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An Overview on RFID Technology Instruction and Application

Fatah Chetouane

Faculty of Engineering, Université de Moncton, Moncton, E1A 3E9, New Brunswick Canada (Tel: 506-863-2074; e-mail: fatah.chetouane@umoncton.ca)

Abstract: This paper provides a non-exhaustive, rather earlier than recent, overview of contributions in the field of Radio Frequency Identification technology (RFID), and its use in several sectors. The multidisciplinary nature of this emerging technology requires skills from various engineering fields. Due to the growing use of RFID in various economic sectors, it seems essential to educate engineers, and technicians, to better master this technology. For this purpose, an RFID engineering technology curriculum may be established using different approaches. This paper discuss an approach to integrate RFID technology within usual engineering curriculums by stressing its link to usual disciplines such as industrial, electrical and computer engineering. A case of an RFID laboratory established at the Université de Moncton (UdeM) is shown. An RFID-based automation of a flexible conveyor system application, carried out in this laboratory, is also described.

Keywords: Data privacy, Data transmission, Electromagnetic waves, Flexible automation, Identification, Programmable logic controllers, Software engineering.

1. INTRODUCTION

RFID (Radio Frequency IDentification) is a wireless communication technology used to capture data, which may be linked to different identification attributes (serial number, position, colour, date of purchase, etc.) of entities carrying RFID labels (tags). The data collection process is based on an exchange of electromagnetic waves between RFID tags and RFID interrogators (readers). This Automatic Identification and Data Capture (Auto-ID) technology is capable of providing further labelling granularity when compared to barcodes and previous Auto-ID technologies. For instance, with RFID, it is possible to allocate different identification codes for similar items, and different levels of identification allowing better visibility and tractability in logistical and manufacturing processes. Over the past five years, several groups (economic, social, military, healthcare, and political) became aware of the potential to innovate and improve the efficiency of their processes using RFID technology. The use of RFID tags is increasing, and their communication performances, and level of standardisation, are being continuously refined. For instance, the development of new communication protocols such as, the Ultra High Frequency Generation 2 (UHF Gen 2), brought an unprecedented level of reliability, and information security to this technology. Based on these recent trends, fostering RFID knowledge and expertise in students' skills, becomes crucial to most engineering programs. This paper attempts to present few academic studies conducted on RFID technology. The studies are organised into three categories, based on the RFID technology 3C concept: *Context*, *Capture* and *Control*. The subsequent section suggests an approach for RFID technology instruction, by indicating engineering disciplines or courses which can be modified, or created, to this purpose. The remaining sections present an RFID Lab founded, at Université de Moncton (UdeM) in 2007, with the financial support of The Natural Sciences and Engineering Research Council of Canada (NSERC). Its physical layout and equipment specifications are exposed. A manufacturing automation application, linking programmable logic controller (PLC) and RFID technologies, for the control of industrial conveyor, is successfully tested at this laboratory. The application goal is to demonstrate, how more operational flexibility can be added to a contemporary PLC-based manufacturing automation, using RFID technology.

2. RFID SYSTEM COMPONENTS

RFID integration to any process is usually achieved according to three facets: *Context*, *Capture* and *Control*. In the context facet, one must explore the evolution environment of the process subjected to RFID integration, by studying the environmental conditions under which RFID tags will be operating. Inventorying information to collect from the process, and identifying communication constraints/obstacles inflicted by the process environment (interference, reflection, and other communication obstacles) must be investigated. The capture facet deals with the selection of RFID equipment (tags and readers) to ensure accurate data collection from the explored process and environment. At this stage, operation frequencies, RFID tags reading range, RFID antenna locations, power control, information privacy and security issues are among few factors to be adjusted, for efficient data capture, and reliable RFID interrogation zones design. The control facet deals mainly with RFID system real-time control (middleware link to other enterprise applications, EPC database, graphical user interfaces), and business intelligence rules implementation (information processing, system response to RFID tag triggered events, control rules, algorithms). Usually an RFID middleware is developed based on the constraints dictated by the context, and capture facets. A basic RFID system is generally made of the following components:

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- RFID tags fixed to entities with unique electronic product code (EPC) per entity (wireless RFID network);
- Networked RFID readers, and real time databases;
- RFID antennas for information exchange between the tags wireless network and middleware/control platforms.

There are two types of RFID tags: passive and active. A passive RFID tag is powered by the electromagnetic energy, radiated from RFID reader antennas, based on backscattering. A passive tag can't transmit radio waves of its own, and its information storage capacity and computing capability are limited. It can be read only at short range (0.6 to 3 meters). An active tag is powered by an on-board long-life battery that provides sufficient energy to allow independent communication capability within greater range (approximately 90 meters). To establish communication between RFID tags and readers, antennas are required. There are several types of antennas for active and passive RFID systems: linear, circular, wide band, narrow band, single and dual polarized antennas. Antennas are usually selected according to their beam width (for narrower or wider coverage): a circular antenna has more inductance than a linear one, thus, it induces scattered waves in several directions, ensuring a wider interrogation zone coverage. Figure 1 shows the architecture of a basic RFID network. The right side describes RFID middleware functionalities (user access, control interface, interaction with enterprise database and servers), while the left side describes the ad-hoc wireless RFID network integrated to the physical process under supervision/control.

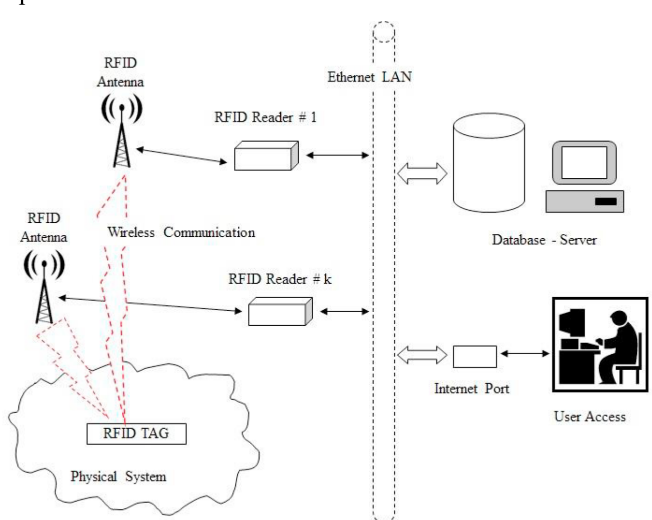

Fig. 1. Generic architecture of a basic RFID system.

Some RFID middleware are application specific, however the tendency is to ensure technological flexibility (compatibility with different RFID equipment), application flexibility (quick setup of different applications), and access flexibility (multiusers, concurrent and remote access).

3. PAST DEVELOPMENTS IN RFID

Research contributions on RFID technology can be classified according to three themes: RFID systems design, RFID system applications, and RFID system threats and regulation issues. While more recent applications can be reported as this technology still growing, we chose to report earlier studies conducted during the eight past years.

3.1 RFID Systems Design

This research theme includes studies made on the design/installation of RFID systems, and software components (tags, antennas, middleware). The goal is to select and fine-tune RFID system parameters in order to achieve efficient data capture. Most studies are conducted using experimental approaches. Relationship between tag reading range, reader scattered power, and antenna gain can be empirically investigated (Keskilammi et al. 2003), (Penttilä et al. 2006), while different technologies, for instance antenna (Sydänheimo et al. 2006), can be compared with respect to identifying information (size, shape, material of a specific object). Contributions using analytic methods for optimal RFID system parameters selection are scarce. Other studies focused on systems middleware architecture and development, using attributes identified as critical to RFID system performances (Jongyoung, and Naesoo, 2006). Among those attributes, one can quote, RFID equipment firmware, tags reading rate, and sharing resources protocols for multi-user systems. RFID system design is mostly achieved using experimental (trial-and-error) approaches, such approach can be resource-intensive and time consuming. A potential research to undertake is to provide RFID system developers, with formal and simulation-based tools, allowing fast RFID systems performance testing and design, in seamless off-line manner.

3.2 RFID System Applications

This research theme includes studies on the integration of RFID technology in various activity sectors. Most applications are reported from the manufacturing sector: production monitoring and control (Huang et al. 2007), (Schuh et al. 2007), (Zhou et al. 2007), and supply chains management (Chow et al. 2007), (Chow et al. 2006), (Ngai et al. 2007), (Rekik et al. 2008), and (Wang et al. 2008). Other studies regarded RFID use as an avenue to simplify the control and management of complex systems such as: efficient management of recycling process (Parlikad and McFarlane, 2007), drugs traceability for pharmaceutical industry (Adams, 2007), bookstore inventory control (Coyle, 2005), patients flow management in health care facilities (Fisher and Monahan, 2007), airport baggage routing and handling (Wong et al. 2006), food safety and labelling (Ngai et al. 2008), and in-building asset tracking and management (Ni et al. 2004). The growing number of these applications confirms the capability of RFID systems to achieve operational efficiency and reduce costs. RFID technology must be assimilated and effectively integrated to effectively manage the production of goods and services.

3.3 RFID System Threats and Regulation Issues

RFID data transmission through the air interface raises privacy issues, as it can be captured by hidden readers, or routed to malicious databases. Any RFID tag data relating to an entity (objects, animals, humans, etc.) present within an RFID system reading range can be captured by an uninvited third party and snip its entity data attributes, causing privacy breach, and compromising users safety and security. This research theme includes studies to improve user authentication and privacy (Reid, 2007), and communication protocols to secure RFID data transmission (Rieback et al. 2006). Several threats and risks linked to RFID equipment are also studied such as: RFID tag cloning and RFID reader denial of service. Several avenues are being explored to secure interrogation zones at the physical level such as: Faraday cages, limited range transmission, and on-demand reading of RFID tags. Despite the notable progress made towards overcoming these concerns: EPCglobal Inc. guidelines, Auto-ID Lab research at Massachusetts Institute of Technology (USA), many vulnerability issues still not solved (and may not be) as long as there is no enforcing regulations on the use of RFID.

4. RFID ENGINEERING CURRICULUM

Facing the increase of RFID technology adoption in various activity sectors, it becomes crucial for most engineering curriculums to provide their enrolled students with the opportunity to learn RFID technology principles, and to experiment with its integration challenges. There is a need for programs that provide more than just basic notions of RFID, to create new bodies of knowledge for this emergent technology. Based on the 3C concept framework explained above, there is an attractive match of RFID engineering to three disciplines namely: industrial, electrical and computer science engineering disciplines. An RFID engineering program can be located at the crossroads between these three disciplines according to the 3C framework shown in Figure 2.

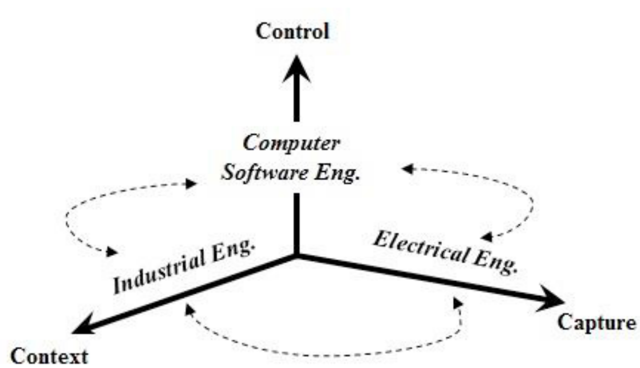

Fig. 2. RFID engineering according to the 3C framework.

4.1 Industrial Engineering

RFID engineering requires knowledge of several concepts from industrial engineering, particularly, project definition and management, resources and operations scheduling, risk and quality assurance, information inventorying, and return on investment analysis. Knowledge of supply chains and logistics, warehouse management systems, material requirement planning (MRP), lean manufacturing (just-in-time, production efficiency, Kanban systems) is also crucial, since RFID integration is frequently directed toward solving challenges encountered in these segments. The success of RFID integration into a process is often judged by the obtained process performance metrics, and not by RFID as a technology of its own.

4.2 Electrical Engineering

An RFID engineering curriculum may share several courses with electrical engineering discipline. Electromagnetism, radiofrequency (RF) physics, communication, and electrical circuitry design are necessary materials to understand the physical principles governing RFID systems. Transmission performance in an RFID wireless communication system can be analysed using link budget equations: received power (dB) = transmitted power (dB) + gains (dB) − losses (dB). Backscatter radio link budget losses in RFID system include refraction, reflection, and fading due to multipath propagation. Operating frequency of RFID systems can range from 125 kHz to 2.45 GHz, containing near and far field propagation. This provides several opportunities for studying backscattering, magnetic coupling, and interference in a typical field propagation course. An extension for RFID engineering is the study of sensor networks and antennas design. Active RFID tags are usually equipped with self-powered wireless sensors. Their numerous applications in various activity sectors (cold supply chains monitoring, datacentre operations, goods delivery tracking, indoor building automation, ambient intelligence, etc.) offer a wide spectrum of projects to undertake. Interrogation zones reliable coverage require knowledge in antennas design and selection. Antenna design and sensor network materials are substantial add-ons to any RFID engineering curriculum.

4.3 Computer and Software Engineering

RFID hardware systems are usually bridged by RFID middleware to higher level enterprise systems, where other business information (accounting, payroll, time cards, billing, shipping and receiving, etc.) can be accessed and/or updated. An RFID middleware assists with the filtering, aggregation, and routing of captured tag data by monitoring their stream and directing it to the appropriate enterprise system database. It can be perceived as the gatekeeper, manager, and the translator of the captured process data (business value). The success of RFID integration to a process is directly affected by its associated RFID middleware features and performances (user interfaces, security and authentication protocols, updates, upgradability, etc.). To attain a successful design, a good background in computer science engineering, that is inclusive of hardware and software skills, is essential. An RFID engineering program should include a good selection of software engineering courses such as software architecture, real-time databases design, networking, and design of graphical user interfaces. Topics on secure communication protocols, authentication methods, EPC guidelines and encryptions techniques, can also be valuable add-ons for the design of reliable and secure RFID systems.

5. RFID LAB AT UNIVERSITÉ DE MONCTON

With the financial support of the Natural Sciences and Engineering Research Council of Canada, we set up an RFID Lab at the Université de Moncton, during summer 2007. The initial goal was to support newly launched industrial engineering orientation (industrial systems and automation) within an existing electrical engineering program. Several new courses were introduced in this context, among them a course coded GELE5119: programmable logic controllers and RFID. The GELE5119 course is aimed toward the efficient use of RFID technology in manufacturing systems control, with special focus on shop-floor automation. The RFID Lab presently contains the following equipment:

- IF61 smart reader (Intermec Inc.)
- ALR-9650 reader (Alien, Inc.)
- IA33A circularly polarized antennas (Intermec Inc.)
- IT65 rigid passive UHF tags (Intermec Inc.)
- ALN-9540 passive UHF Squiggle™ tags (Alien Inc.)
- RFID simpleware from BlueBean, Inc.
- Twido-40DRF programmable logic controller, and TwidoSuite language (Schneider Electric Inc.).
- Pallets and reconfigurable conveyor (FlexLink Inc.)

Figure 3 gives an overview of the RFID Lab. The conveyor has three stations equipped with pneumatic cylinders for pallets blocking and diverting. It can be fully controlled by programmable logic controller (PLC).

Fig. 3. Overview of the RFID Lab at Université de Moncton.

The IA33A circular antennas, mounted on flexible tripods, are used to support communication between RFID tags (fixed on pallets) and RFID readers. The IF61 RFID reader features computing and networking capabilities, allowing us to run RFID applications remotely. Middleware coded in an object-oriented languages (Java, C#.Net) can be executed on the IF61 reader, enabling it to filter, store and manipulate information received from RFID tags and directing them to the user personal computer (PC) see Figure 4.

Fig. 4. IF61 reader linked to user personal computer.

The PC is also connected to the PLC allowing the control of the conveyor, and its different stations, using TwidoSuite automation language (Ladder diagram, GRAFCET or instruction list). RFID simpleware is a software solution that allows RFID tags information to be tracked in batches and captured from multiple readers. The information can be saved as data file or Microsoft Excel sheets. This helps users to quickly grasp RFID data capturing concepts, and start mapping simple applications for testing or demonstration purposes. The RFID Lab is a key resource for RFID solution showcase and for designing RFID teaching curriculums.

6. RFID-BASED INTELLIGENT AUTOMATION

Several applications on coupling RFID technology with industrial automation were developed at the RFID Lab. An application for automatic sorting of entities based on their type is described in this section. Three types of entities typically: type 1, type 2 and type 3, are manually loaded on the conveyor with RFID tagged pallets. The loading can occur randomly at any time. The system must be able to automatically divert the correct pallet at its corresponding station. For a pallet with a type j entity (j=1, 2 or 3) arriving at a station k (k=1, 2 or 3) the system takes the following series of actions:

- If j=k: the pallet is blocked (while conveyor running) → the entity is diverted from the pallet by an automatic air cylinder → the empty pallet is released.
- If j≠k: no action is taken for pallet j at station k.

Circular antenna is installed beside each station to detect the arrival of pallets and send their captured tag data to the IF61 reader. These RF identification data are decoded, and validated, prior to triggering any action from the Twido PLC (stopping a pallet). A simplified view of the setup is depicted by Figure 5. In this application, the RFID tags are programmed with only entity type information. Other information such as location on the conveyor, status, entry time on the conveyor, history of use etc. can be easily added in the future according to the complexity of the application being studied. This flexibility allows studying several functioning modes with little process re-configuration. The

IF61 reader is equipped with a powered general purpose input output circuitry (GPIO). This enables it to directly monitor and control field devices such as presence detectors, signal lights, without requiring extra devices and power supplies. In our setup, the IF61 GPIO is used to send a signal to the Twido PLC I/O card (PLC is considered as a filed device) to launch the appropriate PLC control at the station "k" where antenna detected an arriving pallet "j" (only if required j=k).

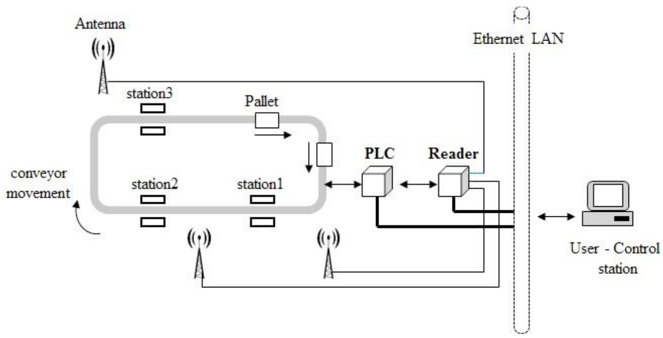

Fig. 5. Shop-floor RFID-based automation.

The pallet captured tag information (hexadecimal format) is used by the IF61 reader to generate and send a binary input signal through its GPIO port to the Twido PLC inputs. Depending on the PLC input address a specific automation subroutine is executed in TwidoSuite to take the appropriate action by the PLC (divert pallet "j" at station "k", or do nothing).

This experimental setup uses GRAFCET program as the main control layer to ensure the desired operation of the conveyor. Due to the approximate coverage boundary of an antenna, a pallet RFID tag could be read as entering a given station but still in fact quite far from it. Thus, if the PLC triggers an early action at this station while the pallet didn't arrive yet, it is considered as a dysfunctional operation. In our case, this problem is overcome by reading a pallet RFID tag only when the station proximity sensor detects the pallet in at station (not approaching the station). Other approaches can be investigated such as: programming of intelligent timing functions, pallet localisation by concurrent reading of all antennas, triangular localisation procedures, etc. Other challenges are power losses and radio signal reflexion, in the presence of conveyor metallic structure. Some of these issues are currently being studied in collaboration with students enrolled in the RFID course and project. Developed solutions are used as a knowledge base to cultivate RFID technology awareness and preparedness and also exposed as showcases for potential industrial collaborations.

7. CONCLUSION

This paper presents an overview of some previous contributions in the field of Radio Frequency Identification technology (RFID) and its use in several activity sectors. In light of these contributions, a framework on RFID technology integration into current educational and training curriculums is depicted and discussed. This framework is based on the 3C concept explained within. Disciplines such as industrial, electrical and computer engineering seem to offer a greater potential of skills to any RFID engineering curriculum. A brief description of the RFID Lab we set up at Université de Moncton was provided. The RFID Lab main target is to provide RFID training in electrical engineering and support research in the field of RFID-based intelligent automation. This RFID Lab offers opportunity for students to grasp knowledge and acquire hands experience in RFID integration applications (industrial engineering orientation embedded in electrical engineering program). In conclusion, as RFID integration may often be synonym of costly investments, intensive experimentations, and real process reengineering. It is important, in our opinion, to develop virtual commissioning, testing, and simulation tools and techniques, due to the noticeable lack of such contributions.

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