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Potentials for Radio Frequency Identification in AEC/FM

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Abstract: Radio frequency identification (RFID) technology has proved to be very effective in industries as diverse as aircraft manufacturing to health and care. The construction industry has been slow to take up on RFID and this paper will discuss the merits of the technology in its potential for application within the construction sector. The paper reports about the prototypical implementation of RFID-based information management in FM-scenarios. The prototypes were tested at University College Cork (UCC). The general applicability of RFID for decentralised information management could be demonstrated.

Key words: computer-based maintenance of Infrastructure; intelligent construction site; RFID technology

Introduction

Radio frequency identification (RFID) technology is used extensively by many other industries such as manufacturing or retail. However, in the construction sector RFID-technology has only been implemented on very few projects and usually as a test of the functionality of RFID technology[1,2]. In order to promote RFID within the construction industry this paper examines potential application scenarios for RFID technology in the several stages of the building life-cycle.

The first part of the paper examines the primary motivation for the use of RFID technology within the construction sector and roughly specifies application scenarios such as decentralised information management. The second part of the paper discusses RFID hardware and their technical aspects.

The final part involves the discussion of two prototypes developed at University College Cork (UCC) which tested RFID hardware and software to determine its usefulness to application scenarios in the construction and facilities management sectors with an emphasis on facilities management.

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1 Motivations for the Usage of RFID in the Construction Sector

RFID is an automatic identification technology to which digital data can be written and read on so called tags by a reader using radio waves. RFID tags are attached to physical objects for the purpose of identification, tracing, or tracking information related to this physical object.

The primary motivation of this chapter is to develop scenarios for customer-oriented solutions for products and flexible, full-service concepts for manufacturing, assembly, commissioning, and operation of built artefacts. RFID in the construction industry can apply to many areas such as supply-chain management, quality control, material and labour tracking, security, safety, inspection, maintenance, documentation, and decommissioning or deconstruction. The wide scope shown in this strategy is indicative of the areas already covered by other industries in the use of RFID. It shows that many engineering tasks require the personnel to work in a “mobile office” mode.

Quality can be controlled as component installers would be able to connect to a website (using the ID stored on the RFID-tag) to download manuals and drawings. Safety can be managed during lifting and

installation as correct weights and handling procedures can be verified quickly and easily.

The material-flow can be tracked and material can be located quicker and more efficiently. Savings can be made in supply and installation time brought about by the use of RFID. Security from RFID tagged items allows tracking of tools and equipment to prevent theft which can be substantial on uncontrolled sites. Finally, due to EU regulations with respect to waste and the environment the process of deconstructing a building will allow demolition and waste removal contractors determine through RFID what material should be treated as either waste disposal or recycling material.

1.1 Supply chain management (SCM)

Leading light gauge steel frame manufacturers/erectors currently produces fully insulated "ready to install" wall panels. A typical two storey four-bedroom house can be erected to wall plate level in two days, thus leading to shorter build time and a quicker return on cash flow.

For the construction management team the most preferential system under these circumstances is to have a just-in-sequence delivery of parts and components. The ideal RFID-supported solution would be for the complete supply chain to allow items in the process be tracked and traced in real time (see Fig. 1).

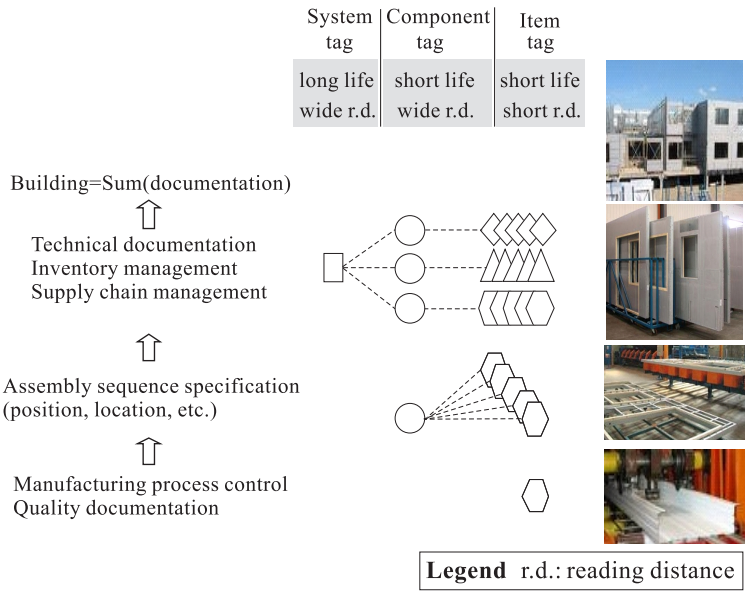

Fig. 1 Information flow and RFID-specification in SCM

1.2 RFID for decentralized data management

In most large scale "as-built" projects there are vast numbers of components, suppliers, inventory, and complicated design details that require monitoring, maintenance, repair, and replacement.

The benefits of using a decentralised information management system would be the storage and retrieval of technical documentation and performance data allowing engineering and maintenance crews to make timely decisions. RFID has the capability to allow such information being accessed in a safe and "independent" mode through applications using PDAs or laptops whilst external (outsourced) staff is working out in the field.

RFID technology allows ad hoc communication between the engineering crews and the equipment and material in place. In supporting a decentralised system for engineering and maintenance the basic concept will be of ad hoc networks that do not need any complex underlying IT-infrastructure to manage the network and where wireless communications will be employed in a simplified (but secure) way.

Through RFID-tags attached to physical objects field crews can "link" these physical objects with their "virtual representation" in remote databases and carry out simple information retrieval tasks. Additionally, context relevant information specifying the surrounding environment can be collected as well. Finally, RFID combined with sensor technology has the ability

to measure physical, chemical, and other types of properties of built environment systems supporting the diagnostics of service systems (see Fig. 2).

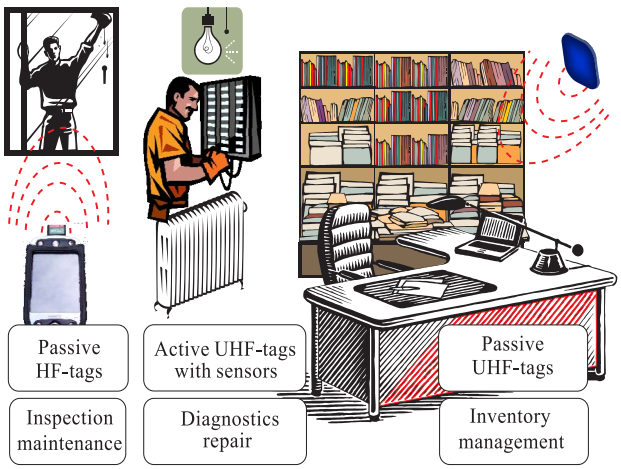

Fig. 2 Major activities and RFID-specification in FM

2 Components of RFID Systems

RFID systems consist of the following components: (1) transponder, (2) reader (optionally with antenna), and (3) management software.

2.1 Transponder

The transponder is an electronic data storage unit, which is attached to the item to be identified. RFID-transponders (also called tags, see Fig. 3) can be classified using different classification categories.

- Power: Active or passive
- Data-accessibility: Read only or read/write
- Data transmission:
  - LF: Low frequency (135 kHz)
  - HF: High frequency (13.56 MHz)
  - UHF: Ultra high frequency (869-915 MHz)
  - µW: Microwave (2.45 GHz)

A transponder can be classified as

- Active tag: which is powered by an internal battery. Active tags can be tracked from far away.
- Passive tag: which obtains the electrical energy from the electromagnetic field generated by the reader and has limited data transmission range.
- Semi-passive tag: which has batteries, but unlike active tags it does not use the battery power for communication with the reader.

Fig. 3 i-Q8 transponder by identec solutions

Most of the tags are "packaged". This protects them from the environmental elements such as rain etc. which otherwise could create readability problems. Table 1 shows examples of transponders.

2.2 Readers and antennas

Readers perform communication with the transponders via integrated or external antennas. They can be classified by

- Operating frequency, or
- Operation mode, i.e., fixed or hand-held.

The antenna is the device that transmits the radio signal to the transponders. The design of antennas is

Table 1 Examples of transponders and capabilities used for our demonstrators

Name / Packaging	Manufacturer	Memory	Type	Frequency	Reader range
Glue tag	Phillips	896 b	Passive	HF	< 1 m
Papercard	TI	2048 b	Passive		Few centimeters
Foil label	Phillips	896 b	Passive	HF	< 1 m
Glue tag	TI	2048 b	Passive	HF	< 1 m
Disc tag	TI / Identec	2048 b	Passive	HF	< 1 m
UHF tag		64 b (RO) / 2 Kb (RW)	Passive	UHF	1 m - 5 m
Smart label	Tricon	64 b (RO) / 2 Kb (RW)	Passive	UHF	< 6 m
i-D2 (Card w. LED)	Identec	64 b	Active	UHF	< 6 m
i-Q8 / i-Q32 (Block w. sensor & LED)	Identec	7855 B (i-Q8) 32 431 B (i-Q32)	Active	UHF	< 6 m
Plastic block	Tricon	64 b (RO) / 2 Kb (RW)	Active	UHF	< 100 m

very important as it will impact the data transmission range of the system. Most systems operate as simple loop system, but for larger ranges special gate antennas are required (see Fig. 4).

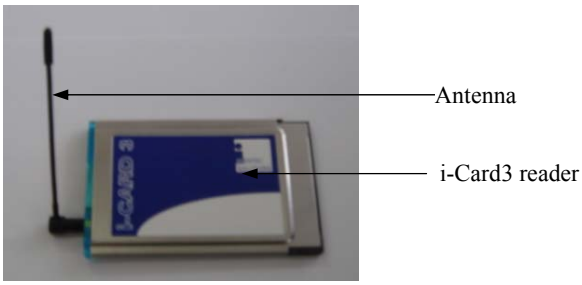

Fig. 4 Identec UHF i-Card3 reader and antenna

3 Prototypical Implementations

Students and researchers of the Chair of Information Technology in Architecture, Engineering and Construction at University College Cork (Ireland) have successfully designed, implemented, and installed prototypical RFID solutions to demonstrate the potentials of RFID for supply chain management, facilities management, maintenance, and inspection.

3.1 Scenario 1: RFID for decentralized data management in construction-supply chain management

In multiple thesis we developed a scenario based on the introduction of RFID for manufacturing, delivery and placement (supply chain) of pre-cast concrete elements[3-7].

The tags we used to implement our prototypical demonstrator were active UHF tags (types i-Q8, and iQ 32: manufacturer identec solutions) with a memory of 7855 B (iQ8) or 32 431 B (iQ32), respectively.

It was envisaged to attach at least one transponder to a dedicated pre-cast element to store an identification number for each element, the manufacturer of the element, the order date, the job-reference, the quantity of reinforcement, the concrete grade, and the site reference. The screenshot below (Fig. 5) shows how the relevant data is written and read to the transponders using a mobile reader operated by site staff.

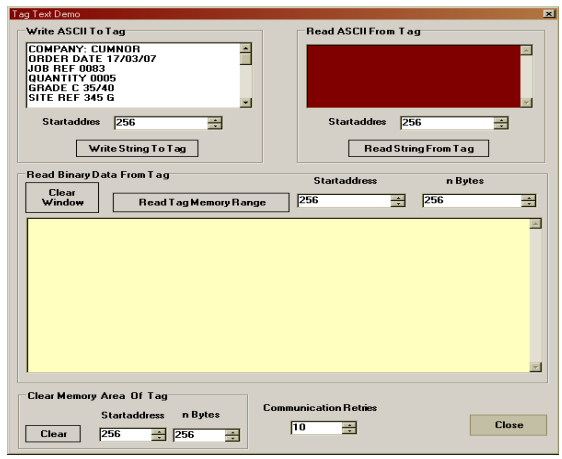

Fig. 5 i-Card3 screenshot (Identec solution)

Site reference and job-reference represent the link to the supply chain management system. The "element-ID" is "assigned" to the identifier and the position of the transport vehicle. The position of the transport vehicle can be determined by GPS (see Fig. 6).

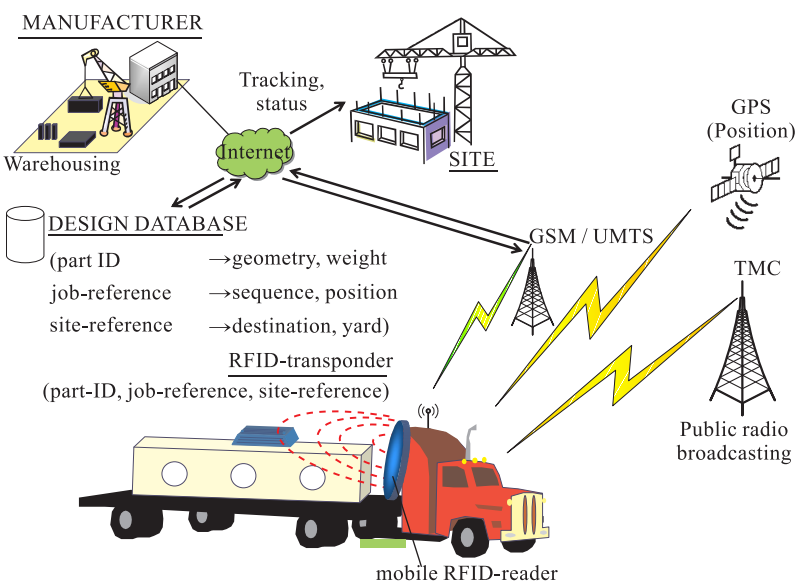

Fig. 6 SCM-scenario

Additionally, the identification number may be used to access further technical documentation in a (remote) design database. This completes the paperless transfer of data from supplier to end-user and should give the engineers all required data to ensure a safe and correct usage of an element in a given structure.

Either mobile readers or gate readers on-site can identify all transponders in the reader range. Each individual transponder may be read or new information can be uploaded to specify the status of the element in a specific phase of its life cycle.

3.2 Conclusion for scenario 1

There are many advantages attributed to the introduction of RFID technology into the SCM-processes of the construction sector[2], such as

- Greatly cutting down on the manpower needed to track the pre-cast element concrete.
- Placing less responsibilities on site staff.
- Making the delivery process "transparent" and improve opportunities to adjust and control SCM.
- Improving the documentation of manufacturing process and material used (quality control).
- Improving the availability (traceability) of relevant information in case of rebuilding / conversion.

3.3 Scenario 2: RFID for facility management

In another series of student projects we successfully designed and installed integrated RFID-based information into a web based prototype supporting facilities management scenarios, such as maintenance and inspection of heating, ventilation, and air conditioning systems[4-6]. The prototype was aimed at two users – the engineering expert responsible for producing and maintaining the technical documentation, including inspection and maintenance manuals and 3D models, and the tradesman responsible for performing inspection, maintenance or replacement work on the site.

RFID hardware and associated software[8] were utilised and connected to a MySQL database. Hardware for the prototype was situated in a laboratory of the Civil and Environmental Building. RFID technology included UHF active tags with integrated sensors to monitor the performance of building components. HF passive tags were used to collect various equipment serial numbers and to monitor the occupation profile.

PHP was used as the tool for interface development (see Fig. 7). It was decided that technical drawings and 3D-models should be accessible through a web based solution.

Fig. 7 Desktop interface with video-display, chat, 3D-navigator, and activity documentation (taken from Ref. [9])

The information was stored in the database and the gate reader regularly checked if a person had entered the room. On entry an RFID swipe card was marked red and the 3D model was updated.

In order to create 3D models a free version of Google SketchUp was chosen as it quickly allows the creation of models of rooms and buildings. For exporting to a user interface Google SketchUp with VRML

was chosen. VRML, although not the newest of standards, is well established and allows the user a variety of browser plug-ins from which to choose from.

Video cameras were already installed to the rear and front of the room. Moving 180° horizontally and 90° vertically these cameras provided an almost complete view of the room. Using Java virtual machine (JVM) and associated website plug-ins views from the camera were automatically transferred to the remote engineering expert's desktop interface.

Although the user can decide what perspective they wish to view their orientation is provided by a view that the tradesman sees as he first enters the room. Also provided for in the 3D-model is the position of the RFID tags in order to make finding them easier. Using the user interface to click on a particular tag allowed the tag data to be extracted from the database. The tradesman could also read data from the RFID tag itself.

In the case of the tradesman a wirelessly connected PDA was used. For PDAs the two main browsers are Internet Explorer and Opera. These cater the much less functionality that occurs with PDAs. The mobile device interface did not provide for 3D models but did provide two dimensional plans of the room (see Fig. 8)

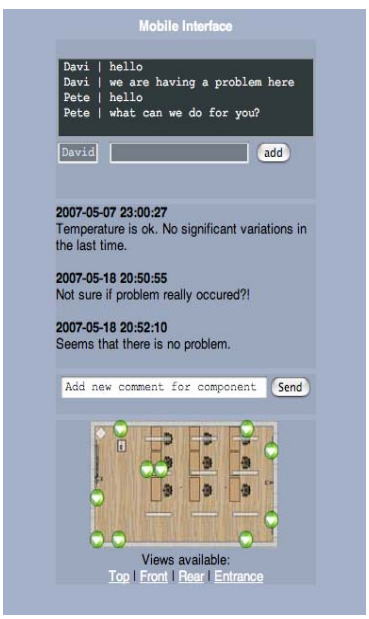

Fig. 8 Mobile interface with chat, activity documentation and 2D-Navigator (taken from Ref. [5])

It was requested that the prototype should support both LAN-access and GPRS/UMTS/3G connectivity. Additionally, an RFID-Reader was installed.

The tradesman could make decisions based on the information that was read either from the database or from the individual tags placed around the room. The main use of the prototype in this situation was to support the maintenance processes related to the heating system. The active RFID tags with integrated sensors monitored the temperature of individual radiators.

Although the tradesman could not retrieve historical performance data about the tagged equipment, they were able to request such information from the engineering experts through the PC-desktop chat interface. Real time data stored on active RFID-tags with integrated sensors was monitored by the tradesman to test working conditions and comfort aspects. As an example there could be a situation where a tag could respond only under a particular condition such as when a thermal monitoring tag detects an extremely high temperature on a particular radiator on the system. This could alert the tradesman and lead to the radiator being checked or having a routine maintenance check.

3.4 Conclusion for scenario 2

We have demonstrated in principle the application of RFID-technology in FM-scenarios. However, there is still a deficit with respect to the integration of different RFID technologies (e.g., HF and UHF-tags). Furthermore, problems related to "high-density" installation of different radio technologies in buildings (e.g., RFID, W-LAN, and wireless sensors) needs to be further analysed.

4 Conclusions and Future Work

This paper has illustrated the potentials of RFID-technology in the construction sector. Basic scenarios were developed. Principle feasibility studies were performed by students with laboratory conditions.

For a successful technology transfer into the construction and FM-sectors it will become crucial to involve industry partners in the future development steps.

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