The Reliability of Wireless Sensor Network

B. Juhasova, I. Halenar, M. Juhas

Abstract—The wireless communication is one of the widely used methods of data transfer at the present days. The benefit of this communication method is the partial independence of the infrastructure and the possibility of mobility. In some special applications it is the only way how to connect. This paper presents some problems in the implementation of a sensor network connection for measuring environmental parameters in the area of manufacturing plants.

Keywords—Network, communication, reliability, sensors.

I. INTRODUCTION

THIS paper presents some problems in the implementation of a sensor network connection for measuring environmental parameters in the area of manufacturing plant, which is approximately 600km^2. A sensor stations are used to control the air quality in a given area. The object of our research is to design the optimal deployment of sensors in the given area, suggest a way of communication and maximize the reliability of data transmission in the network. The main objective of this article is a brief description of the telemetry system and suggestion of increasing the transmission reliability possibilities.

II. DESCRIPTION OF THE TELEMETRIC SYSTEM

The whole system is represented by 24 measuring stations. They are located around the production plant in three areas. The first circuit of measuring stations (5 measuring points) is located on the property of a factory. Consequently, within a radius of 3-6 km, there are another 15 measurement points. Finally there are 4 more station in a distance of 15km. The sensor stations observe 9parameters of air quality, including power supply. Data recording is provided by central server. Thus, we are able to process data with any suitable tool, for example Matlab [1].

As deployment of sensors in the field is very appropriate, the situation is appropriate for using some type of wireless communication. When taking into consideration a difficulty of transmission capacity, it is necessary to realize, that there is a small amount of data transferred at regular intervals [3].Such transfer is not bandwidth consuming. Therefore, the capacity of the network can be relatively small [6]. The entire system must be reliable and the transmission must be guaranteed even in emergency conditions.

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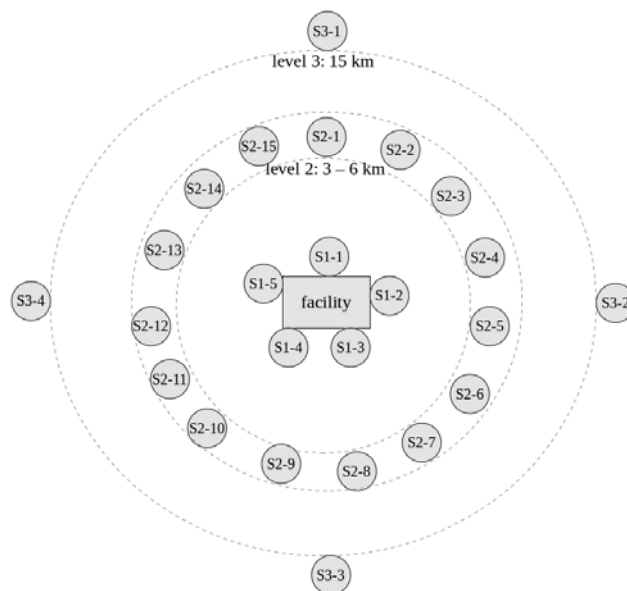
Fig. 1 Positions of sensors in monitored area

III. PROPOSAL FOR AN APPROPRIATE TRANSMISSION TECHNOLOGY

An intended usage is the most important parameter for the implementation of wireless network. We need to consider three main factors in designing of a data network. Firstly, we need to collect data form sensors. Secondly, client's or base stations' requirements of mobility arise. At last, thirdly, a connection to the data storage is created via the Internet. This phase is not necessary from the beginning.

The implementation of the communication system must meet the intended requirements in necessary extent, and thus compromise of each transmission technology would be fulfilled.

It is of course necessary to take into account existing systems and the interoperability between them. According to the location of the project and the current technical condition we are taking into consideration four types of transfer technology.

We must take into account necessary landscape restrictions such a terrain, climate, existing hardware and intended use. We believe that the practical implementation will be built on one from following technologies [5]:

- cellular data network (GPRS)
- IEEE 802.15.4 (radio transmission)
- IEEE 802.11x (Wi-Fi)
- IEEE 802.16x (Wimax)

IV. INCREASE TRANSMISSION RELIABILITY

The correct system operation of the desired quality depends

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on proper function of its elements and links. The structure of every system consists of elements with different physical properties, uses various physical phenomena and contains mechanical, electronic, control and informative elements. One of the essential features characterizing the functionality of systems in their use, as well as their readiness to use is defined with the general term reliability.

It is necessary to establish a method for increasing the reliability and security of the chosen form of wireless data transmission by designing.

Reliability of the system, but in particular its readiness, to be increased, can usually be achieved using backup functional elements or blocks and their appropriate inclusion into the system structure.

This way of increasing confidence is common in all systems and occurs equally in information technology. These elements can be hardware as well as software and are used as backup elements. They assume a function of faulty elements in case of a malfunction.

Because such system contains more elements than necessary for its function, such solution is called backup. Creating redundant structures is called "redundancy" and although this name evokes the meaning of "unnecessary", it has a different meaning in terms of improving the reliability and availability of systems.

We have to emphasize, that it is not possible to increase the reliability over a confidence level of the least reliable functional element, whose failure will cause failure of the entire system.

The reliability and rapid repair of each element in a system depends on a number of technical, technological and economic factors. If the reliability of the system is beyond the capabilities of elements, it is necessary to solve the problem of increasing the entire system reliability [4].

The most commonly used methods for increasing the reliability of transmission systems include parallel structure, which means parallel backup. In our case it means usage of at least two independent ways to transfer data.

It is, of course, definite that the overall reliability of the system increases with number of redundant structures. The optimal number depends on given operating conditions.

Probability that the transmission system will be functional is given by the probability that the failure of all its elements do not occur simultaneously.

Fig. 2 Parallel transmission paths

As failures of individual system elements are independent phenomena and failure and failure-free operation are opposites, the probability of failure-free system operation (as an opposite of a failure operation) in accordance with applying de Morgan's Law is defined as a result of multiplication of phenomena opposite to the failure probability of any element, so:

$$1 - P(t) = \sum_{k=1}^{n} [1 - Pk(t)] \tag{1}$$

Now we can formulate probability of a failure-free function:

$$P(t) = 1 - \sum_{k=1}^{n} [1 - Pk(t)] \tag{2}$$

With increasing number of elements in the structure $P(t)$ converges quickly to the value of 1 which means that the probability of failure-free operation of the system is close to certainty. The structure readiness is not disturbed by repairing of one or more elements, and therefore using a backup compilation can theoretically reach 100% operational readiness.

The formed parallel redundant transmission path structure is called the active reserve and can be divided into two types. The first one is the replacement deposit, where the backfill is still in operation.

However, it is in standby mode and in case of failure of the transmission it applies actions to a damaged part of the transmission infrastructure. The alternative solution is thus activated only in the case of a failure event.

On the contrary, another option, called permanent backup is activated during the entire operation period of a communication network. In this kind of communication system applications sufficiently reliable transfer is often required, because the interruption in the transmission path can lead to various undesirable consequences.

Specifically, in systems endangered by serious consequences of transmission interruption it is necessary to use the backup (redundant) path and transmitting equipment in addition to the simple transmission path, which are used in case of a failure of the original path.

Installation ways and methods, creating alternative transfer routes, as well as use of elements are specific for each case. However, the effect of reducing the failure rate in the transmission resulting in increasing the reliability has a general character.

We can think about a simplified example of two connected communication nodes. This connection may be unidirectional when collecting data from sensors, in case of graphical information systems and more complex systems of data collection it is often bidirectional.

We can state that a connection can be made up of N channels, while the transfer itself is operational, if M-roads are. [2] In the simplified case of data communication, at least one transmission path must be operational. Thus, the system is
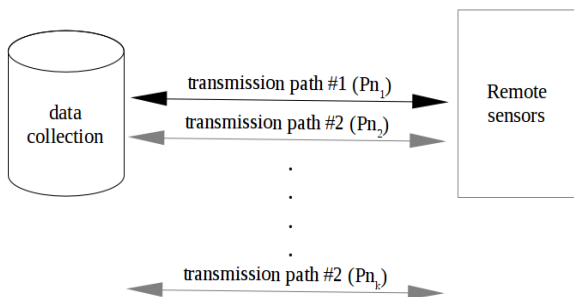
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operational if $M < N$ paths are functional, while in this case $M = 1$. The remaining transmission paths can be in a state of repair, eventually, disorder.

The probability that such transmission system (m, n) is operational can be described by the following formula:

$$P(m, n, P) = \sum_{k=m}^{n} (n/k) P^k (1 - P)^{n-k} \qquad (3)$$

where

- formula (n/k) means operation n over k,
- P is probability of operability of every element form the set of n elements ,
- number k takes the values $k=m,m+1,.....,n$.

Let us suppose a system in which a number of independent transmissions N equal three and the minimum number of operational transfer routes (M) equal to one. Consequently $M=1$. In this case, the probability of using this system may be expressed as follows:

$$P_v(m, n, P) = \sum_{k=1}^{3} (n/k) P^k (1 - P)^{n-k} \qquad (4)$$

The availability of communication sources is commonly stated as a percentage of time. Conventional systems in real-life usability reach 97%. Thus, if we consider the probability Pk as the possibility of transmission path use, then the value of the likelihood of using the system after substituting is close to 99%.

The method of increasing the reliability and availability of systems can be used to raise emergency transport routes, energy distribution, increase the reliability of processing and transmission of information in automated production lines, transfer of management and control of large-scale automatically controlled systems and other applications.

V. Conclusion

In our case, the application of those approaches to increase the reliability of communications telemetry system probably leads to the use of two or more independent technology transfers.

For the design of reliable wireless transmission it is necessary to analyze the most widely used methods of wireless data.

In the next work it is necessary to compare transfer technologies mentioned above with each other and consider the benefits of each type. Of course, not every named technology is suitable for the intended method of deployment.

Generally, we can assume using the radio modem (IEEE 802.15.4) as the primary mode of transmission to be satisfactory and subsequently a cellular data networks or microwave data networks using IEEE 802.16x as a backup method of communication [5].

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