# An Experimental Testbed for Using WLANs in Real-Time Applications


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## Abstract

*In this paper we describe an ongoing experiment to determine the feasibility of deploying COTS wireless technology, like IEEE 802.11b networks, in specific real-time application scenarios. Wireless networks are being used in an increasing number of applications, and the focus towards consumer markets has driven the cost down. The deployment of wireless communications is desirable for certain field devices in industrial automation and process control, where wiring might not be feasible and/or not cost-effective. Ensuring real-time performance and stability is not straightforward, however. We propose to use experimental results to determine what kind of performance can typically be expected in different scenarios, thus enabling us to make some assumptions about proper deployment of these technologies.*


## 1. Introduction

Distributed real-time systems need to deal with communications in a way that is not only reliable and stable, but also predictable within real-time constraints. In the past there was for a long time reluctance to use Ethernet in real-time applications, due to the non-deterministic bounds on packet delay in loaded networks. With the introduction of *switched* Ethernet this has changed, and today Ethernet is a popular choice in many industrial applications, because of its maturity and low cost. However, since switched ethernet inherently has a star topology in the physical layer, there may be a higher cost in cabling compared to eg fieldbus networks, which means that some of the cost-related motivation behind the use of Ethernet in field devices is lost.

Wireless network technology is an interesting choice in several areas of process control and monitoring, because of the cost or difficulty of wiring in many situations. The interconnection of mobile field devices in an industrial plant is an example of a scenario where the deployment of a wireless local area network (WLAN) would be desirable[1]. Advantages typically offered by WLANs over wired networks include mobility, flexibility in dynamic environments, and easy installation. Wireless communication networks for the consumer market have recently received much attention, and the IEEE 802.11b WLAN standard has been particularly successful in gaining popularity, thus driving the cost of equipment down.

The IEEE 802.11 medium-access control (MAC) layer defines a distributed coordination function (DCF) for best-effort asynchronous traffic, and an optional point coordination function (PCF) for supporting real-time traffic. PCF implements polling to eliminate collisions, and uses an access point (AP) for control, whereas DCF uses a protocol based on carrier sense multiple access with collision avoidance (CSMA/CA). In an implementation only DCF is mandatory, and thus the support of real-time traffic in IEEE 802.11 DCF networks has been the focus of several research efforts.

Much effort has been placed in the analysis and simulation of WLANs, and several approaches have been proposed to support mixed traffic in IEEE 802.11 by improving the MAC protocol layer ([2],[3],[4]). However, these approaches are often not available to us in the design of a distributed control system, since we have to rely on standard components provided by manufacturers and in the real-time operating system (RTOS).

To enable us to make some assumptions about the performance of wireless commercial off-the-shelf (COTS) components in a real-time application we propose to conduct a series of experiments to measure throughput and timeliness in different scenarios. By using analysis and simulations on a model of the network it is difficult to get clear results, because there are so many variables and uncertainties, eg with buffers in different protocol layers. In our opinion a good way of telling if something works, is to actually try it out.

Some other experiments conducted on IEEE 802.11b networks have mainly concentrated on best-effort throughput [5]. Another experiment on traffic over 802.11b networks is described in [6].

## 2. Experiment

In conducting the experiments we make use of COTS hardware that we have access to, and make use of our surroundings to represent different scenarios. Initial focus has been on IEEE 802.11b networks, but hopefully the same considerations can be used when experimenting with other WLAN technologies, like eg Hiperlan2[10].

### 2.1 Traffic issues

In an automated factory environment there are typically a large number of sensors, where some generate real-time data. These are sent periodically or per request to processing units over the network; this is commonly referred to as a producer-consumer problem. We will consider the real-time traffic to consist of frequent short packets, which can be transmitted across the network using eg UDP/IP.

Both one-to-one (unicast) and one-to-many (multicast) transmission between producing and consuming nodes can be considered.

### 2.2 Environment

The performance of any WLAN technology depends greatly on the environment in which it is being deployed. In the case of a weak signal the bandwidth will suffer from degradation. We will use the same experimental setup in different scenarios to reflect this issue.

The *shielded* environment consists of an underground room which is thus shielded from outside noise. The environment should prevent radio interference (much like a Faraday cage), and provide an “ideal” case for our experiments.

Experiments in the *rough* scenario are conducted in an experiment hall with a lot of electrical equipment, pipes and wiring, resembling a real industrial plant. This hostile environment should provide us with a certain degradation of the signal, similar to actual industrial use.

Finally the *office* environment provides us with some results in an open office environment, which is convenient for ongoing testing. This is also similar to the environment that is listed in the specifications of the network devices.

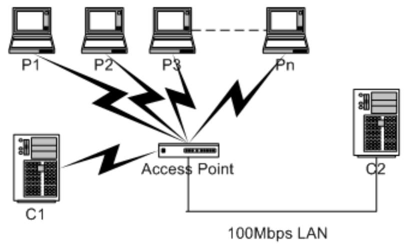


**Figure 1. Experimental Setup**

### 2.3 Experimental setup

A number of producer nodes P1, P2..Pn are set up to generate traffic meant for consumer nodes C1, C2.. By analyzing received data in the consumer nodes we can produce statistics for network throughput with varying packet size and send rate. When comparing throughput we are not so concerned with the amount of data transferred as we are with the timeliness of delivery. Packet loss because of collisions is also considered, and the wired C2 (Figure 1.) provides us with some comparison data for the wireless consumer node C1.

The 802.11b network cards used may be produced by different vendors, giving them different characteristics, and this must be accounted for. The WiFi-certification should ensure that the behaviour is somewhat similar, however.

The access points (APs) available for testing may have different features and characteristics, like eg buffer size. Using a PC to implement an AP is also possible, using Linux or similar OS with bridging capabilities. By using the PC as AP we can control the behaviour of the AP, and it is also possible to implement some prioritizing scheme in the AP for ensuring real-time QoS.

### 2.4 Synchronization issues

There is a need to measure the contributions in packet delay and latency introduced by different parts of the network, specifically the TCP/IP stack and the OS. One way of achieving this is to measure delays with the nodes connected to a high-speed (100Mbps) switched network, and assume that this network has negligible delay compared to the WLAN technology of interest.

By instrumenting the system properly we can then find the contribution from each part of the network, and thus get a separate reading on the performance of the WLAN.

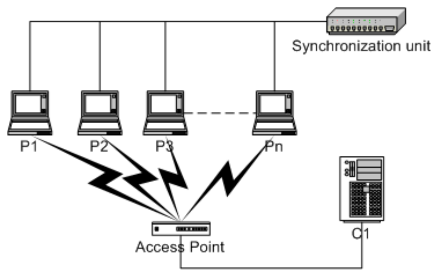


**Figure 2. Synchronization of nodes**

In order to flexibly be able to control the setup we will utilize a synchronization network consisting of I/O channels to each node (Figure 2.). This is necessary to achieve tightest possible synchronization of the nodes. An external unit can then signal each node when data should be generated and transmitted. By using a RTOS like QNX [7] we achieve improved control over the timing of the nodes, as well as minimizing delays caused by the OS.

### 2.5 Tools

The *ttcp* [8] and *NetPIPE* [9] utilities are well suited to conduct a series of tests, and can produce results to be transformed into graphical representations. NetPIPE is a particularly useful tool for visualizing network performance based on throughput and/or latencies, and it is also protocol independent, which lets us compare results with non-TCP/IP networks. A simple test using NetPIPE between two computers using 10Mbps Ethernet (a common office hub) and the same test with one of the machines (a portable computer running linux) communicating through an AP gave us a *network signature graph* as seen in Figure 3.

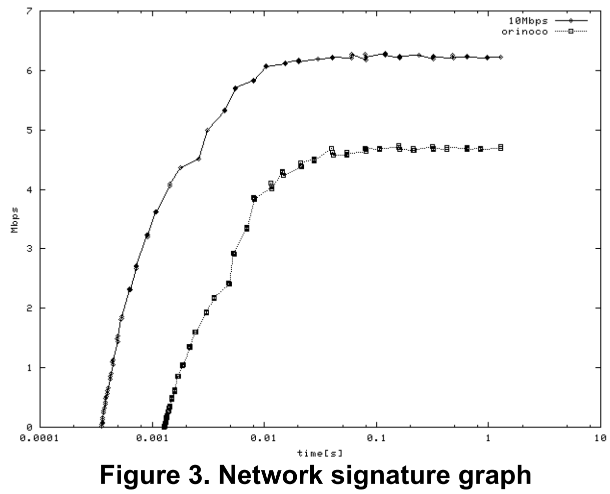


**Figure 3. Network signature graph**

From this graph we can easily read that common Ethernet has a lower latency (the first data point of each graph) and also a higher throughput than the 802.11b orinoco network. Analyzing blocksize vs throughput and timing are other options with this tool.

For conducting the tightly synchronized tests we need to write our own suite of utilities. This is necessary to gain full control over the time domain of the transmission.

## 3. Current and future work

Currently we are setting up the network for conducting the experiment, and we should hopefully see some results soon.

By using the same equipment in future experiments we will be able to compare results with other WLAN technologies, like HiperLAN2, IEEE802.11a and others.

## 4. References

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