

# Challenges in RFID Enabled Supply Chain Management

by **RFID Study Group at Pennsylvania State University**

**R**adio frequency identification (RFID) devices have rapidly taken center stage at retail and commercial product shows around the globe. Two most commonly cited advantages of RFID are supply chain visibility and theft reduction.

## In 50 Words Or Less

- Many organizations are ill-prepared to handle the coming flood of data that will accompany radio frequency identification (RFID) implementations.
- The availability of real-time RFID information regarding both product supply and demand will enable firms to improve supply chain execution by dynamically adjusting production, distribution and marketing decisions.

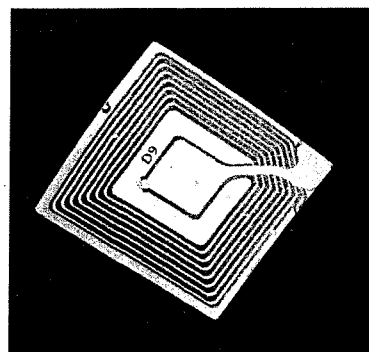
Most of today's RFID pilot projects focus on achieving 100% read rates, but the next challenge is to learn how organizations can exploit RFID data to improve quality and reduce cost.

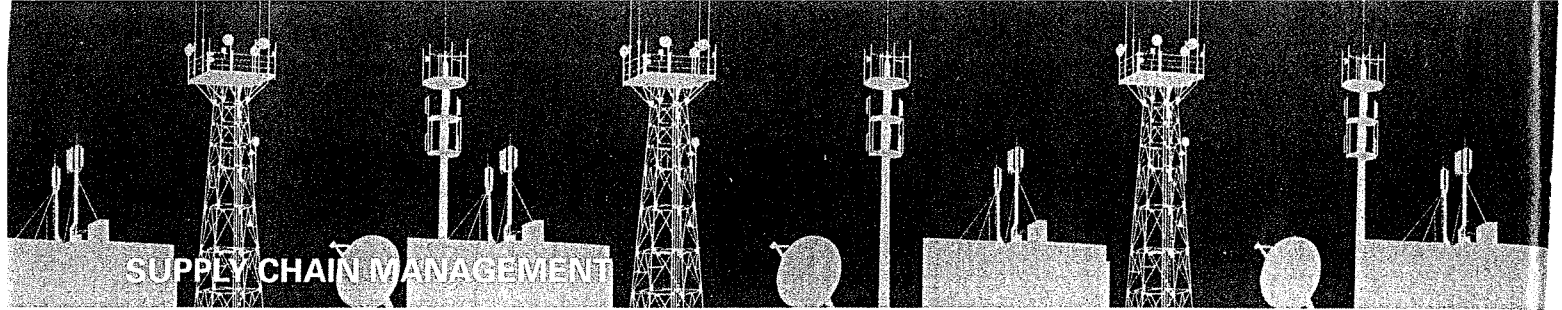
Supply chain management has been identified as the fastest growing RFID application through 2008.<sup>1</sup> Many organizations are ill-prepared to handle the coming flood of data that will accompany RFID implementations.

While RFID has received increasing attention during the past few years from both industry and academia, there appears to be a gap between how RFID is applied in practice and its role in academic literature.

## RFID Definition

Most definitions of RFID emphasize its technological aspects. For example, it is a technology incorporating the use of electromagnetic or electrostatic coupling in the radio frequency portion





of the electromagnetic spectrum to uniquely identify an object.

But there are larger implications of this technology, such as RFID's impact on the way physical systems are measured and controlled. In this sense, RFID provides data on three important characteristics:

1. Identification of individual items, as opposed to stock keeping unit (SKU) type.
2. Identification of an item's specific location at an instant in time.
3. Automated provision of this information in or near real time.

We define RFID as a set of technologies that provide network delivered information services dependent on physical object identities captured by radio waves.

The definition is purposefully vague about the specific details of the technology. The first part of the definition could equally apply to bar code technology; but the phrase "captured by radio waves" rules this out. RFID technology based on radio waves provides an important advantage—it permits a level of automation impossible with bar codes, which must be manually scanned.

Supply chain management involves the coordination of procurement, production, inventory control and distribution of products to provide high customer satisfaction at low cost. Because supply chain systems are complex, dynamic and stochastic, the detailed real-time data provided by RFID technology can be used to make real-time assessments of the supply chain and real-time management decisions.

### **RFID Opportunities**

While the opportunities are exciting, there are challenges to be met in implementing RFID.

The opportunities we see for RFID enabled supply chain management all draw from the three characteristics of RFID data highlighted earlier. The automated provision of information means there are sufficient data to characterize the long-term and instantaneous behavior of the system as viewed through the network of RFID reader stations.

This characterization is systemic rather than local, because the individual items and the time stamps

permit tracking items as they traverse the supply chain network (at least through the parts that are visible through the RFID network). These characterization data can be used to improve the quality of management decisions that have been based in the past on incomplete and less timely data.

The real-time nature of RFID data brings unique opportunities and challenges for data mining. The data mining community typically refers to real-time data as streaming data to stress the continuously updating nature of the data.

The unique opportunity brought by the real-time streaming data is the ability to perform online mining of changes. However, it is demanding to conduct advanced analysis and data mining over large and rapidly changing data streams to capture trends, patterns and exceptions in real time.

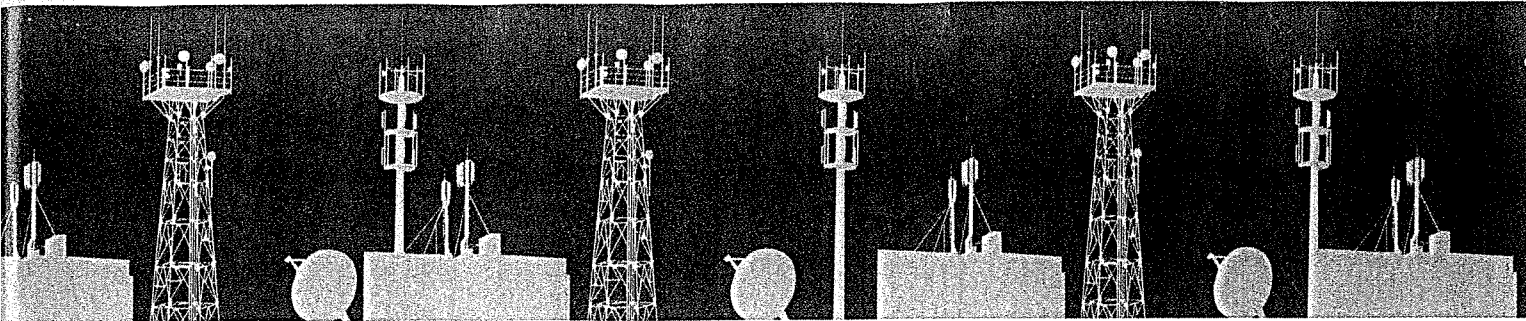
### **Data Mining and Control Charts**

Application of the computationally light temporal data analysis techniques could bring great value in practical supply chain applications. One example is the application of the control chart idea to RFID data.

Monitoring the difference between the numbers of reads for a given lot of items from time,  $t$ , to  $(t + 1)$ —points within control limits data—suggests the lot is moving as planned. Such ordinary variation can be used to characterize the reliability or quality of the process.

The out of control points can be associated with special causes, which can be addressed on a case-by-case basis. If you take the hypothesis testing point of view for statistical process control (SPC), the importance of determining in-control probability distributions becomes apparent. The time and location stamped RFID data make this possible. By selecting data for particular locations and time periods, you can construct summary data sets to estimate distributions of item counts.

In addition to being real time, supply chain RFID data are also closely connected to the supply chain network structure. RFID technology provides data characterizing product flows within the supply chain network, at different granularities, at real or near real time and for large volumes of products. Thus RFID provides the potential to monitor the progress of items through the supply



chain using control charts.

In this case, determining appropriate in-control distributions is complicated by a number of factors including:

- Special dependency structures induced by the supply chain network.
- Right censored measurement data for product that has left one reader but has not arrived at the next.
- Nonvisible transit segments.
- Different potential views of the same data depending on the level of aggregation.

### Improved Models and Decision Tools

RFID technology can provide managers with real-time supply and demand information. Unfortunately, traditional production, transportation, inventory models and decision tools are not equipped to take advantage of real-time information.

For example, without real-time information, the state of an inventory system is described by the inventory position (on hand stock plus the on order quantity minus the back-ordered quantity). With real-time information about product sales, stocks at other locations and updates about timing of goods in transit, the system state becomes dramatically more complicated.

In traditional models, inventory decisions could be based on inventory position. With RFID, much more information can now be considered when supply and demand decisions are made.

### Modeling and Analysis

RFID presents a number of implications related to technology for the applicability and use of decision making models. Granularity, frequency, accuracy and breadth of information affect three types of decision support models: supply chain network, inventory and event management.

**Supply chain network models:** We define a supply network as a set of producers, transporters, storers, distributors and sales outlets that are economically dependent and exchange goods and services. A supply chain is a special instance of a supply network in which raw materials, intermediate materials and finished goods are procured exclusively as products through a chain of processes that supply one another.

The issues described later apply in the case of a set of interconnected firms in a supply network, but the implications certainly can apply to supply chains as well.

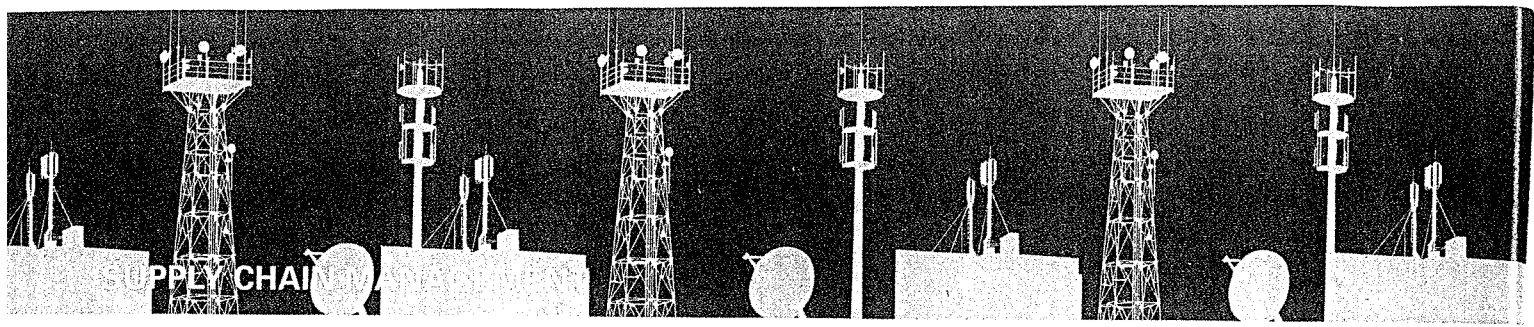
RFID can be used to elicit supply network structure and dynamic behavior of that network. The actual flow of product—in terms of timing and sequence—could differ substantially from what is

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specified in planning documents (and assumed by supply chain decision makers). Specialized data mining techniques could be developed to extract product flow patterns within the supply chain network based on temporal, network structure and product correlation. To build these models of supply networks, information exchange beyond two-way communication of business partners will be necessary.<sup>2</sup>

Given system level information on the supply network, it is possible to construct models that characterize network structure and performance. Network structure can be captured by a qualitative model that provides a directed graph showing the flow of products between partners.

A quantitative representation attaches to each (directed) arc a set of numerical characteristics representing the quantity of products flowing, the time period, the distance or a combination of these numbers.



A network model might focus on a single product type (commodity) or it might be multicommodity. The level of detail of the network can vary from local level movement (for example—from a storage area to a production line) to high level models (for example—from one firm to another).

Lower level models are often incomplete—they describe only a portion of the supply chain network. A partial supply network usually consists of the immediate neighborhood of a vertex.<sup>3</sup> Complete supply networks can be built by combining partial supply networks, and this is facilitated by RFID and partners' willingness and ability of to share their RFID data.

Given a network model, numerous structural analysis tools can provide information to the supply chain manager. Connectedness can be used to judge the criticality of suppliers and transportation activities. Network flow models can identify bottlenecks and opportunities to increase throughput. Network topologies for different commodities might identify opportunity for new collaborations, and network correlation structures could lead to more effective production and inventory planning.

**Inventory models:** Scientific inventory management seeks to answer two basic questions on inventory:

1. When should we order or produce new inventory?
2. How much inventory should we order or produce?

The answers come from the trade-offs among a set of competing considerations such as ordering or production cost, holding cost, shortage cost, salvage cost, lead time, revenue, discount rate and demand—which together form a relatively standard set of components of any inventory models.

RFID allows managers to gain new visibility on two components in inventory models: lead time and demand. Traditional inventory models assume limited visibility when looking forward into the demand and backward into the supply, knowing relatively little about how many products will be demanded and how long it will take to receive inventory replenishment orders.

RFID allows better estimates of demand by combining historical data and real-time data, and better estimates of supply by real-time monitoring of the

physical position of inventory replenishment orders in the supply chain.

**Event management models:** The real-time nature of RFID technology will allow new methods for real-time management decision making. Supply chain event management (SCEM) is the process of automating supply and demand adjustments and notifying and empowering managers to make such adjustments.

It has significant potential to reduce firms' operating costs while maintaining or improving customer service. SCEM actions might include:

- Redirecting product intended for one location to another.
- Using an alternative transportation mode temporarily for a set of products.
- Changing product mix in production or reallocating products to different supply chains.
- Using pricing and rebates to affect product demand and product substitution.

The ability to intelligently redirect products also will influence strategic level decisions such as capacity investment and market development activities.

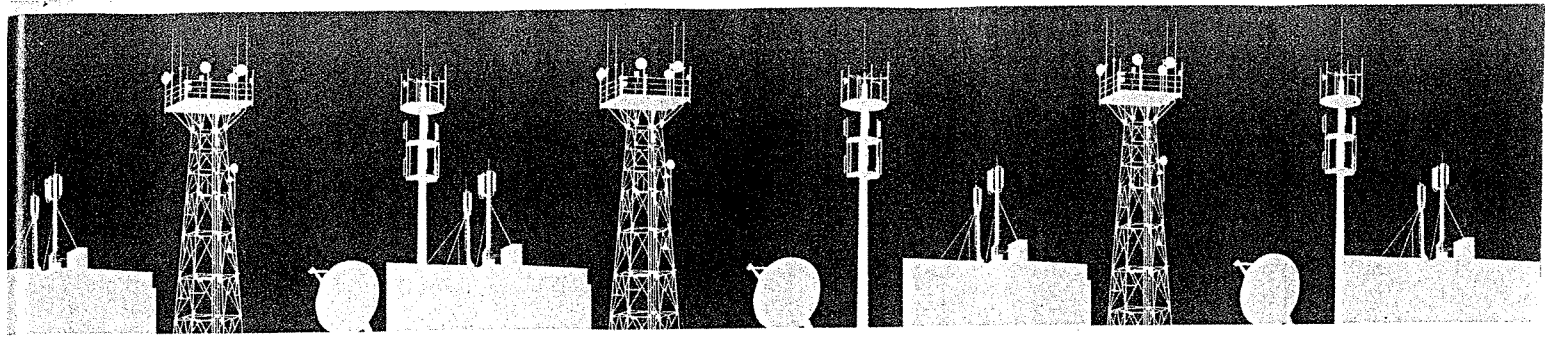
## Data Avalanche and Research

The potential for value from RFID technology is great, but the vast amount of distributed, detailed data makes it hard to derive this value.

RFID systems have the potential to generate huge volumes of data rapidly. An organization must have an essential data management infrastructure to transit, store, process and share the RFID data across the organization and with trading partners.<sup>4</sup> Such an infrastructure must provide solutions to problems of scalability, integration of inherently local RFID data, and access and sharing rules.<sup>5</sup>

To make effective decisions with the data acquired, the RFID data users need the right tools to process data and analyze the impact of their decisions.<sup>6</sup> Academic researchers need to develop and assess new methods that take advantage of the RFID environment. Such areas of study include:

- Control charting for item progress through supply chains to provide a valuable tool for supply chain event detection and management.
- Developing SPC technology to enable this monitoring. The key characteristics are issues of determining rational subgroups, handling



censored data, efficiently characterizing multivariate dependencies and relating control chart results at different levels of system view.

- Developing distributed data structures and report functions to allow decision models to access the required information efficiently.

### More Questions to Consider

Many research questions relate to RFID enabled event management:

- How well do myopic event management rules perform? Based on our interactions with supply chain professionals, we suspect managers making dynamic adjustments might tend to make myopic decisions—for example, addressing a product shortage by expediting or reallocating product.
- How do myopic reactions affect long run performance?
- How much better might optimal event management rules perform?
- Are there qualitative ways optimal rules tend to differ from myopic rules?
- How will the ability to make more informed dynamic reactions affect tactical and strategic decisions such as capacity investment, market development activities or customer service level targets? For example, the ability to dynamically react to match supply and demand might increase optimal capacity utilization, allowing a relative decrease in capacity investment.

Like technologies that preceded it, such as personal computing and the internet, RFID provides rich new areas for the research community. Answers to these questions will help firms exploit the value RFID can bring to their operations.

### Privacy and RFID Data

When releasing data to the public, statistical agencies are required to protect the confidentiality of survey respondents' identities and attribute values. Similar issues might arise for RFID data. Data collection with RFID technology has two features that suggest privacy might be an issue:

1. It is now relatively easy to collect large quantities of item level data in real-time fashion.
2. It is possible to link data collected by different

companies at different times and places with networking and computing power to enable the effective use of RFID technology.

The links among item level data elements, such as raw census data, pose a serious privacy issue. It would be feasible to conduct a census of all goods made and their purchasers quite inexpensively, in an unannounced and undetected fashion.

It has long been an important research issue to protect identity information in census data.

There will likely be trade-offs between levels of encryption and statistical or managerial usefulness of the data.

Research is needed to design specific algorithms to satisfy specific needs. For example, an algorithm can scramble the real-time data of a customer's credit card number and what was just purchased at a checkout counter. Ideally it should be an irreversible encryption that maintains certain statistical inference capability.

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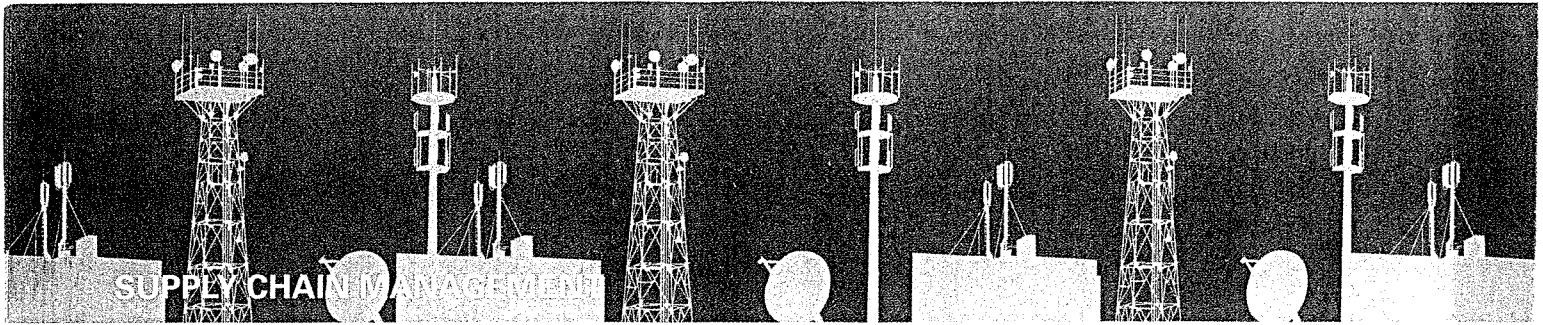
### Challenges Ahead

RFID technology provides both opportunity and challenges for the future of supply chain management.

The availability of real-time RFID information regarding both product supply and demand lets firms improve supply chain execution by dynamically adjusting production, distribution and marketing decisions. This capability will be enabled by better visibility of supply chain status and behavior.

The success of these initiatives will depend on several key developments: effective data mining and monitoring methods, and information technology





innovations that provide efficient access to large distributed data sets while providing required levels of privacy.

#### NOTE

*This article was the result of work by a study group organized by Dennis Lin at Penn State University's department of supply chain and information systems. The group included Russell Barton, Henry Bi, Michael Freimer, Zan Huang, Dennis K.J. Lin, Jun Shu, Douglas Thomas and Susan Xu. The article was edited by Barton. Lin is an ASQ fellow.*

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