Real-time control for the transmission of information in wireless networks

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Abstract

Wireless networking is constantly improving, changing and though basic principle is the same. Instead of using standard cables to transmit information from one point to another (or more), it uses radio signals. This paper presents a case study considering real-time remote control using wireless UDP/IP-based networks. The aim of this work is to reduce real-time remote control system based upon a simulation model, which can operate via general communication networks, which on bodies modern wireless technology.

The first part includes a brief study of wireless communication principles as well as a short description of the current system. The second part describes measurement of the system and in addition to analysis of the test results. The conclusions which are made based upon the measured data of the system. Also, the encountered problems during the test simulations are raised up. A simulated process for the model is used instead of a real one in order to get comparable results; however, it indicates a good research tool and a basis for future work in the real-time remote control research. Also, some future development schemes of the system are discussed as well.

Keywords: UDP/IP, Wireless network, Wireless local area network, Remote real-time control

Introduction

The type of wireless network, described in this article has had many various names in the past, including terms like packet radio networks or multihop radio networks. The current commonly name used actually for a network managed by an Access Point (AP) is infrastructure network. Wireless Local Area Network (WLAN) has its standard since 1997 when IEEE released the norm 802.11. There are three popular wireless communication standards 802.11a, 802.11b and 802.11g. Wireless networks can be built by using any of the three, but each has its advantages and disadvantages.Table 1 shows the comparison between them. If you want to set up wireless network, a 802.11g standard based up on slightly higher cost but with higher bandwidth support is recommended.(1)

The purpose of Wireless Networks is to provide all features and benefits of traditional LAN technologies such as Ethernet but wirelessly. WLAN works without limitations of cabling using either infrared light (IR) or radio frequencies (RF) as a medium. Since infrared light requires the line of visibility for communication, the RF network is far more popular for its long range, higher bandwidth and wider coverage. The current WLAN technology uses the 2.4 GHz frequency band, which is the only unlicensed band in most of countries.(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. Such device could be for instance a microwave oven, an unshielded motor or other wireless appliance. (1,2)

The beginning of wireless started with Guglielmo Marconi as he began working with radio waves. In 1896, Marconi successfully obtained a patent and established the Wireless Telegraph and Signal Company, the first radio factory in the world. In 1901 the first signals were sented across the Atlantic Ocean . The military found use for this wireless technology and configured the wireless signals to send data that was heavily encrypted, making it difficult to be cracked, which proved to be especially useful during World War II for the Army and Navy . The first radio telephone network for commercial use was made available to consumers by Bell Telephone Company in the early 1950's. The problem with this network was that only a limited number of people could be on the network (3). Eventually this technology was further developed in order to support more people and to be more reliable. In 1971, researchers at the University of Hawaii developed the world's first WLAN, or Wireless Local Area Network, It was named ALOHAnet (World of Wireless Networking). In 1982, AMPS (Advanced Mobile Phone Service) system specification became the radio telephony standard of the United States. (4)

Description of the Control System

Simulated models are used in order to represent a servomotor and a controller. Each of them is simulated in a separate industrial computer and connected via wireless network. The requirement of the project is to control position as well as rotation speed of the shaft. Therefore a multivariable control has to be used. The basic scheme of the control system is depicted in figure 1.

- Description of the system set-up

This section tends to explain few terms of the current infrastructure system represented in figure 2.

- Programmable logical controller (PLC)

The programmable logical controller is a flexible industrial computer, intended for use in a wide range of industrial machines and applications of processes. 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 programming of basic math functions that can be used for simulating controllers or other processes.(5)

-Wireless Access Point (AP)

Wireless access point performs functions similar to a hub in a cable network. Moreover it works as a filter for network traffic. It usually supports roaming which enables users equipped with wireless client adapters to freely move through a building. In addition to this, it also acts like an Ethernet bridge forwarding data from wireless devices to cabled devices and vica versa. Project required many parts of the IEEE specification, unavailable in most of commercial APs. These features include: support of multicasting traffic, since the PLC needs it for communication, 11 Mbps data rate, bridging, 40 and 128 bits encryption, and roaming.(5,6)

-Wireless Workgroup Bridge (WGB)

It is a small, stand-alone unit, that provides wireless infrastructure connection for Ethernet-enabled devices. A device connected to a bridge communicates with a network infrastructure through a Wireless Access Point. The main idea of using Workgroup Bridge is to simulate WLAN-in-PLC integrated unit.

- Special hardware requirements

The first challenge was to find an Access Point that meets all requirements of the project; one of the crucial criterion was the support of multicast traffic, needed for downloading the initial PLC software from the server. After intensive testing of many Access Points, we can conclude that only Cisco Aironet 340 Series Access Point could fully satisfy all necessities.

Another problem was caused by the bridging function. As can be seen from figure 2, system requires more than one Ethernet interface. Although two Access Points were implemented, the system could bridge the data only to one interface. As a result additional workgroup bridges had to be introduced to the system.(6)

The Measurement of Wireless Performance

There are many ways of to measuring the performance of a wireless network. The two most important ones are throughput and delay. The throughput is a rate at which bits are transformed from a source to a final destination and it is measured in bits per second. The delay is defined as a time difference from the time when a bit enters the network at its source node to the time when it is correctly received at its destination node.

The delay measurement is critical especially for real-time applications such as real-time control or voice and video applications. However, real-time applications can afford to lose some packets. On the other hand, for a data transfer delay may not be so important, but accurate and complete reception is the crucial problem. The same problems of Quality of Service (QoS) known from TCP/IP networks also exist in wireless networks; furthermore, it means that the replacement of wired with wireless communication shall avoid changes in control design.(7,8)

There are some other measures such as the mean delay value or percentage of lost packets. One difficulty concerning the measurement is the analysing tool. Hence, regarding the purpose of this work to determine the network performance, an easy algorithm for measuring the delay effect was developed (figure 3).

The principle is to measure the cycle delay caused by the network properties. Each packet transmitted from PLC1to PLC2 goes from workgroup bridge 1, through access point, to workgroup bridge 2 and finally to PLC2. After reaching PLC2, the value is sent back to PLC1. This gives us sufficient opportunities to measure the time difference between the time of transmitting the packet, and the time when the same packet arrives to the PLC1 again.

Additionally, the algorithm also calculates sent, lost and correctly delivered packets. Note, that the algorithm has an internal timer, which causes the program waiting for the delayed packet for a certain time. If the timer is exceeded a lost packet is indicated.The traffic was limited to specific clients using MAC address filtering, in order to enable more reliable reference measurement. Another issue was to rule out the wireless traffic used for normal office work at our institute. (1,2,5)

Measurement Results

Measurements were held under the following conditions:

A – all devices were located inside one room on tract about 40 square meters.

B – one of the workgroup bridges was placed behind 4 walls in an other room, distant about 45meters. Although there were usual disturbances in the building, such as mobile phones, computers and other wireless access points, the influence to the measurements was very small (see figure (4)). The testing showed, that the only device, which affected the wireless transmission was a microwave oven, which caused high lost of packets; however, this can be decreased by setting the device parameters such as robustness, RTS threshold etc.

Table 2 shows the main values of the measurement under condition A and B, and with certain type of encryption. It can be seen in figure 4 that the most of the values are between 16 and 18 ms, which is sufficient time for considered real-time model. On the other hand, it is clearly seen that the measured values dramatically vary, which leads to a problematic implementation of a real-time control algorithm, especially some advanced approaches concerning varying delays should be implemented.

Analysis of Results

The purpose of this work was to develop a test suite for wireless remote real-time control studies, to get reliable time delay values of an observed sample.

According to measured results following perceptions can be discussed. Since the value of time delay fluctuates, as can be seen in figure 5, it can be declared that all results were reliable; there was no value over 38 milliseconds register and all packets were delivered. On the other hand if there is a needed to control a device, which requires consistent regulation, difficulties can be met and this oscillation should be eliminated. This will be one of the future tasks for this project. In addition, measurement of lost packets was undertaken under different conditions; therefore we may conclude that only the poorly shielded microwave oven causes some interference with the built WLAN. The implemented prototype of a wireless remote-control environment is designed to be easily transported for on-site testing to an actual industrial site and therefore it is a good base for future work.

Discussion

There are many industrial environments, which can interfere with built wireless local area network, 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 not source of disturbances.
Another challenge, which should be investigated, is the behaviour of the graph showing distribution of delays (figure 4). The most probable explanation seems that a task interval, defined in a PLC, can influence the measurement.

Conclusions

- A wireless system was built, implementing Programmable logical controllers, Wireless Access points and Workgroup bridges.
- Several problems were overcome including difficult selection of an Access point, bridging and multicasting.
- Current testing brought a lot of new ideas for future development of the project such as implementing a real-time model of a process as well as a new control algorithm dealing with varying delay.
- Another issue is the on-side testing in a real industrial environment. This could help us to find new, yet unknown sources of disturbance.

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Table (1): comparison between wireless communication standards

Types	History	Bandwidth support	Frequency band	uses
802.11b	1999	11Mbps	2.4GHz	home network
802.11a	1999	55Mbps	5 GHz	radio frequency
802.11g	2003	55Mbps	2.4GHz	Wireless network

Table(2). Measured out values (in milliseconds), timer = 100 ms

Encryption	Con.	Mean	Min	Max
NO	A	15.6	10	29
	B	16.1	11	33
40 bit	A	16.2	10	38
	B	16.6	11	38
128 bit	A	15.3	10	28
	B	16.6	10	35

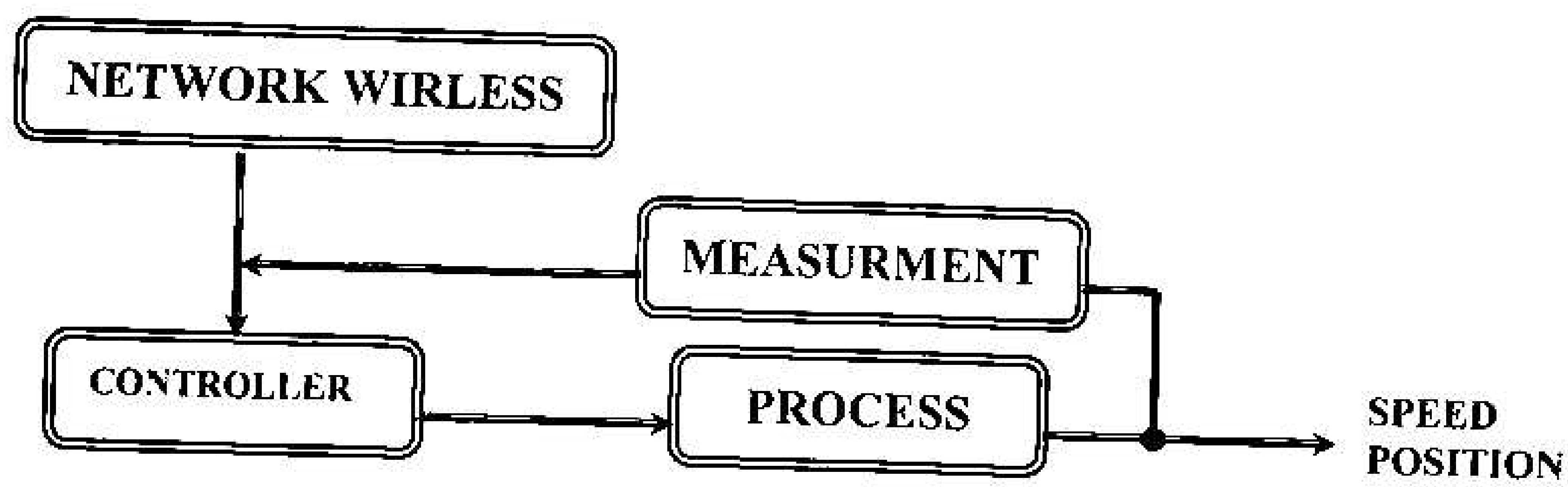


Fig (1): Control system description

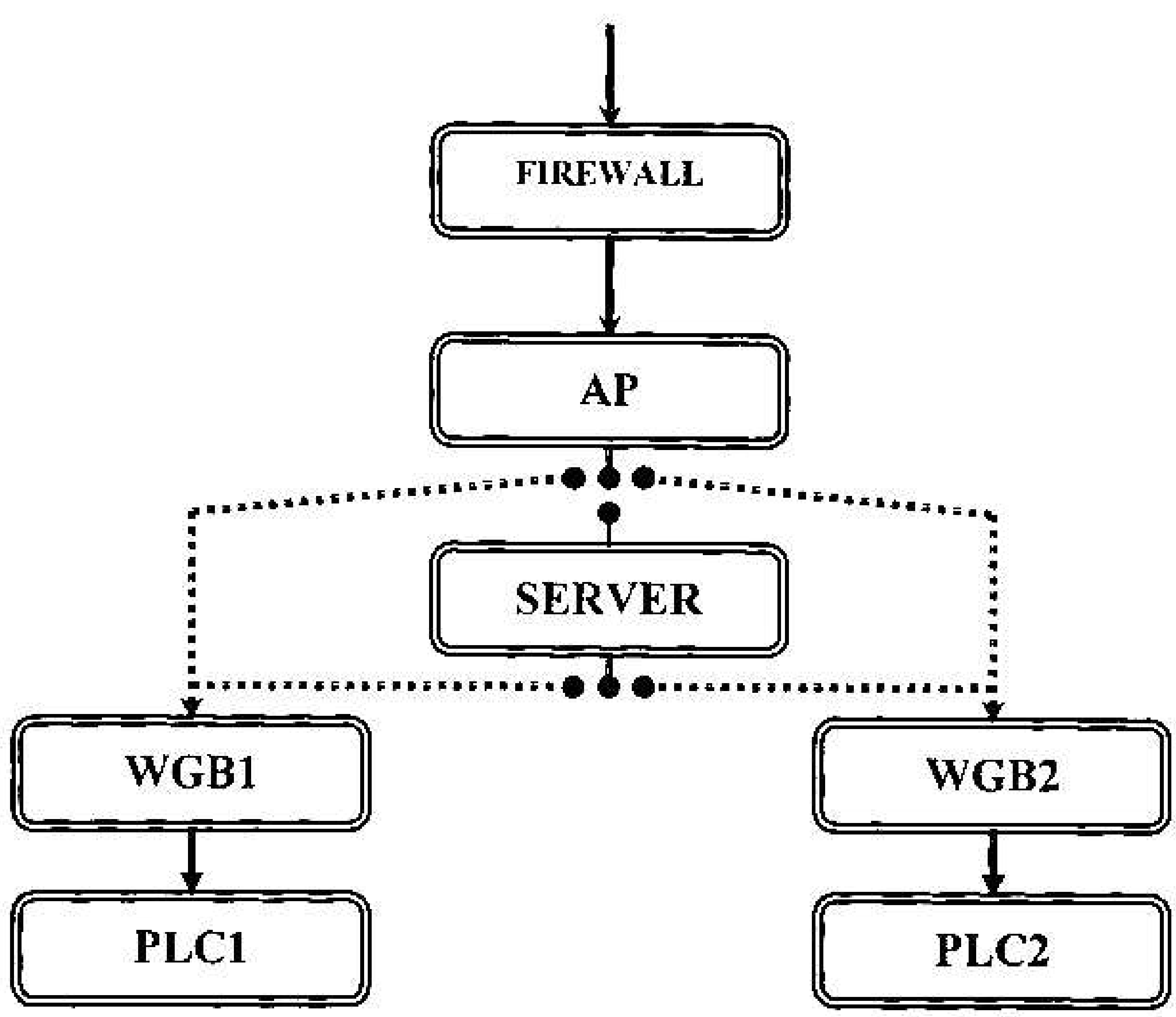


Fig (2): System Description

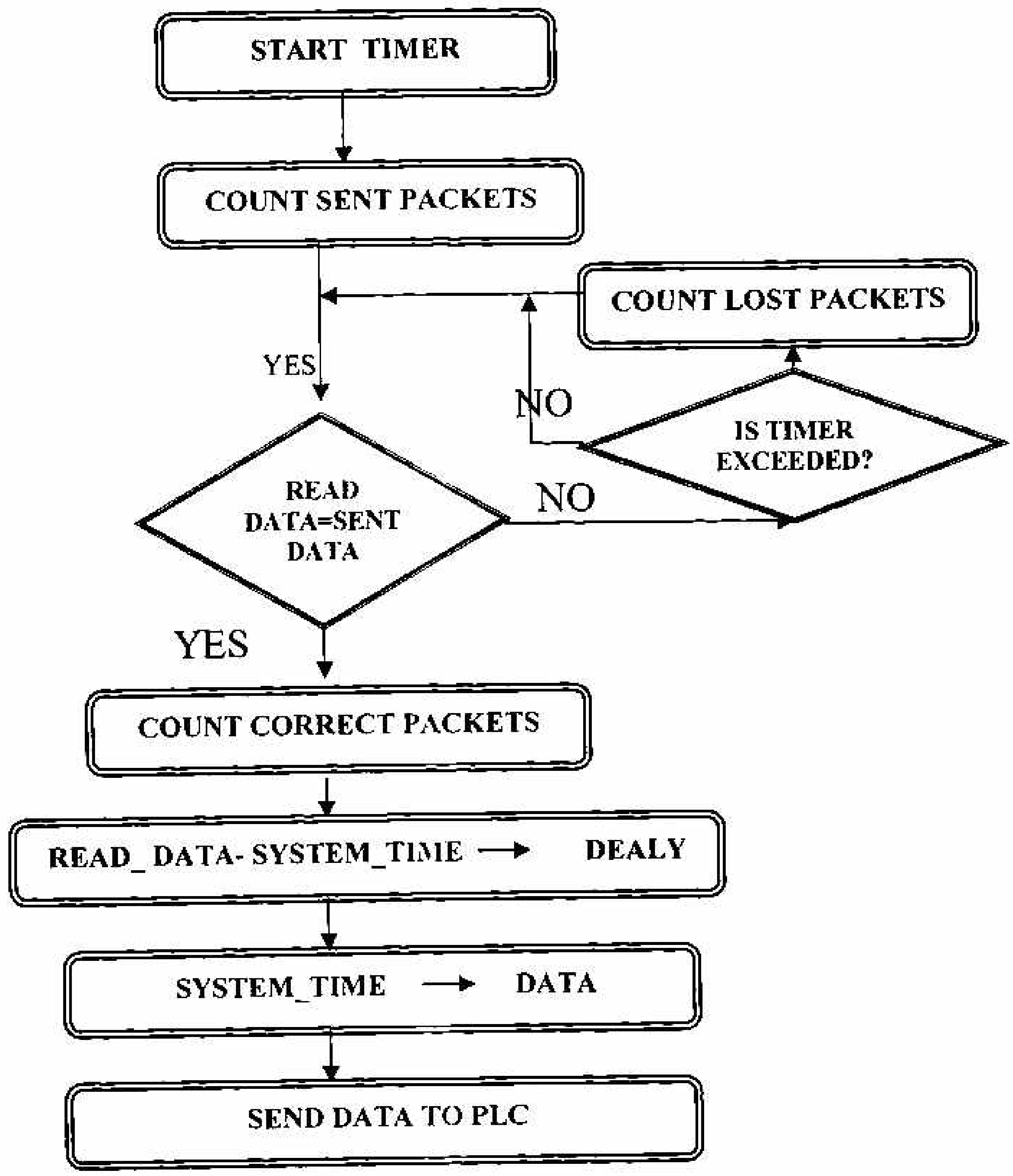


Fig (3): Flow chart of the measuring algorithm

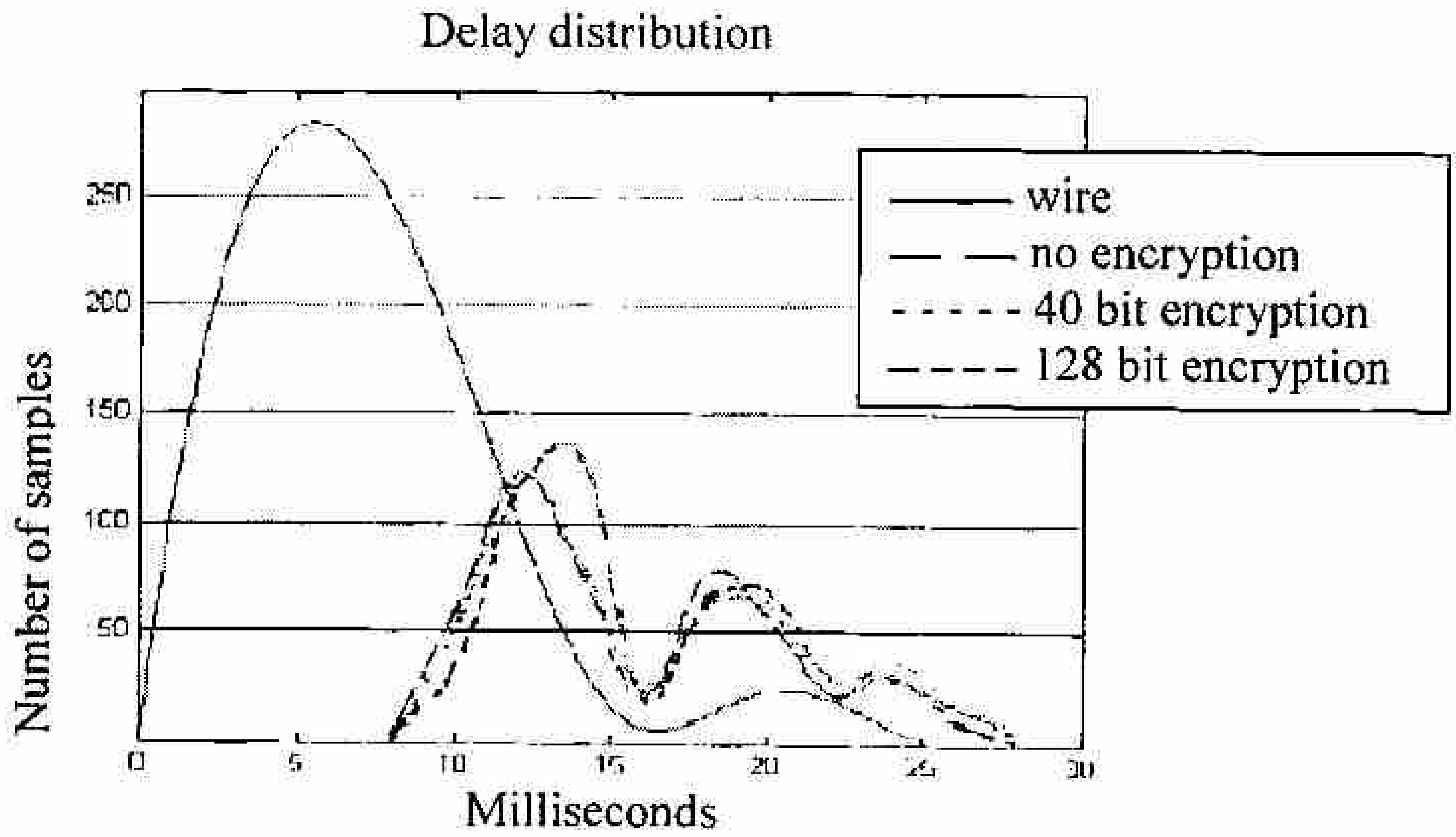
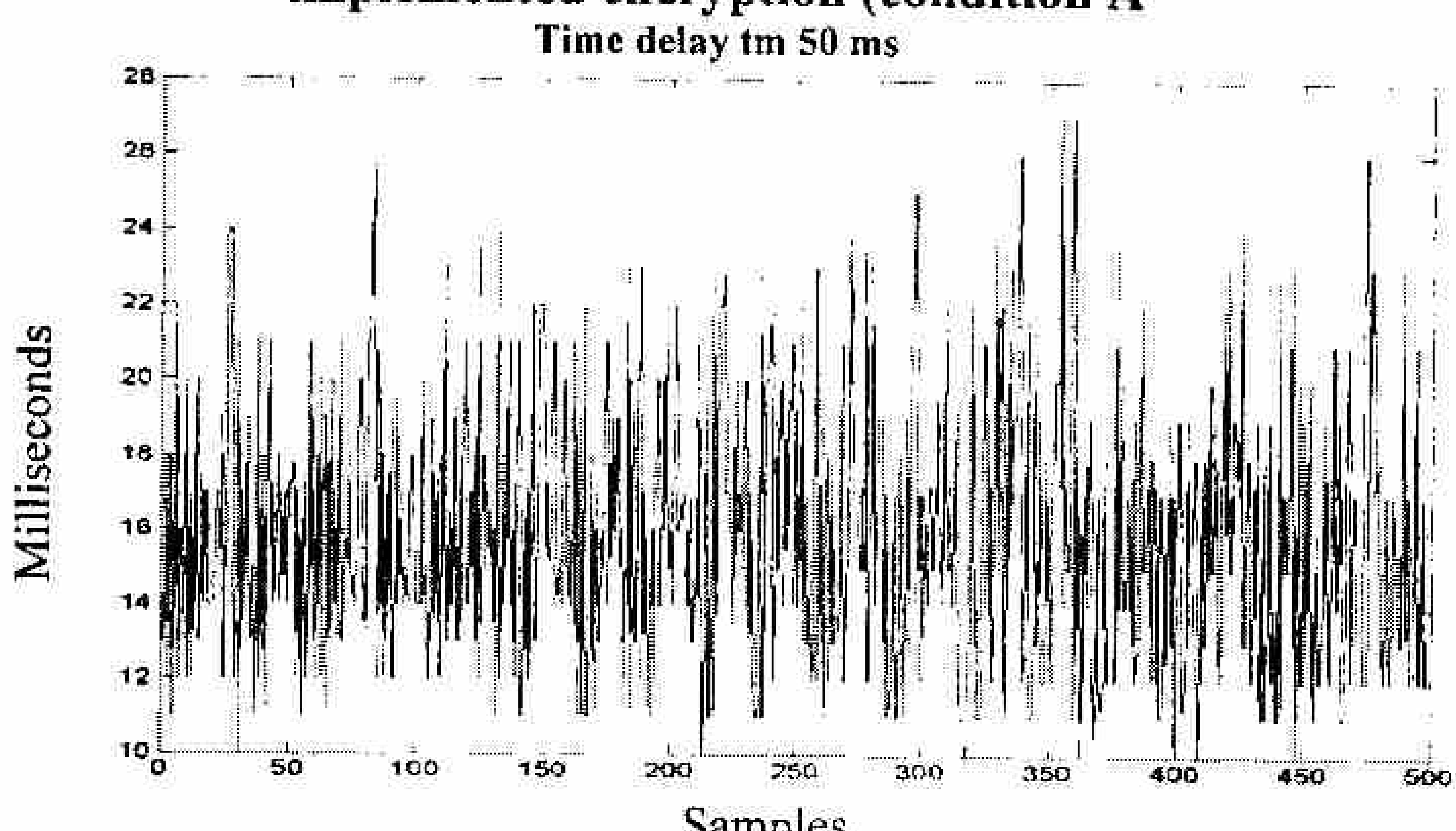


Fig (4): Example of delay distribution with and without implemented encryption (condition A



Fig(5): Example of measured

التحكم في الوقت الحقيقي لانتقال المعلومات في الشبكات اللاسلكية

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الخلاصة

الشبكات اللاسلكية تتطورُ بشكل مستمر ومتغير، وإنْ كان المبدأ الأساسي هو نفسه. فبدلاً منْ استعمال كابلاتَ قياسيةَ لإرْسال المعلوماتِ من نقطة إلى أخرى (أو أكثر)، فهي تستخدم الإشارات اللاسلكية.يقدم هذا البحث دراسة لحالة تنظر في الوقت الحقيقي للتحكم عن بعد باستخدام اللاسلكي المستند الى ربط UDP/IP. والهدف من هذا العمل هو تقليل الوقت الحقيقي للتحكم والسيطرة اعتمادا على أنموذج محاكاة، التي يمكن ان تعمل عبر شبكات الاتصالات العامة ، التي تجسد التكنولوجيا اللاسلكية الحديثة.

ويشمل الجزء الأول دراسة موجزة عن مبادئ الاتصالات اللاسلكية وكذلك وصفا موجزا للنظام الحالي. ويصف الجزء الثاني مقياس النظام فضلا" على تحليل نتائج الاختبارات. الاستنتاجات التي تتم استنادا إلى البيانات المقاسة للنظام. وأيضا ، المشاكل التي واجهتها خلال تجارب المحاكاة وما تابعها. ،عمليات المحاكاة للنموذج والتي استخدامها بدلا" من للأنموذج الحقيقي من اجل الحصول على نتائج مقارنة ومهما يكن فانها تشير إلى أداة جيدة للبحث وأساسا للعمل في المستقبل للسيطرة على الوقت الحقيقي للتحكم عن بعد. وكذلك تم مناقشة بعض خطط التنمية ألمستقبليه