

Generic Wireless Control System – Case study

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Abstract— Due to the increasing number of various types of wireless networks and their applications there is also an increasing demand for systems enabling to process and display data to be understandable not only to machines but also to people. This article describes a generic wireless control system for data and event logging with Ethernet connectivity and internal web server. It is based on the IQRF platform and an Ethernet gateway by MICRORISC s.r.o. The system is fully user-adaptable by programming wireless module with operating system in C language and a web application using PHP scripts.

Keywords- IQRF, GW-ETH-01, mysql, sql, php, web, datalogger

I. INTRODUCTION

Current industrial equipment utilizing wireless communication often requires not only data transfer, processing and administration, but also to be displayed in a user-friendly format. Another need may be data accessibility from everywhere.

Example: Wirelessly transferred data between two industrial devices in hexadecimal format is 001F2A3B. This code is understandable for a machine but for a human the following record is more illustrative: Upper limit: 50°, lower limit: 10°.

The task is to design equipment allowing turning of pump vanes controlled either at the pump or from a remote station, and also via Internet. At the same time there is a request to archive all events regarding given equipment. The archiving must proceed automatically within a period specified by the user. The system should be as robust as possible, with low power consumption. The device is placed inside the vane, which is why cables cannot be used for interconnection.

Thus, a wireless solution has been chosen. At present, several wireless platforms are available: ZigBee [8], MiWi [9], IQRF [2], etc.

ZigBee is a wireless communication technology based on the IEEE 802.15.4. standard. It is relatively new, effective from November 2004. It is intended for low power devices in PAN (Personal Area Networks) and low range (up to 75

m). Thanks to multihop ad-hoc routing communication is enabled also for higher distances without direct visibility. ZigBee is primarily used in industry and sensor networks. It works in license-free bands 868 MHz, 902–928 MHz and 2.4 GHz. Transmission rates are 20, 40 and 250 kbit/s.

IQRF is a platform for *low speed, low power, reliable and easy to use wireless connectivity*.

- RF bands 868 MHz and 916 MHz (ISM)
- Based on transceiver modules with built-in operating system (OS)
- Fully open functionality depends just on user-specific application written in C language
- Packet-oriented communication, max. 128 B per packet
- Range up to several hundred of meters per hop, up to 240 hops per packet
- Extra low power consumption: 900 nA or 2 μ A standby, 35 μ A receiving
- Low bit rate: 1.2 kb/s – 115 kb/s
- No license fee

Based on comparison of available platforms, their features, availability and costs, the IQRF platform has been selected.

This article is separated into the following sections: Section II briefly describing the IQRF platform, Section III introducing a web application to manage data, and Section IV describing a real application SIGMA.

II. IQRF

IQRF is an abbreviation for *intelligent connectivity using radio frequency*. It is a complex communication platform with modular components for easy user applications. It was introduced in 2004 [10]. It is intended for reliable packet-oriented low power data transfers, either peer-to-peer or in complex networks. Application domains are telemetry, e.g., AMR, Smart metering, WSN, Smart grids, automation of buildings, e.g., Smart house, HAN and cities (Smart city, street lighting), industry and services. This platform is

suitable for almost any electronic equipment where wireless communication is needed, e.g., remote control, monitoring, alarm, displaying of remotely acquired data or connection of more devices to a wireless network. The platform is described in [2].

A. Transceiver module

IQRF transceiver module (TR) is a basic communication component of the platform, used not only in common end devices but also in all IQRF gateways, routers, etc.

It is an intelligent electronic board with complete circuitry needed for implementation of wireless RF connectivity with several peripherals and interfaces. It includes a microcontroller with a built-in operating system (OS) supporting MESH networking, serial EEPROM memory, voltage regulator (LDO) and optionally also temperature sensor and built-in PCB antenna. Besides general I/Os, SPI running in OS background, I²C and UART standard serials can directly be used. The tiny compact module with highly integrated design, typically in SIM card format 25 x 14.9 mm, requires no external components. Several TR types are available differing in performance, MCU type, memory size, peripherals, antenna options and dimensions.

Due to extra low power consumption, e.g., 35 µA while receiving TRs are suitable even for devices with extreme requirements for battery life. TRs work within the license-free ISM band, 868 MHz in Europe and other countries or 916 MHz in America and other countries. All communication parameters are software selectable.

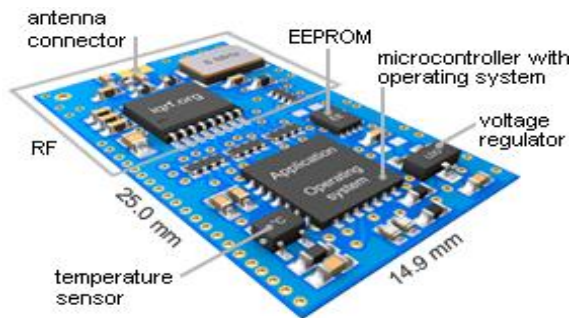


Figure 1. Transceiver module

B. IQRF GATEWAY GW-ETH-01

The GW-ETH-01 Ethernet gateway [1] enables connectivity between an IQRF wireless network and a local LAN and Internet. The gateway has an internal web server allowing communication via HTTPS. Up to two concurrent links are allowed at the same time. Additionally, communication via the UDP transport layer is possible using the IQRF proprietary UDP protocol.

The main GW-ETH-01 parts are 16b MCU, Ethernet driver, EEPROM memory, temperature sensor, IQRF TR module with antenna and backup accumulator.

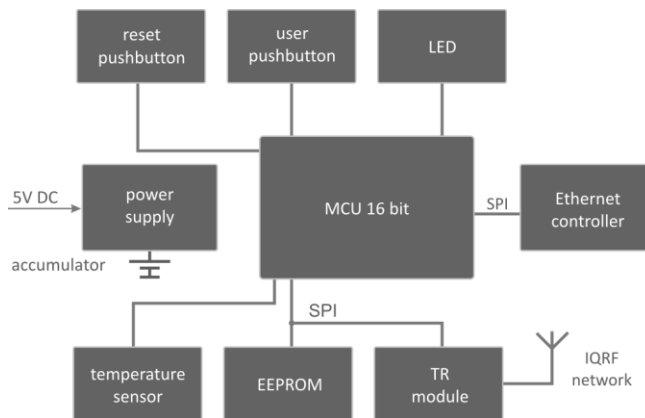


Figure 2. Block diagram of GW-ETH-01

One of communication modes with internal IQRF module is a Datalogger [3]. In this mode, operation depends solely on the application in an internal TR module. All data sent via SPI from the TR module to the GW are stored in a circular buffer in the GW without modifications. Every packet is equipped with numeric code and time stamp. Data can be read from this buffer via the HTTPS interface, or user data can be sent via HTTPS to the TR module.

Buffer parameters:

- Buffer size 7 kB (7 168 B)
- Packet size
- Serviceable data 1 to 41 (fixed but user selectable)
- Overhead 8 B



Figure 3. Example command for communication with the Datalogger

GW-ETH-01 can be used, e.g., for:

- Remote monitoring and control
- Data acquisition
- Data storage – datalogger
- Connection of more IQRF networks to single PC
- Access to an IQRF network from more points
- Time synchronization from time servers
- Interface to home automation, etc.

III. WEB APPLICATION

Preconditions:

- TR in GW and TR(s) in user system are programmed according to given needs.
- The GW must be set in the Datalogger mode
- In case of Internet connection, the GW must be registered and connected to IQRF DNS server (Domain Name Server) www.iqrfdns.org [5]. Then the GW polls the DNS server for its own IP (Internet Protocol) address.
- Database server, e.g., MySQL or MS SQL running and a database created for user application on the computer where the application is hosted.
- Web server, e.g., Apache or IIS (Internet Information Server) running on the computer where the application is hosted.

Application is designed as a web application based on *three-layer architecture: Database, Application and Presentation layers*. For security reasons, communication runs on HTTPS protocol (*Hypertext Transfer Protocol Secure*) between GW-ETH-01 and the web application.

The foundation of the application is a *Database layer* using the DBMS (Database Management System) [7]. The *Application layer* is created above the DBMS. It includes most of the application logics and ensures communication with the other layers. *Presentation layer* means web browser software for interactive user access. This three-layer architecture is suitable primarily for easy extendibility. Changes in application logics or database scheme can be done without the necessity to intervene in the Presentation layer, and therefore without intervention in the client part of the application.

Then the application can be written in PHP script programming language [4] using the datalogger PHP functions downloaded from [1] and hosted on the server. More gateways can be used by a single application. The application need not be hosted on the user's server, but it is possible to use the server provided within the IQRF platform for this purpose.

Database layer

As a result of analysis, the database scheme has been designed. Then scripts in the SQL language have been generated to create the database. As an actual database server, the **MySQL** [4] has been selected. It is a powerful multiplatform database under GNU General Public License which can be easily implemented for Linux, MS Windows and other operating systems. Communication is possible via the SQL language. Like other SQL databases it is a dialect of this language with several extensions.

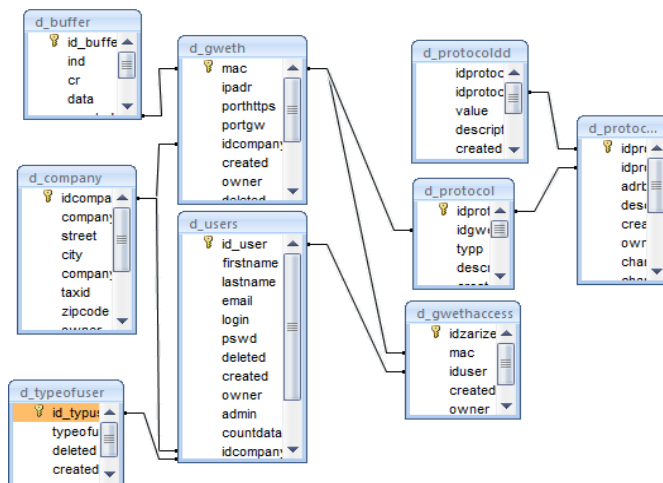


Figure 4. Basic database schema

Application layer

User interface and an interface for graphic outputs from the database are integral parts of the database application. For more comfortable user access to data the web interface has been selected. It is written in PHP.

IV. REAL APPLICATION – SIGMA

One of the real IQRF applications is control system SIGMA for turning of pump vanes. It allows control from the control panel at the pump as well as remotely from the control room. Additional requests are a possibility to control the pump, i.e., to change vane angle or the pump configuration remotely via Internet and supervision over events related to given pump.

To enable also manual control from the GW, GW-QVGA-01 gateway with touch screen can be used instead of GW-ETH-01.

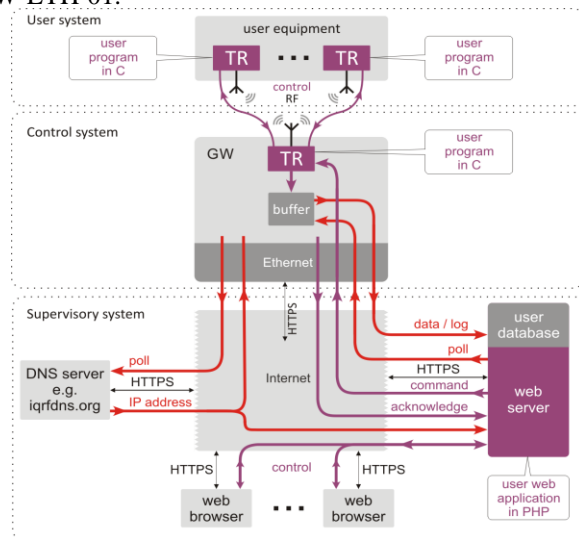


Figure 4. Block diagram of complete system

A. Analysis

Requirements:

- Automatic reading from the data buffer
- Data displaying, filtering and search
- Pump configuration
- Changing the angle of pump vanes
- Remote management – status, setup GW-ETH-01 parameters, ...

Based on these needs with respect to GW-ETH-01 restrictions followed from parameters mentioned above, a solution using a web application has been developed.

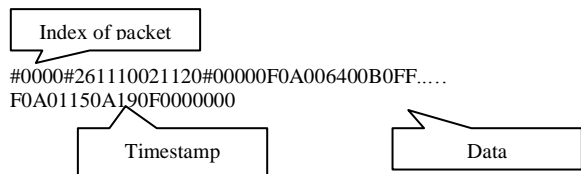
Structure of records (packet) in a data buffer:

A record consists of three parts:

- *index of packet* (2B),
- *timestamp* (6B)
- *data* (41B).

The index of packet range is 0000 – FFFE.

Example of a packet:



Maximum number of packets is **146** in the data buffer.

$$\max = \frac{\text{Buffersize}}{\text{length(index)} + \text{length(timestamp)} + \text{length(data)}} \quad (1)$$

$$= \frac{7168}{2 + 6 + 41} = 146,286$$

The buffer is circular (if full, the oldest data is overwritten). Thus, timely buffer reading and data processing must be ensured regularly.

B. Solutions

The application includes three parts:

- Automatic reading from the buffer
- Administration part
- User part

1) Automatic reading from the buffer

The principle of automatic reading of the buffer:

GW-ETH-01 requests IQRF DNS server to detect its own IP address regularly (in 10 min increments in this case). The IQRF DNS server verifies the MAC (*Media Access Control*) address whether it is in allowed range (00.1F.D5.xx.xx.xx). Then it returns the IP address of a given device. Additionally, the server checks whether the device is registered in application SIGMA. If it is, the server requests GW-ETH-01 to send the data buffer and the GW returns the

content. Application SIGMA recognizes new records (compared with last reading) and stores them in the database. This principle is depicted on Fig. 4.

Example of communication:

Request: <https://www.iqrfdns.org?IP=001FD5000048>

Answer: Requested IP Address: 81.25.21.74

2) Administration part

The administration part is intended for:

- Managing of individual registered devices (GW-ETH-01), i.e. adding or removing devices, setup of rights and changing of registration data like the IP address, MAC address, etc.
- User access management of the application, i.e. adding or removing users, changing their rights, usernames, passwords, contact information, etc.
- Defining of individual packets (events) transferred in the network. Based on this definition, the data is displayed then in the user part of the application in a format understandable to humans. Only packets undefined in the network are displayed in HEX code.

The principle of event definitions for individual packets: Visualization of the data of the packet should correspond to user definition. The first byte is the Event header specifying the type of the event. The user can fully define descriptions for individual types to be displayed in the user part of the application. For example, information, error or warning can additionally be differentiated here. The body of the event with variable length follows. Data is visualized in five fields in this example (see Fig. 6): hexadecimal address of the byte in the string, data length, description of the byte, range of allowed values and a coefficient for recalculation.

Figure 6 shows the resulting definition of the event.

Address	Number of bytes	Description	Range	Range	Coefficient	Add
0x01	2	ID SIGIN-01	-	-	1.00	Change
0x03	2	ID SIGCOM-01	-	-	1.00	Change
0x05	2	ID SIGCONT-01	-	-	1.00	Change
0x07	2	Current location of system	-20 - 20 °	-20 - 20 °	10.00	Change
0x09	2	Top work position	-20 - 20 °	-20 - 20 °	10.00	Change
0x0B	2	Lower work position	-20 - 20 °	-20 - 20 °	10.00	Change
0x0D	2	Upper limit position	-20 - 20 °	-20 - 20 °	10.00	Change
0x0F	2	Lower limit position	-20 - 20 °	-20 - 20 °	10.00	Change
0x11	2	Prescaler	330 - 834	-	1.00	Change
0x13	2	Angle for analog loop 4 mA	-20 - 20 °	-20 - 20 °	10.00	Change
0x15	2	Angle for analog loop 20 mA	-20 - 20 °	-20 - 20 °	10.00	Change
0x17	1	Enable / disable control from a particular source	0b00000001 Allowed to change positions of buttons of analog current loop 0b00000100 Allowed to change location via Ethernet 0b00000111 Allowed to change positions of buttons, analog current loop, via Ethernet	-	1.00	Change
0x18	1	Accu voltage	0 - 256 V	0 - 256 V	10.00	Change

Figure 6. Example – the RESET event definition

Example of data log:

```
#0000#261110021120#0002010403060514006400CEFF7800B0FFA401C
EFF64000088
```

The value 0x00 (red) indicates a reset event in this particular case.

Example of definition of current angle (see Fig. 6):

It is a 2B information at address 0x07. Recalculation coefficient is 10. Allowed range is from -200 to 200 which means angle from -20.0° 20.0°. E.g. 1400, LSB first at this address (see the log example above) means hexadecimal value 0014, decimal value 20 and the angle is 2.0°.

The application is fully generic. Individual definitions of bytes and events can be easily added, modified or deleted.

Example: It is discovered during operation that there is a need to include additional information to the packet, e.g. number of revolutions per minute. The administrator just modifies the packet definition by adding the information about the address of given record in the packet, data length and adds its meaning in "human" speech.

An example of data visualization is shown on Figure 7.

Packets can be defined not only for SIGMA, but for various applications. The only restriction is packet-oriented communication. Packets can have different lengths.

User management allows adding and removing users, change data and setup rights. There are three types of users:

- User – with access to User part of application only
- Administrator – with access to both User and Administration parts but with restrictions
- Super administrator – with access to all parts of application without restrictions

Type	Time	Data
🔍	03.02.2011 06:16:36	Req position Detail
🔍	03.02.2011 06:15:36	New position Detail
🔍	03.02.2011 06:14:36	Req position Detail
🔍	03.02.2011 06:13:36	New password Detail
🔍	03.02.2011 06:12:36	New time Detail
🔍	03.02.2011 06:10:36	The device is working - alive Detail
✖	03.02.2011 06:08:35	Msg error Detail
⚠	03.02.2011 06:08:35	Reset Detail
✖	03.02.2011 06:08:34	Msg error Detail
🔍	03.02.2011 06:08:34	New position Detail
🔍	03.02.2011 06:08:33	Req position Detail
🔍	03.02.2011 06:08:33	New config Detail

Figure 7. Event list example

3) User part

This part is intended for users to handle data, e.g., visualization, filtering and search and if having proper rights also to change pump configuration, e.g., limits and work

values. If commands received via Ethernet are allowed, vane angles can be changed too.

Data can be exported to XLS format for further processing (if the user has permission to export).

All activities accomplished in both Administration and User parts are logged. The log is accessible in the Administration part.

V. ACKNOWLEDGEMENT

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VI. CONCLUSION

The web application described in this article is designed to be as generic as possible and work with various applications utilizing the IQRF platform. This approach has the following advantages: Visualization is independent of the application layer. Thanks to the IQRF DNS server to read data from the device buffer it is not necessary to program any additional functionality. Handling is very intuitive and no extended training of users is needed. IQRF protocol, the Apache web server, as well as the MySQL database are free resulting in no additional costs required to run such applications.

Specific functionality can be achieved by programming TR in C language using OS functions and web application in PHP script language using the set of PHP functions.

Tests have been completed, and, at present, the SIGMA application is delivered to its final user for operation in practice.

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