A REVIEW OF EMERGING SMART RFID IN HEALTHCARE

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ABSTRACT

This paper reviews emerging Smart RFID applications in healthcare. These types of 'smart' applications typically extend the role of traditional RFID to encompass aspects of sensor and control for applications that are non obvious but leverage the existing RFID infrastructure.

***Keywords**: RFID, Smart RFID, medical devices*

INTRODUCTION

The current scope of radio frequency identification (RFID) technology in healthcare includes conventional as well as emerging 'smart' RFID devices and applications. A primary objective of RFID applications in healthcare is to automate manual processes as well as to reduce the time required to track and locate assets, including vital supplies and people, thereby resulting in improvements in institutional efficiency and productivity [1]. Ultimately, RFID applications in healthcare can support healthcare service providers in decision making functions and arduous tasks typical within a complex clinical environment. It is generally acknowledged that there are 'ten cutting-edge RFID hospital applications, present and future' [2]:

1. Asset (equipment) tracking and management;
2. Doctor and nurse-find/monitoring;
3. Patient monitoring/movements;
4. Patient safety bracelet with chart information;
5. Pharmacy prescription fill;
6. Chargeable equipment billing in patient rooms;
7. Preventive maintenance reminders;
8. Uniform/scrub dispensing;
9. Access control – identifying nurses and doctors entering surgical suites; medicine rooms; and,
10. Surgical tool sterilization and monitoring.

As there is increasing pressure towards improving the delivery of healthcare services and hospital management practices, this list will continue to grow.

Overall, there are many emerging RFID inventions that can offer drastic improvements in processing times associated with medical records retrieval, efficiency of services, reliability of medical diagnosis, dispensing of medications, and personnel management [3]. For instance, at the patient point of care (POC), Smart RFID-enabled medical devices deployed within an RFID framework, can serve to correctly identify patients to receive – and care providers authorized to deliver – a prescribed medical treatment or procedure in a "fail-safe" manner [4]. Considering the broadly classified range of applications, it is expected that RFID in healthcare will continue to evolve and find acceptance as technology hurdles are circumvented and barriers to entry regarding standards, security, and privacy concerns are addressed [5] [6]. This will open up new opportunities for innovation and deployment of Smart RFID in healthcare.

This paper provides an overview of the state-of-the-art of Smart RFID in healthcare, outlining some of the limitations and difficulties associated with the technology and its deployment.

SMART RFID ENABLED MEDICAL DEVICES

This section overviews Smart RFID-enablement which incorporates the less obvious means of augmenting conventional RFID with sensor, control, and activation. Several of these Smart devices are equipped with an advanced RFID device for identification as well as the enhanced functionality, enabling deployment only when corroborated with the correct patient and medical treatment, and thereby conforming to the medical compliance standard expressed as 'the five rights of medical treatment'.

First-generation RFID applications have been in commercial use for well over 20 years. These conventional applications in healthcare are primarily based upon identification, for example technologies and methodologies for improving patient POC and reducing errors based on barcodes and RFID [7] [8]. In general, conventional applications enable systems to be built around inventory tracking and control. Extensions include pharmaceutical supply chain inventory and tracking for medical reconciliation. Tied into a hospital management system, they hold considerable potential to reduce adverse drug events (ADEs) at the patient POC. This is accomplished through corroboration of the patient ID with the drug prescribed by the physician. These technologies carry increasing potential as the supporting electronic technology improves and connectivity protocols become standardized [9]. One of the limitations with early adoption of both RFID and barcodes is that they are inherently submissive, allowing for identification with little or no support for interactivity and automation.

Second-generation or 'Smart' RFID-enabled healthcare solutions offer an expanded functionality beyond conventional RFID tagging alone. While conventional RFID is typically reserved for supply chain management, incorporating identification, asset tracking and locating, Smart RFID-enabled devices incorporate the functionality of control (sensor and actuation) facilitated by microelectronics technologies such as system-on-chip (SoC) [10]. Within this expanded capability, applications can incorporate an RFID enabled electromechanical lock used in combination with a pervasive health informatics platform. In a medical compliance configuration, this serves to mitigate against undesirable medical incongruities and can be implemented in a number of devices for applications requiring proper identification and corroboration for medical treatment and testing.

Smart RFID also introduces novel designs for integration with evolving and legacy POC systems. The control and communication for these devices can be derived from the interaction of an RFID reader and tag in conjunction with the associated electronics and overseeing medical information management system. Smart RFID-enablement, with its enhanced functionality, lends itself to improved fail-safe or 'intelligent' medical devices, medical compliance and reconciliation systems encompassing medication prescription, transcription, administration, and pharmacological preparation, and physical and biological (e.g., vital signs) sensor-based functional-monitoring modalities. The benefits of Smart RFID are compounded when used in conjunction with conventional RFID tagging (e.g., RFID badges, wristbands) for identifying patients, healthcare providers, and medical supplies and equipment.

• **Smart Infection Management:** a hand-washing (sanitizing) hygiene surveillance and compliance system, implemented across an entire healthcare facility, can be an important tool in the prevention and spread of infection. This application is representative of the capabilities of enhanced Smart RFID-enabled dispensers and washing stations, as it can reduce the risk of widespread (nosocomial) infections causing patient harm or even death due to staff and visitor non-compliance in high susceptibility areas.

• **Smart Container (Pill-bottle):** eCAP™ developed by Medi-icECM™ offers solutions for patient non-compliance and securing the pharmaceutical supply chain according to FDA requirements [11]. eCAP™ serves as an electronic reminder and monitoring system, tracking medication usage without active patient input. It is a medication compliance technology that comprises a Smart RFID tag embedded in a closure for medication bottles and the like.

• **Smart Coupler:** a medical tubing (or channel) interconnect incorporating the functionality of Smart RFID-enabled fail-safe locking technology is manufactured by Colder Products Inc. [12]. The two-piece Smart coupler consists of a male and female sub-miniature plastic connector containing an integrated RFID tag and RFID reader, respectively, typically used for connecting medical and surgical equipment, including blood-pressure cuffs, blood analyzers, analytical instruments, and IV infusion bags. When two pieces of the connector are joined for coupling, the RFID reader scans the tag. If there is a mismatch or incompatibility, the error could trigger an alarm and/or completely disable the coupling function to prevent an open channel. In addition to this Smart technology ensuring that the equipment is hooked up properly, it also ensures that healthcare providers are not reprocessing and reusing devices that are intended for disposal. By programming the Smart coupler system (RFID reader) via a computer interface, application specific data and rules can be customized for the particular application.

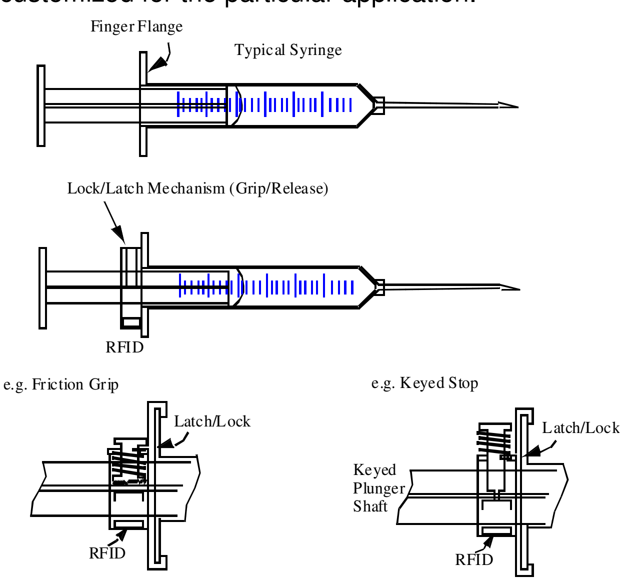

Figure 1: Smart Syringe (User Operated – Control Mechanism at Finger-Flange)

• **Smart Syringe:** A further example of a Smart RFID application in healthcare is the Smart syringe as illustrated in Fig. 1. The Smart syringe extends the basic injection principle of a standard syringe in that it offers much greater capability and purpose via integration with an RFID-enabled capability. A Smart syringe has a bi-directional communication channel along with a microcomputer interface. The capability therein incorporates a controller that authorizes the operation of a manual or automatic mechanical injection plunger with a lockable-latch or pinch-off regulating mechanism, thereby modulating the flow of fluid through a syringe. The Smart syringe incorporates an 'intelligent' RFID tag and accompanying interface (in situ and/or ex situ) in a method to control the mechanical operation of a plunger either i) manually enabling or precluding an instance of user operation of the syringe plunger regulating mechanism, or ii), automatically enabling or precluding an instance of power assisted (e.g., electromechanical) operation of the syringe plunger regulating mechanism. Hence, in addition to facilitating flow by activating a syringe plunger regulating mechanism (opening, closing, or modulating), this Smart syringe assembly incorporates a lockable-latch which will prevent unauthorized, erroneous, or inadvertent operation. In the field, information will be available as to the status of operation (metrics, performance), maintenance, and serviceability [10].

The RFID-enabled Smart syringe can be identified with an RFID reader juxtaposed with a mobile or handheld computer, computer on wheels, or a stationary communicating computing device. In this configuration, the RFID reader can thereby be used to interrogate the Smart syringe status as well as identify patient (via RFID wristbands, neck-fobs, or badges), healthcare provider, and other medical supplies and equipment used. The handheld computer can provide on or off-line audio and video status as to the authentication and compliance of the medical procedure or treatment in real-time. Upon identification, corroboration, and authentication among patient, care provider, and medication preparation in the Smart syringe, the interrogating RFID reader could be used to activate or preclude the Smart syringe latch and/or plunger regulating mechanism according to the prevailing medication compliance protocol.

Another Smart syringe application has been developed by Covidien for the safe delivery of prefilled contrast media to patients [13]. It uses RFID-enabled technology to create an 'intelligent' interface between a contrast media syringe and an accompanying power injector. It automatically precluded the injection of contents from a previously used RFID-enabled syringe by physically altering the attached RFID label, thereby potentially reducing medical errors and increasing the efficiency of CT imaging.

• **Smart Implantable Devices:** Smart RFID medical devices are extending beyond traditional uses by incorporating various sensors and actuators, likely to be widely available as implantable devices [14]. The integration of implantable RFID with bio- and chemical sensors is of great interest, in that the combination can be used to create new devices for both diagnosis and even treatment. These types of hybrid RFID devices can be used practically and robustly (both in vitro and in vivo) with broad clinical efficacy.

• **Smart Blood-glucose Monitor:** glucose monitoring is one healthcare application area that may be better served with an 'implantable' insulin pump in combination with an RFID SoC sensor-pad (affixed transdermally or implanted), to be used by diabetic patients without the requirement for taking blood samples subcutaneously several times per day. For example, Digital Angel Inc. is developing an implantable glucose-sensing RFID-enabled tag, making it easier for patients to monitor their blood-glucose levels [15]. Intestinal and esophagus monitoring with pH and temperature sensors fall into the same class of device; they offer a minimally invasive means of biopsy and diagnostics, facilitated as a direct result of RFID-based SoC technology.

• **Smart Bandage:** there are several RFID-enabled bandages (also called diagnostic skin patches) currently under development. Gentag uses RFID-enabled mobile phones to 'poll' for application status using embedded temperature, pressure, and other sensors situated with RFID [16]. Versions of Smart bandages can assess fever, monitor damaged tissues, perform controlled drug delivery, and perform transdermal glucose sensing and monitoring via RFID. Patients can then self-monitor (e.g. after surgery) and have the option of transmitting their wound status directly to a remotely located overseeing physician's PDA. ECI Biotech is developing similar Smart bandages to detect gram-negative and gram-positive bacteria through a sensor chip that could also be interfaced with RFID. A Danish group is dedicated to helping diabetics manage their lesions using Smart bandages studded with many tiny sensors that could also be monitored by RFID [17]. This facilitates diabetics' foot health and reduces the risk of amputation and physician visits. Finally, a Smart Band-aid prototype developed at the University of Calgary attaches to a patients' temple for wireless temperature monitoring [18]. Such a device could also appropriately be fitted with telemetry via RFID.

• **Smart Cabinets (Shelves):** in order to improve hospital inventory management (control and documentation), billing efficiency, and workflow automation, cabinets and shelves have been proposed which are RFID-enabled. Mobile Aspects has developed iRISupply™, a Smart cabinet solution platform which includes the tracking and management of clinical processes for utilization of supplies, devices, instruments, equipment, and medications [19].

• **Smart Beds:** hospital beds (employing Hill-Rom's NaviCare™ Smart Hubs solution), when used in conjunction with POC medical devices, have been proposed for improving clinical workflows for nurses and to reduce the clinical documentation burden for front-line caregivers by automating medical device data transmission to EMR systems [20]. The communication is provided by way of wired or wireless direct bed connectivity to EMRs, which could also be supported by an RFID infrastructure to enable the 'Smart Room' of the future.

It should be recognized that both conventional- and Smart-RFID are not panaceas to solve all healthcare management issues, as they have current technological limitations characteristic of many new technologies and are fraught with privacy and security concerns. Additional considerations include the reuse of devices (i.e., 'Smart Sterilization'), which implies an additional constraint that may require the device to be subject to temperature, chemical, pressure, and/or electronic processes not otherwise required in less sterile environments. As with other medical devices, clinical grade Smart medical RFID-enabled devices will be required to meet the stringent standards and guidelines of various governing bodies for the healthcare industry. These include mandates regarding security, information integrity (encryption), and privacy. Clinical grade RFID-enabled devices will also be required to meet rigorous EMI and EMC (electromagnetic interference and compatibility) guidelines as their rate of adoption increases. Thus, Smart RFID-enabled medical devices come with an associated overhead, but are not superfluous in deployment, and can be used within the framework of an engineered POC system [21] [22]. Currently, the capacity exists for seamless integration with purposeful function, and an evolutionary path to improved overall medical compliance.

SUMMARY

Over the next several years, one expects to see a significant push for improved healthcare services and medical records adoption demanding quicker, better, and cheaper POC and clinical biomedical testing and diagnostics. To fulfill this need, opportunities will continue to emerge for both conventional- and SoC-RFID-based Smart healthcare technologies, and they will play a viable role toward the ongoing goal of improved patient safety and quality of care [4] [23].

Considering 'doing no harm' with respect to patient care takes precedence, the adoption of Smart RFID in healthcare technologies will help serve in mitigating the direct costs of otherwise preventable substandard or risky patient care, resulting from injury, increased hospitalization stay, permanent disability, or even mortality [7] [21]. It also follows that Smart RFID will help circumvent institutional damages due to negligence in patient care – leading to the undesirable indirect costs of litigation and compromised reputation.

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