CASE STUDY: UTILIZATION OVERVIEW OF THE WIRELESS HOSPITAL CONCEPT

Marko Härkönen, Muhammad Ikram Asraf, Matti Hämäläinen
Center for Wireless Communications
University of Oulu
Oulu, Finland

Jukka Riekki, Mikko Polojärvi
Intelligent Systems Group
University of Oulu
Oulu, Finland

ABSTRACT

In hospitals a lot of time of staff is used to supporting tasks which could be redirected to patient care using more efficient processes. Also the use of wired devices might be difficult in many cases. This paper provides an overview of the wireless hospital project's hardware and protocols used in wireless data transfer to and from a portable device to a server. The paper will give an idea why the proposed hardware used is suitable for this kind of application. Hospital processes and logistics have been globally under a lot of examination lately.

I. INTRODUCTION

This paper reviews wireless solutions that can be used to improve logistics and processes at hospital environment. The work is a part of currently ongoing wireless healthcare research activities at the University of Oulu, Finland. This paper is extension to the work presented in [1].

Many hospitals are faced with the fact that there is a need of more wiring in order to plug more devices on the network. Nowadays there are lot of cables attached to a patient in order to examine and monitor patient's health condition In many cases cables are on the way if patient needs to be moved. Moreover in many parts of the hospital the use of cables can be inconvenient or even dangerous. It is difficult to move patient if there are many cables attached to him/her, and also people can stumble over cables.

Concept of wireless hospital is a very interesting field of study. In many cases when building a wireless environment the aim is in robustness, simplicity and energy efficiency rather than in high speed data. The following discussion is based on the ideas and work carried out by the WILHO Consortium in Oulu region in Finland [2], whose goal was to improve the utilization of wireless technologies in hospitals and promote the wireless hospital concept globally.

The rest of the article is organized as follows: In the first part system is shortly introduced. In the second part selected technologies are explained. Next the access technologies are described and then the application is introduced. The fourth chapter decribes the visions of the different environments where the developed system can be utlized. Finally, the future activities are addressed.

II. SYSTEM DESCRIPTION

Our research goal is to integrate radio frequency identification (RFID) technology in the hospital environment. For this purpose, tiny RFID-tags can be placed with patients, doctors or equipments. Tags can have information about persons or equipment and tags can be used to authenticate staff or patients. Having tags on the equipment and reading tags always when moving equipment would help to keep a database up to date and also help with locating equipment. These tags can be read from RFID reader device, which are connected wirelessly with a portable device carried by a doctor or a nurse. We focus primarily on low-rate medical applications deployed in different environment while considering the emerging low-rate wireless personal area network technology as specified in the IEEE 802.15.4 standard [3] with implementation of 6LoWPAN [4].

To experience the required technologies, a CC2420 single chip which operates at 2.4 GHz, also being IEEE 802.15.4 compliant and including ZigBee ready radio frequency transciever is currently deployed. When the user reads an RFID-tag with the reader, information is send through the ZigBee radio to a portable devices and the data is displayed on the screen or is forwarded to electronic patient record using wireless local area network (WLAN). Communication can be done also through wireless access points (WAP) [1]. Figure 1 gives a rough overview of the system architecture. More detailed description of them system and technologies utilized can be found from [1].

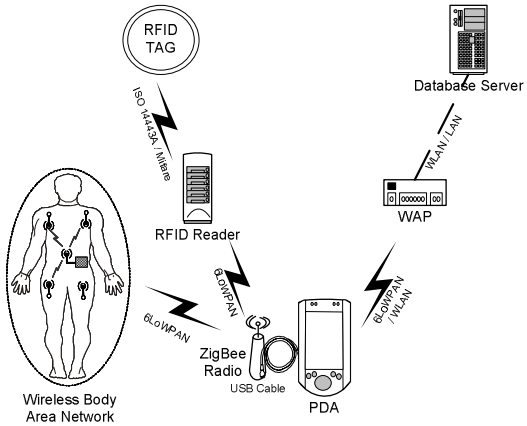

Figure 1: System architecture.

III. USED TECHNOLOGIES

In the localization accuracy point of view, an ultra wideband (UWB) technology is superior due to the high time domain resolution achieved with its sub-nanosecond pulses [5]. UWB can be used also when the amount of data is high, very fast links

need to be established or transmission power needs to be limited [6].

When the data rate requirements are not so high, radio techniques such as ZigBee, Wibree [7] and Bluetooth [8] can be used [6]. In WILHO project the wireless RFID-reader used is meant to cover one room. Reliability of the communication between RFID-tag, RFID-reader and handheld device was tested to be adequate. Detailed description of the tests can be found from [9].

Passive RFID-tags suit our purposes quite well, because reader provided power for the the tag and it uses contactless technology. This made possible very small size of the tag and tags not to be dependent on outside power source such as battery. RFID-tag was also better solution because it can hold much more data than, for example, barcode systems, it does not need a mechanical contact like a smart card and manufacturing costs of a tag is cheap [10].

Nowadays there are few PDA (Personal Digital Assistant) -devices with embedded RFID-reader available in the market. These devices were not suitable for this research, because small reader separate reader was needed that could send data to a different device too if needed. For example if the user wants to get the reader data on his laptop or personal computer, he/she can get data directly from the RFID-reader. Wireless connection is needed between RFID-reader and personal computer in order to succeed in this.

IV. Access Technologies

In our project Nokia 770 was used as a portable device. Nokia 770 is an internet tablet with WLAN 802.11 b/g, Bluetooth specification 1.2 and USB 2.0 [11]. This device was chosen for our project also because it runs a Linux operating system and therefore is quite easy to program for our purposes. There are also many open source applications available for it. Applications can be found from the maemo.org web-site [12]. Maemo.org is an open source development site for internet tablets.

IEEE 802.11b specification is designed for the manufacture of WLAN devices operating in the 2.4 GHz spectrum [13]. Data read with RFID-reader is forwarded from the portable device through WLAN. WLAN technology is already a part of quite many medical systems. To make the communication transparent a wireless access points (WAP)[14] are deployed for hospital environment. The communication among different IEEE 802.11 enabled devices can be achieved through WAP. Also the IEEE 802.11 technology is very mature and there are many devices available on the market. Support of data communication and localization is good in IEEE 802.11 based radios. [6]

If mobile phone would be used instead of a PDA it could be possible to use cellular network as access network instead of ZigBee.

A. NanoStack

The Sensinode's micronode has been programmed with NanoStack [15]. NanoStack supports the IP 6LoWPAN [16] wireless sensor networking solution for very limited low-power wireless devices. The architecture is made up of the NanoStack protocol solution for embedded wireless nodes along with drivers and tools for accessing wireless nodes from a PC. NanoStack is executed as a single task in the FreeRTOS environment [17]. This allows reduced memory usage and provides an effective way for flow control. Protocol modules are always executed sequentially. Nanostack 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 a protocol stack operation. NanoStack can flexibly hold a large variety of protocol elements which are configured together into stacks. A protocol stack can include everything from ZigBee and transmission control protocol / internet protocol (TCP/IP) [18] to traditional wired controller area network (CAN).

Anything that can be accessed through a socket-style interface can be implemented in NanoStack. NanoStack includes the following protocol elements: IEEE 802.15.4 [19], network manager, NanoUDP and 6LoWPAN.

The nRoute Protocol (nRP) [15] is used in communication between a host PC and a serial device to allow PC access to the local sensor network for network monitoring, system diagnosis and data collection purposes. nRP is also used in communications between PC tools and nRoute over TCP sockets. nRP is discussed in detail in the nRoute Protocol Specification [15]. Figure 2 shows layout of the Nanostack, micronode, and nanonode software running on gateway node.

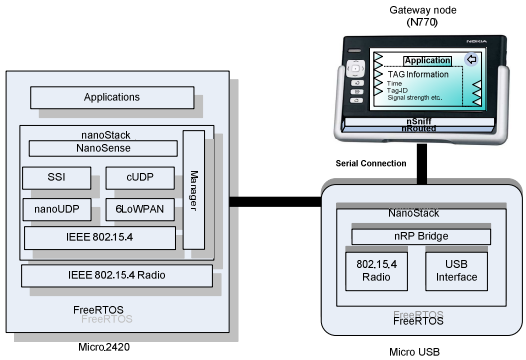

Figure 2: Layout of the Nanostack hardware and software [1]

1) Micro.2420 and Micro.usb

Micro.2420 node can be stacked with Micro.usb to have connection with N770. Micro.usb module provides USB interface to the PC / Laptop. The board gives a serial connection over USB for debugging, supplies power to the stack, and enables microcontroller programming. In addition Micro.usb can be used with a rechargeable battery, which is automatically charged when the node is powered by USB. The USB virtual serial port can be used on any PC with a serial terminal for debugging or control purposes, or with the NanoStack PC tools [15]. These are illustrated on the figure 2.

Micro.2420 is the core of a Micro Series node. It is a fully operable standalone communication node with an accessible connector for easy sensor and user interface (UI) element operation. Micro.2420 runs on 2 NiMH batteries or on bus-supplied 3.3V power. It integrates a flexible TI MSP430 microcontroller with a TI 802.15.4 radio capable of 100 m transmission range. This radio is very flexible, offering a 250 kbps data rate and an ad hoc communications with a wide variety of topologies. The microcontroller and radio are supported by both the FreeRTOS [17], NanoStack and TinyOS [20].

V. IDEASILO APPLICATION

In WILHO project a laundry order application called Ideasilo was created by ISG-laboratory. Application uses RFID and IEEE 802.15.4 technologies to communicate with portable devices and RFID tags. This application was designed so that it is easy to convert for other needs in the hospital, and also it can be used in totally different environment.

Ideasilo abstracts the communication with the wireless RFID reader. An application receives a general event when an RFID tag is read and the RFID reader sends the data to the N770. Ideasilo offers also a general user interface that can be configured for specific applications. In practice, Ideasilo contains general C++ classes that can be specialized based on the application's requirements.

Two applications have been implemented on top of Ideasilo so far: an ordering application and a data management application. When a nurse needs to order clothes for a ward, she/he starts the ordering application. The ordering is made by touching the tags associated with different clothes. One possibility to place the RFID tags is to use a poster that contains all tags. Another option would be to place the tags in the locations of the ordered items, for example, on shelves.

When the ordering application is started, an empty ordering form is displayed. As a tag is read, the corresponding item is added in the order form. The user can modify the data, e.g. the amount. When all the items have been entered into the order form, the order can be send forward directly from the terminal.

The data management application lets the user to browse the information related to tags and to modify the information. When a tag is touched, the information related to it is fetched from a server on the Internet and shown on the terminal's display. The shown information can also be edited and the changes can be updated to the server

VI. APPLICATIONS OUTSIDE HOSPITAL

In WILHO project, the focus was to provide means for the hospital staff to make their work easier and more effective using wireless technology. Also from the patient side, it would be much comfortable if they do not need to be attached with any cables. Some of the applications needs user activity and others are passive. For example, in some applications user needs to press button of the reader to activate transaction while in others user just has to go to certain area and network detects user and starts transaction.

This technology is also easy to modify for different needs, with relatively small modifications. This technology can be used for example at hockey stadium, butcher's shop, supermarket or paper factory.

At a hockey stadium, the number of free seats could be checked with a PDA when a customer arrives at the stadium. Customer could also buy a ticket using PDA even before actually entering the stadium. Seats could have RFID-tags and clients could read the tag with RFID-reader and PDA. This operation would send a confirmation to the server that customer has found his/her seat. If the client would happen to leave his seat, he/she could get updates of the match send straight to the PDA so they would be updated during their absence. The customer could also buy refreshment from a vending machine by reading a RFID-tag from machine if he would have payment application running on the PDA. Also the security personel could carry PDA devices and get information about how many seats are free and if there are some problems they would get the information about the conflict send straight to their handheld device with a map of the location. After dealing with the conflict security personel could make a confirmation by touching a RFID-tag with his/her RFID-reader, if enough of these confirmation tags are placed around the stadium. Also there could be security application that detects, if user tries enter restricted area and sends warning to the user's PDA and informs security about the event.

In butcher's shop all the meat could be tagged with RFID-tags upon arrival to the shop. RFID-tag could have information like arrival time to the shop, description of the meat, and expiration date. All the updates could be saved to a database on the server and also send to the staff's PDA devices. This would make sure that all the staff would know what is the status of the meat locker so they would know exactly how much meat they have and when to order more. Using PDA and RFID-reader, staff would also be able to locate certain meat easily. Also the customers could get information and offers send to their PDAs upon the arrival to the shop if they have butcher shop application running on the PDA.

In bigger supermarkets it would be useful to have real time inventory tracking system. Quantity of the products on the shelf and updates could be send to the PDA's carried by the staff of the supermarket. For example, if some product would run out from the store, an alarm could be send to the PDA carried by the staff that are responsible of the stocking up. Real time stock monitoring can be gained with this technology. Also the stock information or is there a need to order more could be easily checked with this technology. Map of the location of the product could also be provided. If there would be a need to place an order it could be done using PDA with RFID-reader and WLAN access. Order could be made immediately on the spot when lack of certain product is noticed. This operation would save time. Customers could also get information about offers send to their PDA's upon the arrival to the supermarket, if they have right application running on the mobile device. Customer could also type on the PDA a product name that they are looking for to get a map of the supermarket with location of the product. Also price of the product, additional informa-

tion of the product and alternatives could be send to the PDA. Customers could be provided with some information even before their arrive inside the supermarket. For example when a customer arrives to the parking lot, there could be a gateway that customers have to drive through. Customers could have a parking payment application running on the mobile device when they check-in to the parking lot. After going through the gateway, application running on the PDA could prompt user. With user agreement he/she could receive information about the empty parking spaces and information about the offers on their mobile device. When leaving the supermarket and upon paying parking with a payment application, map could be send to the PDA so it would be easier for customer to locate their parking space. In case of accident, information about the accident and map with location of accident could be send to all the wireless terminals on the area. This would increase safety and decrease response time.

Also this technology could be modified to be used in the paper factory. Real-time tracking could be used to track equipments inside factory, inventory or staff. Efficient storehouse tracking would save time, work and money. Real-time tracking of the staff would increase safety, because locations and number of the staff members would be known all the time. In order to do this all the staff and visitors could be provided by small tag with relevant information and the intelligent infrastucture could help staff and specially visitors movement around the factory. For example, if visitor would get lost or would try enter to restricted areas notification could be send to the personnel. In case of emergency alarm could be send to the mobile terminals carried by staff on the area. Or, for example, as soon as certain cleaning operation is completed message would be send in order to save time. Also environment aware sensors could be deployed on the areas with toxic chemicals in order to increase safety. Alarm from the sensor node could be send to all the PDA's in the case of toxic spill.

This technology could be useful also in fast-food restaurant. Order could be placed using PDA upon the arrival to range of restaurant's WLAN, if customer has an order application running on the PDA. Customers could go straight to table equipped with RFID-tag. Customer could read tag with RFID-reader which could send information through PDA to the restaurants server that customer has arrived to the certain table and staff would be able to take the right order to the right table. Also in drive-through order could be made with PDA before actually arriving to the restaurant. Also inventory could be handled with real-time tracking.

These are only few examples where this kind technology could be utilized. Potential application area is much wider.

VII. Future

Wireless medical care is relatively new field of study and there are several companies already developing commercial products. There are still many problems to solve, but the competition in wireless hospital technology and applications will increase radically in the future. A portable device with the RFID-reader offers a possibility to ease the work of the hospital staff, specially decreases need of writing, printing and delivering papers to a right person. Applications and devices has to be reliable and easy to work with. Even though in our research this system is targeted to a hospital use, it is easy to adapt for different kind of environment, for example depot, supermarket or factory.

VIII. Acknowledgements

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