

Bluetooth and Wireless LAN Applicability for Real-time Control

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ABSTRACT

Continuous need for replacing the cables and deployment of mobile devices in industry leads to active research in utilization wireless networks. The wireless connection should meet the reliability needs of the wired systems and serve the processes in real-time. Main topic of this work is to discuss the convenience and applicability of Wireless LAN and Bluetooth networks for industrial control purposes, whether the demands of confidence and real-time control can be equally satisfied.

This paper describes industrial real-time control application using wireless IP-based network. The simulated model rather than the real system was chosen for acquiring more reliable results and depressing the process disturbances in the control loop. The measurements of the system consist of controlling algorithm and program intercepting the response delay in communication between two nodes. The devices allowing the wireless transmission (Wireless LAN, Bluetooth) instead of cables were integrated. First measurements were done using the Wireless LAN system configuration, the Bluetooth setup was used in the second part - two sets of comparable results were obtained. The measurement conditions and the problems encountered during the research are concluded in the end of the article. The results can give a hint about the implementation and use of wireless technologies in the industry fields.

1 INTRODUCTION

Wireless technologies acquire more important place in market every day. Their utilization is being investigated not only in telecommunication, but also in industry. The advantages that wireless technologies offer, lead to various number of possible applications and services, which may be used in industrial fields. Intensive research proceeds at IP based controlling over wireless networks, which will together with Internet relieve remote control.

Though the wires limit properties of many applications, they still guarantee the main issues of industrial requirements – real-time communication (speed) and reliable link. This project poses its goal to investigate the possibility of wireless technologies - Wireless Local Area Network and Bluetooth - to satisfy such requirements.

2 WIRELESS NETWORKS AND THEIR INDUSTRIAL APPLICABILITY

The purpose of Wireless Networks is to provide all features and benefits of traditional LAN technologies such as Ethernet but wirelessly. Wireless Networks work without limitations of cabling, using as a medium either infrared light (IR) or radio frequencies (RF). The current WLAN and Bluetooth technology use the 2.4 GHz frequency band, which is the only unlicensed band in most of countries /1/.

Transmissions over a wireless medium are based on two modifications of a spread spectrum method, which are standardized by IEEE 802.11b and used in WLAN and Bluetooth. The first method is Fast Frequency Hopping Spectrum (FFHS) supporting data rates up to 2 Mbps. This method is also being used by Bluetooth devices. The second method is Direct Sequence Spread Spectrum (DSSS) and it supports data rates up to 11 Mbps /2/.

There are certainly many advantages of replacing cables by a wireless medium. The most significant are mobility, flexibility, cost saving, installation in difficult-to-wire areas and reduction of installation time.

The main problem of wireless networks is the unreliability of the wireless medium, caused by a reflection, multipath effects and the crucial interference with other devices, which use the same frequency of 2.4 GHz /1/.

Power consumption is also a concern since supply power lines are not normally available everywhere. A pure battery solution might not be attractive since the benefit of wireless is soon lost if battery replacement becomes necessary. Alternative power solutions need to be considered and special attention needs to be taken on an individual case basis /3/.

Bluetooth refers to a short-range radio technology aimed at simplifying communications among electronic devices. Bluetooth is mostly known in the telecom market; however, the Bluetooth application possibilities are many; industry applications containing Bluetooth communication is a new area being investigated. This work aims at making a study of Bluetooth in a real-time control system. Bluetooth is not initially designed for real-time applications; it is designed for common data/voice transmissions, ad hoc networks and cable replacement purposes, and this is a barrier to overcome since industrial applications are somewhat different. The messages in industrial communication are often short but typically demand robust security of delivery and fast transfer. This requires support for enhanced Quality of Service and the ability to deal with external disturbances. Bluetooth has currently an ARQ scheme (except for voice packets), which makes a deterministic data transfer difficult /3/.

Usability and suitability of Wireless Local Area Network (on top 802.11b specification) for industrial purposes and its comparison to Bluetooth is being researched by many companies. Bluetooth alike, WLAN was not originally designed for industrial applications and suffers from the same defections, as described in /1/. Implementation of new standards such as 802.11a or 802.11g can rapidly enhance WLAN usability in real-time considerations - the new norms introduce faster transmission technologies, but they do not bring more reliability. Another issue that might improve suitability of WLAN for industrial applications is design of a predictive controller dealing with varying delays or control algorithm that handles missing data or packet timeout /1/.

3 SYSTEM DESCRIPTION

The aim of this research is to find the use of wireless network in industrial environment. As described earlier, the main issues of industrial applications are time-critical delivery and reliability of the communication channel. For this purpose two measuring algorithms were designed, in order to detect the properties of wireless network and its suitability. Simulated models of a servomotor and a controller were running in separate industrial computers and connected via wireless network and algorithm which measures Round Trip Time (RTT) was applied. The same algorithms were proposed to use, so that results obtained from Wireless LAN solution could be transparently used for comparison to Bluetooth composition.

3.1 Systems Setup

The intended system configuration can be seen from the Figure 1. The system set-up consists of several parts, including Programmable Logical Controllers (PLC) as well as devices used for wireless transmission – Bluetooth and WLAN Access Points. The Figure also shows personal computers with software tools used for programming and network monitoring, and server necessary for booting and synchronization of the PLCs.

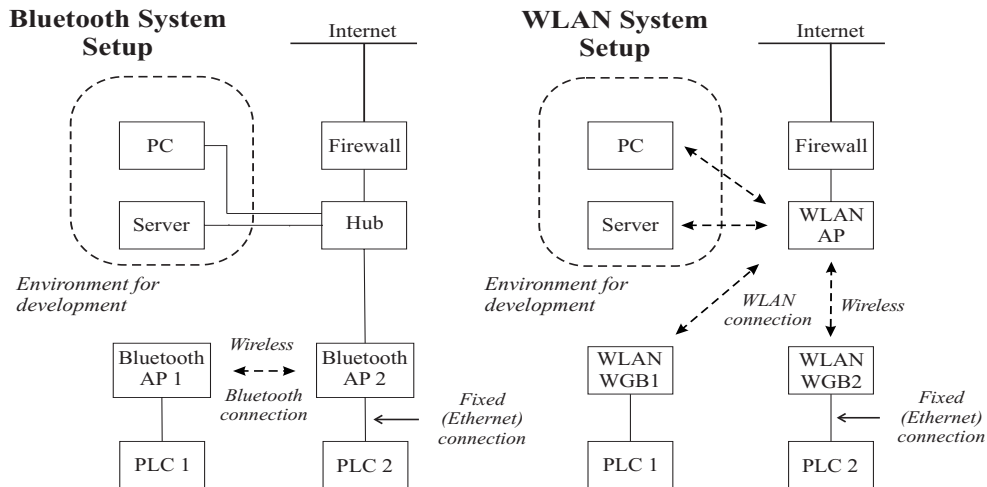


Figure 1. Bluetooth and WLAN system setup.

3.2 Controlling applications

Measurement of a Round Trip Time - the algorithm works in following manner: information of a current system time, belonging to PLC1 is copied to a packet and transmitted through the wireless network (WLAN or Bluetooth) to PLC2. After reaching PLC2, the value is sent back to PLC1 through the same way only opposite direction. Then, the received time is subtracted from the actual system time of PLC1, resulting in the RTT value. Additionally, the algorithm also calculates sent, lost and correctly delivered packets.

The necessity of designing own testing algorithm was due to complexity of the whole system, including PLCs with their own operating system. Therefore the algorithm is built-in as a standard PLC program, so that resulting time involves also the time needed for calculation of the PLC operating system.

Control algorithm – the algorithm utilized in the system handles the usual control routine according to the Figure 2. Two separate programs were designed, each of them running simultaneously in certain PLC. The first PLC acts as a discrete P or PI controller, while the second PLC is running a simulated model of a DC motor.

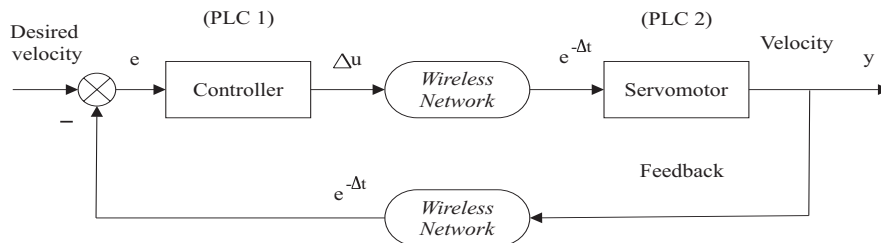


Figure 2. DC-motor controlling algorithm

It should be emphasized that all testing algorithms were intended for industrial computers. Industrial computers are supplied with very limited user interface, therefore special software programming environment is needed for program codes designing and uploading them to PLCs, as well as for on-line measurement purposes.

3.3 Hardware and Special Requirements

Programmable logical controller (PLC) is a flexible industrial computer, used in a wide range of industrial machines and application processes as well as in harsh environments where normal PC would suffer from dust, vibration and others. A PLC has typically modular construction and a wide scope of input/output modules. It consists of a computer hardware, which is programmed to simulate the operation of individual logic and sequence elements. The PLC also supports computational capabilities, necessary for evaluating the obtained results [1].

The PLC, used in this project is equipped with an Ethernet UDP/IP communication based unit; however it is not able to handle routing and other networking functions. The PLC can only communicate with devices that have certain range of IP addresses, which became a problematic issue when trying to set the communication between PLCs over the Bluetooth link. The future development of industrial computers may lead to implementation of wireless transmitters (i.e. Bluetooth) as internal plug-in units. The networking properties then might be relieved as in normal PCs.

Wireless Access Points - In order to satisfy the requirements of the research, it was needed to find devices that would offer connectivity between Wireless and Ethernet interfaces. One of the crucial criterions was the support of multicast traffic, needed for downloading the initial PLC software from the server; another problem caused bridging two different physical layers. Although two Access Points were implemented, the system could bridge the data to one interface only. In the WLAN system setup, two additional workgroup bridges were deployed.

Bluetooth Access Point used in this work is an intelligent unique application platform supplying all major mobile IP interfaces, capable of providing full IP routing services combined with NAT and DHCP client/server and firewall, but does not have satisfactory proxyARP solution. In the time of testing, the Bluetooth protocol stack supported LAN access profile only, which became together with properties of PLCs an obstacle for fully functioning communication.

4 MEASUREMENTS AND RESULTS

The measurement tests proceeded in office/laboratory room, where all devices were located on tract about 35 square meters. For WLAN system setup additional scenarios were adjusted, where one of the workgroup bridges was placed in distant room. There were usual sources of disturbance in the building, such as mobile phones, computers, other wireless access points, microwave oven and copying machines. The testing showed that the only device, which affected the wireless transmission considerably, was a microwave oven – it induced packet losses while interfering with WLAN devices [2].

The Figure 3 shows the example of measured delay distribution with WLAN different data rates. It can be seen that the most of the values are between 15 and 25 ms, which is sufficient time for considered real-time model. On the other hand, it can be seen that the measured values change in certain range, which leads to implementation of an advanced real-time control algorithm, dealing with varying delays. The graph of delay distribution also shows that when using smaller data rate, the mean value of the delay increases. The trend is expected also for Bluetooth system setup, while Bluetooth transmission speed is designed for less than 1 Mbps.

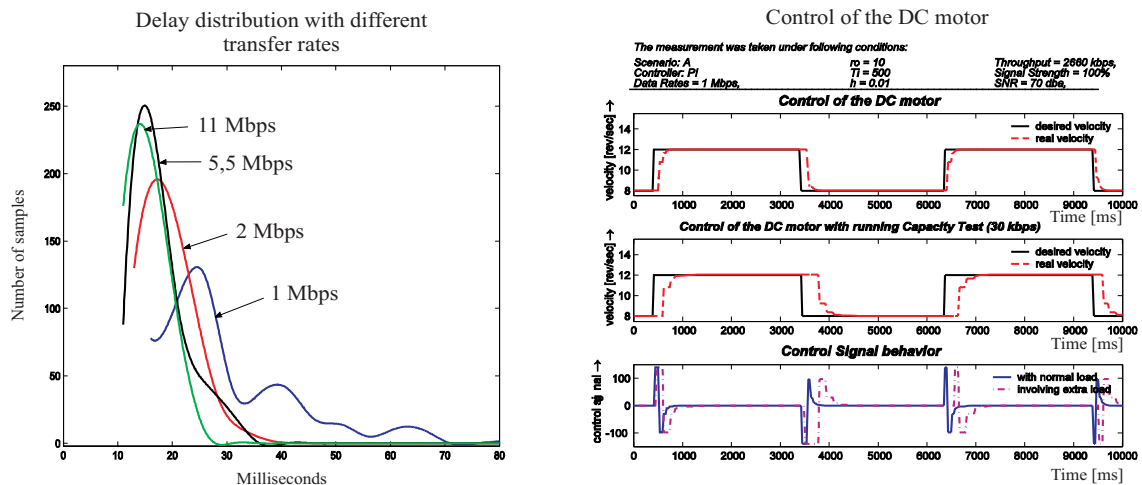


Figure 3. Delay distribution at different data-rates and DC-motor control

Figure 3 also shows the control results of simulated DC-motor application, using the 1 Mbps data rate of WLAN. For comparison the picture shows a graph with control behaviour while running capacity test (additional load going through WLAN Access Point) on the second subplot. It is clear to see that the control had slightly worse behaviour when the capacity test was running.

5 DISCUSSION AND ANALYSIS

The Bluetooth standard is technology, which was invented recently and its original use was designed mainly for mobile phones. This became a problem in the research as the industrial environment demands different properties. The complexity of the required tasks and the combination of the devices used for the measurements induced that it is not possible to accomplish all the intended measurements yet - the technological problems related to routing and bridging the packets between Bluetooth Access Points and PLCs were not solved by the date of writing this paper. According to writer's knowledge, present market does not offer Bluetooth device which could handle this "out-of-the-box" problems. Additionally, the LAN profile, which is the most expanded in Bluetooth devices nowadays, is not sufficient for the purpose of our measurements. It is necessary to deploy PAN profile, which is being released by many factories only now and promises standard LAN-like features.

The WLAN system configuration has been set tested and obtained results were treated and analysed in /1/. Only the poorly shielded microwave oven causes interference to WLAN and additional load to Access Point slows down the traffic and control.

There are many industrial environments, which can interfere with built wireless networks. Those devices include unshielded engines, electric supplies and other devices that can evoke packet losses; therefore the area of the coverage network devices has to be properly explored, whether there is no source of disturbances, which might be crucial part in i.e. factory halls.

6 CONCLUSION

A wireless system was built, implementing PLCs, Wireless Access Points and Workgroup bridges in the first and Bluetooth Access Points in the second test case. Several problems arose during the research, including Bluetooth profile complications and difficult selection of WLAN-set, which would support bridging and multicasting. A microwave oven was discovered as the biggest source of disturbance. The future work aims on challenging the communication problems related with Bluetooth Access Points and industrial computers. Another issue is the on-side testing in a real industrial environment. This could help to find new, yet unknown sources of disturbance.

7 REFERENCES

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