3-1-2006

Radio Frequency Identification: The Initiator of a Domino Effect

Xihui Zhang
xihui.zhang@memphis.edu

Tao Hu

Brian D. Janz

Mark L. Gillenson

RADIO FREQUENCY IDENTIFICATION: THE INITIATOR OF A DOMINO EFFECT

Xihui Zhang
The University of Memphis
xihui.zhang@memphis.edu

Tao Hu
The University of Memphis
taohu@memphis.edu

Brian D. Janz
The University of Memphis
bdjanz@memphis.edu

Mark L. Gillenson
The University of Memphis
mark.gillenson@memphis.edu

Abstract

Radio frequency identification (RFID) technology can be the initiator of a domino effect. To an organization, the adoption and deployment of RFID technology and the resulting influx of data, information, and knowledge will impact not only its IT infrastructure, but also the quality and timeliness of its business intelligence and decision making. This paper first provides an introduction to RFID technology and surveys a variety of its applications. Then it examines and discusses in detail the effects of RFID on an organization's IT infrastructure, business intelligence, and decision making. It also discusses propositions, which can serve as a basis for the development of specific hypotheses to be empirically tested in future studies. Finally, it provides a conceptual research framework that illustrates the domino effect initiated by the use of RFID technology.

Keywords: Radio frequency identification (RFID), IT infrastructure, business intelligence (BI), decision making

Introduction

Radio frequency identification (RFID) is a technology that can uniquely identify objects using radio frequency transmissions (Xiao, Yu, Wu, Ni, Janecek, and Nordstad, 2007). Contrary to the public impression, RFID is not a new technology. The technology originated decades ago and was first used in World War II as a means of identifying ships and airplanes as "friend or foe" (Levinson, 2003). However, it just recently has gained enormous attention in industry, in media, and in academic research (Loebbecke, 2005). Among those big names that are lining up behind RFID technology, Wal-Mart and the U.S. Department of Defense are the two most influential initiators and adopters. Other big names in global retailing include Carrefour, Gillette, Home Depot, Marks & Spencer, Metro AG, Procter & Gamble, and Tesco (Levinson, 2003). The major reasons why RFID is "making a splash now" include the increased scope of the problems it solves, the increased maturity of the technology, and the decreased cost of deployment (Want, 2004).

The promises of RFID are absolute inventory control, subsequent cost reductions, and increases in margin (Levinson, 2003). RFID technology has the potential to bring "total transparency" to supply chains because it has the ability to feed supply chain management systems with detailed information regarding the "whereabouts" of products in the supply chain in real-time. This real-time information, in turn, enables decision makers to make better, real-time decisions. In today's highly competitive and rapidly changing marketplace, making better and quicker decisions is becoming a necessity for companies to succeed or even to survive.

The adoption and deployment of RFID seems inevitable: (1) more RFID-based applications are generated literally on a daily basis, (2) the technology is getting more advanced, and (3) the cost of deployment of the technology is constantly being driven down. However, studies on the impact of adoption and deployment of RFID technology on organizations are scarce in IS and management literature. Therefore, it is imperative that more research should be done on this subject. We believe that RFID technology can be the initiator of a domino effect since it can set off a chain reaction in an organization that starts with the use of RFID technology and the resulting influx of data and information and knowledge, proceeds through changes in IT infrastructure, and ends with improvements in business intelligence and decision making.

Huber (1990) proposed a conceptual theory of the effects of advanced information technologies on organizational design, intelligence, and decision making. Advanced information technologies are partially defined as "devices (a) that transmit, manipulate, analyze, or exploit information; and (b) in which a digital computer processes information integral to the user's communication or decision task" (Huber, 1990, p. 48). He also advanced fourteen propositions to be served as a basis for the development of specific hypotheses. The broad logic integrating these fourteen propositions is that availability of advanced information technology leads to use of advanced information technology; use of advanced technology leads to increased information accessibility; increased information accessibility leads to changes in organizational design; both increased information accessibility and changes in organizational design lead to improvements in the effectiveness of intelligence development and decision making (Fulk and Boyd, 1991).

Based on Huber's conceptual theory described above, this paper examines the potential domino effect initiated by the use of RFID as an advanced information technology with an emphasis on the impacts of RFID on an organization's IT infrastructure, business intelligence, and decision making. Although RFID technology itself is not sophisticated, we argue that its potentially ubiquitous usage will have a tremendous impact on individual organizations and society as a whole.

The organization of the paper is as follows. It begins in the next section with an introduction to RFID technology and a survey on a variety of its applications. It then examines and discusses in detail the effects of RFID on an organization's IT infrastructure, business intelligence, and decision making. Propositions, which can serve as a basis for the development of specific hypotheses to be empirically tested in future studies, are advanced during the examination and discussion. And finally, a conceptual research framework is provided to illustrate the domino effect initiated by the adoption and deployment of RFID technology.

RFID Technologies and Applications

RFID Technologies

A radio frequency identification (RFID) system is a special kind of sensor network to uniquely identify objects using radio frequency transmissions (Xiao et al., 2007). Basic components of an RFID system include tags, readers, and an application system. A tag is a chip that is attached to or embedded in an object. It contains the object's unique identification information. A reader reads/interrogates tags for their unique identification information. A typical reader consists of three components: antennas, a transceiver, and a processor. A reader and its corresponding tags exchange data and energy between them through their antennas when they are actively communicating with each other. An application system is responsible for cataloging tags' information obtained from readers (Xiao et al., 2007).

Tags vary in size and shape. A tag's size ranges from the size of a grain of rice to two-inch squares (Ayre, 2005). Tags can be shaped like a watch battery, a flat disk, a thin cylinder, a cracker, a credit card, or a cigarette pack (Keshiwani, 2005). A typical RFID tag consists of a chip, an antenna, and an optional power source (Chawathe, Krishnamurthy, Ramachandran, and Sarma, 2004). The chip is used to store data (up to 1,024 bits) using one of a variety of naming schemes. EPC-96, one of the most popular naming schemes, is based on a 96-bit code. The EPC-96 scheme divides 96 bits into four parts: header, EPC manager number, object class, and serial number. The EPC (electronic product code) is the minimum information carried on a tag (Smith and Konsynski, 2003; Want, 2004). EPC-96 can accommodate approximately 268 million companies. Each company can have 16 million different product classes. Each product class can contain over 687 billion individual items. All in all, EPC-96 scheme enables identification of 1.5 quintillion objects (http://www.eforceglobal.com).

Tags can be active, passive, or semi-passive (Angeles, 2005). Active tags use batteries to power the microchip's circuitry and broadcast signals to the reader. Passive tags do not have batteries and are powered by the electromagnetic waves sent out by a

reader which induce a current in the tag's antenna. Semi-passive tags use both batteries and waves sent out by the reader (Angeles, 2005). Tags also differ in weight, cost, read range, and lifetime. Compared to active and semi-passive tags, passive tags are much lighter and less expensive, offering virtually unlimited operational lifetime but very limited read ranges (Ni, Liu, Lau, and Patil, 2004).

Readers are devices that communicate with tags. An RFID reader typically consists of antennas, a transceiver, and a processor. The antennas are used for sending/receiving radio signals to/from tags. The transceiver and the processor are used to encode/decode data (Xiao et al., 2007). Upon receiving a tag's radio transmission, a reader performs error checking, and then communicates with an application system for further actions (Xiao et al., 2007). A reader has a finite "read range" that depends on the tag type, the reader's power, and the frequency used to communicate between the reader and tags (Angeles, 2005). Passive tags have smaller read ranges since they rely on outside power and thus weak signals, whereas active tags have larger read ranges since they have their own power sources and thus strong signals. Higher-frequency tags can be read from longer distances but they require more energy output from the readers (Angeles, 2005).

RFID Applications

RFID applications are numerous and far-reaching (Weinstein, 2005). RFID technology is still emerging and so are its applications. However, Smith and Konsynski (2003) point out that "as with any new technology, it is extremely difficult to anticipate the full scope of these applications and implications until it is more widely used" (p. 308). This section provides a survey of a variety of RFID applications that are most interesting and currently running, including those for supply chain management, electronic payment, tagging animals or people, tracking equipment, documents, or baggage.

In supply chain management, RFID tags are used to track products throughout the supply chain – from supplier delivery, to warehouse stock and points of sale (Weinstein, 2005). RFID technology is believed to be able to provide "total transparency" of the supply chain. With RFID technology, companies, as nodes on the supply chain, can know locations and arrival times of parts or products from their upstream suppliers or to their downstream partners. This capability leads to reduced order cycle times, better forecast accuracy, and increased flexibility in responding to unexpected demands. An RFID system incorporated seamlessly with supply chain management systems has the potential to give an organization detailed, real-time or near real-time information. Equipped with this kind of information, decision makers are expected to make better and timely decisions.

One of the most important RFID applications for electronic payment is auto-pay systems on toll roads. SunPass (http://www.sunpass.com) is one of the popular cited examples. In this application, a car has a tag with a unique serial number. This serial number can be used to trace back to an owner and her account in the database; thus the proper toll can be charged to that account. Another important RFID application is instant charges of fuel and convenience store purchases. Both Exxon and Phillips 66 have implemented RFID systems that enable their customers to instantly charge their fuel and convenience store purchases without using cash or a credit card. Customers enrolled in these programs wave a miniature transponder attached to their key chain in front of an electronic reader at the pump or checkout counter (Smith and Konsynski, 2003).

Tagging animals or people poses more challenges than tagging inanimate objects since animals and people can move independently. In addition, most people would not want to be tagged because of privacy issues. In both animal tagging and people tagging, tags can either be attached to the body or implanted under the skin of the living being. RFID tags have been used to identify and locate household pets and livestock, and to identify migration patterns of penguins. The purposes of tagging people can be either for their own good, e.g., patients who need to be monitored constantly, or for the sake of safety of other people, e.g., criminals on parole who should be tracked. Janz, Pitts, and Otondo (2005) implemented an RFID patient tracking system in a trauma unit of a medical center with patients wearing RFID tags on ankle bracelets. The results of their study show that RFID technology may be a good fit for the hospital environment.

Equipment, document and baggage tracking are also widely used in hospitals, libraries, and airports, respectively. Hospitals can use RFID technology to track crucial pieces of equipment, making them easy to locate in case of an emergency. Libraries can tag books, making it possible to easily locate a book in the stacks, prevent theft, and automate the check-out and check-in processes (Weinstein, 2005). Baggage tracking using RFID tags has been implemented in several airports in the USA, including the cities of San Francisco, Seattle, and Houston. These baggage tracking systems are believed to enhance curbside check-ins and also eliminate the need for manual sorting (Smith and Konsynski, 2003).

RFID as the Initiator of a Domino Effect

RFID technologies can be the initiator of a domino effect. The use of RFID technologies and the resulting influx of data, information, and knowledge can set off a chain reaction that, as we suggested earlier, impacts not only an organization's IT infrastructure, but also the quality and timeliness of its business intelligence and decision making. In this section, we examine and discuss these effects in detail. During the examination and discussion, we propose a series of propositions which can serve as a

basis for the development of specific hypotheses to be empirically tested in future studies. Finally, we illustrate this domino effect initiated by the adoption and deployment of RFID technology with a conceptual research framework.

Effect of RFID on IT Infrastructure

The use of RFID technology presents a number of challenges to an organization's IT infrastructure. RFID has the potential to introduce substantial volumes of data. Depending on the reader's query rate on passive tags or active tags' broadcasting rate, RFID can be thought of as a source of streaming data. Streaming data make data streams. Data streams are real-time, continuous, rapid, time-varying, ordered (implicitly by arrival time or explicitly by timestamp), and possibly unpredictable and unbounded sequences of data elements (Golab and Ozsu, 2003). Data streams will pose several challenges to an organization's IT infrastructure in the steps of data capturing, managing, and analyzing.

Within an RFID system, data flows as data streams. At the edge of the network, RFID readers generate data streams; at the center of the network, these individual data streams appear as multiple data streams. However, we do not want to capture all of the data for two reasons. First, it is impractical because of the sheer data volume. Second, it is not necessary because some data are totally useless or redundant. Thus, the RFID system must provide some basic data filtering as well as data aggregation and abstraction functionalities at the data source to remove repeated, useless reads, and to summarize some reads before the data are sent over a network to some central data processing unit. Thus, we propose:

> **Proposition 1:** Use of RFID technology results in more data filtering as well as data aggregation and abstraction functionalities employed at the data sources in an organization's IT infrastructure.

As companies deploy RFID technology, their enterprise architectures will become more distributed (Levinson, 2003). Even after being filtered, aggregated, and abstracted, the volume of the data generated from RFID is still huge. If we ship all of the data on the network, bandwidth would explode. So it is better to distribute the load of the computing tasks across a wider network instead of transmitting all the RFID generated data to the central data processing units. In the meantime, if short response times are required, significant parts of the application must be running on the edge servers or sensor/RFID controllers, thereby shifting intelligence and responsibility from the network center to the network edge (Clauberg, 2004). Thus, we propose:

> **Proposition 2:** Use of RFID technology leads to a more distributed enterprise architecture in an organization.

The adoption and deployment of RFID technology will impact data transmission. Prior to the deployment of RFID, many firms transmit data in batch mode, meaning they upload information every few hours, every shift, daily, or even weekly (Angeles, 2005). However, as RFID technologies become more ubiquitous, to better use RFID capabilities, information needs to be uploaded in real-time mode. Thus, we propose:

> **Proposition 3:** Use of RFID technology leads to more real-time data transmission in an organization.

The massive flood of RFID-collected data also poses big challenges in data analysis. Because of the huge data volume and to assist real-time decision making opportunities, data mining and business intelligence tools have to be used to look for interesting, but hidden, trends and patterns in the data. Thus, we propose:

> **Proposition 4:** Use of RFID technology leads to more use of data mining and business intelligence tools in an organization.

Effect of RFID on Business Intelligence

Business intelligence (BI), is about organizations getting to know their own strengths and weaknesses, as well as those of their competitors. This allows them to better identify opportunities and threats in the business environment. However, BI is becoming more difficult because of the rapidly changing business environment that brings about a growing need for very timely, first-rate business information and knowledge. If an organization's IT infrastructure is able to effectively accommodate the need for capturing, managing, and analyzing the ever-increasing volumes of RFID data, RFID technology can provide an organization with accurate and comprehensive business intelligence in a timely manner. Thus, in summary:

> **Proposition 5:** Use of RFID technology leads to more accurate and comprehensive business intelligence in an organization.

> **Proposition 6:** Use of RFID technology leads to more timely and available business intelligence in an organization.

Effect of RFID on Decision Making

It is reasonable to believe that higher quality business intelligence leads to higher quality decisions, and timely business intelligence leads to timely decision making. The power and ultimate promise of RFID comes in the ability to make decisions from a quality, single source of knowledge. Use of RFID leads us to business intelligence that is more accurate, comprehensive, timely, and available; this business intelligence will enable us to make higher quality decisions in a timely manner. Thus, we propose:

Proposition 7: Use of RFID technology leads to higher quality decisions.

Proposition 8: Use of RFID technology reduces the time required to make decisions.

The Conceptual Research Framework

This section provides a conceptual research framework to illustrate RFID as the initiator of a domino effect (see Figure 1). The broad logic here is that use of RFID technology leads to changes in the IT infrastructure of an organization; changes in IT infrastructure lead to improvements in business intelligence; improvements in business intelligence lead to improvements in decision making. Quality and timeliness are two major metrics for improvements in business intelligence and decision making.

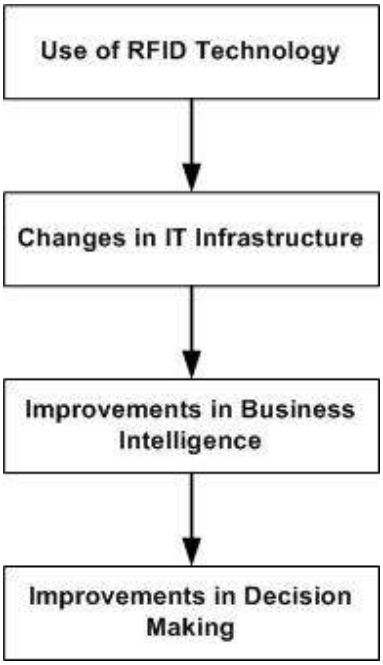

Figure 1: RFID: The Initiator of a Domino Effect

Conclusions

To an organization, the adoption and deployment of RFID technology and the resulting influx of data, information, and knowledge will pose a list of challenges to its IT infrastructure. If used wisely, the data and the derived information and knowledge have the potential to greatly improve the quality and timeliness of an organization's business intelligence and decision making. Of course, there are potential negative effects of RFID technology, such as perceived loss of privacy, which may lead consumers to think that their privacy has been compromised when they purchase products with attached or embedded RFID tags. However, that topic is beyond the scope of this paper.

The contributions of this paper are twofold. It provides academic researchers with a conceptual research framework and a series of propositions on this subject that can serve as a basis for the development of specific hypotheses to be empirically tested in future studies. It reminds practitioners that the impact of the adoption and deployment of RFID technology on an organization may be broader and deeper than they thought.

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