Proposal: ROI of RFID in Supply Chains

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Abstract

We study the question: what is the value of RFID in a supply chain. To answer the question we propose a couple of different models that combine networks and economics. We use networks to model the flow of goods through a supply chain. We use economics to model the loss generated by defective inventory tracking. We model RFID as a tool that improves inventory tracking and study the reduction in loss obtained by employing RFID. We consider both open loop and closed loop models. We also consider static and dynamic models and study equilibria in the dynamic case.

We approach the study of the above models both from an analytic standpoint as well as a computational standpoint. We use the language and theory of computational complexity, mechanism design and microeconomics to study supply chains analytically. However complex chains can be intractable and we are forced to resort to simulations.

For simulations, we propose to model supply chains using three kinds of objects: orders, processes and resources. An order initiates a production activity, following a process and consuming resources. We will model supply chains as hierarchical objects. When a new order arrives, a planning algorithm computes the best way to fulfill the order. With the presence of RFID tags and sensors, the planning algorithm has more information available. We will use sensitivity analysis results from the analytical part and genetic algorithms to determine where the RFID tags and sensors are best placed to optimize the return on investment.

1 Introduction

Consider an enterprise such as Walmart. Walmart has hundreds if not thousands of vendors knit together in a complex supply chain. Even in today’s world with the bar-code it is often the case that the records in computer databases fail to match the physical inventory. The industry is rife with examples such as the checkout clerk who rings up Coke three times even though the customer is actually purchasing one regular Coke, one Diet Coke and one Cherry Coke. This leads to a mismatch between supply and demand, shelves often get filled with goods that don’t move while customers find their demands unsatisfied.

RFID holds out great promise that this problem will be fixed - by tagging individual items with highly specific RFID tags and using automated means it is hoped that inventory can be tracked precisely. To some degree this promise has been borne out by the experience of carriers such as DHL, Fedex and UPS for whom the ”lost” package is almost a relic of the past. In this proposal we propose to model supply chains using networks and quantify the loss due to defective inventory tracking using the vocabulary of supply and demand from microeconomics.

Even though big retailers such as Walmart have mandated the use of RFID nevertheless there is much resistance from 2nd and 3rd level vendors for whom the ROI is far from clear. Today these vendors are often doing a manual ”slap and stick” of the RFID tags to appease big customers such as Walmart. They will see benefits only when their own suppliers use RFID in turn. This
will require further developments in RFID technology to improve the costs and ubiquity of tagging and reading tags. But there is a chicken and egg problem here since only increased adoptions will spur the developments needed to improve the technology and make it cheaper. To accelerate the creation and adoption of this technology it is necessary to get a quantitative handle on the ROI that will be obtained from use of RFID.

2 Proposed Work

We propose a simple model based on network theory to motivate our approach for quantifying ROI of RFID. Consider a graph with nodes and directed arcs with capacities. The graph represents a supply chain with nodes being individual stations along the supply chain. Each edge has a leakage function that defines the amount of a good that is leaked in transit along that edge. Then given a collection of commodities and sources and sinks for each commodity we can frame two problems -
1. concurrent version: find the largest fraction of each commodity that can be sent successfully and
2. sum version: find the largest sum of commodities that can be sent successfully. Now assume you can use RFID on upto k edges to reduce the leakage on those edges to 0. How would you choose these edges to maximize the increase in the value of the solution?

Note that the above model quantifies the benefit of RFID. It is possible to generalize the model further to assume an RFID budget and then to find the optimal use of the budget given costs for each edge for upgrading to RFID. This model captures open loop supply chains very well where the same good can take a variety of paths to reach its destination. One critical aspect missing from this model is the fact that at each node incoming goods are consumed and new outgoing goods are generated according to an appropriate production function; further these outgoing goods may be priced based on certain demand curves.

We now generalize the above network-based model to incorporate the microeconomic aspect of supply and demand. Consider a supply chain as a directed acyclic graph with a multiplicity of goods flowing along each edge. Each node consumes the incoming goods and produces outgoing goods based on a production function that is in turn dependent on the demand curves for the various goods as perceived by that node. We assume a defective inventory model at these nodes. We can model the defect in various ways from assuming a strict leakage model to one in which inventory may be under or over estimated. This mis-estimation leads to a deadweight loss in terms of either unsatisfied demand or surplus supply. Assuming a budget for RFID how would you allocate this budget to the nodes to upgrade to RFID to maximally reduce the deadweight loss?

The above model can be further converted to a dynamic model where the production function is altered as based on experience. It is our conjecture that there exist examples which in a world of perfect inventory tracking would converge to the equilibrium but fail to do so in a noisy imperfect world. It is an interesting question to find the smallest RFID budget needed to equilibrate such non-convergent worlds. All of the above examples can be seen as ways to capture the ROI - or the gain in benefits from the use of RFID.

We believe that there is also scope for additional interesting questions such as: what kinds of markets should be established for the exchange of goods? what interesting variants of trusted third party communication will be needed to prevent selfish agents from subverting the system for their own gains.

It is our belief that many of the models and variants we consider will turn out to be intractable in all but the simplest cases requiring us to run simulations. Simulation software will also be critical for modelling real-world supply chains and seeing what emergent phenomena appear in the course of simulations.
To model supply chains, we will use order, process and resource elements. Each element has a state model.

- **Order elements.**
  Order elements define any industry- and customer-specific data that feature order or communication characteristics (for example, sales orders, purchase orders, or production orders).

- **Process elements.**
  Process elements define any industry- and customer-specific data that feature process characteristics (for example, work plans, services, or recipes).

- **Resource elements.**
  Resource elements define any industry- and customer-specific data that feature resource characteristics (for example, material, work areas, tools, or palette storage).

For example, in the manufacturing domain, an order element describes why a manufacturing activity occurs. A process element describes how to use resources to carry out activities. And finally, a resource element describes the means needed to complete manufacturing activities (e.g., labor, facility utilization, materials, timeframes, etc.).

RFID will help to create piece of mind by accurately tracking how far an order has progressed. Instead of using an object-oriented design for the simulation, we propose to use an aspect-oriented design. The reason is that many crosscutting issues need to be dealt with. Consider order tracking (progress aspect): it cuts across many objects, for example several aggregate manufacturing orders and corresponding detailed manufacturing orders that are all active simultaneously.

We will build the simulation model incrementally, following the Law of Demeter for Concerns (LoDC): Talk only to your friends who share your concerns. Talking to friends who don’t share your concerns is achieved through complex requests. It is our expectation that this approach will lead to a reusable simulation aspect framework. Implementation to be done in AspectJ using XAspects or DAJ.

**References**


[S00] SKYVA International, Inc.