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Smart wireless communication platform IQRF

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1. Introduction

Wireless communications systems are used in different areas of human activity. Wireless communications can be distinguished between licensed and non-licensed, according to the applied frequency band. 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 916 MHz and others. These frequencies are very often used for interconnection of sensors, actuators, equipments, controllers, computers, remote controllers etc. They are used at least in two basic lines of work. The first one is for home automation and the second one is for industrial automation. Communications standards and communication protocols exist in both of these lines.

One such standardized protocol is, for example, Zigbee. It involves a solution based on the IEEE 802.15.4 standard (De Nardis and Di Benedetto 2007) prepared by Zigbee Alliance (ZigBee 2009). Among the proprietary solutions, reference can be made to the technology of MiWi launched by Microchip Technology Inc. (Flowers and Yang 2008), based on the aforementioned standard but simpler than Zigbee from the point of view of implementation and not allowing direct cooperation with Zigbee devices (Huang et al. 2008; Ji et al. 2008; Song and Yang 2008). Among the other solutions available on the market, mention would be made, for example, of the solution promoted by Z-wave alliance.

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 manufacture 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 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 the selected communication solution, and then, it creates a further application extension to implement the actual application functionality of the end device (Ferrari et al. 2007; Ghazvini et al. 2008; Chan 2008; Liang et al. 2008).

The need for this step is obvious from the point of view of the manufacturer of the processor products – the manufacturer wants to supply his products within the framework of the whole communication solution, and because he has the best knowledge of his own products, he creates the Stack referred to above, generally in much less time than each individual manufacturer of end devices would have taken to create his own product. By creating a Stack, he thus makes it possible to participate on communication solutions based on the processors supplied by itself, and it offers them not just to one but to many potential customers.
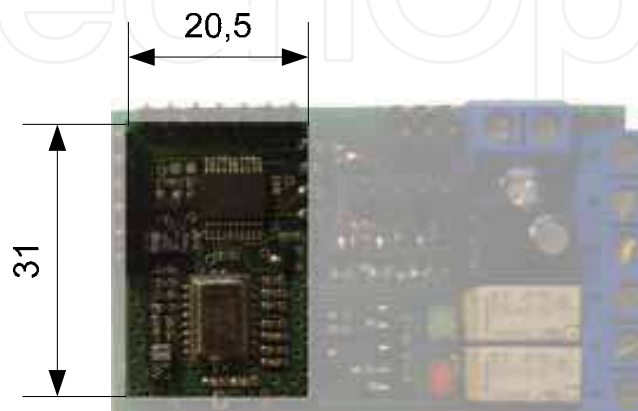
Fig. 1. The first generation of IQRF communication modules

Wireless communications platforms based on the standard communication networks, such as Wi-Fi or Bluetooth, are available on the market place. It is possible to buy a communication module with a simple communication interface that implements all needed functions and protocols. It is not so difficult to implement these modules and networks to the new devices. These solutions are useful for fast communications with greater volume of data. These modules have usually higher energy consumption, so they are not targeting low power applications.
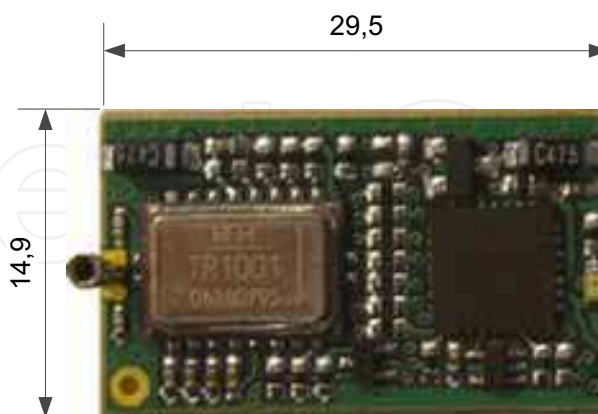
Fig. 2. The second generation of IQRF communication modules

There are also available proprietary solutions like Z-wave (Z-Wave 2009), radio modems XTR-434L (Aurel 2008), nRF24xx (Leonard 2007), RC1280HP (Vojacek 2007), etc. They

usually use master/slave communication model. Sometimes, they offer other integrated peripherals as AD converters, LEDs, or digital inputs/outputs.

Z-wave, for example, uses a mesh network topology with no master node. Any device can originate the message. If the preferred route is unavailable, the message originator will attempt other routes until a path is found to the recipient node. Z-wave rating units cannot be in sleep mode.

The chapter is focused on proprietary wireless communication platform IQRF. The platform supports different network topologies, allows fast and easy implementation to the new applications without deeper knowledge of the issue of wireless communications.

At the beginning of the chapter main features and hardware parameters of the IQRF platform are described. The next section contains description of the IQRF operating system with basic functionality description. Then IQRF gateways and available development tools are discussed. The next section contains description of IQMESH communication protocol used by IQRF platform. At the end of the chapter is a future work description and short summary.

2. Wireless communication platform IQRF

The IQRF platform was designed to address smaller segments of wireless market - buildings automation and telemetry. The platform was developed by Microrisc company (Microrisc 2009b). Main parts of the platform are covered by Czech and US patents (Sulc 2007a; b; c; 2008). These patents cover a method of creating a generic network communication platform, special signal coding scheme, and direct peripheral addressing in wireless network.
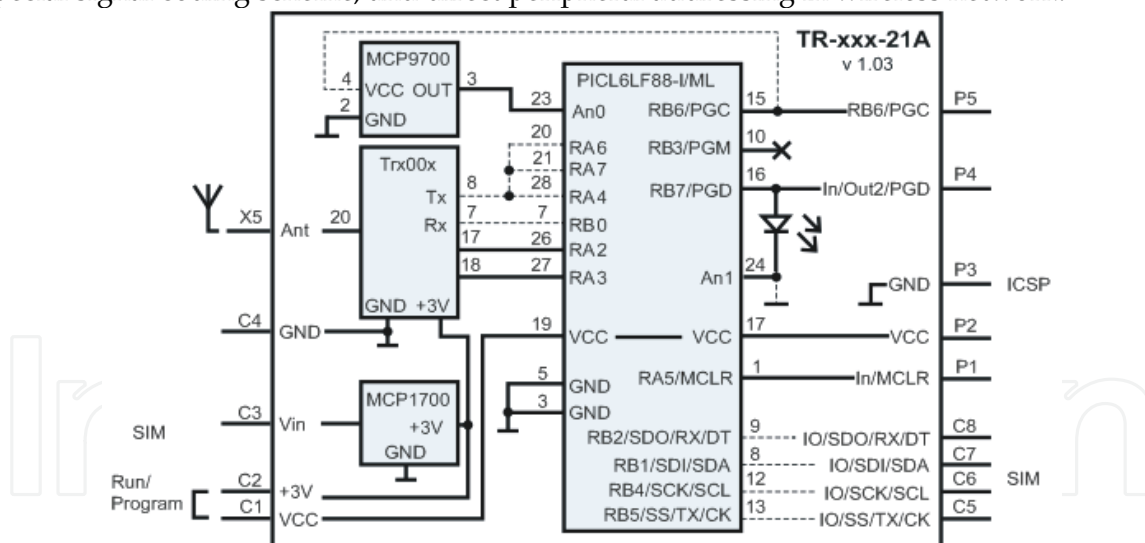

Fig. 3. The block structure of the IQRF module (Microrisc 2008a)

The IQRF platform is based on second generation of short-range radio components produced by RFM Company (RFM 2009). It works in non-licensed communication bands. IQRF communication modules (Microrisc 2008b) are available for 868 MHz and 916 MHz frequencies. Basic features of this wireless communications platform are especially very low power consumption, network possibility, programmable RF power up to 1.3 mW, optionally up to 10 mW, 170 m range, and 15 kb/s RF bit rate, optionally 100 kb/s. The first generation

of IQRF module is in Fig. 1, the second generation is in Fig. 2. Sizes in figures are in mm. The pictures aren't in scale. The second generation module is the same size like SIM card and used the same connector for interconnection with other parts of system. The block structure of the IQRF module is shown in Fig. 3.

Basically, the IQRF communication module has three basic input/output interfaces, one analog input, an SPI interface, and digital ports. Each module contains integrated analog temperature sensor, LED and 3 V linear regulators, which can be used for user application.

2.1 IQRF operating system

IQRF communications modules have own operating system. SW developers don't need to implement any part of wireless communication protocol. They only use prepared functions of operating system for their application. 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,
•   some other auxiliary functions for LED, OS information, delays and sleep mode functions are available too.
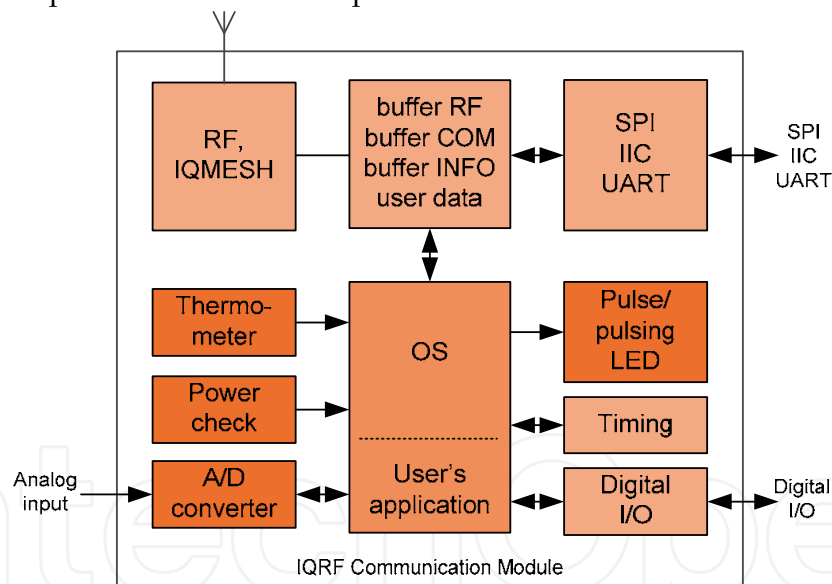Up to 32 bytes is possible to send in one packet.

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, so IQRF OS support functions to create network, with different topology. When IQRF networking functionality is used, it network exist coordinator and unit. They have very similar OS, differences are in the function to control network that are implemented only in the coordinators modules.

To support wireless and network functionality tree 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.

OS also offers functions for timing, power control, reset and integrated LED control. Detailed description of all IQRF OS function is in (Microrisc 2008b).

2.2 IQRF 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.

3. IQMESH

IQMESH (Intelligent Mesh) protocol was defined in 2005 as a basic communication protocol for IQRF device with target to address mainly low power, low data rate, small wireless applications, like a home automation, office automation and telemetry (Microrisc 2008b).

IQRF utilize several unique and patented features, IQMESH protocol was defined to support them.

For instance, the patented method of creating a generic network communication platform with transceivers defines the simultaneous work of devices in two or more wireless networks allowing network chaining (Sulc 2007b). Example of IQMESH network chaining is shown in Fig. 5.

Two networks in Fig. 5, Network 1 and Network 2, are independent IQRF wireless networks. Every such network has one Coordinator (C) and one or more slave Nodes paired to the Coordinator. Both Coordinator and slave Nodes would be configured also as a gateway (GW) providing connectivity to other standards. Multi-bonding mechanism enables in this case the blue node N4 to work as a slave Node in the Network 1 and simultaneously create own Network 2 as its Coordinator. Listening communication in both networks, some packets received in the Network 1 would be forwarded to the Network 2 and vice verse. Specific behavior would be defined by application layer. This mechanism would be used for bridging networks by just few instructions of application code (Microrisc 2008b), would be used in telemetry in power sensitive applications to reduce number of

hops by collecting data from one networks and sending them together. It would used also as a arbitrage mechanism to avoid interfering of two or more networks: One Coordinator would coordinate Coordinators of the other networks, e.g., dedicate time slots to them. It is useful especially in one channel environment, e.g., wireless systems based on ASK (Amplitude Shift Keying) modulation.
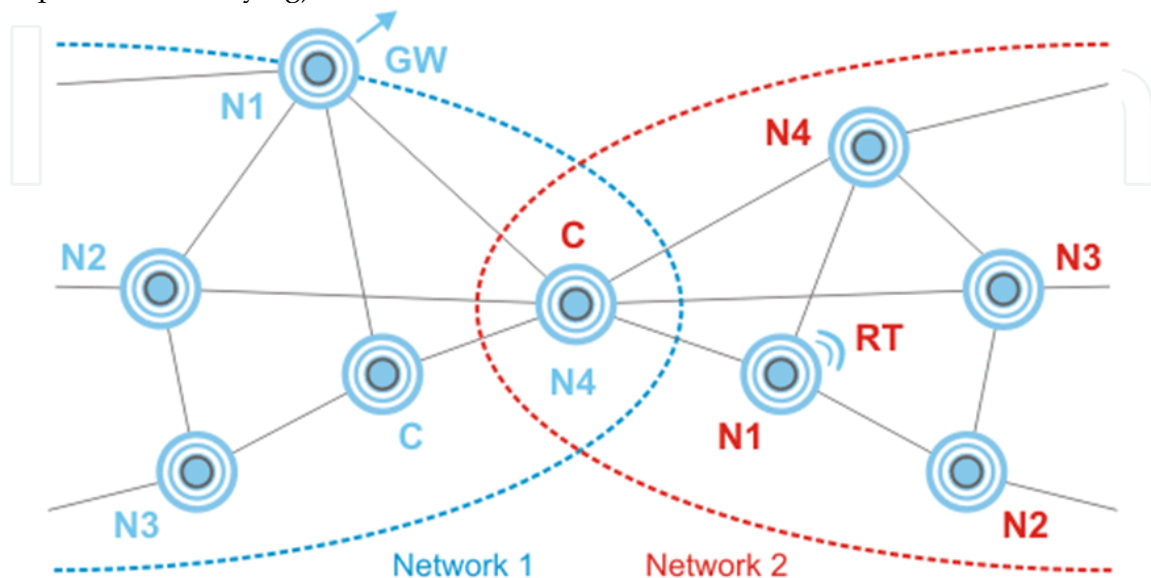

Fig. 5. IQMESH network chaining

Patented transceiver architecture having two layers (basic routines and application layer) provides an easy way to reduce development costs when creating connectivity applications. Transceiver modules already include protocol support in the Basic layer (would be referred also as a Operating System, Basic Routines, Protocol Layer, etc.), while the behavior of the device would be customized by Application layer utilizing routines from the Basic layer. In opposite to Solution stack, there is no need to compile protocol related routines, just application, consequently, it saves time of application development.

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 (Sulc 2007c).

Patented direct peripheral addressing in wireless networks provides an easy way to make open communication platforms utilizing built-in IQMESH features (Sulc 2008).

3.1 IQMESH basic

IQMESH uses mesh network topology supporting up to 240 devices: one Coordinator (C) mastering the network and up to 239 slave Nodes (N). It brings efficient addressing scheme using just one byte both for addressing of device and groups. Each Node provides background routing service for network packets or can be configured as a dedicated router (RT). Both Coordinator and Node can be setup as a Gateway (GW), specialized device bridging IQMESH network and other standards.

IQMESH protocol supports both individual and group addressing, as well as a network broadcasting. Besides standard features like bonding and discovery it also supports also direct peripheral addressing.

IQMESH protocol was defined as a light and portable to the inexpensive hardware with limited resources. Therefore, one byte internal addressing scheme was chosen, enabling to address 240 devices and up to 15 groups.

3.2 IQMESH packets

IQMESH protocol supports a packet oriented communication scheme, both point-to-point and more complex networking topologies (star, mesh). IQMESH protocol is flexible and leaves possibility for future expansion. For instance, there is a byte in the NTW INFO section of the packet defining routing algorithm. This simple mechanism allows to implement and support more rating algorithms and/or to have them application oriented as every application has usually very different requirements. For example, typical Smart House application would be realized with 4-hops and there is a need for fast response, while collecting data from power meters needs usually network supporting much more hops is needed, latency is not a problem.
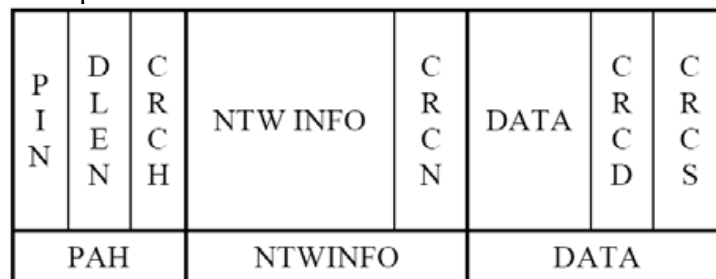

Fig. 6. IQMESH packet structure

Based on application layering, every device can accept and/or reject peer-to-peer communication. Packets for peer - to- peer communication consists of two block - PAH (packet header) and from DATA, while packets for networking communication consists of three blocks - PAH (packet header), NTWINFO (networking information) and DATA. Every block has its own consistency check mechanism to achieve high reliability even in a noisy environment. Basic packet structure is shown at Fig. 6.

PAH (packet header), 3 bytes long block, carries basic information about a packet, such as data length, flags if a packet is intended for peer-to-peer or networking communication, flags indicating system communication, flags indicating routing, direct peripheral addressing, such as encryption and acknowledgment request. NTWINFO (networking information) block has variable length based on PAH flag definitions. This mechanism provides an easy, reliable, while highly complex way to fit many different application needs. For example, Star topology does not need additional routing information which is requested in mesh networks. Setting ROUTEF = 0 will make a packet suitable for Star topology networks, while after setting ROUTEF = 1 six bytes describing the rating algorithm will be added to the NTWINFO.

Data load would vary between 0-255 bytes, while specific IQMESH implementations would support only 64bytes of data. This limitation enables porting of IQMESH protocol even to the smallest 8b microcontrollers.

Detailed IQMESH protocol description and its specifications will be publicly open and available in June 2009 (Microrisc 2009a).

4. Future work

In this chapter, only main functions of the IQRF platform are described. The basic modules are using 8bit microcontrollers (Microchip 2005) with limited space for the end user program. The newest modules are using 16bits microcontroller where is bigger place for user program, for implementation of some security aspect and so on.

IQMESH protocol is scalable allowing future expansion of routing algorithms. Currently new multi channel multihop algorithms utilizing all advantages and unique features of IQMESH protocol are under development.

The future step to simplify application development is to standardize peripherals and services sets (further on referred as HWP profile) provided by a specific application family. For example, a light switch would interpret data in a packet as I/O vector enabling R/W operation to the respective I/O pins of a transceiver module. In addition to the above I/O function, the transceiver module would support standard services like a bonding to and unbinding from the IQRF network. In this case, the application layer of the module will include a program sequence, interpreting packets as commands for R/W operations enabling access to peripherals and services of the module.

5. Conclusion

IQRF is new wireless communication platform for home/office and industrial automation. It has its own operating system for fast and easy implementation to user application.

The platform development tool contains software and hardware resources for rapid application development and prototyping.

IQRF platform implements IQMESH protocol. The protocol was defined as a light and portable to the inexpensive hardware with limited resources. Therefore one byte internal addressing scheme was chosen, enabling to address 240 devices and up to 15 groups. IQMESH protocol supports networks with up to 240 devices, one Coordinator and up to 239 slave Nodes. Each Node provides background routing service for network packets. Both Coordinator and Node can be setup as a Gateway (GW), specialized device bridging IQMESH network and other standards. IQMESH protocol can be fully or partially ported to the smallest 8 bit microcontrollers.

IQMESH implements several unique and patented features - a special signal coding scheme brings higher data throughput, higher reliability and noise immunity, two layer transceiver architecture reduces development costs, simultaneous functioning of devices in two or more wireless networks allows network chaining and finally, the mechanism of direct peripherals addressing in wireless networks directly supported by IQMESH protocol provils an efficient tool to build up open platform for wireless communication.

IQMESH protocol is scalable and ready to support new routing algorithms. All currently supported routing schemes are ported to the smallest 8b microcontrollers. IQMESH protocol definition will be opened, as well as public release of the definition, in June 2009. (Microrisc 2009a)

6. Acknowledgement

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Mobile and Wireless Communications Network Layer and Circuit Level Design
Edited by Salma Ait Fares and Fumiyuki Adachi

Mobile and wireless communications applications have a clear impact on improving the humanity wellbeing. From cell phones to wireless internet to home and office devices, most of the applications are converted from wired into wireless communication. Smart and advanced wireless communication environments represent the future technology and evolutionary development step in homes, hospitals, industrial, vehicular and transportation systems. A very appealing research area in these environments has been the wireless ad hoc, sensor and mesh networks. These networks rely on ultra low powered processing nodes that sense surrounding environment temperature, pressure, humidity, motion or chemical hazards, etc. Moreover, the radio frequency (RF) transceiver nodes of such networks require the design of transmitter and receiver equipped with high performance building blocks including antennas, power and low noise amplifiers, mixers and voltage controlled oscillators. Nowadays, the researchers are facing several challenges to design such building blocks while complying with ultra low power consumption, small area and high performance constraints. CMOS technology represents an excellent candidate to facilitate the integration of the whole transceiver on a single chip. However, several challenges have to be tackled while designing and using nanoscale CMOS technologies and require innovative idea from researchers and circuits designers. While major researchers and applications have been focusing on RF wireless communication, optical wireless communication based system has started to draw some attention from researchers for a terrestrial system as well as for aerial and satellite terminals. This renewed interested in optical wireless communications is driven by several advantages such as no licensing requirements policy, no RF radiation hazards, and no need to dig up roads besides its large bandwidth and low power consumption. This second part of the book, Mobile and Wireless Communications: Key Technologies and Future Applications, covers the recent development in ad hoc and sensor networks, the implementation of state of the art of wireless transceivers building blocks and recent development on optical wireless communication systems. We hope that this book will be useful for students, researchers and practitioners in their research studies.

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