

LEVERAGING COMPLEX EVENT PROCESSING FOR RFID APPLICATIONS: A CASE STUDY IN HOSPITALS

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ABSTRACT

Radio Frequency Identification (RFID) has emerged as a key technology for automatic data collection and asset tracking and has been adopted in a variety of industries. However, the large volume and high velocity of data poses a major challenge for maintaining data processing efficiency and effectiveness. One viable solution for dealing with this challenge is Complex Event Processing (CEP), which can extract meaningful events for business applications. This paper examines different aspects of applying CEP model to RFID applications. We present the motivation, benefits and framework and walk through a scenario to study CEP-embedded RFID applications in hospitals.

Keywords: Complex event processing; RFID; Healthcare; Hospitals; Middleware

INTRODUCTION

RFID is a rapidly developing technology widely believed to be the next generation innovation for automatic data collection and asset tracking. Compared to traditional barcode scanning, RFID does not require line-of-sight for readers to capture tag information, and it can read multiple tags simultaneously from a longer distance. RFID has been adopted in a wide variety of industries such as supply chains, mass transit, healthcare, entertainment, manufacturing, retail and logistics. Major corporations such as IBM, SUN, Microsoft, Oracle and others have developed generic middleware systems for RFID applications. Current RFID middleware systems capture raw readings from readers, filter and aggregate the data, and finally yield cleansed RFID raw events. However, RFID raw events only provide low-level information such as electronic product code (EPC), reader identification and timestamp, which are not directly related to business processes. Therefore, the ability to quickly transform these raw events into business events useful for decision-making becomes a central issue for realizing the maximum value from RFID technology in business [23].

Complex Event Processing (CEP) is an effective solution to real-time event stream processing for today's dynamic business environment. Compared to the traditional delayed analysis methods used in relational database, CEP involves continuous processing and analysis of high-volume and high-speed data stream to detect business-critical issues in real time so as to support business decision making. Thus, it helps predict business opportunities and associated risks. Potential applications of CEP include real-time financial market data analysis, IT security event

correlation, fraud detection, airlines operations monitoring and network monitoring and management [1]. However, its use in RFID-enabled applications has been limited.

This paper examines the limitations of applying existing event processing methods to RFID-enabled business applications and presents a feasible solution by leveraging current CEP approaches to unique RFID applications to enhance operational efficiency and insight.

MOTIVATION AND RELATED WORK

Although RFID technology has shown significant benefits for business process automation, the unique characteristics of RFID data, such as huge volume, dynamic and temporal features, pose new challenges for data processing and management. Existing RFID systems are typically composed of three layers of event processing: reader, middleware and application layers. The middleware deals with low-level data cleaning such as filtering and aggregation according to temporal and spatial granules [7]. Although the cleansed RFID event flow generated from RFID middleware contains little false and duplicate data, it is still in large volume and involves no contextual information or business logic. Thus, ironically, immediate access to the crushing load of data does not automatically translate to business insight, agility and competitive advantage but can rather cause the opposite effect – information overload [18]. In addition, current applications were not built to provide real-time responsiveness and operational efficiency, and thus do not provide a specialized component to detect situation changes and give immediate updates.

The CEP model was designed specifically to address issues around processing real-time events in distributed systems and has been studied extensively in the past [3] [17] [29]. Some studies focused on detecting complex events for rule-based business activity management in ubiquitous computing environment [2] [6] [8] [14] [15]. Other studies focused on the use of CEP in context-awareness middleware design based on service-oriented architecture [5] [11] [12] [16] [19] [24]. However, these studies are generic in nature, and did not address various characteristics unique to RFID technology.

Recently, several researchers have started to introduce CEP into RFID-enabled applications. The traditional event-condition-action model, based on active database systems, could not be directly applied to RFID systems because RFID data differs from traditional data due to its temporal nature and the existence of non-spontaneous events [4] [28]. Dutta et al. [4] borrowed the idea of representing complex RFID events with the help of state diagrams and used that concept to propose an efficient way to handle real-time events in a distributed RFID middleware system. Wang et al. [41] proposed CEP as a means to create complex events from an RFID data stream that can then be used as a foundation for business application logic. However, they did not assess the benefits of a CEP-enabled RFID solution to a particular application domain. Son et al. [25] proposed an efficient method to create business level events using CEP based on RFID standards. However, they did not incorporate other non-RFID sensor data such as temperature and humidity. Other works include developing frameworks to extend RFID events with business rules [21] or developing RFID systems for supporting situation awareness [9] [10] [20] [22] [26]. Xu et al. [30] applied XML into RFID event management and Kim et al. [13] proposed a framework for rapid development of RFID applications.

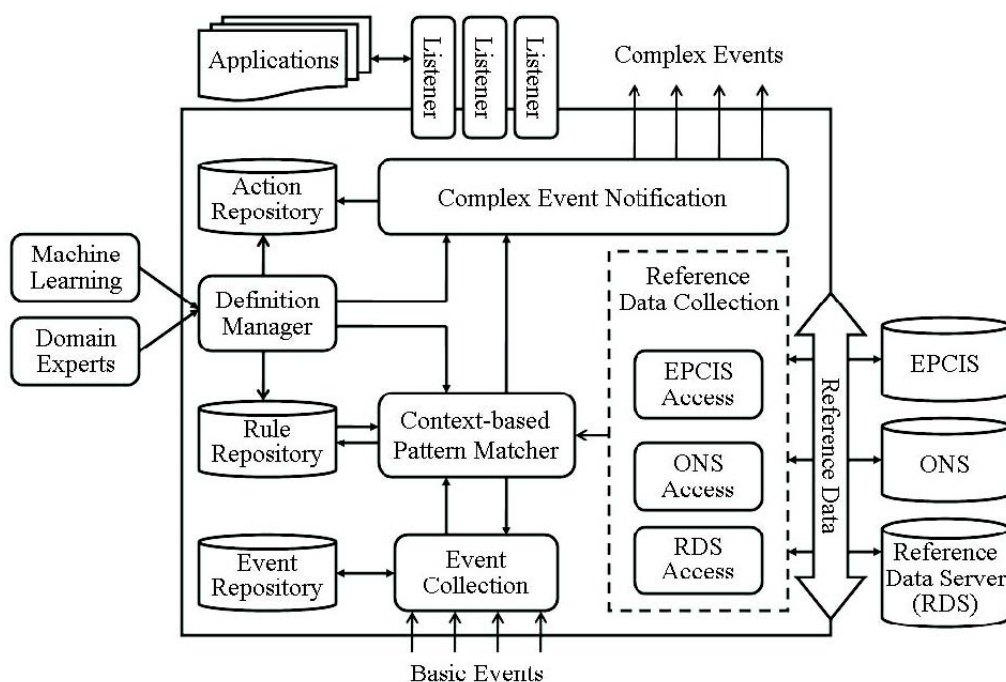
Nevertheless, most of these works only introduce the framework without a detailed description of the complex event definition language or how their CEP engine works. Others give detailed descriptions on how their CEP engine works but fail to address the wider issues of how to integrate CEP with RFID middleware and business applications. In contrast, this paper presents a comprehensive CEP-embedded RFID solution for business process automation.

ADOPTING CEP FOR RFID APPLICATIONS

To address the existing event processing issues in RFID applications, we propose a CEP-embedded RFID system. Compared to the existing RFID event-processing model, an additional CEP system is integrated into the architecture to process the clean RFID data received from RFID middleware and non-RFID data flow from external sensors (e.g. temperature sensor, heartbeat measure). The CEP system uses a CEP language to process event streams and detect complex events by matching events to the predefined business rules in the rule base. Complex events, which are built from RFID basic events, combine reference data to provide semantic meanings and integrate data stream events with business rules to deliver application level events and actions. In the last step, these complex events, which are high level and contain business logic, are then used for back-end applications (e.g. enterprise resources planning, customer relations management, and hospital information systems).

The design of the CEP engine is crucial for the system performance. We propose an event-oriented and rule-driven architecture for RFID complex event processing (See Figure 1). The engine contains five key modules: Event Collection, Context-based Pattern Matcher, Complex Event Notification, Reference Data Collection and Definition Manager Component.

Figure 1: The RFID-enabled CEP engine



CASE STUDY

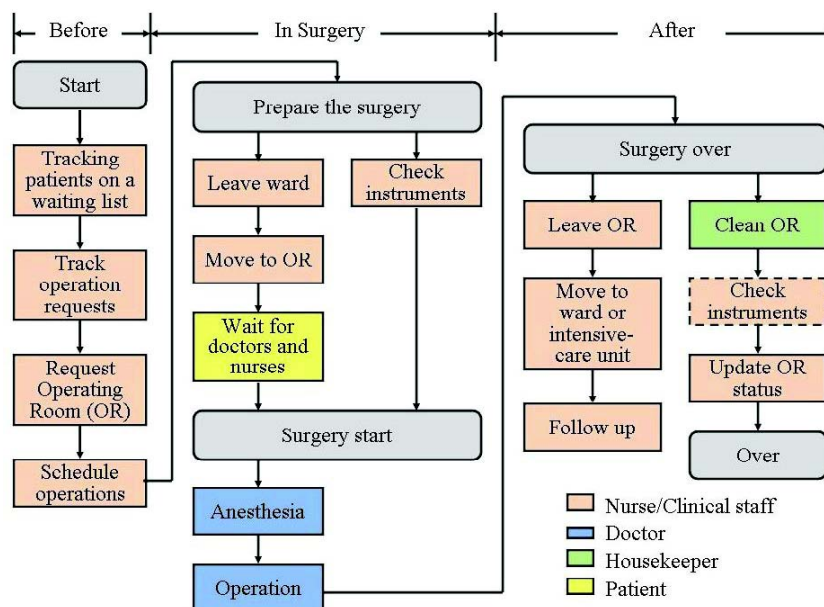
In this section, we illustrate how CEP can be used in conjunction with RFID in hospitals to provide additional benefits to the healthcare industry.

Hospital background and challenges

Located in the northeast of USA, H hospital is a premier academic medical center, committed to enhancing the quality of life through improved healthcare to patients, the professional preparation of those who will serve the health needs of others, and the discovery of knowledge that will benefit all. Although H hospital has gained a significant patient satisfaction rate during the past several years, it faces major difficulties and challenges in technology and system integration because it has a wide variety of legacy systems, some sorts of paper-based documentations, and is lacking object-tracking system to provide timely response to emergent situations.

Surgery is a one of the most complicated and critical operations in H medical center. It has 23 operating rooms (OR) and performed more than 23,000 surgeries each year. The surgery process requires extensive information sharing, coordination, real-time emergent situation detection, along with the ability to initiate alarms requiring immediate reactions. Figure 2 shows the workflow of surgery operation before using RFID and CEP technology, from which we identify current challenges.

Figure 2: Surgery workflow (Adapted from [27])



During this surgery process, several emergent events might happen, which if not attended to could cause, among other things, critical surgical instruments to be missing from the OR, potentially resulting in patient death. Without RFID technology, tracking patient and asset location in real time is impossible. As a result, finding the patient or an instrument in emergency

can be very difficult. Another potential problem includes manually checking patient's medicine, which leads to human error that directly results in medical accidents. Finally, CEP technology offers the ability to detect critical situations in advance, thus avoiding many potentially serious situations. For example, the nurse may mistakenly send the patient to a wrong OR so his/her surgery will be delayed. Or during the operation, if there are indications that a patient may be in danger of having an unexpected heart attack, an additional medical device might be needed for emergency use; however, if it does not get sent to the right OR in time, severe consequence might occur. Therefore, this dynamic and sometimes unexpected environment raises more challenges for surgery operations.

Solution to the challenges

To solve the mentioned challenges, CEP-imbedded RFID technology is proposed aimed at revolutionizing business processes such as managing surgery in hospitals. The solutions to different challenges are illustrated in Table 1.

Table 1: Current challenges and solutions for surgery management

Current challenges	Solution by RFID	Solution by CEP
Unable to track patient location (e.g. be moved to restricted area)	Tracking patient flow	Sending alert to clinical staffs when patient is at wrong place
Unaware the patient has been waited for too long	Tracking patient flow and conditions	Sending alert to clinical staff
Unaware the required medical instruments is missing	Checking the existence of all required instruments	Sending alert to inform clinical staffs the missing instruments
Unable to track the location of instruments	Assets tracking	Sending alert to inform clinical staffs the missing instruments
Unaware the incompatibility of the patient and medicine/dose	Check the identity of the patient and medicine	Sending alert when incompatibility is found
Unable to detect emergent situation and handle it timely (e.g. heart attack)	Check the identity of the patient and medicine/dose	Detecting and reacting to critical situation by predefined rules
Expensive/reusable instruments are thrown away by accident or missing for unknown reason	Asset tracking	Sending alert to clinical staffs when this situation happened

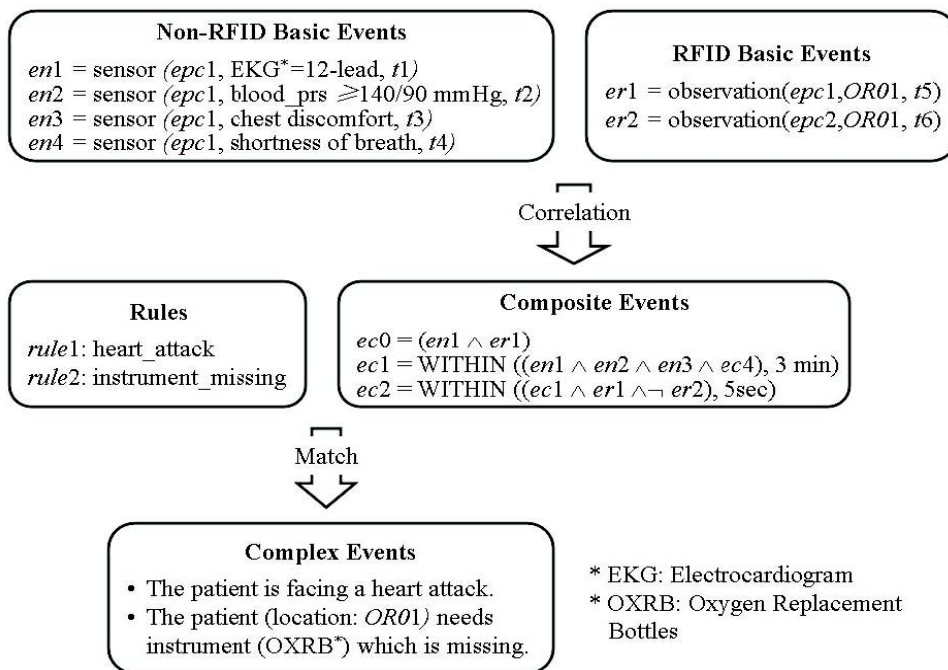
Illustration of CEP model

In this section, we present an example to help understand the relationship among basic, composite and complex events, and how rules are defined to detect complex events. A detailed example is given to describe how CEP is used to detect heart attack situation during the surgery process. Figure 3 shows how basic events, composite events, and complex events relate to each other.

By correlating basic events and match them to predefined rules, we are able to detect emergent situations, make quick decisions and take immediate actions. For instance, the composite event

ec1 is found to match rule1 (heart_attack), so the complex event “The patient is facing a heart attack” is detected. Similarly, *ec2* is detected to match rule2 (instrument_missing) so the critical situation “The patient located in OR01 is facing a heart attack and needs instrument OXRB which is missing” is detected.

Figure 3: Illustration of basic, composite and complex events



CONCLUSION AND FUTURE WORK

This paper presents a comprehensive analysis of why RFID applications need CEP, what CEP is and how CEP can be applied into RFID applications. To illustrate the benefits of CEP-embedded RFID systems for applications in the real world, we conduct a case study of how RFID and CEP technologies would interact in a hospital application. Challenges in current hospital are carefully examined followed by our proposed solutions. This case study can serve as a model for cost benefits analysis for hospital stakeholders, as well as other businesses who are considering adopting RFID.

However, fitting CEP technology into RFID applications is still at the conceptual exploration stage. More factors needs to be examined to realize this framework. Our future research directions include developing a CEP system for RFID applications, examining how to make the CEP engine work more efficiently for RFID data and determining the best event processing language for integrating RFID data into related business applications. In addition, we will research the use of rule definitions in different applications to better detect business opportunities and risks.

(The references available upon request from W. Yao at wxy119@psu.edu)