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Bedside Patient Data Viewer Using RFID and e-Ink Technology

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Abstract In the daily routine of hospitals, which work with paper based medical records, the staff has to find the appropriate patient file if it needs information about the patient. With the introduction of ELGA the Austrian hospitals have to use specific standards for their clinical documentation. These structured documents can be used to feed an e-Ink reader with information about every patient in a hospital. Combined with RFID and security measures, the clinical staff is supported during the patient file searching process. The developed experimental setup of the Bedside Patient Data Viewer demonstrates a prototype of such a system. An Amazon Kindle Paperwhite is used to display processed data, supplied by a Raspberry Pi with an attached RFID module for identification purposes. Results show that such a system can be implemented, however a lot of organizational and technical issues remain to be solved.

Keywords. Bedside technologies, Radio frequency identification, e-Ink display

1. Introduction

Recent developments in the field of IT and healthcare have heightened the need for mobile patient monitoring systems. Studies and products are available for different medical fields. Such solutions include the ORBIS^{ME} system by AGFA Healthcare [5] and the IntelliVue Mobile Patient Access by Philips Healthcare [6]. Both provide the possibility of monitoring and viewing medical patient data at bedside or wherever needed. The major advantage of those systems is the mobility. Nowadays time management is crucial for the overall workflow within hospitals due to increasing costs for the medical care [4]. A mobile patient data viewer system enables the medical staff to monitor patients by the help of portable tablets or PDAs. The results are increase of process speed and effective workflows. This leads to lower costs, compared to the usual handling of medical records [3]. However, questions have been raised about the safety, interoperability and effectiveness of such monitoring systems. The ORBIS^{ME} system by Agfa Healthcare [5] and the IntelliVue Mobile Patient Access by Philips Healthcare [6] require both their own specific Hospital Information System.

This work seeks to address the mentioned issues and explores these problems by developing a prototype bedside patient data viewer. Radio frequency identification (RFID) is a common method used in industry whenever specific identification is required. Via a RFID reader it is possible to identify various people and distinguish

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between them regarding their specific permission of working with patient data. The E-Ink technology is very attractive as it is low in energy consumption compared to usual LCD displays. Therefore RFID for identification of persons and access control and E-ink technology were selected.

2. Methods

For developing a bedside patient data viewer the following parameters and methods were considered in the search for suitable solutions. The functions and requirements for use within hospitals were taken into account.

2.1. Radio Frequency Identification (RFID)

RFID is a widely used method whenever specific security measures, like access control, are required. It is a wireless communication method that uses electromagnetic fields within the radiofrequency range. One of the applications is the automatic identification of persons (access control) [7]. This is achieved by tracking and identifying specific RFID tags within the electromagnetic field of the RFID reader. These so called "tags" store information and are powered by electromagnetic induction within the readers range. Once this area is left the tags are not sending information any longer. The diameters of such areas vary from a few centimetres to hundreds of meters. The RFID reader reads the information send by the tag. It interprets the data and recognizes the person ID in this case. This approach of using RFID as identification measure enables fully automatic function without the need for manual interaction and without line-of-sight contact. Therefore it can be applied in rough environments like the hospital [7].

For the implementation the NFC/RFID breakout board by Adafruit industries is utilized [9]. The used RFID controller is one of the most popular Near Field Communication (NFC) chips. It enables both reading and writing of tags or cards. A Raspberry PI microcontroller is used to communicate with this chip. Communication is possible via UART, I^2C and SPI. Consequently major flexibility is available at programming the RFID function. Furthermore the open source NFC SDK “libnfc” is used [9]. This setup enables to determine the person's ID and consequently check the permission to access patient data. This permission model is part of the security aspect of this project to restrict access for unauthorized personnel. As the RFID reader recognizes a tag the microcontroller uses this information and queries the database to check the role of the person. Subsequently only the accessible patient data at this permission stage is shown on the display.

2.2. E-Ink Reader

E-ink displays offer a wider viewing angle compared to conventional displays, moreover they are comfortable to read. Because of the usage of a reflective display, the ambient light is reflected which leads to reduced eye fatigue. Furthermore E-Ink displays only consume power if there is a change of the displayed content (bistable), which leads to decreased average energy consumption compared to LCD displays [8]. The Kindle Paperwhite, offered by Amazon, is used as E-Ink reader in this project. It has a display size of 15-centimeter, an included battery and integrated WIFI. This device has been chosen because of its mechanical and electronic properties, its fast availability and the existence of software libraries that enable the development of additional functions.

2.3. Additional components

In order to enable communication between the Kindle and the microprocessor via WLAN an external TL-WR702N WLAN-N Nano-Router (TP-Link, Nanshan, China) was used. For the experimental setup an USB battery pack was used as power supply. The EasyAcc® Super provides 4 USB ports with each of them delivering 5V at 0.5A. Further developments are going to focus on applying the bedside power supply in order to minimize the risk of low running batteries.

2.4. Related Standards

According to IHE and HL7 standards the patient data is queried via an interface of the hospital IT infrastructure. For example, the patient basic information set can be asked via a Patient Demographic Query (PDQ) from a Master Patient Index [1]. The Patient Bedside Data Viewer should furthermore act as a document consumer to get the latest information out of CDA documents for the presentation on the display from the hospitals Cross-Enterprise Document Sharing facility (XDS). The relevant sections are parsed and then displayed on the E-Ink reader.

3. Results

The experimental setup consists of a Raspberry Pi, an RFID reader that is connected to the Pi, an E-Ink reader, a nano router and a Notebook. The Kindle, RFID reader module and the Raspberry Pi are connected together via WIFI. The nano router is used to set up a local Wireless LAN network and static IP addresses are assigned to the devices. A mobile battery supplies the router, Raspberry Pi and RFID module. This enables to place and demonstrate the system without the need of a stationary power supply. Moreover hospital beds are not always supplied with energy.

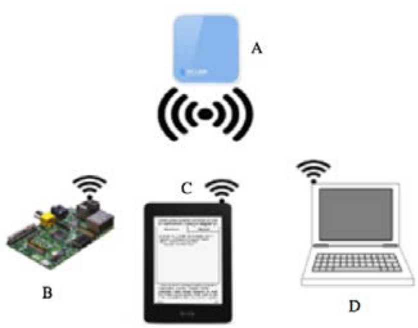

Figure 1. Experimental setup, Part A: Nano Router; B: Raspberry Pi; C: Kindle Paperwhite; D: Notebook

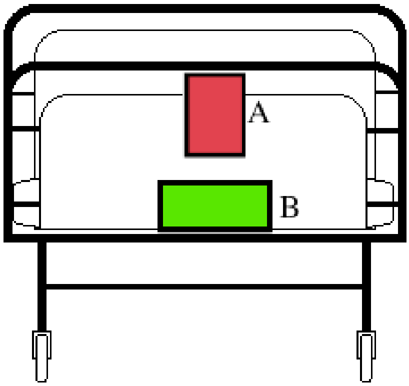

Figure 2. Front view of a typical patient bed with the display and control box attached. The red rectangle (caption A) represents the Kindle Paperwhite and the green one (caption B) the casing containing the NFC module and the Raspberry PI.

The Raspberry Pi, together with the RFID reader, is the supplier of the information for the E-Ink display. There is an Apache web server instance running which also supports PHP. It enables an external access via the HTTP protocol, which is supported by the Kindle Paperwhite (Beta browser). In fact, the Raspberry Pi with the attached RFID module is the main unit of the project. It handles the communication with the Hospital Information System and prepares the data for the E-Ink reader.

3.1. Patient Bedside Data Viewer Workflow

The Bedside Data Viewer Workflow starts with the doctor entering the room and picking up the display that is attached to the front of each patient bed. Each display is assigned to a certain bed and therefore a patient within the HIS. The second step marks the identification via RFID and the user log in. A popup window occurs on the display and requires the log in data of the recognized person. This method is applied to restrict the use to authorized personnel and to prevent wrongfully identified personnel. Afterwards the permission settings are checked, information is gathered and the related patient data displayed on the E-Ink display. Therefore the last relevant CDA documents of the patient (since his admission) are queried, parsed and displayed. Touching the information entry, which will cause the loading of the full CDA document, can expand the limited overview. Due to the limited resolution of the Kindle, the display of full CDA content is limited. It is, for example, not possible to view DICOM images.

The displayed information about a patient is divided in four sections:

- *Basic Demographic Information*
  This section includes the basic dataset. In includes the first name, second name, gender, date of birth, address, city, country, postal code and phone number
- *Visit Related Information*
  Problem/Diagnoses*,* Associated Problems*,* Last procedures performed
- *Last Vital Signs*
  Glucose Level, Blood Pressure, etc.
- *Medication*

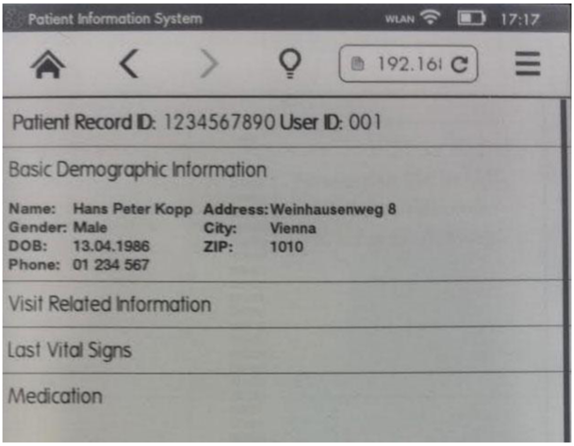

Figure 3. Sample user interface displaying four information available sections

The user is able to look into the details of the four headlines by touching the specific topic. The details are dropped out and the other sections are closed on the device (Figure 2). After a timeout or logout, the content of the display is deleted and the process can be started again.

The first step in the short description of the workflow is the identification of the user. This step is important, because an unauthorized information access should be prevented. For this purpose, each user has an own, personal RFID tag, which ID is stored in a staff database. Furthermore different roles are available, depending on the privileges a user has. That means, that each user RFID tag is related to a role and the personal data, moreover each patient data access is logged with date and time to prevent misuse. Depending on the role, a user has been given, only specific patient data is displayed on the device.

3.2. Casing

To enable the experimental setup to be applied within hospitals and more specifically attached to patient beds, a casing was designed to house the Raspberry PI, RFID reader, nano router and the battery pack. A CAD drawing was designed to fit those parts together in a compact box. It is recommendable to mount it to the bottom of the patient bed. However the various types of patient beds and their respective structure as well as security aspects need to be considered. If this is not possible it is recommended to place the box at a safe place nearby the bed.

4. Discussion

4.1. RFID Security Considerations

For security reasons and patient safety, no patient information is stored on the RFID tag itself. The tag only contains an ID. When somebody reads the tag he can't do anything with such an ID. Authorized devices can use the RFID tag ID to find the corresponding patient ID and query the stored data. For the administration of the RFID tags a RFID assigning tool was programmed in JAVA. This tool allows a user to add and delete tags from patients. It also displays the tag history of each registered patient.

Each doctor has to wear such a RFID tag in order to enable the usage of the data viewer. These tags are available in various designs. ID cards, key chains or trinkets are available and can be chosen the by user regarding its preference. Regardless of which type of design is chosen, the tag itself needs to be attached to ones chest or hip region in order to enable communication with the RFID reader.

Another aspect that needs further considerations is the range at which the RFID reader is able to recognize RFID tags. The range needs not to be as big as possible. Wide areas could cause problems when other people of the staff besides the doctor or nurse enter the patient room first. The RFID reader would recognize the first person within this area and would load the user profile of the incorrect person. Consequently this person would need to log out of this system in order to enable the doctor to use the display. A solution for this problem is to include a user password when operating the display as described in the workflow. When the system recognizes a RFID tag the system request a password for this specific user. Consequently the risk of wrongfully logged in people would be minimized.

There is also the question about the timing of the removal of the shown patient data from the display. The simplest solution would be to remove it after a certain time period if there is no action being performed. Another option is to configure and attach a RFID tag to the display itself. The RFID reader would recognize this tag when the display is put back into the attachment. As a result the display would close the session and remove the patient data.

4.2. Network and IT implementation

Hospitals have different security policies dependent on their IT infrastructure and security considerations. It can be expected, that the Linux distribution can be configured to meet the necessary security requirements (HTTPS, TLS/SSL, etc.) [11] of a hospital IT environment. It is moreover necessary to give the Raspberry Pi the needed permissions to access the required services (PIX/PDQ/KIS, XDS). On the hardware itself, measurements like the deactivation of the USB ports can be taken to prevent an unwanted direct data exchange.

According to the IHE initiative, there are many security and privacy concerns with mobile devices. Solutions can be the usage of ATNA, Enterprise User Authentication (EUA) and Cross Enterprise User Assertion (XUA) [12]. It seems that the IHE is developing profiles especially for mobile devices [13, 14].

4.3. Data handling

It is proposed, that the information for the different sections of the information overview is extracted from related CDA documents of a patient. That means that the information has to be collected. Another approach is the "on the fly" generation of a CDA document on request. This document can include all the information that is needed by the Raspberry PI. Therefore just one CDA document has to be parsed for displaying.

4.4. Operability

The results of this study indicate that the operability of the display when wearing gloves needs to be observed. The Kindle Paperwhite features a capacitive display. However within the environment of the hospital there are some risks when using capacitive displays. Usually the medical staffs wear latex gloves due to hygiene reasons. Often it is mandatory for doctors and nurses to wear gloves when working with patients. This however leads to a decreased conductibility of the person wearing gloves. Consequently it also decreases the capability of operating capacitive displays.

This may rule out the use of capacitive displays in environments like the hospital. Nonetheless it is still possible to operate the display even with latex gloves. The crucial point is the thickness of the gloves. Medical latex gloves do not act as an insulator and are very thin compared to other gloves. Consequently capacitive displays can be used when wearing such [10]. However this fact needs to be tested with common medical hospital latex gloves in order to verify this statement.

4.5. Costs

The costs have been estimated according to the experimental set up and therefore cannot reflect the true costs when applied in a hospital. This calculation does not consider the costs for the casing and IT infrastructure like WiFi and hospital information system.

Table 1. Estimated costs of the experimental set up for a hospital department with 20 patient beds

Part	**Price in €**
Amazon Kindle Paperwhite	129
PN532 NFC/RFID controller breakout board - v1.3	28
MiFare Classic (13.56 MHz) tag assortment - 1KB	7.2
TP-Link TL-WR702N WLAN-N Nano-Router	17.99
EasyAcc® 12000mAh PowerBank	34.99
Total Costs for the experimental set up	217.8
Costs for a hospital department with 20 beds	4343.60

5. Conclusion

This project was undertaken to design a bedside patient data viewer and explore radio frequency identification and E-Ink technologies in this scenario. The most obvious finding to emerge from this project is that RFID provides possibilities to ensure security when working with patient data. Individual tags restrict the use to authorized staff. The second major finding was that the E-Ink technology is very well suited for the use within the hospital environment. The major advantage of these displays compared to other commonly used tablets is the significantly longer battery service life. The costs of such patient data viewer systems are difficult to compare, as there is no exact matching product. Nonetheless the costs are lower compared to similar products that include whole information systems.

Taken together, these results suggest that it is possible to develop an applicable bedside data viewer system to improve the time efficiency and workflow within the hospital, when examining patients. There is, therefore, a definite need for development and improvement in this area. Nonetheless further work needs to be done to implement a reliable security concept when working and manipulating patient data.

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