Enhancing Sensor Network Capabilities through a Cost-Effective RFID Tag for Sensor Data Transmission

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Abstract. The use of Radio Frequency Identification (RFID) technology for the automatic transmission of physical parameters in wireless sensor networks, could undoubtedly pave the way to a large class of attractive applications, ranging from healthcare, automotive, diagnostic systems, robotics and many others. Nevertheless, although some RFID tags capable to transmit sensor-like information are already on the market, only a restrict number of sensors, such as those for temperature or pressure measurement, can be easily miniaturized and embedded in the RFID chip. The integration of more complex sensors, in fact, appears to be complicated and extremely expensive. In this paper, a cost-effective general-purpose multi-ID tag is proposed. It can be connected to generic sensors, and is capable to transmit a proper combination of ID codes depending on the actual value at its input. Such a tag represents the natural evolution of standard RFID technology: neither the digital design nor the cost of the tag is substantially modified.

1 Introduction

The use of Radio Frequency Identification (RFID) tags as elementary nodes of a wireless sensor network is not new [1,2]. RFID technology, in fact, allow the easy building of very dense networks with no-power consumption nodes and at a reasonable cost, not comparable with that of other technologies. However, in most of the related applications, the sensor network is basically used to extend the working range of the RFID systems, by collecting the ID-codes and other static information from the nodes and by sending such data to the processing center.

Different kinds of sensor networks, instead, use more sophisticated and expensive wireless sensors as nodes. The exchanged information, hence, will be the actually measured values from the spatially distributed sensors. Such networks consent to afford more challenging issues where the cooperative monitoring of physical parameters (including hostile environments to humans) is critical; environmental monitoring, target localization, automatic diagnostic systems, surveillance, fire detection, are only a few of the possible examples [3,4]. Nevertheless, oppositely from the RFID case, the wireless interface for the sensors strongly impacts upon the costs, thus limiting the diffusion of such networks. Many different wireless technologies, in fact, are mature for the transmission of data measured by generic sensors, much more than the inex-

Catarinucci L., Tarricone L., Colella R. and Esposito A. (2008).
Enhancing Sensor Network Capabilities through a Cost-Effective RFID Tag for Sensor Data Transmission.
In *Proceedings of the 2nd International Workshop on RFID Technology - Concepts, Applications, Challenges*, pages 175-180
DOI: 10.5220/0001742101750180

pensive RFID. Compared with RFID, for instance, Wi-fi, Bluetooth, GPRS, UMTS, GSM are capable of guaranteeing wider transmission distances, higher bit-rates as well as larger amount of exchangeable data.
Unluckily the benefit/cost ratio of such technologies is not always appropriate for the addressed applications. For example, when a capillary diffusion of physical sources is needed it cannot be leaved out of consideration, thus imposing the choice of a cost-saving wireless technology. Moreover, the possibility to be easily interfaced with Internet could be another added value.
On such basis, the integration of wireless sensor networks with RFID-based sensor systems appears to be the most practicable way. It is worth mentioning that some UHF RFID tags with embedded sensors of temperature and of pressure are already available on the market [5] and that they are inexpensive and rather accurate. Nevertheless, different kinds of more complex sensors cannot be easily integrated, so that a general purpose solution would be attractive. Ultra High Frequency (UHF) RFID technology, in fact, is quite inexpensive (passive RFID tags are as cheap as few euro-cents), is naturally compatible with Internet [6] and it guarantees a reading range which is adequate for many applications. In order to give the reader a better idea of the potential impact of RFID-based data transmission technology, the significant problem of the remote healthcare [7] could be taken as an example. In such a sensor network, some critical physiological parameters of patients are continuatively monitored, and the elaborated collected data are available in real time through Internet, allowing de-facto the remote assistance. As apparent from Fig. 1, a large number of different kinds of wireless sensors is necessary (oxygen saturation, temperature,

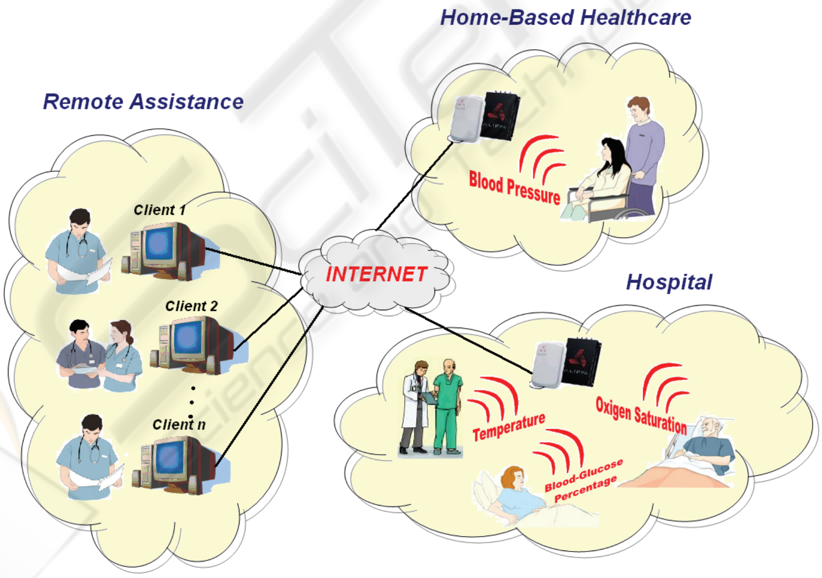

Fig. 1. A realistic scenario where RFID-based sensors could be applied. The monitored physiological parameters of each patient, wherever he/she is (at home, at workplace, in hospital), are transmitted through a cost-effective RFID-based technology and, once decoded, sent through Internet to the remote assistance centers.

blood pressure, etc.) depending on the patient number and pathologies. Moreover, the indoor environment assures short wireless distances (a few meters) to be covered. In this work, hence, a cost-effective UHF Sensor-Tag (S-Tag), capable to be connected to a generic sensor and to transmit towards the RFID reader the measured parameters, is presented. Such a tag, schematically represented in Fig. 2, samples the value measured by the sensor and transmits in real-time a combination of different ID codes; each combination corresponds to a different level, so that the quantized waveform of the input will be received by a standard RFID reader.

The paper is structured as follows: in section II the working principle and the prototype design of the S-Tag will be presented. In Section III, the results related to the application of the S-Tag to a temperature sensor will be discussed, and finally in Section IV conclusions will be drawn.

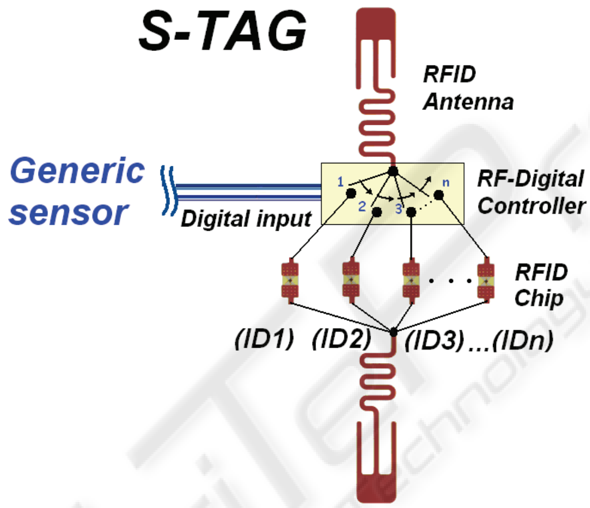

Fig. 2. A simplified scheme of the designed RFID sensor tag. The value measured by a generic sensor is used in input, and its quantized version is transmitted by means of a proper set of IDs.

2 RFID Sensor Tag Design

In this section we describe the architecture of the proposed S-Tag in the UHF range (865-870 MHz). Such a tag takes advantages from the standard RFID technology, maintaining most of its peculiarities. This allows to maintain the compatibility with all devices already available and worldwide standardized [6].

As already mentioned, the working principle of the proposed S-Tag is as simple as effective. Indeed it allows the transmission to the reader not only of its own ID (as in traditional RFID systems) but also of further information corresponding to a coded version of the data generated by the generic sensor the S-Tag is attached to.

More specifically, from the mere point of view of the implementation, the most important thing is the realization of a system able to associate a different ID code to each informative “bit” of the quantized real-time value in input. A certain number of

IDs, hence, is mandatory, in order to effectively transmit the measured value. This is done in a non-direct way, without modifying the RFID internal logic.

Such a theoretical approach, here generically called “multi-ID”, can be practically implemented by following at least two different strategies: on one side the “multi-chip” tags strategy, with RFID tags consisting of only one antenna and many chips, each one with its own ID code (see Fig. 2). On the other, the “multi-tag” strategy, where each ID is transmitted with a different tag controlled by appropriate RF integrated switches. Both of them have been realized and tested by the authors. Even though some interesting differences could be discussed, for the sake of brevity we omit here any further detail and we indifferently refer in the following to multi-ID S-Tag, regardless to the actually implemented strategy.

In Figure 2, for instance, the data measured from a sensor is used to control the integrated RF switches which select the appropriate IDs to be transmitted. Actually, the S-Tag being a general-purpose device, the sensor signal must be preventively quantized through an ad-hoc circuit embedded in the S-Tag. Of course, the number n of bits used for the quantization must be equal to the number of IDs. It is evident that 2^n-1 different configurations are admissible, so that n must be accurately chosen depending on the desired accuracy.

In Fig. 3, the illustrative scheme of the realized S-Tag is sketched. The circuit represents a 4-tag RFID transponder that allows 15 ON/OFF tag combinations (2^4-1, one of them being not allowed) corresponding to 15 different sensor parameter values. In particular, the four tags we used belong to the family Gen 2 Squiggle™ ALN-9540 EPC Class 1 (860-960 MHz). Each tag is activated/de-activated by high frequency switches, operating with 2 switching pins controlled by 4 pins of a CMOS integrated circuit. All four inverters are then controlled by a 6-pin connector, that is directly connected to the external sensor system. This is composed of a sensor circuit with a digital output (e.g. a temperature probe) and a control software that has been implemented *ad hoc* for this application.

3 Results

In order to test the proposed S-Tag in a practical application, the case of the remote-healthcare previously introduced in Section I and represented in Fig. 1, is considered. More specifically, the body-temperature of a patient is remotely monitored through a temperature probe (a thermometer) connected to the S-Tag (tagged patient). It is worth highlighting, though, that for the sake of brevity, reported results are focused only to temperature detection, but there is no restriction neither in the number of sensors, nor in the sensor typology. Details related to other parameters (such as pressure, pH) will be given in the oral presentation. In Fig. 4 some results showing the time variations of temperature in correspondence of an ideal situation (for clarity purposes, temperature has been varied faster than reality, the temperature of a patient being supposed to normally vary much slower) are graphed. Provided that the model seems to respond in a very good way to the fast temperature variations, this is no doubt true also in the slower case. Here, the RFID reader is supposed to be at different distances from the tagged patient and temperature variations are imposed by an artificial external source. Fig. 4 refers to three different distances, namely 1.5 m (Fig. 4a), 2.0 m (Fig.4b) and 2.5 m (Fig.4c). Results show the accuracy of our model to detect temperature by using RFID-based wireless technology. It should be also noted that at higher distances from the reader the signal tends to present some spikes, but they can be easily treatable through elementary software filters.

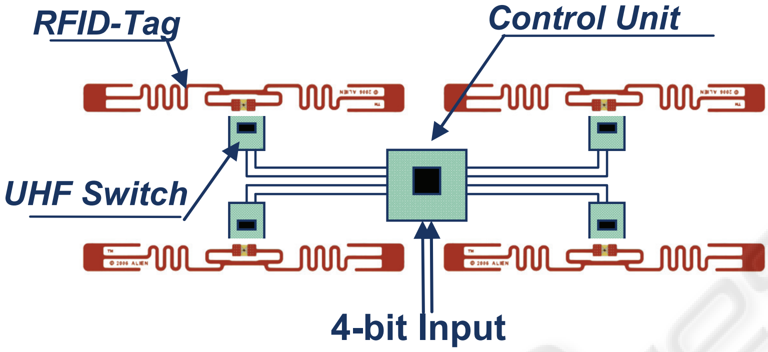

Fig. 3. Illustrative scheme of the implemented S-Tag.

4 Conclusions

In this paper, a novel general-purpose multi-ID and cost-effective RFID Tag (S-Tag) for sensor data transmission, has been presented. When connected to the digital output of any sensor, the S-Tag will transmit the measured value by using the standard low cost RFID technology. The application to the body-temperature monitoring of a patient has been presented, showing a perfect accordance between the values actually measured and those received by the RFID reader. The very low cost of the solution, the compatibility with traditional RFID technology as well as its easy interfacing to generic sensors, make the S-Tag a good candidate for enhancing RFID-based wireless sensor network capabilities. The eventual presence of spikes due to momentary lapses of the signal can be avoided by elementary filtering procedures.

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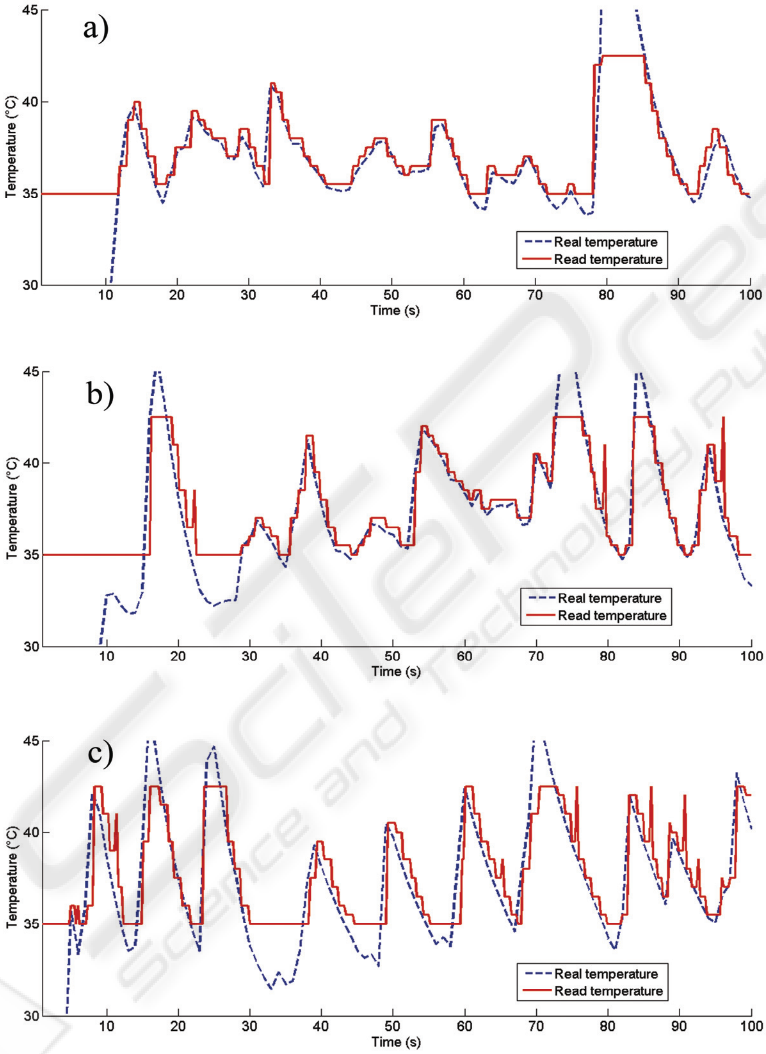

Fig. 4. Temperature variations in °C versus time of a tagged patient. Three different patient-reader distances have been reported: a) 1.5 meters; b) 2 meters; c) 2.5 meters.