Wireless Automation Network Stability Evaluation

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Abstract **- This paper describes stability testing of new wireless communication platform for automation, summarizing currently used wireless modules and technologies from different vendors and comparing their main advantages and disadvantages. Based on the wireless modules study, we have chosen one of the promising technologies for deeper analysis in real home environment typical for wireless automation applications. Two typical test-cases for wireless communication parameter evaluation are described within the study in order to determine the limits of stability and low error rate. Further, the statistical method used is described and testing results along with the main advantages of tested wireless communication platform are discussed. This new wireless communication platform was designed and developed especially for home automation and telemetry projects and test case results prove the suitability of this wireless communication technology for home and office buildings environment.**

Keywords - Home Automation; IQRF; Wireless communication; Stability testing.

I. INTRODUCTION

With the advance of networking technologies and wireless communications, the popularity and the applications of Wireless Sensor Network (WSN) are increasing. Wireless connectivity has grown-up considerably in recent years and current trends show that the Wireless Sensor Networks will be an integral part of our lives, more than the present-day personal computers [1][2][3][4]. The driving forces for this development include the ease of access and flexibility in ad-hoc situation or temporary network setups supported by wireless connectivity, avoiding restrictive wired connection that relies on copper and fiber optic cabling.

Wireless sensor network consists of a quantity of spatially distributed wireless sensor nodes and actor nodes, which are densely deployed in wide areas. Wireless sensor networks use battery supplied sensing and I/O devices. A sensor node, also known as a sensor pod or a mote, is an autonomous subsystem in a wireless sensor network, which is capable to monitor physical or environmental condition or perform some data processing. The communication infrastructure intended to monitor and record conditions at diverse locations is an important subsystem of wireless sensor network. This subsystem sends that data to processors in the network. Each node in a sensor network is typically equipped with a radio transceiver. Sensor nodes gather information and send them to a central node (sink) or to actors for appropriate actions. Usage of Wireless Sensor Networks with low energy demands, low weight and intelligent networking features seems to be the most cost effective solution for many application areas. These devices incorporate wireless transceivers so that communication in short distances over a Radio Frequency (RF) channel is enabled. Wireless Sensor Networks can be used for many applications in various application fields such as automation of the buildings, machines, in the monitoring product quality or conditions at agriculture, medicine, and healthcare. Our goal related to this article was to find and validate technology for intelligent wireless network with low power consumption.

Section I and Section II are summary of existing technologies. A general overview of available wireless solution targeted to the small home automation applications and their main parameters and limitations is described in Section II. Following section defines case studies and issues of testing of the wireless communication platforms. Statistic tool and evaluation method is described in the Section IV followed by the measured results in Sections V and VI. Conclusion of final measured values and their short assessment is in the last Section VII.

II. STATE OF THE ART

Various wireless communication solutions are available from different vendors in the market. These solutions support different network topologies. Many of them are based on 802.15.4 [4] 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 (Table 1).

Probably, the most known standardized protocol that works on non-licensed bands is Zigbee [13]. It is a solution based on the IEEE 802.15.4 standard prepared by the Zigbee Alliance [6]. This standard was developed by consortium of industrial companies especially for building automation [7][8]. There are also special applications for industrial control, e.g., [9] [11] on remote access to the system and using small, independent wireless devices, [10][14][15] on building automation and telemetry applications, or an alarm system suitable for pervasive healthcare in rural areas [12]. Among the proprietary solutions, a reference can be made to the technology of MiWi launched by Microchip Technology Inc. [16]. 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. From other solutions available on the market, mention would be made, for example, of the solution promoted by Z-wave alliance [17][18].

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, lower reliability, and increased network complexity.

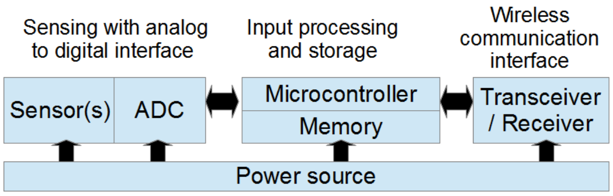

Figure 1. Block diagram of wireless sensor module

Wireless sensor module with RF measurement signal transmission is liable for collecting data from sensor when they could be recorded, configuration and switch on of other sensors and assuring other functions that are related to sensors. A sensor node is accomplished for gathering sensory information, performing some processing, and communicating with other linked nodes in the network. For example, the sensor module could be configured to allow a microcontroller to determine when a value of critical parameter has been reached or exceeded. Effectiveness of Wireless Sensor Networks (WSN) relies on the communication parameters of interconnected sensors' nodes, which are typically transmitting power, baud-rate, error-rate and their detection range or sensitivity to received signal.

These WSN technologies are determined especially for monitoring environmental and physical conditions, such as temperature, pressure, sound, vibration, humidity, and motion. WSNs applications are often used to perform many critical tasks and sensor networks applications have to meet strict rules and parameters to reliably and error-rate.

A failure of a component or components of a network may result in malfunction in the area of sensing, data processing, and communication. From this point of view it is necessary to evaluate the availability and reliability of application services as two important dependability factors [4].

A. *Mesh networking RF modules and improvement of reliability via redundancy*

RF modules are enabled for mesh networking and robust mesh networking topologies are preferred solution for developed applications. For example wireless sensor modules organized in a network in within the area of interest allow for monitoring of environmental conditions, events, or processes. A wireless mesh network is a communication network made up of nodes structured in a mesh topology. Multiple nodes cooperate to transport a message to its destination. Each of the nodes is able to cooperate with each other in transmitting packets through the network, especially in adverse conditions including the impact of powerful RF interferences.

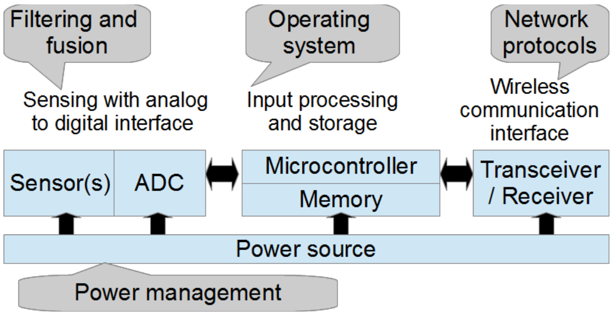

Figure 2. Important aspects of system architecture for wireless sensor networks

The mesh network features adaptability, self-configuring, flexibility, scalability and high-rate data transmission. This technology delivers scalable and self-healing properties: nodes are working in coordination with each other to create a network. Each node in the mesh network is connected to at least one other node and if a device or its link in a mesh network fails, data are sent around it via other redundant interconnections between network nodes. Nodes are talking to each other in a way that gets a message to a desired point using the applicable path and when a node is not in use, it will sleep using very little energy.

Table 1. Different RF modules of various manufacturers designed for operation in the license-free ISM bands

Producer, RF module type	Frequency range
Microrisc, TR-52B	868 MHz and 916 MHz
Texas Instruments, CC2500	2400- 2483,5 MHz
Aurel Wireless, XTR-434	433,92 MHz
Sonmicro, SM130	13,56 MHz
Panasonic, PAN4555	2,4 GHz
Micrel, MICRF600	902-928 MHz
LS Research, ProFLEX01	2405 - 2480 MHz
Hope RF, RFM12-315	315, 433, 868, 915 MHz
Friendcom, FC-221/AP	433, 868 ,915 MHz
Shanghai Sunray Technology, SRWF-1028	403, 433, 470, 868, 915 MHz
Microchip Technology, MRF24J40MA	2,405-2,48 GHz
Aurel Wireless, RTX MID 3V/5V	433.92 MHz
Digi International Inc., XBee RF	2.4 GHz
Dorji Applied Technologies, DRF7020D13	433Mhz

The mesh topology offers multiple redundant communications paths throughout the network. This redundancy, which is insensitive to the workload, enhances the overall reliability of the network: if one link for any reason fails, the network automatically routes messages through alternative paths. The degree of redundancy, which is a common strategy to enhance the reliability of systems, is essentially a function of node density. When one node can no longer work, the rest of the nodes can still communicate with each other, directly or through intermediate nodes. The redundancy improves the general reliability of the network simply by adding more node, links are more reliable without increasing transmitter power in individual nodes.

Table 2. Different RF modules of various manufacturers designed for operation in the license-free ISM bands

Producer, RF module type	Special firmware protocol	Modulation
Microrisc, TR-52B	IQMESH protocol	FSK
Texas Instruments, CC2500	No	2-FSK, GFSK, OOK, MSK
Aurel Wireless, XTR-434	No	FSK
Sonmicro, SM130	No	UART, I2C
Panasonic, PAN4555	SNAP® (Synapse Network Application Protocol)	Timer/Pulse Width Modulation (Tpm)
Micrel, MICRF600	No	FSK
LS Research, ProFLEX01	SIMPLE ProFLEX01	OQPSK
Hope RF, RFM12-315	No	FSK
Friendcom, FC-221/AP	Yes	3FSK
Shanghai Sunray Technology, SRWF-1028	No	GFSK, FSK
Microchip Technology, MRF24J40MA	No	FSK
Aurel Wireless, RTX MID 3V/5V	No	ASK
Digi International Inc., XBee RF	No	PWM0
Dorji Applied Technologies, DRF7020D13	No	FSK

B. *Wireless networking protocols for security and efficiency*

Network protocol is critical element of the networking and ensuring communication functions across implemented wireless network. Network protocols facilitate device identification and data transfer, and it is the special set of instructions that manages the communications among devices on a network. Network protocols play significant role because they are used for transmitting network packets across the network and are able to provide the altered types of paths to do the access to the network.

Network protocols also deal with the topologies of the network and can also take work in increasing the speed of data transmission. The aim is to use robust wireless communication protocols that are energy efficient and provide low latency. Principally a network protocol is defined as the set of regulations and rules of networking, which are needed for communicational process. The protocol software components are interfaced with a framework implemented on devices operating system. Different types of wireless networking protocols are utilized to achieve smoothly communication, and there are various competing schemes for routing packets across networks. As a base for unlicensed operation, standardized and proprietary protocols such as Bluetooth, ZigBee or WiFi are used and some RF modules manufacturers have their own protocols (see Table 2).

C. *Transceivers operating in the ISM band*

Governments regulate the use of various frequency bands and a license is necessary to operate in certain frequency bands. The industrial, scientific, and medical radio bands (ISM bands) are unlicensed frequency bands defined by the International Telecommunication Union Radiocommunication Sector (ITU-R). The ITU Radiocommunication Sector shows an important role in the worldwide organization of the radio-frequency spectrum. This part of the radio spectrum can be used without a license in most countries. License-free utilization is generally allowed in these bands though there are some differences in national regulations. These portions of the radio spectrum were originally reserved internationally for the use of radio frequency energy for industrial, scientific and medical purposes rather than communications. Despite the original purpose of ISM bands, there has been a large extension in its use in short-range, low-power, wireless communications platforms. Today the industrial, scientific and medical unlicensed Sub-GHz radio frequency bands are used for low-power wireless short-range wireless transfer of data at relatively low rates in point-to-point and more complex network topologies.

The employment of ISM equipment produces electromagnetic interference that disturbs radio communications in case of using similar frequency – the communications device must accept any interference produced by ISM equipment. Sharing the radio spectrum between various wireless devices that can work in the same environment may lead to oppressive interference interrupting radio communications or substantial performance degradation that makes use of the same frequency. The communication device working in these bands should reckon with consequences of the interference produced by ISM equipment because users do not have any regulatory protection. These undesirable effects are composed in densely occupied city areas with large numbers of wireless computer accessories, wireless remote controllers or keyboards, cordless phones, Bluetooth devices, microwave ovens, and other devices which occupy the ISM band.

Table 3. Power consumption for various RF modules from different manufacturers

Producer, RF module type	Receiving current R_X	Transmitting current T_X	Sleep mode
Microrisc, TR-52B	35 µA - 13 mA	(14 – 24) mA	2 µA
Texas Instruments, CC2500	8,1 µA - 19,6 mA	(11,1-21,5) mA	400 nA
Aurel Wireless, XTR-434	(10-12) mA	(24-32) mA	100 nA
Sonmicro, SM130	180mA	180mA	30 µA
Panasonic, PAN4555	37 mA	30 mA	1 µA
Micrel, MICRF600	12 mA	10 / 23 mA	N/A
LS Research, ProFLEX01	25 - 35 mA	125 - 175 mA	8 µA
Hope RF, RFM12-315	10 mA	13 - 21 mA	0,3 µA
Friendcom, FC-221/AP	<65mA	<120mA	<25µA
Shanghai Sunray Technology, SRWF-1028	32-38mA	300-550mA	N/A
Microchip Technology, MRF24J40MA	19 mA	23 Ma	2 µA
Aurel Wireless, RTX MID 3V/5V	4,5-6,5 mA	13-20 mA	8 mA
Digi International Inc., XBee RF	50 mA	45 mA	< 10 µA
Dorji Applied Technologies, DRF7020D13	28 mA	35 mA	5 µA

D. Power consumption for transmit, receive and sleep modes

Building an energy efficient wireless network is one of the major efforts. Energy efficiency characteristics during routing are important in order to achieve energy savings. RF power consumption is very important parameter to be considered while designing battery powered systems. Typical module allows three different operating modes (Table 3). For the purpose of data receiving or transmitting there is a transmit mode and receive mode, and the sleep mode is designed in order to reduce the power consumption. Sleep mode can be activated by sending a sleep command, or by setting the module to return to sleep mode at every turn after data transmission.

In sleep mode, all of the system's interfaces shall support their necessary electrical levels and shall be able to wait for the next wake up period. When transmit mode is selected the module attempts to initialize an RF transmission and in combination with receive mode initiates an RF connection with other modules.

III. Case Study Description and Problem Definition

Small battery operated wireless sensor nodes are in our network used for automatic monitoring in the system. This application not only expects wireless signal coverage but also needs undisrupted service and reliable connectivity. The key aspect of wireless channel is the monitoring and evaluation of the channel quality. Most of the models of radio wave propagation involve questions related to the "free space" radio wave propagation [19].

Radio waves emit from a point source of radio energy, traveling in all directions. Obstacles such as physical and structural components of a building, furniture and fixed or movable structures, or the ground can impact signal propagation paths. Especially ferrous materials, such as steel and iron, can drastically alter signal propagation characteristics, communication distances, link quality, and many other factors [20].

Reflection, diffraction and scattering cause radio signal distortions and give rise to signal fades, as well as additional signal propagation losses. Indoor use of wireless systems creates the necessity for evaluation of indoor radio (RF) propagation. Any obstacles in the pathway would be harmful to RF transmission; radio signals penetrate obstacles in ways that appear hardly predictable. The final composite signal is made up of a number of components from the various sources of scattered and diffracted signal components or reflections from different directions.

To better understand this effect in our case study we at first evaluated the communication characteristics when sensor nodes were placed in various locations and distances. Absorption of RF energy resulted in loss of signal strength and reduced transmission distances. RF signals from wireless sensor nodes are air radiating from a transmitter and propagating through a medium in all directions. We need to understand the communication distance of individual nodes as well as to evaluate how and where to install the nodes.

The WSN in this case study is based on the IQRF (Intelligent Radio Frequency) wireless communication platform for industrial and home automation. This is the technology that was specifically developed for wireless sensor mesh networks by Microrisc company [21]. Typical application scenario of home automation with IQRF communication technology for a smart house is shown in the Fig. 3. Wireless sensor network as part of network infrastructure is depicted in Figure 3, sensing and controlling is accomplished by means of connected sensors and actuators. Upon detecting a relevant stimulus (signal) by sensors in the sensor field, sensors send reports to a sink node.

Networking collectively many of cheap wireless sensor nodes lets accurately evaluate a remote processes by utilization of the data from the individual nodes [25].

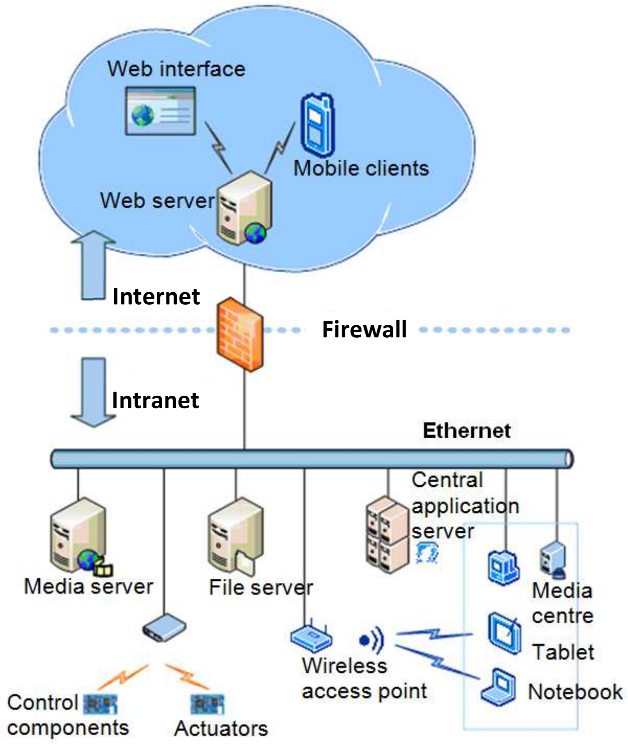

Figure 3. Block diagram of the telemetry and control for smart house

The main parts of the platform are covered by Czech and US patents [22][23][24]. For our experimental purposes, the standard IQRF components and development tools have been used. This wireless solution could be used for wireless connectivity necessary for telemetry, remote control, displaying of remotely acquired data, connection of more equipment and building automation. The implementation of IQRF transceiver modules works in non-licensed communication bands, license-free ISM bands 868 MHz in EU, 916 MHz in US, 433 MHz in EU, US and other countries.

Basic features of the IQRF communication platform are especially extra low power consumption (1 µA in the sleep mode and 35 µA in the on-line mode), available networking functions, programmable RF power up to 3.5 mW, SW selectable in steps, up to 170 m communication range, 15 kb/s (optionally 100 kb/s) RF bit rate. A transceiver module is the basic communication component needed for realization of wireless RF connectivity and can work as a node or a network coordinator. The IRQF modules could be integrated into any electronic device via SIM (Subscriber Identity Module) card connector. The low power consumption predetermines these modules for battery powered applications. The transceiver module is equipped with the IQRF operating system supporting functionality for the user application. There are RF functions for transmitting, receiving, network bonding, routing, main parameters configuration, EEPROM access functions, and IIC (Inter-Integrated Circuit bus) and SPI (SPI - Serial Peripheral Interface) communication functions. Data processing, for example, encoding, encryption, checksums, adding headers, is evaluated automatically by IQRF operating system during the communication. The other functions of operating system are three buffers and some other auxiliary functions. IQRF operating system is buffer-oriented and allows sending up to 32 bytes in one packet.

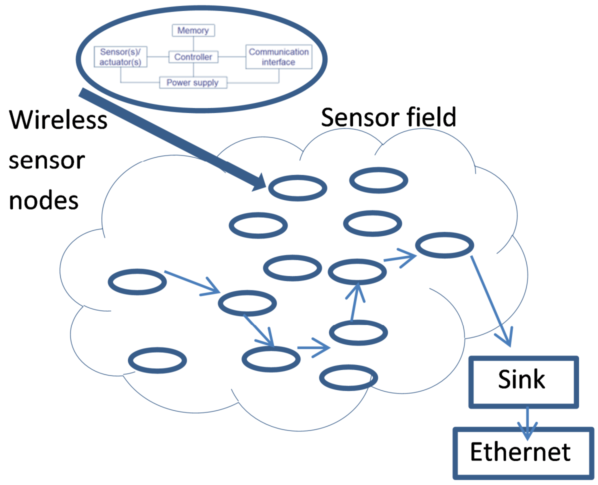

Figure 4. Wireless sensor network as part of network infrastructure

This application case study demonstrates simple data collection from wirelessly connected sensors. The network used for our experiment consists of one coordinator and a set of communication units. This is the basic star network topology where a sensor network is created around a core coordinator. The packet is wirelessly sent by operating system to the coordinator and the quality of the communication is statistically evaluated.

IV. CASE STUDIES AND USED DATA EVALUATION METHOD

For wireless communication parameters measurement were used two basic measurement criteria. The first one examined communications' parameters and wireless technology limits under typical building environment with the set of rooms separated by the plasterboard walls and the second set of measures was done in a long hall without any physical obstacles to test free space signal propagation.

A. *Statistical description of the wireless network stability*

The binomial distribution $B(n,p)$ with parameters n and p gives the discrete probability distribution of independent observations by the number of observations in the group that represent one of two outcomes. This distribution describes the behavior of a count variable X if the number of samples n is fixed, each sample represents "success" or "failure", each sample is independent, and the probability of "success" p is the same for each outcome.

The binomial distribution gives the approach to dependability evaluation for wireless communication. We expect that in the stable wireless network each type of outcome has a fixed probability, and by evaluation of the proportion of individuals in a random sample we could evaluate the stability of the network. They are the sequences of independent transfers in the communication model with two possible outcomes ("success" or "failure").

B. Statistical description of the wireless network stability

We extract samples of a certain size from the ongoing Wireless Sensor Network in our case study related to the stability testing of the channel quality. These are the sequences of independent transfers with two possible outcomes ("success" or "failure") in this experimental situation. The fraction or proportion of "failure" items can be expressed as a decimal or as a percent (when multiplication by 100 is used).

From the statistical point of view, the number of failures is the random variable. Common-causes and special-causes are the two distinct origins of variation. One common-cause variation is the noise within the system and is inherent to the process. It could be removed by making modifications to the process. Special-causes are unusual, not previously observed variation, which is inherently unpredictable. There are only common-causes in the stable system and the statistical monitoring and control could be used for stability evaluation.

Each run that is accomplished is then a realization of a Bernoulli random variable with parameter p. The binomial distribution $B(n,p)$ with parameters n and p gives us the discrete probability distribution of these independent observations. If a random sample of n units of transfer realization is selected and if k is the number of units that are nonconforming, the k follows a binomial distribution with parameters n and p according to following equation

$$P(k) = \binom{n}{k} p^k (1-p)^{n-k} \;\; \forall\, 0 \le k \le n \qquad (1)$$

We expect that in the stable wireless network each type of outcome has a fixed probability and by determining of the proportion of individuals in a random sample we can evaluate the stability of the network in setting condition. The np-chart such as Shewhart control chart with underlying binomial distribution can be used for the stability evaluation [26]. The sample size is constant and the amount of the unsatisfactory is plotted in a graph along with regulation limits. The regulation limits are defined as

$$n\bar{p} \pm 3\sqrt{n\bar{p}(1-\bar{p})}, \qquad (2)$$

where n is the sample size and $\bar{p}$ is the estimation of the long-term mean. Rational subgroups for our testing are composed of the transfer of packets under essentially the same experimental conditions.

V. STABILITY EVALUATION OF INDOOR RF PROPAGATION (THE CASE STUDY OF MORE RF PROPAGATION OBSTACLES)

In this application case study, there were five transmission units in five various rooms each separated by the plasterboard partitions. There are two changed factors in this experiment: eight various levels of transmitting power and the time of the day. In each run, 80 data transfers were executed each of which consisted of 500 data frames. The selected scenarios cover most typical usages of this technology.

The number of failures in the communication was then evaluated. Failure in our case study indicates that the data frame was not received or there was a bit error in the data transfer (mismatched CRC). The results from this first experimental case study are summarized in Figure 6. There are two factors influencing the results. The mark (a) in the graph highlights the independence of the number of failures on the RF power. For a distance that is higher than 5 meters, it is necessary to optimize the RF power value. The mark (b) in the graph highlights the special-causes variation. The influence of parasitic effects such as the interference from microwave, treadmill, vacuum cleaner etc. has not been tested. These parasitic sources of wireless signal interference have unpredictable and hardly tested behavior which rapidly varies in every application conditions.

Experimental results were evaluated by using the np control charts (see Fig. 3 and Fig. 5). An np-chart is a plot of the number of failed items observed in a sample where n is the sample size and p is the probability of observing a defective item when the system is in control without affection of special cause variation. The statistical distribution of the number of failed items is assumed to be binomial. The observed number nonconforming (NP) is plotted against the control limits (UCL – Upper Control Limit, LCL – Lower Control Limit), which are statistically determined. These limits are usually calculated as three standard deviations from the mean, so there is around a 99.73 percent probability that a data point representing actual value of tracked parameter will be within those limits in the case of stability.

For the purpose of statistical evaluation of this wireless communication, experiments were used np control charts. The results of this analysis are summarized at the control charts (Fig. 6 and Fig. 8). If a data distribution is approximately normal the fluctuation of the points between the control limits (UCL, LCL) is due to the common cause variation. Then about 99.7 percent of the data values are within three standard deviations: $\mu \pm 3\sigma$, where μ is the arithmetic mean and σ is the standard deviation. Any points outside the control limits related to the six standard deviation empirical rule could be attributed to a special-cause variation. There are some cases where special-causes are affecting the results. Out of control points are marked as “1”. Overall interpretation of created np control charts for this part of experiment leads to these conclusions:

- The higher distance between the transmitter and receiver is in the relation to the special-cases variation existence and communication failure.
- The higher RF power gives the higher probability for wireless communication without failures.

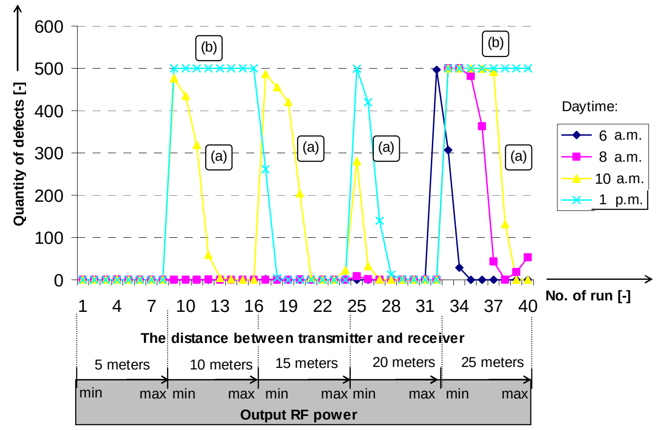

Figure 5. Wireless stability evaluation (the case study of more RF propagation obstacles)

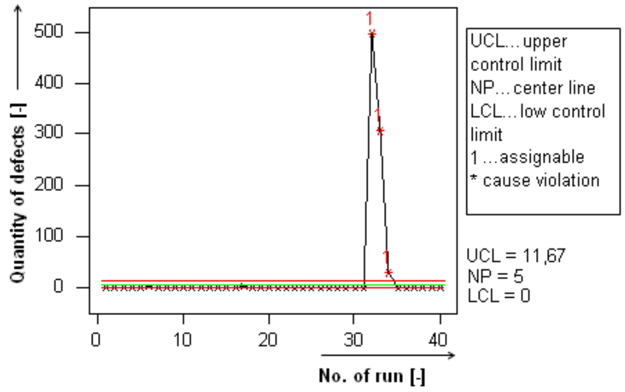

Figure 6. NP chart of wireless stability evaluation for the measurement at 6 p.m. (the case study of more RF obstacles)

VI. STABILITY EVALUATION OF INDOOR RF PROPAGATION (THE CASE OF THE FREE SPACE RF PROPAGATION)

In this part of the experiment, there were five transmission units in five various places in a region, which is free of all objects that might absorb or reflect radio energy. Eight various levels of the RF power and the various daytime are changed in this experiment. In each run, there was 80 data transfer execution, which each consists from 500 data frame. The number of failures in the communication system in this configuration was then evaluated. The results from this part of experimental case study are summarized in the Fig. 7.

We could see that there are some communications problems related to the setting of the RF power. The RF power needs the optimization according the distance between the transmitter and receiver. These situations are in the Fig. 7 depicted by mark (a).

Communication with the fifth transmitter unit located in the distance 25 meters for the receiver is affected by special cause variation in this case. This is the limiting distance that the signal is able to penetrate at the building environment in this experiment configuration. The reason for this is a hardware solution based on the used inbuilt antenna. Transmitting power is independent on the voltage level from the battery. If critically low value of battery voltage is reached transmitter stops operation and goes to switch-off state. Also temperature will not affect the result, because of the automated periodical crystal recalibration. Other parts of the transmitted do not have high temperature dependence.

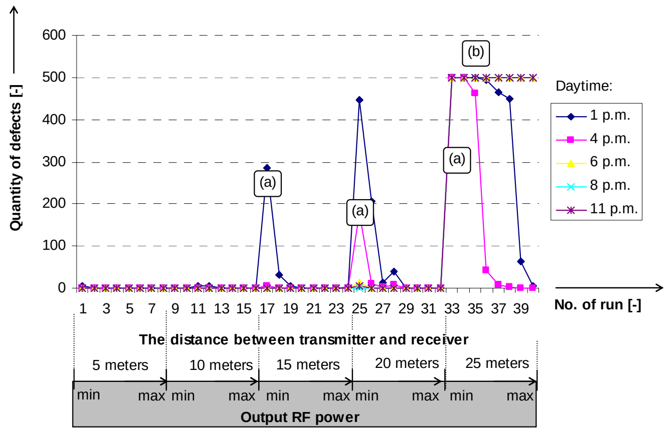

Figure 7. Wireless stability evaluation (the case study of the free space propagation)

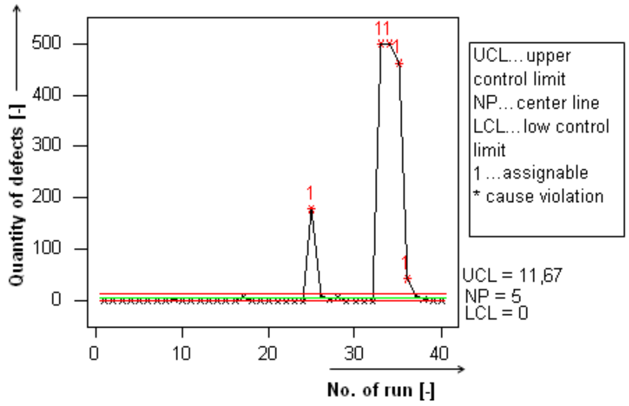

Figure 8. NP chart for wireless stability evaluation (the case of the free space propagation, 4 p.m.)

The mark (b) in the Fig. 7 is related to the communication failure and the special cause variation case.

The number of communication problems in comparison to the case of more RF propagation obstacles is smaller. The requirements for higher RF power are smaller and the overall stability is better. The higher RF power gives the higher probability of wireless communication without failures.

VII. Conclusion and Future Work

Our goal related to this article was to find and validate technology for intelligent wireless network with low power consumption. 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. As a typical representative of the low-cost wireless communication technology IQRF presents ideal solution for home automation and office or light industry applications. As such, this platform was designed especially for home automation and telemetry applications.

This paper describes stability testing of the IQRF wireless platform in some real cases. We have focused on the long-term stability test and the verification of the parameters required for implementing the network. Proposed case studies have proved suitability of this technology to typical application scenarios, test their real communication parameters under buildings environment and determine limits. We are using real test cases i.e., sequence of events (actions) whose purpose is to find defects in a communication transfer. Based on the statistical result of measured data analysis, optimal node distance and output RF power to communication defects ratio can be set. Output RF power influences power consumption and then operation time. Optimal combination of distance and output RF power in specific operation conditions under different environments is therefore highly needed and can significantly improve operation time and minimize communication failures.

Real tests proved wireless communication abilities of IQRF, which fits to the requirements for usage in home automation and telemetry applications and also in the currently developed automatic stochastic system.

Our future work covers implementation and testing of selected wireless technology under real application conditions in the wide wireless sensors network.

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