Realizing Greater Business Value of Contemporary RFID Systems

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Abstract — **RFID has been gaining momentum in the last few years. To-date many enterprises, in particular suppliers, have found themselves in a position that they must implement RFID to comply with well-publicized high-profile mandates (e.g. Wal-Mart and US DoD). Therefore, many early RFID solutions just did enough to satisfy the commercial and contractual requirements. The solutions mainly focused on technical features like tags, readers, basic tag-reader communications, etc. Future RFID implementations such as in supply chain management and businesses need to include a more comprehensive and inter-relating set of capabilities and to embrace a systematic and integrated architectural approach in order to take advantage of the long-term benefits of RFID technology. This paper proposes a holistic architectural approach that can be used to gain an understanding of the "next big thing" technology, the architectural considerations for designing and implementing successful RFID systems to fully realize greater business value. It is grounded in industry observations and real-world enterprise architecture practice.**

Keywords — **RFID, architectural approach, business value realization**

1. Introduction

A lot of progress has been made in the 59 years since Harry Stockman's work [1]. However, RFID has been gaining momentum only in the last few years thanks to several important initiatives led by the US Department of Defense (US DoD) and by private-sector retailer giant Wal-Mart in mandating RFID requirements in their business dealings with suppliers and service providers. Today, RFID technology comes in a myriad of forms enabling an ever-expanding range of practical applications to transform business operations all over the world. RFID technology can be found embedded in almost everything from razor blade packages, clothing and books to prescription medicines to parts of an aircraft. It has the capability to help track inventory, prevent counterfeiting (of money, drugs ...) and even fight terrorism.

Despite the pervasive, upbeat future and paradigm-shifting nature of RFID technology the mass uptake anticipated by the market earlier has not yet materialized. To-date many enterprises, in particular suppliers, have found themselves in a position that they must implement RFID to comply with well-publicized high-profile mandates such as those of retail giant Wal-Mart and mega-department US DoD [2-3]. Therefore many early RFID solutions just do enough to satisfy the commercial and contractual requirements [4]. The solutions mainly focus on technology components like tags, readers, basic tag-reader communications, reader integration and co-ordination and data filtering capabilities. These so-called "slap-and-ship" and "tag-at-source" RFID systems failed to leverage the ways that RFID can generate operational efficiency and strategic business advantages. These implementations yielded minimal business benefits.

Moreover, traditional RFID systems are highly-specialized, closed loop applications that use proprietary technology [7]. Future RFID implementations such as in supply chain management and businesses need to include a more comprehensive and inter-relating set of capabilities [5] and a systematic architectural approach to take advantage of the long-term benefits of RFID technology [6] such as achieving a business advantage over the competitors, etc... For example, they will require more distributed and adaptive RFID systems that are capable of learning and reacting in a proactive manner to changes in their environment. They should focus on communication and interaction with other systems and parties within an enterprise or between enterprises (extended enterprise). They should also include business process management, data management and integration [8], reader and device management [9], stakeholders' consultation and management, service management, security and privacy and open standards for wider interoperability. Gartner [10] recommends that when examining the suitability of a potential RFID deployment, end-user organizations need to consider some key issues including technology, business processes, business case, architecture, standards, security, etc. Following on this line of reasoning, we anticipate a need for a well-grounded, holistic and service-oriented architectural approach that is capable of overcoming the disadvantages of the traditional centralized and technology-oriented RFID systems.

The structure of the paper is as follows. Section 2 provides a brief overview of some related works. The holistic and service-oriented architectural approach is presented in Section 3 followed by the Conclusion in Section 4.

2. Brief Overview of Related Works

In the past RFID system architectures to support information processing and decision making have generally been of a centralized nature. This architectural approach

assumes a central location where all data is received, analyzed and where smart decisions are made. As a result, information that helps in streamlining business operations might not be available at the right time. Abdel-Naby and Giorgini [11] observed that in asset tracking, inventory and shelving applications, RFID systems could have jamming situations where many RFID tagged objects are moving at the same time and in the same direction. They proposed a framework that positions multi-agent architecture inside standard RFID design. The only additional multi-agent architecture layer sits between the RFID-Readers layer and RFID-Backend layer. The framework mainly addresses the RFID technology and system components of a standard RFID implementation.

Large IT vendors put forward their own RFID architecture of various flavors. These include an architecture framework for RFID from IBM [12], Edge-to-Enterprise RFID Architecture from BEA Systems [13] and Intel together with Oracle with service-oriented enterprise architecture framework for designing RFID solutions [14]. All the above vendors see the long-term benefits of an architectural approach. However, these architecture models/platforms/frameworks are very IT centric as one would expect. Furthermore, the majority of these frameworks tend to be structured in such a fashion that makes it easier for the vendors to demonstrate the fit of their product portfolio.

EPCglobal also published its own framework [15] called "EPCglobal Architecture Framework". EPCglobal defines it as "a collection of interrelated standards for hardware, software, and data interfaces, together with core services that are operated by EPCglobal and its delegates, all in service of a common goal of enhancing the supply chain through the use of Electronic Product Codes (EPCs)". It broadly defines the principles, standards and components that are necessary for the development and implementation of the EPCglobal network. As such, it is essentially a "closed loop" RFID technical architecture framework that enhances interoperability through the use of EPCs, common standards, EPCglobal core services that are operated by EPCglobal and its delegates and world-wide technology infrastructure including EPCglobal Network with Object Naming Service (ONS) registry similar to Domain Name Service (DNS) used on the Internet.

While Hardgrave, et al. [16] did not propose an explicit architecture model as such, they presented a useful and simple three-level RFID Assimilation Hierarchy. Their model demonstrates that as an organization proceeds up the hierarchy the depth of RFID assimilation is increased. In the long term, companies must move from pure mandates compliance (e.g. slap-and-ship, tag-at-source solutions) - "shallow assimilation" - to understanding and leveraging the data to create business value - "deep assimilation".

3. Holistic and service-oriented architectural approach

Successful RFID system implementation is more than just technology and interconnections that can traditionally be satisfied by the use of the 7-layer OSI model. RFID systems are implemented to meet enterprise business needs. To help ensure business – RFID investment alignment, a holistic enterprise architecture approach is required. Moreover, inherent weaknesses in current enterprise architectures, for example, centralized data processing, lags and delays in processing, point solutions, etc., makes them less suitable to handle vast amount of RFID-generated data used in retail operations and real-time decision-making at the edges of the business. Successful RFID systems implementation requires service-oriented and distributed architectures. We propose a holistic and service-oriented RFID architecture model to help enterprises to realize greater business benefits of their RFID implementations. The model is shown in Figure 1 below. The blending of RFID OSI layer model and enterprise architecture layer concept is quite novel. The hybrid architectural model recognizes the engineering and computer communications "root" of the RFID technology as well as the enterprise architecture and service-oriented approach necessitated by the business transformation potential RFID will bring to many enterprises.

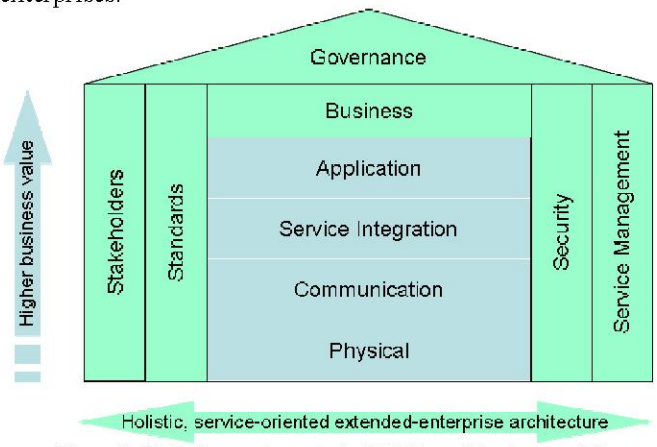

Figure 1: Holistic, service-oriented RFID architecture model

The purpose of the proposed layer model is multi-fold. The horizontal layering (Application, Service Integration, Communication and Physical) is basically for modular and easy implementation. This is analogous to the OSI reference model and TCP/IP protocol stack as shown in Figure 2.

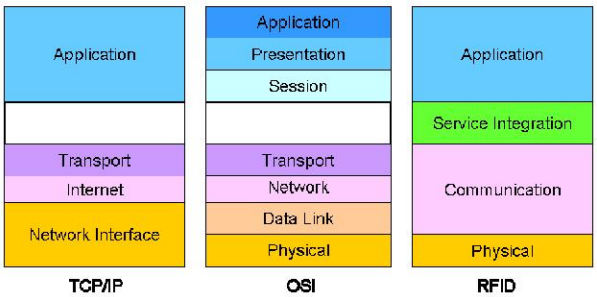

Figure 2. TCP/IP, OSI and RFID "stacks"

The remaining layers namely Business, Security, Standards, Service Management, Stakeholders and Governance, complete the holistic and service-oriented architecture model for effective contemporary RFID systems. It is noted that the vertical layers touch all horizontal layers. In other words, the services provided by these layers apply to all corresponding

horizontal layers. Thus they might be added to the horizontal layers if so wished.

We now describe the components of the proposed RFID architecture model in the following sub-sections:

Physical Service Layer

It is equivalent to the Physical layer in the OSI model. This layer represents the RFID "technology" components such as readers, antennas, passive, semi-active, active RFID tags, sensors, motes, etc. RFID-tagged objects and multi-function smart devices incorporating RFID functionalities (e.g. smart phones) can be considered as components of this layer. The physical layer has been and still is a key focal point for the RFID industry despite the shift toward the higher layers.

Communication Service Layer

This layer provides the equivalent functions of the Data Link, Network and Transport layers of the OSI reference model. These include reader networking both wired and wireless. It also handles the communication link and the RF coupling between an Interrogator (Reader) and Transponder (Tag), the Media Access Control (MAC). This layer has been a focus of extensive research by the academic community (e.g. [17])

Integration Service Layer

This is a new layer that is created for RFID to efficiently handle a huge volume of raw RFID data in real-time. It also provides a means to integrate the back-end enterprise applications with the data from RFID infrastructure. It is a service-oriented integration layer that will become an important ingredient of the extended enterprise RFID business solutions.

Application Service Layer

This layer consists of various "back-end" enterprise applications that support the business and process information captured by the RFID systems. This includes systems such as Inventory management, ERP, Retailing and so on.

Business Service Layer

RFID has the capacity to enable business transformation. To benefit from the implementation of RFID technology, it is often necessary for the enterprise to re-engineer its business processes. This layer deals with enterprise business services, business goals, objectives, business processes, etc. Another key feature of this layer is its ability to act as a business-to-business process integration between business partners. As RFID evolves and matures as a technology, it will become an integral component of an enterprise's business architecture. RFID system architectures should align with the business architecture that supports the enterprise's business objectives.

Security Service Layer

RFID systems are subject to security attack like any other information systems. Therefore security needs to be built into the RFID system design. This layer straddles across all horizontal layers. As it touches all layers, it also encourages a holistic, end-to-end and multi-layer defense mechanisms (defense in depth). A related aspect of security is privacy that needs to be handled with utmost care [18]. Real concerns have arisen out there not just from the so-called "radical" consumer groups calling for the blanket boycott of RFID technology but also from seasoned practitioners.

Standards Service Layer

Standards are critical for many RFID applications especially in open supply chains extending across many enterprises. Adopting approved open international standards will enhance interoperability and reduce costs substantially in the long run. RFID standards development works are generally undertaken at the international level. Key standards organizations include ISO, EPCglobal and ITU-T. There exist regional and national organizations/bodies that also develop a number of RFID standards.

Service Management Layer

This layer focuses on delivering and managing RFID systems as a service. Best service management practices such as ITIL, COBIT are recommended. Increasingly in the service-oriented world, business process management (BPM) becomes critical especially in an extended supply chain RFID operation. This layer is often considered as an after-thought after RFID systems have been implemented. There are several vendors who are providing software and hardware tools to help manage RFID systems. Standards bodies have also been actively involved in providing solutions (policies, standards, etc.) to address RFID service management issues.

Stakeholders Service Layer

In the context of RFID system architecture, there exists a multitude of stakeholders, some of them are obvious, and some are not. They can be our trading or business partners, consumers, our own workers, and so on. Each has its own influence on our architecture. Identifying stakeholders and understanding their needs and concerns are critical in developing RFID solution architectures. Moreover, controversial technologies such as RFID can not be successfully implemented without the broad acceptance by its users. The European Commission (EC) announced plan in early 2007 to create a stakeholder's group to advise the EU on its RFID strategy [20].

Governance Layer

It is a subset of the corporate governance and includes but does not limit to governance structure, processes, rules and procedures. It also involves governance at national, regional and international levels, for example RFID regulation, policies and so on. This component is often overlooked or given a scantily attention.

Advantages of the proposed architecture model

We believe that past approaches to RFID implementations generally suffer from many deficiencies ranging from a point solution to too much technology-focused. Continuing with these approaches will run the risk of failure of not realizing the real benefits that RFID can bring to the business.

The proposed RFID architecture model will:

- provide a robust framework for RFID architecture and strategy
- improve awareness and understanding by de-constructing the complexity of RFID technology into a layered view
- encourage a holistic view of the impact of the RFID strategy on the enterprise business vision
- bring together and enhance collaboration between the engineers, IT and business groups
- provide the basis for the engineering, IT and business groups to share a common understanding and vision of a RFID-enabled enterprise

- encourage enterprise-wide (and extended enterprise-wide) focus rather than silo focus
- encourage an open rather proprietary approach
- assist customers to evaluate RFID vendors' offerings in a systematic and comprehensive manner

Evaluation of the proposed architecture model

The authors have used the proposed RFID architecture model to develop a taxonomy of the currently known RFID technology implementations [19]. The model and taxonomy will help gain a better understanding of the "next big thing" technology, the architectural considerations for designing and implementing successful RFID systems. It is also our intention to use the proposed architecture model to guide future research including development of RFID systems for real-world applications and study of cross-layer interactions/issues, and so on.

The proposed architecture model should also be evaluated by studying sample real-world cases to see how it would help these enterprises realize greater business value.

4. Conclusion

We have presented a novel, holistic and service-oriented RFID architecture model that is grounded in the observations of the difficulties of many RFID system implementations to fully realize the business benefits and in real-world best architecture practice. It provides a robust framework for the enterprise's RFID architecture and strategy. It encourages a holistic, enterprise-wide rather a point solution and silo approach. The model also provides the basis for the engineering, IT and business groups to share a common understanding and vision of a RFID-enabled enterprise. Enterprises need to move up the "stack" and take a holistic, extended-enterprise approach to gain business comparative advantage. The proposed model will require more "field testing" to verify its effectiveness in meeting enterprise business needs.

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