Ambient Intelligence in Mobile Field Work

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Abstract— **In this paper we will demonstrate the current state of ambient intelligence in industry by reporting about our industrial pilots related to mobile field work. These pilots presented later in details are a mobile maintenance solution 1) for greasing, 2) for electricity meters, 3) for vehicle services, and 4) using RFID technology in production line.**

RFID, mobile technologies, ubiquitous computing

I. INTRODUCTION

RFID technology has already been applied over 60 years before it has found its way to large scale applications [1]. Currently RFID markets are progressing rapidly. According to European Commission [2] in 2006 alone over one billion RFID tags were sold worldwide and by 2016 it might be over 500 times this number. The European markets in these estimations will grow from €500 million to €7 billion by 2016. According to Roussos & Kostakos [3] the basic idea about RFID and its usage in different kinds of application areas seems to be simple and straigthforward to implement. However, they have underlined that this technology is considerable complex to use from systems, software and networks perspectives.

Nevertheless, during the last years this technology has proved its benefits in different kinds of application areas. RFID technology has for example applied succesfully in ticketing such as in London underground [4]. In retail, RFID is already used in supply chain management. However, benefits for the consumers as added value services are still in piloting phase. As an example RFID has been piloted succesfully in smart carts [5]. In addition, large scale implementations can also be found in inbound logistics for tracking assets [6] or for maintenance work [7].

These succesful implementations show that RFID technology has developed to the stage that this technology can be applied effeciently with certain limitations. Moreover, developers have to be aware about these limitations. Especially harsh industrial environments in which metal surfaces are the main element the use of RFID is still challenging. In addition, metal surfaces are not the only challenge in industrial environments. For example temperature, humidity, electro-magnetism, and pH are critical factors for the use of RFID technology efficiently.

Furthermore, in many application areas reading distance is a criterium which causes challenges for a succesful implementation. Currently the most used standards related to RFID integration with mobile devices are ISO 14443A (ISO 2001) and ISO 15693 (ISO 2006) standards which are specified for High Frequency (HF) readers with 13,56MHz radio. Ultra High Frequency (UHF) readers are used mostly only in more robust industrial mobile devices. On the other hand just lately, Nokia revealed the first UHF compatible mobile device E61i which is still in a prototype phase [8].

As a result of a frequent use of HF readers in mobile devices reading distances are typically just few centimeters [3]. In many use scenarious this kind of reading distance is suitable. Moreover, longer distances can also cause problems as misreadings. However, identifying objects especially in industry with just a distance of few centimeters is a factor which has to be taken into account when designing applications. Therefore mobile devices are not used frequently in industry. The typical industrial devices are designed for harsh conditions and these devices can be found both with HF and UHF readers. These UHF readers in mobile devices enable longer reading distances. But then, a long range reading has consequences such as in size with bigger antennas and in power consumption.

These limitations have to be taken into account when choosing suitable devices. One of the most challenging issues of development processes are readability issues. In many circumstances RFID readers can be attached in the environment instead of using RFID technologies in mobile devices. Reasons for this consideration are mainly related to the challenges in a long range reading with mobile devices. This is especially problematical with passive RFID tags. However, these tags are already relatively cheap and usable not only in an effective automatic identification of objects, humans, and other species but also locations, and increasinbly media content and mobile services [3].

Like a short literature review above shows RFID has proved to be a suitable identification technology in many application areas. Also maintenance work which is also discussed in details in this paper has been studied in large scale applications such as in Legner's studies [7]. However, challenges related especially to harsh industrial areas still exist and more research in this area is still needed. In this paper we will report our experiences gathered from harsh industrial environments. The reported pilots have been designed for mobile field workers, namely mobile maintenance solutions 1) for greasing, 2) for electricity meters, 3) for vehicle services, and 4) using RFID technology in production line.

II. Mobile Maintenance Solution for Greasing

A. Background and Objectives

In this pilot the goal was to implement a mobile solution for a robust industrial PDA which has been integrated with an RFID reader. The requirements for the solution were as follows. Solution has to show for the user the maintenance task locations and maintenance information. Moreover, the user has to be able to report executed tasks based on RFID identification. As a result maintenance workers do not carry paper prints about task locations and maintenance information. Furthermore, the pilot has also to include a desktop solution for administrators who are managing task routes.

B. Implementation

In the desktop solution the administrator is informed about valid dates of maintenance tasks, maintenance route, and previous maintenance information. In addition, the administrator can create and delete maintenance tasks, maintenance route, and create and configure users with user rights. Currently there is no need for data exchange in real time. Therefore information about maintained tasks is transferred via desktop PC (USB) to the server. In the case a user is unable to finish his maintenance route the status of this route is informed for all users as unfinished. Also information about matured maintenance routes is shown for the users.

C. First Experiences

In the first tests we have used three different types of mobile devices with RFID readers (Figure 1). One of them was a HF reader (Gao RFID reader with Windows CE 5.0 OS) and the others were UHF readers (NordicID PL3000 reader with Windows CE 6.0 OS, and Psion WAP G2 reader with Windows CE 5.0 OS).

Figure 1. Identifying greasing task location with mobile RFID reader (UHF).

Based on experiences gathered from first tests RFID identification based on UHF seemed to be more suitable for these harsh conditions. On one hand the use of UHF enables longer reading distances which is crucial when RFID tags can be unreachable or in challenging locations. On the other hand the use of UHF enabled also more alternatives on finding suitable tags which could be used in metal environments (for example Intermec Large Rigid Tag – EPCglobal Gen 2).

III. Mobile Maintenance Solution for Maintaining Electricy Meters

A. Background, Objectives and Implementation

This pilot had in principle same kinds of features like used in greasing solution. In principle the user has again a robust industrial PDA with an RFID reader and task locations which were in this case electricity meters were attached with RFID tags. A customer of this pilot had special requirements for usability issues. The implemented solution consisted of mobile solution for NordicID PL 3000 RFID/UHF reader and Confidex Ironside tags (EPCglobal Gen2) designed for metal surfaces, and desktop solution for managing and administrating maintenance tasks and information. Data exchange also in this case was implemented via USB cable.

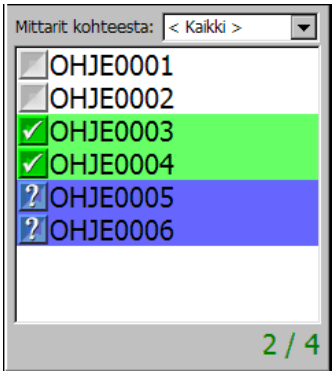

Figure 2. A list of meters with color codes.

B. First Experiences

Like already mentioned the customer had special requirements for usability. For example colors were used in visualizing status of task locations – white for meters which are not needed to be checked, green for meters which are already checked, and blue for the meters which are not yet checked (Figure 2).

When arriving to maintenance task location, user can begin maintenance procedure by clicking a special button (yellow one in Figure 3) which will command RFID reader to identify an object. An example of usability features is also the use of button lights. That is to say by highlighting buttons the solution will help users to make inputs effectively.

Figure 3. RFID identification by clicking the scanning button.

This solution was implemented by avoiding the use of stylus. The user is now able to do all the basic routines with RFID identification and with buttons. Only some textual inputs have to be done with stylus. In these cases we desinged a bigger keyboard which can be used with stylus or even with fingers. The first experiences about this pilot have also been promising.

IV. Mobile Maintenance Solution for Vehicle Services

A. Background, Objectives and Implementation

A mobile maintenance solution for vehicle services differs from previuos pilots. In this case the use of RFID had to integrate on mobile ERP system. As an application area was chosen vehicle services. The mobile ERP system has been designed for Windows Mobile devices. Therefore HTC 6500, slightly more robust than normal PDAs, was chosen with Wireless Dynamics SdiD 1020 RFID adapter (HF reader). This combination is a compromize in which costs were prioritized as higher criterium than industrial robustness.

B. First Experiences

The implemented solution was tested first by users which are maintaining forest harvesters, forwarders, and tracks. The users were able to identify maintenance objects automatically based on RFID identification. By identifying the object the user was able to get easily information about maintenance history, and current maintenance tasks. In Figure 4 is shown the used device with the RFID reader.

Figure 4. A mobile device with RFID adapter for maintaining vehicles.

V. Using RFID Technology in Production Line

A. Long-term Piloting and Gathered Experiences

Pipe production line is a harsh industrial environment with metal surfaces with dust, high temperatures, and vibrations. Therefore this pilot has been tested exceptionally long period. In the beginning we focused separately on work phases, and we aimed to find the most usable devices (Figure 5 and Figure 6) in these harsh conditions. Metallic pipe components (e.g. pipes with links, elbows, bends or extensions) were marked with 13.56 MHz high frequency (HF) tags in the work cell at the start of the production line. HF tags were used because near field RFID technology has better immunity to electrical interference and environmental noise than ultra high frequency (UHF) technology. In every work phase the pipe components were identified by mobile or stationary RFID readers, which were integrated to production managements systems so that after identification they could give guidance efficiently with back-end systems to the workers. The machine operators could get instructions and drawings, for example, about the actual pipe component to help them in assembling, processing, and maintenance tasks.

After testing RFID separately in work cells we concentrated in racking and tracing of pipe components via RFID technology through the whole production line and to delivery and transportation to the customer. The customer company can utilise the information stored in RFID tags to ensure that the right pipe components have arrived and are stored, e.g. in the buffer storage. In cases of reclamation, RFID tags can be used to trace the date and time when component was produced and potential problems in the process.

Figure 5. RFID readers which were tested in pipe production: Feig ID ISC.PRH101-B (left side) and Motion Computing F5 (right side).

B. Results

Results of long-term piloting included design, HW&SW development, and integration into existing data systems. The main research challenges were to ensure adequate RFID tag mounting on metal objects, and coping with the harsh conditions of the industrial environment. Due to the high number of objects to be tracked the obvious approach utilising high-cost specific RFID tags was rejected. Our approach was to develop protection methods allowing usage of common low-cost RFID tags in harsh conditions. Development led to a patented solution [9] where multilayered structure gives possibility to use these heat-resistant RFID tags in surface treatment processes where temperatures can momentally rise up to several hundred degrees.

Figure 6. Identifying pipes in production line with Psion WAP G2 reader.

VI. FUTURE WORK

Currently we are active in embedded system development. As an example how we have combined gathered knowledge about RFID technologies with embedded system development is a solution in which a mobile device was integrated with RFID reader and with 6LoWPAN (IEEE 802.15.4 based radio) node. In this pilot ACG Identification Technologies' Multi ISO RFID module and Radiocrafts' RC2301 module were integrated to Kitwrx 456 mobile handheld device. As a demonstration a shutter control solution was implemented (Figure 7).

Figure 7. Shutter control solution based on 6LoWPAN communication.

One of the future directions will be using ubiquitous computing in geosensor networks. We have for example designed a geosensor node which is consisting of GPS receiver, 6LoWPAN radio, and sensors such as temperature, humidity etc. [10]. These geosensor can be monitored remotely over internet or measured in situ with mobile devices. In Figure 8 the latter one use case has been showed.

Figure 8. Requested geosensor information with Kitwrx 456 device.

VII. CONCLUSION

We have found in these pilots that industrial environments are much more challenging than environements in which RFID has typically been tested (such as retail, and logistics). In the industrial environments with lot of metal surfaces the cost-effectiveness concern can arise from amount of specific high-cost RFID tags. On the other hand, we have recognized that in all cases commercial solutions are not yet available in the market. We have managed to solve this problem with approach of using common low-cost RFID with some protection methods described in section IV [9].

Finding ideal or at least most suitable devices for operators in industrial environments is a challenging research problem. For example in our case we have considered totally more than 10 RFID readers and tags varying both HF and UHF standards, varying both mobile and fixed readers, and wide range of different types of tags including different size, shape and material.

These pilots have convinced us that the ambient intelligence based on RFID will reduce possibility of human errors and can also increase automation and is thus very much user friendly approach by nature. Usability and user interfaces of mobile devices were still found to be very important in our pilot solutions.

Finally as a conclusion based on our successful experiences with the industrial pilots reported in this paper we dare to anticipate that RFID of WSN based ambient intelligence in mobile field work will explode in future even in harsh industrial environments.

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