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RFID BASED SOLUTION FOR COLLECTING INFORMATION AND ACTIVATING SERVICES IN A HOSPITAL ENVIRONMENT

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ABSTRACT

In this paper we suggest a novel approach to collecting information in a hospital environment and to activating locally available services using a mobile terminal and a wireless RFID reader. We have implemented a small 802.15.4 and NFC compliant RFID reader that communicates with a Nokia 770 mobile terminal in a wireless fashion. This system enables various useful applications in a hospital environment. Information related to devices, patients, or medication can be brought to the terminal's display with a single touch, or a communication link can be established between the terminal and a device, for example. We describe the system architecture, the implemented prototype, and the first experiments.

I. INTRODUCTION

Wireless technologies provide new ways to control information flow and access services in a hospital environment. We suggest using RFID technology to initiate information flow and to activate services. In our approach a staff member carries a mobile terminal and a small RFID reader that communicates wirelessly with the terminal. This approach enables various useful applications. A staff member needs to just touch an RFID tag with the reader to display patient or medication information on the mobile terminal's display, to establish a communication link between a medical device and the terminal, or to read the values of sensors carried by a patient, for example.

While traditional readers use wires to operate [1], the RFID reader implemented in this research uses state-of-the-art wireless technology. Furthermore, usually an RFID tag is carried and the reader is attached to a device to be operated. With our wireless reader, the tags are placed in the environment and the more expensive reader is carried. This enables a variety of applications, as multiple tags can be used to enable different applications.

RFID technology has already been used in hospital environment. For example, in Taiwan RFID technology has been used to track down SARS patients to prevent spreading of the disease [2]. Because of the pressing need to contain the spread of SARS, some hospitals initiated preliminary RFID projects as early as October 2003. These projects achieved significant results [3]. However, RFID readers were installed in the environment, not carried by the staff.

Our system architecture is described in general in the next chapter. In Chapter 3 we describe in more detail the technologies used with the wireless RFID reader and its communication scheme with a Nokia 770 mobile terminal, while Chapter 4 is more about the actual implementation of the devices. In Chapter 5 we present experimental results using the wireless RFID reader and finally, Chapter 6 contains a discussion.

II. SYSTEM DESCRIPTION

We suggest the system architecture shown in Figure 1 for collecting information and activating locally available services in a hospital environment. Information producers and locally available services are marked with RFID tags. A user (a staff member) carries a mobile terminal and a small RFID reader that communicates in a wireless fashion with the terminal. When the user reads an RFID tag, the information associated with the tag is shown on the terminal's display or the corresponding service is activated. The data read from an RFID tag can be used either by an application running in the terminal or it can be relayed to an application running on a server. Furthermore, the application can either use the data read from the tag or tag data can be used to establish a communication link with a data producer. In the first case, the tag can contain, for example, a patient identifier. In the second case, the tag might contain the Bluetooth parameters that are required to configure a communication link with a medical device, for example.

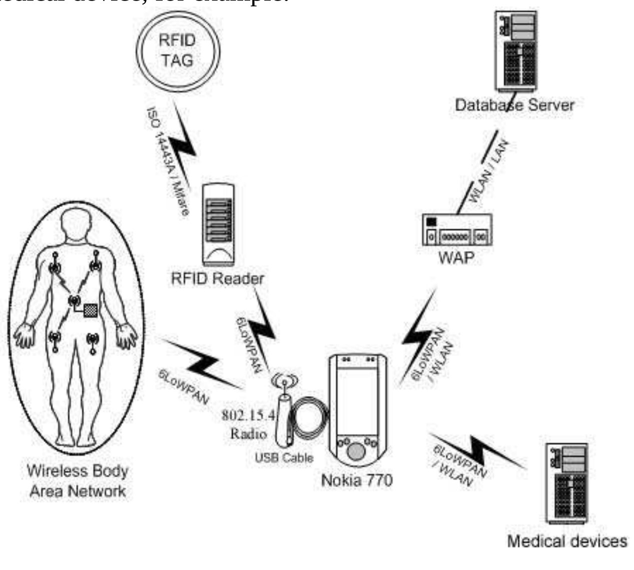

Figure 1: System architecture.

In this research we implemented a wireless 802.15.4 [4] and NFC compliant [5, 6, 7] RFID reader. At the first stage the reader and the handheld mobile terminal, a Nokia 770, communicate only with each other using the 802.15.4 radio. When the reader is brought near an RFID tag, it reads the tag's content and delivers the read data to the terminal over the wireless connection. As the reading distance is short, the user has to nearly touch the tag with the reader. Hence, reading events can be interpreted as commands given by the user. Both the RFID reader and the Nokia 770 use an 802.15.4 compliant radio to establish a connection with each other.

The reader and the tags are compliant with the NFC format. We chose an NFC compliant technology because of standardization. We now have straightforward rules on how to read and write data to a tag and how to communicate between NFC enabled devices using inductive coupling (RF field generated by the RFID device). Standards also allow other devices to read the same RFID tags. For example, Nokia already has a phone model containing an NFC compliant RFID reader.

III. TECHNOLOGIES

Our reader consists of two modules, an 802.15.4 radio module running NanoStack [8] and an NFC compliant RFID module. The RFID module enables reading of Mifare Ultralight and 1k RFID tags, which hold NFC compliant data. When this data is read, it is further transmitted wirelessly to the mobile terminal by the 802.15.4 radio module. Albeit the final device should communicate with every 6LoWPAN enabled device on the network, the prototype RFID reader communicates only with the handheld mobile terminal, a Nokia 770, using the nanoUDP protocol found in NanoStack.

A. 802.15.4 standard

IEEE 802.15.4 is intended to be a specification for low power networks. It can be used for wireless monitoring and control of lights, security alarms, motion sensors, thermostats and smoke detectors, which are all found in hospitals. Yet we can stretch this technology even further to handheld devices such as wireless mobile terminals, wireless RFID readers and portable sensor belts with RFID tags.

802.15.4 compliant wireless networks are called WPANs (Wireless Personal Area Networks), thus they are used to convey information over relatively short distances. Unlike WLANs (Wireless Local Area Networks), connections effected via WPANs involve little or no infrastructure. This feature allows small, power efficient, inexpensive solutions to be implemented for a wide range of devices. [4]

We chose the 802.15.4 standard for radio communication between the RFID reader and the Nokia 770 mobile terminal, because of its ad-hoc capabilities and ultra low power consumption. Unless it is transmitting, the radio uses only a few microamperes per hour. This is achieved by turning the radio into a sleep mode when not needed, while keeping the transmitting periods as brief as possible. This way we increase the operating time and the lifespan of the whole device with ways not possible using WLAN technology.

B. NanoStack

NanoStack is a protocol stack responsible for encapsulating data packets before sending them wirelessly from one device to another. It is a solution for embedded 802.15.4 compliant wireless nodes, along with drivers and tools for accessing wireless nodes from a PC. NanoStack contains both NanoUDP as well as 6LoWPAN protocols. The whole protocol stack is presented in Figure 2.

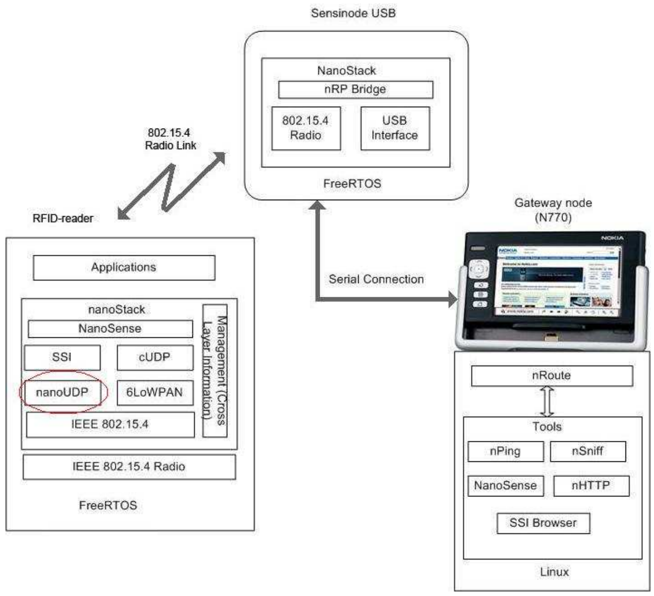

Figure 2: Internal components of NanoStack architecture.

NanoStack is executed as a single task in the FreeRTOS [9] environment. This allows reduced RAM usage and provides an effective way to control flow, as protocol modules are always executed sequentially. Stack usage analysis is also simplified, as the protocol modules do not use direct function calls between each other. The main stack loop is responsible for module handler execution. Buffers move along a single buffer queue, which ensures that the user application is not blocked during protocol stack operation.

C. NFC format

Near Field Communication is a standard-based, short range wireless connectivity technology evolved from a combination of contactless identification and interconnection technologies. NFC compliant devices operate in the 13.56 MHz frequency range, over a typical distance of a few centimetres. [5]

NFC enables a simple and safe way to communicate between two NFC compliant RFID enabled devices or one device and one NFC compliant RFID tag [5]. The devices can be RFID readers, mobile phones, etc. The tags are specified to be Mifare (ISO 1443A standard) or FeliCa type tags operating at 13.56 MHz. The two commonly used Mifare tag models can store 512 bits and 1024 bytes of information.

The ISO 18092 standard defines communication modes for NFCIP-1 (Near Field Communication Interface and Protocol) using inductive coupled (RFID) devices operating at the centre frequency of 13.56 MHz. The standard defines both the active and the passive communication modes of NFCIP-1 to realize a communication network between NFC enabled devices and between a device and a NFC compliant RFID tag. The standard specifies modulation schemes, coding, transfer speeds and frame format of the RF interface, as well as initialization schemes and conditions required for data collision control during initialization. Furthermore, it defines a transport protocol including protocol activation and data exchange methods.

Data is communicated as NFC Data Exchange Format (NDEF) messages that are composed of records, which can contain, for example, a URL or location data [6]. Applications use record types to identify the semantics and structure of the record content. The URI (Uniform Resource Identifier) type is for storing URIs on tags and for communicating URIs between NFC devices. The Text type contains a freeform plain text field to describe, for example, a service or tag contents. The Smart Poster type is for storing URLs, SMSs, or phone numbers on tags. Actions that trigger an application in the device can be described as well. In addition, record types can be specified using absolute URIs and MIME types. How to store a URL into a tag using the NDEF format is presented in Table 1 [7].

Table 1: Writing a URL into a tag.

Offset	**Content**	**Length**	**Explanation**
0	0xD1	1 byte	SR=1, TNF=0x01 (NFC Forum Well Known Type), E=1, MB=1
1	0x01	1 byte	Length of the Record Type
2	0x08	1 byte	Length of the payload
3	0x55	1 byte	The URI record type ("U")
4	0x01	1 byte	URI identifier ("http://www.")
5	0x6E 0x66 0x63 0x2E 0x63 0x6F 0x6D	7 bytes	The string "nfc.com" in UTF-8

IV. IMPLEMENTATION

We have implemented the wireless RFID reader shown in Figure 3. The implemented reader consists of two modules, an 802.15.4 radio module called Nanomodule [10] and an RFID module. The RFID module consists of a reader part made from an NXP's NFC ready PN512 chip [11] and an antenna part integrated on the same PCB with the chip. The module also has a battery holder and a connection for the Nanomodule. At the first stage our RFID reader enables reading of NFC compliant Mifare Ultralight and 1k RFID tags and communication only with the handheld mobile terminal, Nokia 770.

Figure 3: Prototype of the wireless RFID reader and a Mifare Ultralight RFID tag.

A. *Nanomodule*

The Nanomodule seen in Figure 4 is an integrated SoC (System on Chip) radio module. The module runs a complete protocol stack, NanoStack, and applications that eliminate the need for a separate application controller. The module requires only an external power source to operate as an independent communication node. Applications are programmable using an in-circuit serial interface. Nanomodule integrates an 802.15.4 radio offering a 250 kbps data rate and ad-hoc communications with an 8051-based microcontroller. The radio is flexible, offering a more than 100 m communications range. [10]

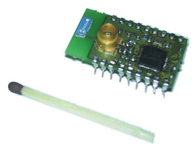

Figure 4: Nanomodule with a chip antenna for an 802.15.4 radio, an external antenna connector and a SoC.

B. *RFID module*

The RFID module is assembled around NXP's PN512 RFID reader chip. The PCB was designed to accommodate not only the PN512 and a power source, but also the Nanomodule and an integrated antenna for RF field generation. A RF field is necessary for the tags to power up and communicate with the reader.

NXP's PN512 RFID reader chip is a highly integrated IC for contactless communication at 13.56 MHz. The PN512 supports Mifare (ISO14443A), Felica and NFCIP-1 (ISO 18092) communication modes. The PN512 is capable of tag-to-reader transfer speeds up to 424 kb/s and reader-to-MCU transfer speeds up to 5 Mb/s. [11]

Figure 5 shows the RFID module hardware. Nanomodule is connected to the socket located on the left hand side of the PCB while the PN512 RFID reader chip is located at the centre. The PCB is surrounded by the integrated RFID antenna for RF field generation. On the right hand side of the Figure 5 is a Li-ion rechargeable battery with a capacity of 160 mAh running at 3.6 V.

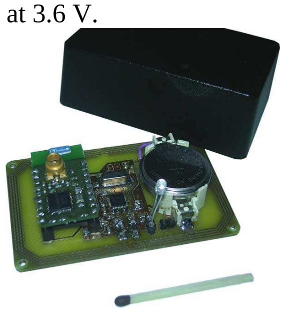

Figure 5: RFID module with a PN512 RFID reader chip (at the centre of the PCB).

The most challenging part when building the RFID module was the tuning of the RFID module's integrated antenna. The resonance frequency of the antenna was measured with a Network Analyzer and the correct tuning components were chosen to set the frequency to 13.56 MHz.

C. RFID tags

We use passive Mifare Ultralight and 1k RFID tags [12] because they follow the ISO 14443A standard and therefore are fully NFC compliant. Passive tags can be read from distances varying from a few centimetres up to a few meters. The Mifare tags have a reading distance of a few centimetres.

A passive RFID tag without an internal power supply can be embedded, for example, into a sticker or under the skin. The RFID reader generates an RF field from which the RFID tags are powered. The electrical current induced in the antenna by the incoming radio frequency signal provides just enough power for the integrated circuit in the tag to power up and transmit a response. Passive tags signal by reflecting the newly modulated carrier wave back to the reader. This means the antenna has to be designed to both collect power from the incoming signal and transmit the reflected signal.

The response of a passive RFID tag can be either just a factory set unique identifier (UID) number or it can contain also additional information that has been stored to tag chip's non-volatile EEPROM. Different UIDs can be used effectively in different applications. An Ultralight tag uses a 7-byte UID, but implements only 512 bits of memory. A 1k tag uses only a 4-byte UID, but implements 1024 bytes of memory. Depending on the application, this could mean a service starts when reading only a 7-byte UID of an Ultralight tag, but waits additional data when reading 4-byte UID of a 1k tag.

D. Nokia 770

The Linux-based Nokia 770 Internet Tablet offers new possibilities for embedded developers. Although positioned as an "Internet Tablet", the 770 has much wider applicability. Bundled software already includes a web browser, an e-mail client, a media player, a file manager, a PDF viewer, a notebook and much more. To support the developer, Nokia offers a complete source distribution and software development kit for the 770's Linux distribution.

Nokia 770 provides 802.11 b/g class WLAN and Bluetooth networking. In our research we added the 802.15.4 capability for receiving WPAN messages. For the most part, the device can be connected to Bluetooth phones or WLAN networks either automatically or with minimal configuration. Ease of use is crucial in 770's intended use as a mobile terminal.

Nokia 770 has a big 4.3 inch 800x480 pixel touch screen with up to 65,536 colours, but no keyboard; the device is controlled by touching the screen. The heart of the device is a 220 MHz Texas Instruments OMAP 1710 SoC processor. By weighing only 0.23 kg and measuring 140x79x18 mm with 128 Mb of onboard memory, a RS-MMC (Reduced Size Multimedia Card) memory slot and an 1500 mAh Li-ion battery (7 days standby), the Nokia 770 makes a good choice for a mobile terminal.

The device runs a Linux-based operating system derived from Linux kernel sources and other open source software. The user interface consists of an application framework, an on-screen keyboard and handwriting recognition.

V. EXPERIMENTS

We have done some experiments to discover some of the characteristics of our wireless RFID reader and the Nokia 770 mobile terminal.

The first experiment was done only for the wireless RFID reader to empirically measure the RF field strength of the reader, the reading distance and the overall reliability of the reading process. The second experiment was to measure packages transmitted from the wireless RFID reader to the 802.15.4 compliant receiver connected to a computer. Correctly received packages against the transmission distance were measured. In this experiment we used the same receiver, which is integrated into the Nokia 770. Based on this experiment we can state that the reliable transmission range between the 770 and the RFID reader is sufficient for this application area. However, we do not report detailed results here as the used 802.15.4 radio modules were early prototypes that will soon be replaced by more mature versions that will have a better transmission range.

The RF field strength was measured by a loop antenna made from an oscilloscope probe and its ground wire. A credit card shaped 1k tag and a round Ultralight tag were used to measure RF field strength with a tag. The measurement was repeated several times with a full battery, with all the distances and with both tags. Average signal strengths from the measurements are plotted in Figure 6.

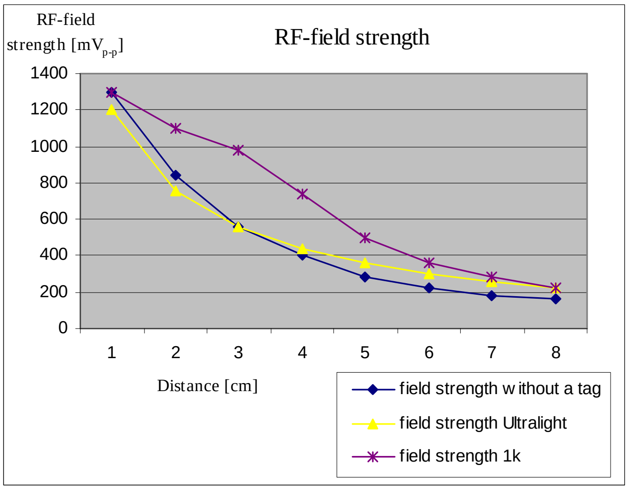

Figure 6: RF field strength comparison against reader-to-tag distance.

During the RF field strength measurements, distances when the reader actually read the tag were marked down. According to the measurements, the reliable reading distance is 4 cm regardless of the tag. Thanks to the internal CRC error detection, all reading errors were detected and the tag was then automatically read again until the correct data was received.

VI. DISCUSSION

The wireless RFID reader and the Nokia 770 mobile terminal together provide great possibilities to ease work processes in a hospital environment. Many hospital processes even today require printing information on paper or handwriting the information down. The 770 terminal brings the information from the hospital information system to the hospital staff, and it also allows information to be entered directly into the information system. RFID technology further facilitates information access and entering. Information can be accessed by a single touch, whether fetching information from the hospital information system or reading values from a medical device. Even if the information has to be written manually, the right user interface can be brought onto the terminal's display with a single touch without navigating in menu hierarchies or entering URL addresses. In fact, any application can be started by a single touch and information can be entered into applications in the same manner. When the logistic and information exchange tasks are done in a more efficient manner, the hospital staff is freed to concentrate on more important tasks.

Our reader prototype reads data from RFID tags and delivers the read data to the 770 terminal. The measurements show that the reliable reading distance is 4 cm. This is a good value, as we want an RFID tag to be read only when the user brings the reader intentionally near a tag. The operating range of the wireless RFID reader's 802.15.4 radio with the internal chip antenna is also quite adequate. In its intended use the wireless RFID reader should cover an entire room with a mobile terminal or in the future a 6LoWPAN access point somewhere in the room.

Construction of the device was quite straightforward. The only concern was about the tuning of the RFID module's integrated antenna for reading RFID tags. Special measurement equipment was needed to tune the antenna.

We will soon start testing the first application that uses the 770 and the RFID reader. In the near future we aim to develop an efficient 6LoWPAN protocol for the RFID reader, enabling it to communicate with every 802.15.4 compliant device in range. Also, a communication scheme for two NFC compliant RFID readers communicating through inductive coupling and a power saving scheme are yet to be implemented. Furthermore, when operating in environment as challenging as a hospital, extensive testing must be done before introducing the device on a larger scale. These tests are planned to take place in the fall of 2007. Finally, we will design a more attractive looking and ergonomic case for the reader.

VII. ACKNOWELEGMENT

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