluetooth, ZigBee and GSM are available. Simple applications can use RS-232 gateway or more useful USB gateway. These simple gateways were developed to allow connection between IQRF and other proprietary solutions. They also allow connecting IQRF and standard PC with user's application.

For more sophisticated applications, GSM or Ethernet gateways are available. To allow interconnection between IQRF and standard wireless solution a Bluetooth and ZigBee gateways are available.

Development tools allow debugging and testing of user applications using supporting software. To provide comfortable environment for a transceiver development kits typically contain interface connectors, battery, interface to user pins and so on.

There is also integrated development environment IQRF IDE that is available for all IQRF development kits. This IDE allows software development with integrated BKND compiler, programming of all IQRF modules. The IDE integrates user application debugging information, SPI communication debugging.

IV. A Case Study

In the next sections, two use cases are described. The first one describes a smart house in vocation program. The second one describes a situation, when owner has to return from vacation earlier.

For our use cases we prepared a small smart house with only a few remotely controlled devices. The central control unit is, in this case, Smart House Central Server with USB – IQRF gateway. This server is possible to program to control whole house. It also allows automatic processes like heating system control or switch on/off lights in selected time periods. The server works also as a network coordinator.

There is selected number of lights. Each of them has IQRF transceiver and is controller remotely through IQRF network. Each light has own remote switch, but in our scenario these switches are not important.

The house is equipped with wirelessly controlled heaters and boiler for hot water.

Because some devices are out of range of Central Server we have to use IQRF Router. Heater 1 is out of range from central server and from the router, but is in range of Light 1. Because each IQRF Transceiver can work on background as a router, we do not need another router.

Whole system is controlled and programed through IQRF Remote Control. This device has graphical LCD and allows direct control of each unit or programming of Smart House Central Server.

In use cases is also a user. The user has access to IQRF Remote Control and has cellular phone with IQRF GSM Gateway phone number. He also knows how to control and program whole house remotely.

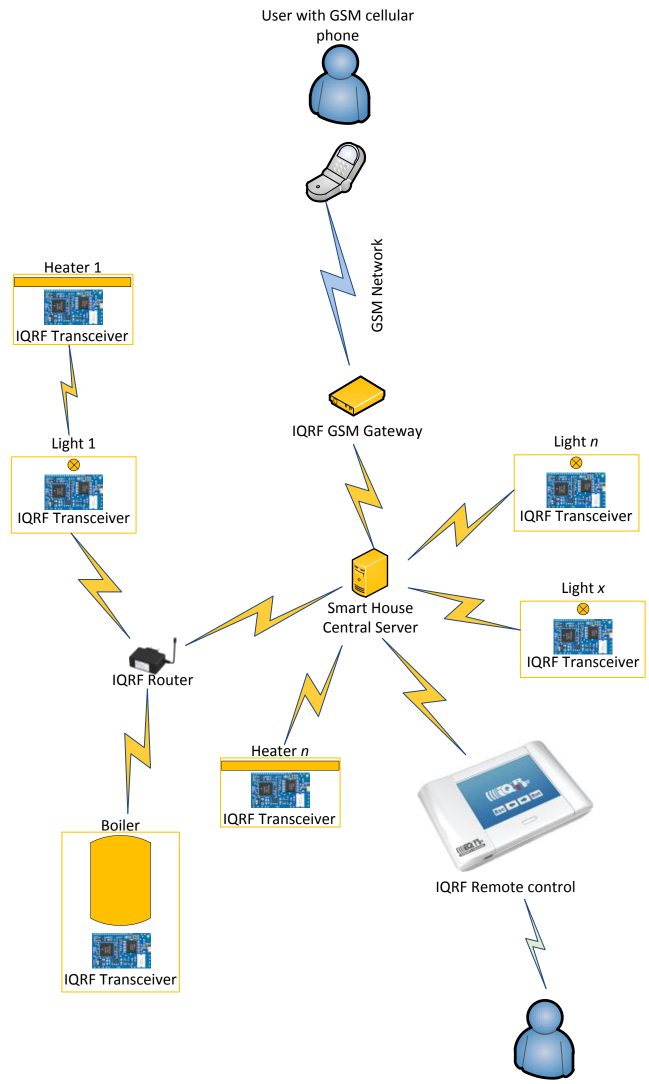

Fig. 5. Block diagram used for a case study

The house also has IQRF GSM Gateway that allows connection from GSM network. The web server is not included in our scenario, but it is another way, how to control whole system.

Network components and their connections of our smart house are shown in Fig 5. Whole communication ways are setup and system is in standard state.

A. Use Case I

It is winter time and the user is going out for vacation. Because nobody will stay in the house for vacation time, it is not necessary to have hot water; also temperature in the house should be lower than in standard time. User will create a new profile called "vacation" through IQRF Remote Control. In this profile will select that boiler is switched off and heating system is switched to tempering only. This profile will store to Central server for future use.

Because on vacation time the house is empty, it is a good time for rubbers. Due to this reason the user will extend vacation profile with automatic light switching. He will select time of switching on and time of switching off for each light. There is also possibility to add random variable for each light. So time will be little bit different each day.

Before the user leaves the house, he will select vacation profile on the remote controller. He also selects the day of return when profile will be automatically changed to standard profile. It is important value, because the heating system has to change temperature from tempering to standard temperature and it takes time.

If the user forgets to change profile he will use a cellular phone to change the profile remotely.

When the user comes back home from vacation he has the same comfort like he leaves home, but during his vacation the smart house saved energy, costs and of course living environment.

B. Use Case II

This use case expands use case I. The smart house is using profile vacation and user is somewhere out. But he has to change his plans, and return back to home earlier.

In this case, he will use his cellular phone to connect through IQRF GSM Gateway to Smart House Central Server. By this way he will change profile from vacation to standard. Internal house system will turn on hot water system and also heating system will try to reach standard temperature immediately.

V. Future Work and Conclusions

IQRF is a new wireless communication platform especially designed and developed for specific requirements from home automation and telemetry. One of the main aims was to offer wireless platform to developers of the end user devices that allows rapid development without necessity of stack implementations.

One of the typical application usages of IQRF is in Smart houses and similar projects. The platform was designed especially for home automation and telemetry projects. Network functionality, available gateways and easy implementation to user devices allow rapid application development without long study period of chosen wireless solution. Developers only use prepared OS functions and work with application layer of communication protocol.

Now we are working on implementation of all features of smart house concept. Patented direct peripheral addressing in wireless networks provides an easy way to make open communication platforms utilizing built-in IQMESH features [25]. This concept is described in details in paper [26]. It will be used as the basis of the concept of IQRF Smart House, building the highest application level and bringing it as completely open platform.

Network functionality of the IQRF platform is based on patented IQMESH protocol. This protocol was defined as a light and portable to the inexpensive hardware with limited resources. IQMESH protocol is scalable and ready to support new routing algorithms. All currently supported routing schemes are ported to the smallest 8b microcontrollers.

To allow integration to other wired and wireless communication systems different gateways exist. IQRF also offer development tools for all products.

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