A Test-bed for a Wireless Identification and Location System for Industrial Items

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***Abstract*—This document describes a proposal for a simple, low-cost wireless location and identification system planned to track a significant number of mobile items in an industrial scenario. There are several industrial processes which would be improved just by keeping track of path along the production and distribution chain of a processed item and its modifications. These data would feedback in its turn, the company information and logistics system. The key problems and requirements of such a system are discussed, as well as some suitable technologies. A proposal for a solution based on low-cost, simple reader/writer devices is shown. Since there are not commercial products that meet the requirements demanded, first step in research will be the development of a custom device, focusing on the design of efficient access protocols for a large number of devices simultaneously attempting to communicate**

***Index Terms*— wireless applications and services, location, identification, industrial environments, value-added services.**

I. Introduction

NOWADAYS most of location services uses complex and expensive communication infrastructure: they are usually based on GPS (Global Positioning System) or cellular communication systems [1], [2]. In both cases, cost of equipment is high, communication may be charged by telco-carriers and the user has only limited control on network operation, therefore any custom application must be tailored to its characteristics. As the offered coverage may be global, the network infrastructure required is also expensive in technical and economical terms.

Surveying industrial needs, there is a number of industrial processes, e.g. stock management, control of workers location or container identification and tracking, which would be improved by using an automated location and identification system, which, in addition, provides some extra information.

Requirements of most of these applications are not so strict: Coverage is bounded to a known area, the environment and its dynamics is defined and it is not necessary continuos availability of information. It is only needed to keep track of certain items (a worker, goods, machinery, food, etc.) when crossing strategical points, both in a production plant and in geographically spread plants, while feeding back relevant information to the management system (logistics, human resources, quality control, etc.).

In addition, most of applications in use require some activity from the item under control. In order to achieve a real automation of the system it would be desirable to demand a minimum extra activity to the item or the entity which handles it (e.g., the worker reading a barcode).

Options for implementing such a location system will be discussed in the following sections. Section 2 shows some problems related to this type of systems. A proposal for a location and identification system based on simple wireless devices is described in section 3. Next, in section 4 requirements for these devices are discussed. Section 5 surveys suitable technologies. Section 6 presents the first steps towards the development of a test-bed. Finally, section 7 concludes the paper.

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II. Problems to solve

An automated location system for industry is interesting when the number of items under control is high. But this fact gives raise to some specific problems and restrictions:

– Economical. Whereas it is feasible to install a GPS or GSM/GPRS device to a truck, it is economically non-viable deploying it on every box in a warehouse or providing it to all the employees of a factory. Besides, conventional approaches do not offer enough flexibility to adapt their particular technology to the real company/industry needs. Finally, the cost of items is usually low, and, therefore, communication devices should be cheap enough in order not to increase the cost per unit.

– Concurrence of a high number of items. Normally, the item communication device reacts to the presence of a reader device and sends information. In an industrial environment, items under control usually cross processing stages in groups (containers, trucks, etc.). Worst case then arises: All the items react simultaneously to the reader presence, which must guarantee an appropriate communication with each one (preventing simultaneous responses from interfering each other) and in a bounded time interval (the maximum time the item container will need to go through that stage).

An industrial framework is usually hostile for wireless

propagation: Noisy and prone to interference, therefore obtaining an adequate coverage in this harsh environment has to be taken into account, with some particular problems in our case:

– Distance from item to reader will be of some meters (in contrast to usual identification systems, in which the item is close to the reader device) and will be probably hindered (e.g., the reading of items inside a truck or container). It implies to increase complexity for the devices, which should be avoided in order not to increase cost.

– A wide coverage radio means, eventually, a higher number of items trying to send information, which makes worse the problem of concurrence.

III. Proposal

A proposal and preliminary study of an open, cost-effective location and identification system is made in this paper. This system is based on simple reader/recorder wireless devices, where:

- Items under control are mobile and carry low-cost wireless devices.
- Item communication devices are reactive: they react in presence of a reader/recorder device stimulus.
- Items can go through several stages within a facility as well as between geographically spread facilities. In our case, possible paths are a priori known.
- Wireless reader devices may acquire information and/or make the item device record information.

The main contributions that the depicted system must show are:

- Simple and low-cost location and identification system.
- Robust and reliable system for industrial environments.
- Scalable: In number of items, coverage area and number of facilities where there are items to control.
- Added-value services by taking advantage of incorporated technology: Thanks to added item intelligence (ability to save, send and receive information) new applications, complementary to location and identification, can be considered and developed to feed back company information systems.

The final result should be a complete automation of industrial processes.

IV. Device Requirements

There are two types of wireless devices with different requirements. Reader devices (which may be considered base stations) collect data from item-carried devices and send them commands or new information. They provide this information to the central database. Their requirements are not very demanding because their location may be fixed, they incorporate a power supply and, generally, have a high power processing.

Item-carried devices can be one of two different types: those that can only send (sender devices) data and those that can send/receive and store (sender/receiver devices) information. First ones are simpler devices, which store previously configured information and transmit it. Second ones can, in addition, gather information (e.g., by sensors) which is sent to the reader and can store data received from it.

The most restrictive requirements are imposed by sender/receiver devices:

– Low cost. The cost of the tracked product cannot be excessively increased.

– Low power consumption. An active device must have enough autonomy and lifespan to last several process and distribution cycles. Medium Access Control protocols should help to achieve this requirement [3].

– Coverage. It must be wide enough to allow a fluent communication between item-carried devices and reader without altering the product normal processing. A trade-off between low power consumption and coverage is needed.

– Intelligence and buffering capacity. Medium Access Control and communication protocols must be implemented on the devices. Furthermore, they must store information from sensors and reader devices.

– Enough data rate. Communication periods with the reader will be short (because the item must continue its process chain) and all present devices must send their information during this short time.

– Spread spectrum techniques and adequate modulations. Protection against errors (due to noise and interference) should be done at the RF stage to avoid implementing it by software.

V. Technologies

Once requirements and functional specifications have been depicted, it is necessary to evaluate the available technologies that suit the aim of this project:

–Radio Frequency Identification, RFID [4]. Commercial available equipment which may match the project requirements. A basic RFID system is made up of an antenna, a transmitter/receiver stage and a transponder, also called RF tag. The tag reacts to an external transmitter stimulus and sends back the information that it electronically stores. These systems usually are passive (no battery), light, cheap and have a virtually unlimited operational life. However their range is limited (2-5m), their storage capacity is not high, the loaded information cannot be modified and their data rate is low. There are also active RF tags (they have a battery) which are read/write devices, with considerable storage capacity. Their range is wider (up to 30m) and their data rates are higher. On the other hand, cost is also higher. Communication protocols supported by them are usually proprietary and cannot be easily modified. However, these latter devices match better the project requirements.

– Microcontroller and wireless transceiver. Integration of a microcontroller, where the intelligence and storage capacity are implemented, and a RF stage. Requirements can be met by a proper choice of the different modules.

– Bluetooth [5]. This technology allows to stablish a short-

range and high speed radio link. Its features may provide a wide variety of applications. It may be a suitable option although today's price of Bluetooth devices is not within the cost-effective requirements but it is expected to decrease in the near future.

– Wireless LAN (p.e. IEEE 802.11x) [6]. Definitively, complexity and cost of these devices do not match requirements. Nevertheless, their use may be appropriate for interconnecting reader devices to the corporate network.

VI. Firsts steps in research

Two phases are foreseen for the development of this project: development of identification and reader devices and interconnection of facilities and integration with the company information system.

A. Development of sender/receiver devices

This first stage includes the study of available identification systems and their suitability for this project. Development of custom devices is also considered.

A scenario, representative of the strictest requirements, has been proposed: devices are grouped in a truck and are read when it crosses by a fixed point where the reader is located. In this case, there will be several tens of devices attempting to simultaneously answer the reader. In addition, it must be guaranteed that, during the transit time through the coverage area, each device can be identified and send its stored information. Finally, coverage area must be wide enough to allow communication between items and reader.

A commercial device has been studied. It is a RFID system from Sokymat [7]. These devices meet the requirements regarding cost and coverage area, with a range around 30 m.

However, they cannot handle simultaneous access of a high number of devices, because the Medium Access Control protocol implemented is too simple.

Therefore, our research is addressed to the development of a custom device, with special emphasis on the design of a proper Medium Access Control protocol. For this purpose, a device quite similar to the tested commercial tag has been selected. It consists of a 8051 microcontroller with an integrated RF stage [8]. Its technical characteristics are: it operates at 868 MHz, it has a 4 Kbytes memory capacity and reduced cost. Data rate can be up to 76 Kbps, it includes a DES (Data Encryption System) cipher module and the microcontroller is totally programmable.

B. Medium Access Control protocol alternatives

Using a microcontroller in the RF tag provides some intelligence and improves flexibility of communication protocols. The aim is a protocol which lets the reader reliably know all present tags and permits to poll them in a bounded time interval.

In general, communication with the reader will be the as follows: The tag is in a stand-by (low-consumption) mode for some time interval. This time can be configured. At the end of this time interval, the tag senses the channel for another time interval, waiting for a frame. If a broadcast frame is received, it answers it in order to communicate its presence. Otherwise, it only answers frames addressed to it.

From this point, two approaches are being considered:

– The design of an efficient Medium Access Control protocol for a high number of tags.

– The design of a master tag selection protocol.

There are several options for the first case [9]-[11]. A classical approach can be: switching to slotted time after the reception of a broadcast frame and generation of a random number to choose the slot to answer. This protocol is called framed slotted ALOHA [12]. Load can be balanced by indicating the number of available slots in the broadcast frame. The reader can increase the number of available slots in the following broadcast on the basis of received responses. If a DES module is available another approach can be used: reader can send ciphered broadcast frames. This way, only subsets of tags that are able to decipher the frame will answer, decreasing the number of simultaneous responses.

In the second alternative, the aim is that only certain tags may answer the broadcast frames. These master tags will send the reader a list of tags identifiers (ID) in their proximity. To achieve it, a distributed master tag (in charge of storing tags ID) selection protocol must be developed. A typical approach would be the exchange of ID frames between tags. The tag with a lower (higher) ID will be the master tag. This approach have a higher cost in terms of battery life, as the consumption will be higher.

In any case, a basic task is to assure that all present tags have been polled.

C. Company systems integration

Next step after developing communication protocols and equipment is integration between information of items under control and enterprise computer and logistics systems.

The scenario is as follows: there are several reader devices spread both in a production plant and in geographically distributed production plants. These devices collect information from the items as they pass by the readers. With this information a trace of a the path followed by the product, the transformations it has suffered, and the environmental characteristics (e.g., temperature) can be generated.

The function of reader devices is just to send information to central database, where it will be processed. Central control will then decide the later action of reader devices. That is, it will provide instructions to reader devices regarding commands or data to be sent to mobile devices.

There are two interconnection levels in this scheme: interconnection of devices in the same plant and plant network, and interconnection of devices and central control.

WLAN is expected to be used by the devices in the same plant, when wired connections are not possible, or even in any case. This choice has clear advantages: network configuration is given flexibility, network extension is simpler, installation and wiring problems (specially pronounced in industrial environments) and costs are cut down, and data rates are

higher. However, most of industrial environments are very noisy and plenty of electromagnetic interference, which causes severe problems to these technologies.

Connection among distant facilities will be made by public networks and Internet Service Providers, unless the company has its own infrastructure.

The problem of time intervals in which information is available also arises at this level. In general, the item under control is in movement and the reader must collect the information and if necessary, send it to the central control, during the time interval needed to cross the reader coverage area. If central control decides an action must be taken on the item, the reader should have the instructions for the item during that time interval. This is a complex problem, since quality of service for the reader-control connection is necessary to guarantee timing constraints. Even though, the reader must be at least able to handle item information and answer it properly in a bounded time interval, either by its own initiative or as a result of central control commands.

VII. Conclusion

In this paper a common industrial problem has been discussed: The need for a simple and cost-effective location and identification system, which provides basic functionality without using too complex and expensive technologies. Many industrial processes may be improved just by keeping track of product path and the modifications suffered either by it or by environmental conditions. A system made up of simple wireless devices can automate these tasks, resulting in a proper solution for this problem and opening the way for new added-value services.

A location and identification system based on low cost and complexity wireless devices has been proposed.

Problems and requirements of such a system have been reviewed as well as some suitable technologies.

Finally, first steps towards the study and development of this system have been shown. A commercial product has been tested and discarded because of its poor Medium Access Control protocol, unable to handle a high number of device responses, a demanding constraint for this system. Next step is the development of a custom prototype, with emphasis on designing of Medium Access Control protocols which can handle concurrent access of a high number of devices in a bounded time interval. Some design alternatives have also been discussed. A second phase of development will be the interconnection of geographically spread facilities and the integration with legacy enterprise information systems.

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