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Custom Active RFId Solution for Children Tracking and Identifying in a Resuscitation Ward.

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***Abstract*—In this work is discussed an active RFId system to track and identify patients in a children's critical care ward. The technical solutions may be very different according to the patients type, age and cognitive conditions and according to the hospital shapes. The proposed system to track and identify patients has been developed taking into account all the constraints induced by the particular environment. The system is composed of five different hardware devices and a tracking software, purposely designed and realized.**

I. Introduction

PATIENTS tracking inside hospitals is a true challenge for bioengineers. The technical solutions may be very different according to the patients type, age and cognitive conditions and according to the hospital building types and shapes. A hospital with separate pavilions requires solutions that may be very different from multilevel monoblock buildings. Similarly, in designing a tracking solution for non cooperative patients, you will face requirements very different from surgical patients or newborns.

Furthermore, if the system must also be used to trace the healthcare tasks like drugs administrations and Electronic Medical Record (EMR) updates, it will have to deal with many other requirements such as the drugs inventory system, the identification of caregivers, the interface with the HIS, the regulatory and privacy constrains. Indeed, the system specifications must be a direct descendant of an accurate design process modelling all the constrains making use of process engineering methods. [1]

This work will discuss the realization of an active RFId system to track and identify the patients of a children's resuscitation ward.

They are all patients with no cognitive abilities and a wide range of variability in age, weight and dimensions (from newborns to overweight children). These patients are often tricky to be identified by caregivers: they could have no alive parents at all; newborns are often similar one to another; senseless patients simply cannot tell you their name, etc.

These patients are frequently moved to other departments inside the hospital for diagnostic tests, surgeries or ward transfers. This raises the risk of rooms misplacement when they come back to the Intensive Care Unit (ICU).

The proposed solution is based on an hardware/software active RFId architecture that identifies ward rooms, cradles/beds and patients with unique ID numbers. It also traces the movements of the patients giving warnings and alerts to the nurses in case of dangerous situations.

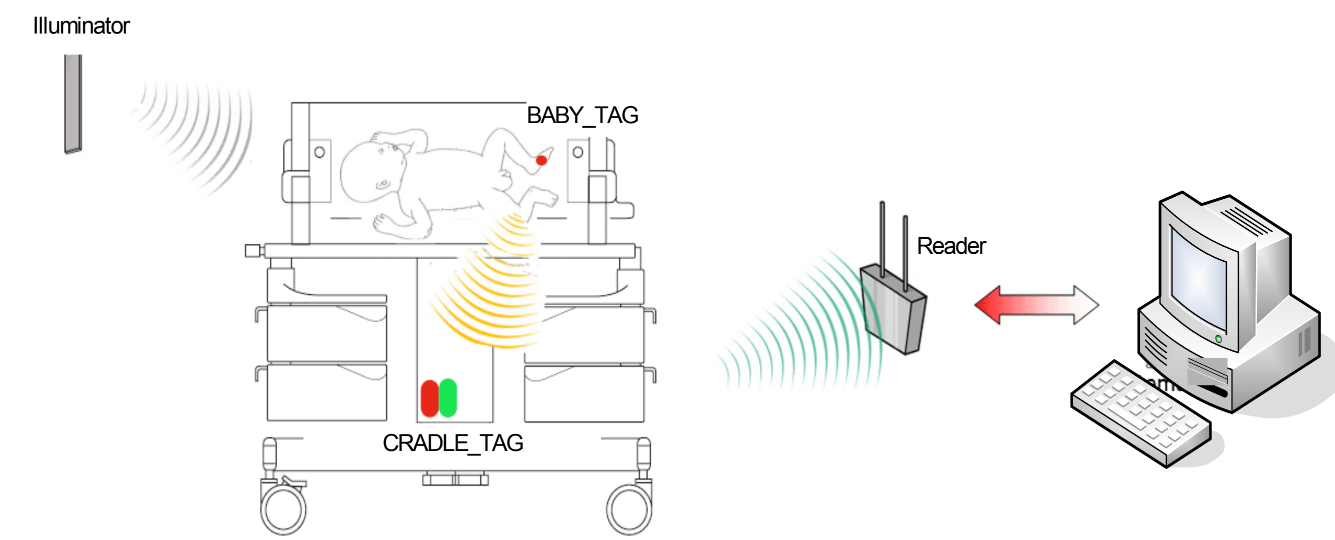

Fig. 1 The active RFId system

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II. RFID SYSTEM

The proposed system has been developed taking into account all the constraints induced by the particular environment. Children in an Intensive Care Unit (ICU) are always in bed, but they can often be moved in a new bed for many reasons (cleaning up, going out, coming from thermal cradle, etc.). They are sometimes not well recognizable one from another, therefore we must reduce as much as possible the removing of their identifying RFId tags (see below). They can be very weak, small and delicate, hence we must be aware of it in designing the tag case.

The system is composed of five different hardware devices and a tracking software, purposely designed and realized in collaboration with Advanced Microwave Engineering (www.ameol.it). [2]

A. *Reader*

This is the only standard device. It is an LX 2002 433 MHz receiver from Advanced Microwave Engineering (www.ameol.it) provided with an omnidirectional monopole antenna. The signal received from the CRADLE_TAG (see below) is joined with the internal date and time and then put on the net using an Ethernet or IEEE 802.11g wireless interface. [2]

B. *Illuminator*

It provides a programmable ID code (the information on the spatial position) and a few more setting commands that are used for programming the operation mode of the CRADLE_TAG entering in the field pattern of the Illuminator; it is obtained from a commercial unit AME LX2101 [2], changing the antenna and modifying the firmware. It consists of a 2.45 MHz PLL oscillator cascaded with an OOK modulator and a medium power MMIC amplifier. It is attached to the ceiling inside the area you want to outline (room, corridor, nurse space, exits etc.) and it is used to create a confined area underneath itself, in which a tag, provided with a 2.45 GHz receiving section, can receive the Illuminator's ID and some more information that you can set via software.

To narrow the area covered by the Illuminator, obtaining a good separation between two adjoining rooms, we introduced an uniform linear array of eight planar patch antennas. The radiation pattern of this antenna has about 30 degrees –8 dB angular aperture. Circular polarization is employed because the orientation of the CRADLE_TAG, that uses a linear polarized antenna, could vary depending on how it is fixed to the bed.

Placing two Illuminators on a line we obtain a well defined "dark zone" where there is no signal: we could use this zone to discriminate two different areas in an open-plan ICU environment or, simply, two adjoining rooms.

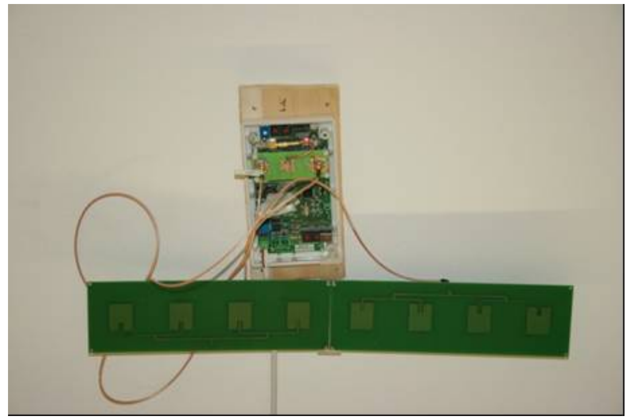

Fig. 2 The Illuminator and the array antenna

C. *CRADLE_TAG*

It is the bedside tag unit to be fixed on the bed/cradle side. It gives a link between the BABY_TAG and the system (Readers and Illuminators). The unit is battery powered to be easily mounted on hospital beds or cradles. This unit actually works as a bridge between the BABY_TAG and the environment since the system is thought to let the children be moved in a new bed or cradle whenever it is needed. It incorporates four sections:

- a 433 MHz receiver to get Baby-ID from the BABY_TAG;
- a 2.45 GHz receiver to get the Illuminator ID (used to spot the spatial area in which the cradle is placed);
- a 433 MHz transmitter to send to the Reader unit a string containing Baby-ID, Illuminator-ID and Cradle-ID;
- a passive RFId reader capable of reading passive RFId tags compatible to ISO15693 standard using a frequency range of 13.56 MHz ± 7KHz (to date in progress).
-

Fig. 3 The CRADLE_TAG

D. *BABY_TAG*

Small, active (battery powered) patient tag fixed underneath the child foot. It can transmit a Patient-ID code to the CRADLE_TAG using a 433 MHz centred band. The device has on board, in addition to a microcontroller, a 3V CR2032 battery, an external 433 MHz transmitting loop antenna and a miniaturized 2.45 GHz receiving antenna. The receiving section is used to program the unit using an Activator (see below) during the admission of the patient to the ICU. The BABY_TAG could also incorporate a passive RFId tag with the same Patient-ID. This lets the caregivers accurately identify the patient when administering drugs or treatments, even in wards not covered by the active infrastructure.

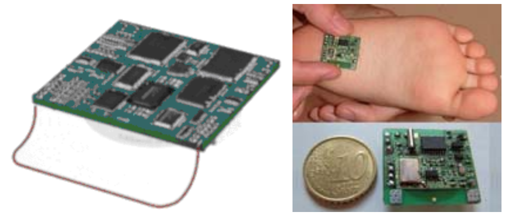

Fig. 4 The BABY_TAG

E. Activator

It consists of a standard portable Illuminator (see above). The only differences are the antenna (a small single patch model) and the ID number: every activator ID starts with '99'. This device is used to initialize the BABY_TAG once fixed to the patient. It also lets the tracking software to link the Patient-ID to the actual patient identity and EPR.

F. Software

A custom software has been developed to implement every step of the identification and tracking process, from the admission of the baby to the ICU, to his discharge from hospital. The software gets UDP packets coming from the Reader unit via Ethernet or wireless LAN and monitors the ward searching for anomalies like room swaps, empty cradles or beds, empty rooms, etc. It is provided with a graphical interface showing the ward map and can log every warning or alarm coming from possible danger situations (see fig. 5). The software is supplied with a "track mode" that is able to find and follow a single patient moving from his room to a surgical block or a diagnostics department covered by the active RFId infrastructure.

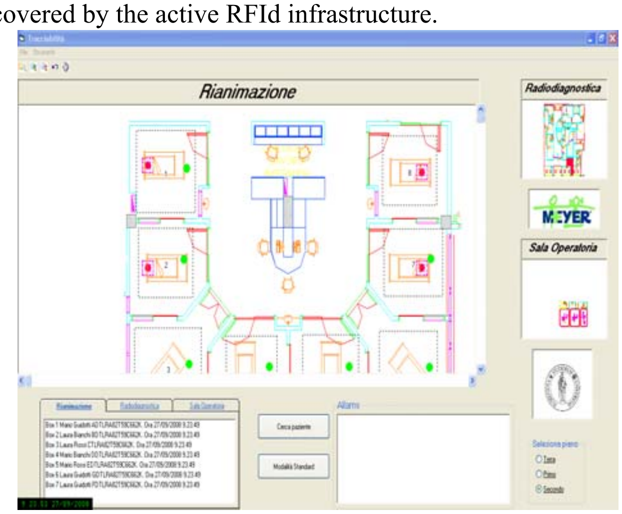

Fig. 5 The tracking software

III. TEST METHODS

We arranged a laboratory test environment in order to replicate and test the real use conditions as much as possible. The whole system has been tested to assess the BABY_TAG to CRADLE_TAG link and the CRADLE_TAG to Illuminator link. Two Illuminators have been fixed to the ceiling at a distance of 4 meters one from the other. The test environmental conditions were a bit worst than the real conditions because in both the test sites we did not have any physical separation between two adjoining 'rooms'; in fact the walls can help in differentiate the field cones of two neighbouring Illuminators. The test procedure are as follows.

A. CRADLE_TAG to Illuminator link test

The CRADLE_TAG is placed upon a holder at about 0.5m from the floor. The test area is divided in small subareas 0.5m wide. For each of these 'cells' we analyzed the strings sent by the CRADLE_TAG to the Reader, received via UDP by a simple terminal software. We started from the most critical positions and performed some tunings at the Illuminators' antenna output power.

Then we mapped the whole environment cell by cell and wrote down the results using a spreadsheet and some colour codes:

- Green = three Illuminator1-IDs one after the other
- Orange = three Illuminator2-IDs one after the other
- Black = no Illuminator-IDs in two messages out of five

We found no interference zones (no Illuminator2-ID in room 1 or vice versa), confirming the optimal separation given by the 8-patch linear antennas. Some 'black' cells were spotted, poorly covered by the Illuminator field cone, in lateral positions. Nevertheless the fully covered area is wide enough to allow a simple placement of the illuminator on the ceiling above the bed (see fig. 6).

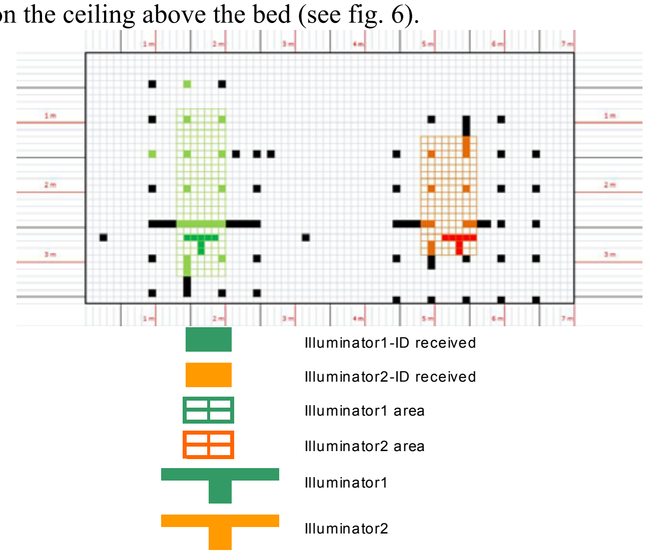

Fig. 6 Map of the coverage in the test environment

B. BABY_TAG to CRADLE_TAG link test

It is crucial that the CRADLE_TAG receiving antenna power is well regulated in order not to receive the signal coming from adjacent BABY_TAGs. You cannot just let the software filter any messages since it must give some alerts when a baby-patient is put into the wrong room. The CRADLE_TAG input power, for the 433MHz link, has been adjusted according to the following protocol.

Two BABY_TAGs are turned on not at the same time, in order to get their transmitting cycles out-of-phase. Then the tags are placed in line with the CRADLE_TAG at a distance of 0,2m and 2m respectively. The input power threshold on the CRADLE_TAG is then adjusted in order to receive only the signal from the nearest BABY_TAG. This is simply checked by looking at the synchronization of the three tags LEDs (CRADLE_TAG LED flashes when receiving, BABY_TAG LED flashes when transmitting).

IV. Results

The designed system can actually give an improvement to the safety of the patients. It provides caregivers with a tool for constant monitoring of the patient location and identity. It is capable of giving warnings and alerts in case of a patient misplacement. Since the CRADLE_TAG is equipped with a passive RFId reader, the system can also be used to enhance the safety and traceability of drugs administering. [3] [4]

Every information received by the software is logged letting the top management use it to perform process analyses: for example, the system could be queried by the hospital to assess the times of the path from the wards to the surgical block.

On the other hand, this solution – as it is – is not useful against kidnappings: the abductor could just remove the BABY_TAG from the baby's foot and the system would be tricked. This capacity is not easily achievable in children's critical care departments: you cannot use locking bracelets since caregivers need a full access to every part of the patient's body to perform injections and to take blood samples.

A good healthcare RFId solution should combine both active and passive RFId technologies in order to get the best results in terms of automation and certainty of identification.

The shown system is now ready to enter the hospital; in the next months it will be tested in a real ICU environment at Meyer Children's Hospital in Florence.

Acknowledgment

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