

Developing a Low Cost RFID (Radio Frequency Identifiers) Middleware for Small Business Applications

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ABSTRACT

The supply chain industry is beginning to invest significant capital to develop RFID (Radio Frequency Identifiers) technology to address the challenges of lean consumption. RFID has emerged as a new strategy for manufacturing supply chains, but complications of technological implementation still exist in applications and software integration, especially middleware. Many software companies have provided solution packages of middleware from prices of \$30K to \$350K, which may not be affordable for today's small business. This paper will describe the development and integration of RFID technology for small business applications with the integration off-the-shelf products as an alternative to more expensive middleware packages.

KEYWORDS

Inventory, Small Business, Data Warehousing, Middleware, Object Oriented Planning, Radio Frequency Identifiers (RFID), Supply Chain, Value Stream, Supply Network Operations (SNO), Data Management Software (DMS), Warehouse Management System (WMS), Unified Modeling Language (UML)

INTRODUCTION

Over the last several years manufacturing in the United States has been suffering. The manufacturing environment has become increasingly demanding. Some of the nations' top manufacturing industries have tried to counter-balance the competitive market by cutting jobs as well as outsourcing. The reality is that the United States spent many years working with preverbal blinders on. While other countries with manufacturing businesses were investing time into find new ways to manufacturer domestic companies were still conducting business as usual with the use of dedicated manufacturing and traditional production schedules. Ultimately the result has been the inability to satisfy the customer demand in a sufficient amount of time. According to AMR research, there is \$3 trillion of inventory and 20% order error rate in U.S. & European supply chains. They conclude that through demand-driven supply networks, supply network operations and information technology investments the cost of supply chains can be greatly reduced.

So can we learn from our mistakes? What are these new techniques to be learned? What will be the impact of these new strategic manufacturing initiatives on the American supply chain? Just recently have American manufacturers invested time into developing new ways to satisfy customer demand. Several new technologies/strategies have emerged to assist American manufacturers with their current state. One of many is Data Driven Supply Networks. DDSN aims at improving responsiveness by controlling the supply chain by using data provided by the customer. The analysts say that operations that are incorporated into Demand-Driven Supply Networks (DDSN) are helping reduce the \$3 trillion of inventory and 20% order error rate in U.S. & European supply chains. In a landmark study published in the fall of 2000, AMR Research identified that upwards of \$400 billion of opportunities exist in North American for trading partners that fully integrate their supply chains. In addition, radio frequency identifiers have emerged as a tool to increase traceability of parts in a system. RFID can provide 100% visibility to inventory in order cut some cost out of a supply chain system. RFID though has not yet been proven in the market place as something that is truly beneficial to a company's bottom line. RFID may afford industry the ability to enhance the status of the manufacturing and supply chain in American manufacturing. But RFID does come with its own set of questions.

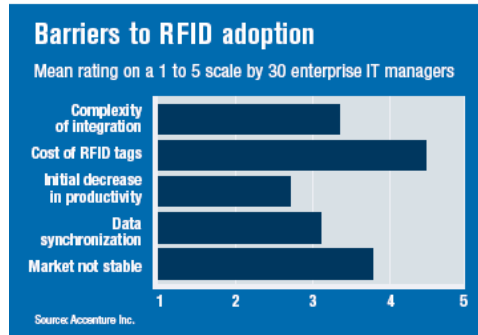


Figure – 01: RFID Barriers (Source: Accenture Inc.)

Figure-01 shows, in a study done by Accenture Inc. research company, that IT managers point “complexity of integration” and “data synchronization” as two major barriers to adopting an RFID system. Both of these issues deal with the ability for an RFID system to be integrated into a company’s way of business; in short developing middleware.



Figure – 02: RFID Tag Uses

Current Industrial Applications

Over the last few years industry has invested significant time and capital to develop RFID technology and electronic product coding. Except for a few trials, though most companies have been taking a wait and see approach to RFID in the supply chain because of high cost, uncertain standards and overall lack of understanding of the technology. Wal-Mart, Bentonville, Ark., has seemingly broken the logjam by declaring that it will begin RFID pallet tracking with some suppliers in 2005. This is an issue for most companies and developers not the concept of RFID but the supply chain infrastructure and software to support the concept that has become an issue. There have been several field trials conducted by the Electronic Product Code (EPC) network sponsored by MIT which assigns a unique serial number to case product pallet, case and item in the retail supply chain. Though Wal-Mart admits that it does not fully understand the impact RFID will have, it does realize the unlimited potential. They site improved on-shelf availability, improved inventory management, more accurate forecasting, labor reduction, inventory reduction and theft reduction as possible benefits. [3]. The Department of Defense has signed off on RFID technology by requiring all of the department’s 60,000 suppliers would have to use the technology by Jan. 1, 2007. The RFID tag contracts awarded by officials at the Army’s Joint-Automatic Identification Technology program were given to several suppliers including Alien Technology (used in this project) and Intermec Technologies.

Industry leaders have already dedicated their resources and investments to the concept of RFID and its advantages to a supply chain structure. In 2002, the Gillette Co. committed to purchase 500 million RFID tags. Retailer United Colors of Benetton recently ordered 1.5 million tags to keep tabs on garments for its 5,000 stores. [4] The Department of Defense, as well as other major retailers including Target and Metro also have demanded specific guidelines for their suppliers to integrate RFID technologies. Seeing this, IBM recently announced plans to invest \$250 million over the next five years and hire 1,000 people to develop and promote RFID applications. Recognizing the difficulty some small-to-midsize business may have with implementing RFID; Microsoft has been testing a RFID software solution for that market. Figure-05 and Figure-06 display the opportunity in the RFID market.

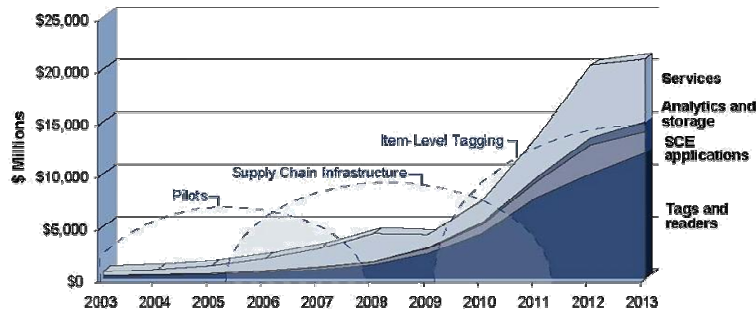
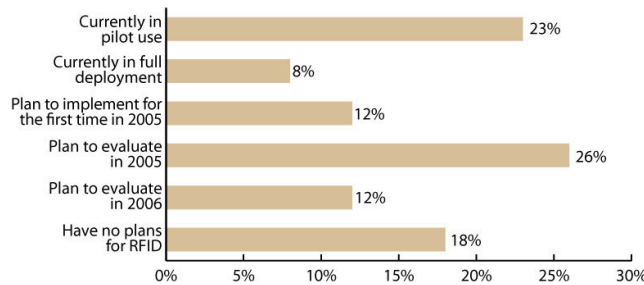


Figure – 03: Forecast of RFID Sales and Services (Source: AMR Research 2003)

As RFID is clearly an early market, AMR Research recommends users develop a long term strategy for RFID in their organization as well as short term tactical requirements for meeting today’s needs. Vendors of the technology should work to combine different technology segments effectively and at a good cost of ownership in order to vie for market leadership. Vendors that can help customers find and exploit positive business models will win. Their research shows that while only 8% of companies are in full deployment, 73% plan to evaluate, pilot, or implement RFID by 2006. The following chart outlines the state of deployment for survey respondents:



Q. Which of the following best describes your state of RFID technology deployment? (n=496)

Figure – 04: RFID Deployment (Source: AMR Research 2005)

With the advent of RFID technology many businesses have been struggling with the ability to gather all of the continuous information gathered by RFID tags in order to make fact-based decisions. Enter RFID middleware. Many software companies have developed solutions to this situation by offering middleware software solution. According to the research firm Venture Development Crop, RFID middleware market is expected grow by 162%; from \$16.4 million in 2004 to \$43.1 million in 2005. Middleware will account for 3% of RFID revenue in 2007 or \$135 million. [5] Several companies have begun to cash in including Dell Sun Microsystems, ConnecTerra and OATSystem. Sun Microsystems offering which competes against existing products from OATSystems and GlobeRanger, among others but believes it has a clear edge over its rivals because of its use of Sun-developed Java and Jini technology to make its systems robust. Sun claims that it’s Java System RFID Software, which the company has been developing during the past two years, is the industry's only highly available RFID solution that can automatically adapt to changing operating environments without requiring system down time or special administration. The offering comprises the Sun Java System RFID Event Manager and the Sun Java System RFID Information Server middleware designed to process streams of data coming from Electronic Product Code (EPC) readers and deliver that data to enterprise applications. Though these offerings maybe state-of-the-art, they may not be ideal for some businesses. Considering that these middleware alternatives may range in cost between \$30K and \$350K; they maybe over qualified and over priced for small business. [6]

PROJECT ANALYSIS

This project will attempt to integrate RFID technology with of-the-self software through the use of scalable middleware in order to convert RFID information to statistical data in order to make data based decisions.

Refined Problem Statement & Requirements

With RFID gaining momentum, larger companies have the capital and resources to explore the its many benefits and have dedicated time and effort into the development of the technology. RFID middleware has become one of the most integral parts of RFID data being integrated into a business model as it allows for the raw data gathered by RFID to be transferred into information useful to business. According to Venture Development Corp., the top three desired features for data monitoring and management functions were data aggregation and integration, data filtering, and data routing. These features, if used correctly in the technology's middleware, can allow for endless possibilities. However, with many small businesses in essence being forced in to the use of RFID by larger customers, these smaller companies will be left to determine to best utilize RFID beyond just the placement of tags on their products for another company's or customer's system to read upon delivery. How can the capital invested in RFID technology be converted into a useful system without realizing the high cost of RFID middleware for system integration? [10] This will answer these questions as well as:

- Can RFID actually contribute to responsiveness through consistent part traceability?
- How do can maintain part information persistence when the RFID technology can only read tags from a limited distance?

But ultimately, can these businesses use off-the-self middleware software and minimal training to convert the information from RFID into organized statistical data in order to make decisions to improve their business strategies? Therefore the proposed middleware application must be able to handle data persistence, system integration and statistical analysis of data in order to make RFID valuable to small business. .

LITERATURE REVIEW

With large industry players such as Wal-Mart embracement the development of RFID, companies have realized the true RFID dilemma; integration. The need for RFID hardware to interface with legacy systems is essential. As prove positive of the importance of RFID middleware large companies such as IBM, Microsoft, OATSystems, Oracle, Sun Microsystems [11] have all dedicated divisions allocated to developing and consulting middleware solutions for RFID that range in cost between \$30K and \$350K.

Though many are trying to realize the benefits of RFID and RFID middleware the Boston, MA based company and one of the early RFID leaders, GenuOne opted out of the RFID application market in May of 2005, stating that the overall market was still in infancy a will take some time to develop a formal marketplace. [12] AMR Research expects by late 2006 for the market to consolidate with clear winners and losers identified. Frost and Sullivan predicted a RFID middleware market of \$23 million for 2004 now estimates \$220 million by 2011.

If RFID middleware, can be defined as the software layer residing between the RFID hardware and the existing back-end system or application software then its function is to extract data from the RFID interrogators (readers), filters it, aggregates it and routes it to enterprise applications such as a warehouse management system (WMS), enterprise resource planning (ERP). Only a few years ago, the average selling price of a single enterprise RFID middleware software license was easily \$125,000 or more per installed site, making it very expensive to bring RFID technology into the supply chain management. For a relatively simple piece of software—in terms of required functions and capabilities—it bore a horrendous price tag for early adopters. The simple fact, today, is that RFID middleware can be purchased for less than \$20,000, and with enough functionality to run most RFID applications. In a statement heard in the RFID community, in 2006, German automotive manufacturer Volkswagen developed its own RFID middleware completely in-house, much to the dismay of many commercial software vendors. [13]

DESIGN: SYSTEM DEVELOPMENT

In order to gain long-term benefits, these suppliers need to intelligently incorporate the data they are collecting to make improvements to their overall business processes. RFID middleware is the tool that companies will use to manage RFID data by routing it between tag readers and the multitude of systems within their businesses. Unfortunately many industries will not have the capital to explore how custom middleware products or programs will be able to handle the flow of RFID data best for there business. [14] To counter-balance this, this project will explore the use of off-the-self software and products to handle this information without loss of data or errors. In short, this project will attempt to integrate of-the-self software through the use of scalable middleware in order to convert the mass RFID information to statistical data to make data based decisions.

This project will attempt to integrate RFID data, Java coding, SQL-based databases (Access), and a GUI (Graphical User Interface).

Equipment and Software

The equipment and software used in this project are all a part of the Reconfigurable Factory Testbed as mentioned previously. This lab is used to simulate the functionality and situations found in a “real world” environment. All the equipment that is found in this lab is industry standard. RFID station found in the lab is just one small part of the system but through the use of TCP/IP connections, it has the ability to alert and update statuses to all other equipment/processes in the lab.

Alien Technology ALR-9780 is a point-to-multipoint network reader. It has the ability to be static in location but read multiple dynamic tags. It operates at an EPC standard frequency of 902.6 MHz – 927.4 MHz, which was described in previous sections as a fairly high range frequency, capable of a range up to 9 feet. This range is most applicable to this project as most industrial applications use this range for pallet and part tracking.

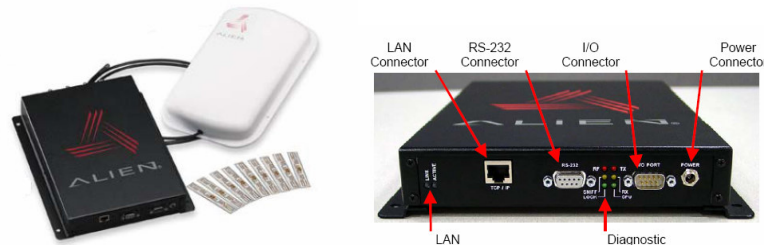


Figure – 05: Alien Technology’s ALR-9780 Reader, Antenna and Tags and Reader Communication Ports

The tags used are Class 1 NanoBlock Tags. They are specially designed to be used with Alien’s ALR-9780 readers. These tags comply with the MIT AutoID Center’s open specification for RFID. Class I tags are “passive” devices. That is, they do not have an onboard power source. They are powered by the RF energy transmitted by the reader. They communicate with the Reader by means of “Backscatter Modulation”. That is, they do not actually transmit anything; they merely change their reflective characteristics in a systematic way and reflect RF energy back to the reader. An analogy to this is the way you can use a mirror to transmit information by reflecting light from the sun.

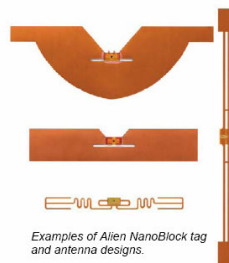


Figure – 06: Example of NanoBlock Tag

InduSoft provides a family of software products for developing applications in Industrial, Instrumentation and Embedded Systems, for all Microsoft operating systems. InduSoft Web Studio is a powerful collection of automation tools that includes all the building blocks needed to develop human machine interfaces (HMIs), supervisory control and data acquisition (SCADA) systems, and embedded instrumentation and control applications.

Other Reconfigurable Factory Testbed equipment and software to be explained in later sections include:

- Amatrol AS/RS
- Amatrol Conveyor System
- Allen Bradley PLC 750KB MEM
- Netbeans Java Editor IDE 4.1
- Microsoft Access
- Rockwell Software RSLinx

- Rockwell Software RSLogix

Data Flow: Current System Operations

Academia provides an excellent opportunity to model “real-world” constraints and modules for test and application of RFID technology. The partnership described in the following allows for the two universities, Morgan State and Michigan to simulate a demand-pull supply chain system acting as a supplier and an assembler. In this project, Morgan State University acts as a subcontractor and partner to the University of Michigan for the purposes of this project. In many ways, Morgan State University acts as a supplier plant that supplies an assembly plant, in this case, University of Michigan. In this project, the two schools aim to simulate the constraints and the capabilities of a “real-world” supply chain environment. The use of a VPN (Virtual Private Network) acts as the communication and control link between the two universities. This connection allows not only private communication between the two parties, but it also allows for the two “factories” to be controlled at distance and through the web.

The lab Morgan State University allows for this research to be tested in an ideal environment. The RFT lab described previously serves as supplier for a manufacturer. It has a limited number of students “employees” and a small product mix. It fits well the definition of a small business and hence validates the development and testing of a RFID middleware system designed for small business in the lab.

Object-Oriented Software Development: Proposed System Development

Object-Oriented software development governs that the software development process takes place in five phases: [12 & 13]

- Requirements Elicitation
- Analysis - Formulate and build problem domain model
- System Design - Analyze problem and break it down into smaller pieces and select general strategies for designing system
- Object Design - Select detail solutions for each piece and decide most appropriate solution
- Implementation - System is realized, domain model is translated into executable representation.
(Discussed in Section 6.1)

This same development process will be applied to the implementation of the proposed middleware package.

System Requirements Elicitation

The requirements of the system in order to fully understand the problem we can begin to be more specific about the requirements of the proposed system based on the experimental equipment. As discussed previously there no exist in the RFT lab a fully functional supply chain structure that can receive and fulfill customer orders. Within the structure of the lab there exists an inventory tracking operation on an Alien RFID application. The RFID reader is fully functional but there still is two problems: Firstly, the RFID reader can gather information on parts that are in a 9ft radius but once that part leaves the that radius it takes all of its information with it. In other words, there is no persistence. Secondly, the RFID application operates independently to the rest of the lab operations and there is no way to make any decisions based on the information gathered by the RFID reader. Therefore the proposed middleware application must be able to handle data persistence, system integration and statistical analysis of data in order to make RFID valuable to the RFT lab and consequently small business.

System Analysis

The analysis phase deals with creating a domain model. Problem domain modeling is an essential part of the software design process. It builds the initial static portion of a model, which is essential when driving your application design forward from use cases. [17] The term "problem domain" refers to the area that encompasses real-world things and concepts related to the problem that the system is being designed to solve. Domain modeling is the task of discovering classes that represent those things and concepts. Classes are used to group related variables and functions. A class describes a collection of encapsulated instance variables and methods (functions), possibly with implementation of those types together with a constructor function that can be used to create objects of the class. There are several UML classes that are defined in this project: All of these actors/classes are involved in one of these four use case scenarios that describe the use of the proposed system

- Install System
- Add/Remove Tag Information

- Analyze Data
- Evaluate System

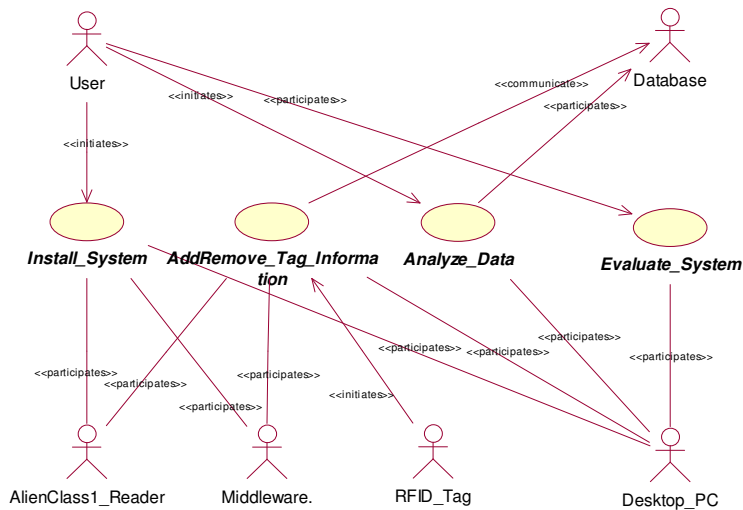


Figure – 07: Use Case Diagram

In Figure 07 we can see how each one of the actors function in a particular use case. The use case that will be discussed in further detail is the Add/Remove_Tag_Information use case. This use case will give the best understanding of how the system components interact with each other to create a seamless application.

1. Part enters the AlienClass1Reader’s frequency
2. The AlienClass1Reader sends a message to the MessageListenerService that a new tag has been added/removed
3. MessageListenerService send an updated message to the MessageListener
4. The TagTableListener receives a message to update the TagTable for the RFID_Application
5. RFID_Application sends updated tag information to the Database
6. Database stores new information

Figure 08 shows a conceptual model and a UML component diagram that displays the interactions between different components of the system described. It describes the process of a tag being read by the reader and the information associated with that tag being store in a database in order to make the data persistent. The orange box is a representation of the actual hardware received if one is to purchase an Alien Technology ALR-9780 Development Kit, as was in this project. The green boxes are realizations of the modified Alien API (Application Program Interface). An API is a set of encapsulated routines, protocols, and tools for building software applications. What has been named “RFID_Middleware” has been modified through the course of this research to handle the functionality in the research lab. All of the other boxes below the RFID Middleware are sub classes that allow for the API to function.

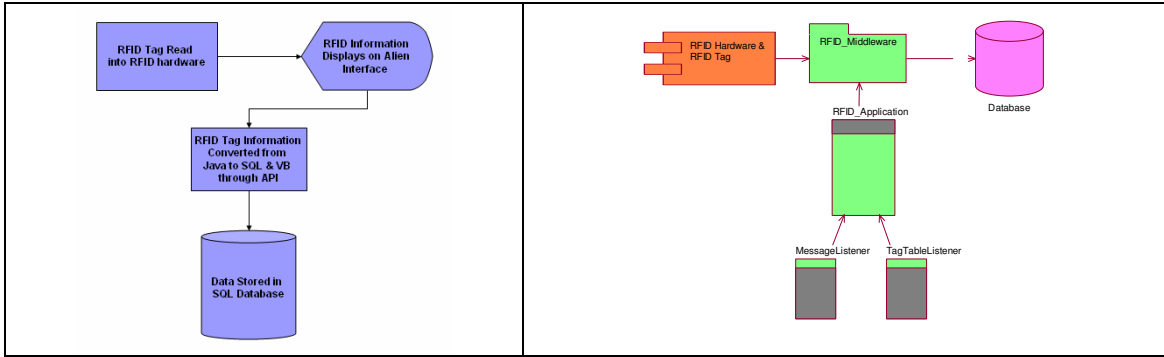


Figure – 08: Conceptual and UML Component Diagrams

The development of the use case diagram and the component diagram, a class diagram can be developed to display the functionality of the middleware system.

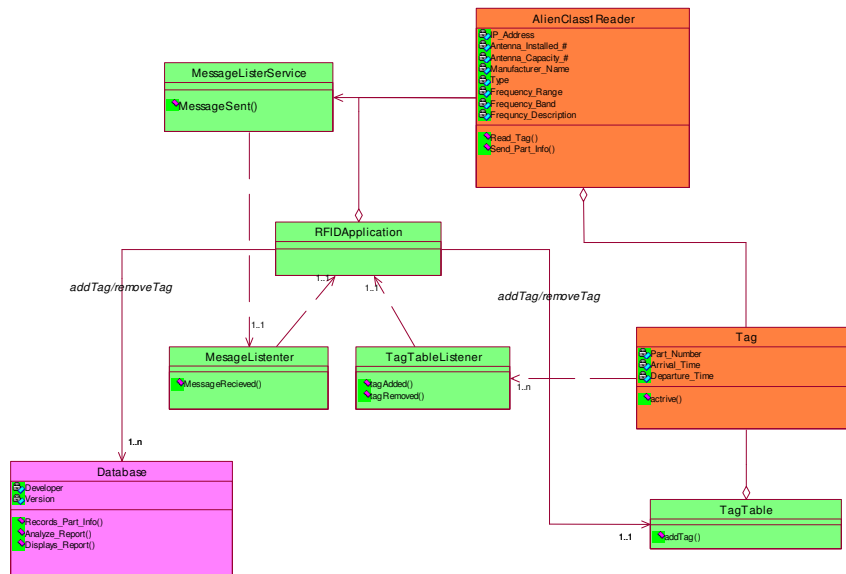


Figure – 09: Class Model

The above class diagram describes a system in which the modified API (the API is denoted by the collaboration of all the classes in orange) allows for all parts read by the RFID hardware to be stored in a database. The user initiates the system at start up. The AlienClass1Reader then initiates the RFID Application Java API which contains the MessageLister and TagTableListener. The TagTableListener waits for a tag to be added to or removed from the AlienClass1Reader’s list of tags stored in its transient memory (TagTable) in order to store the information in a Microsoft Access database.

System Design

The system design phase is used to break the analysis of the project into smaller pieces and possibly group the classes discovered in the analysis phase in to possible class groupings. In this phase the developer begins to develop a conceptual method in which the software will be designed. For the design of this system, the middleware will be developed in a Java editor and it will “handle” portions of the encapsulated Alien RFID API (Application Program Interface). The middleware will then be able to place information gathered from the Java API and use communication between a JDBC (Java Database Connection) and a Microsoft Operating System ODBC (Open Database Connection).

As shown in Figure 20, the proposed system should be able to handle data persistence even if the part is no longer in the frequency of the reader. The below object diagram shows how the middleware system will operate and how the data can persist and how that data can be placed in a database for statistical analysis.

Object Design

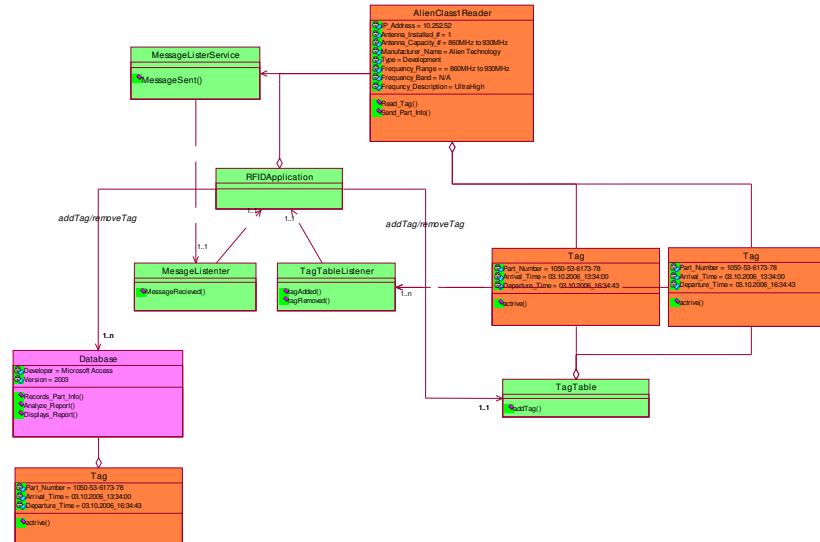


Figure – 10: Object Model

CONCLUSIONS AND RECOMMENDATIONS

In order to determine the value of the “SAM” Middleware System we must look at development time and payment. It is not unreasonable to think that two senior software development engineers could evaluate a system and design a software package for small business in less than 80 hours. According to engineeringssalary.com, a standard charge would be \$50 per hour. That would value the “SAM” of RFID at less than \$8K. Compared to the \$350K – \$30K, this seems to be an affordable solution to the small business RFID problem. This validates that an affordable middleware system can be developed for small business without the high cost quoted by some more notable developers.

With RFID clearly emerging as the new supply chain standard, the opportunity is immense in this new market. Also with an estimated worldwide sales of RFID related middleware and services in the \$220 million dollar range in 2011, there exist the opportunity for small business manufacturers to take advantage of small business system integrators and avoid the high-priced middleware solutions offered by some of the major players in the RFID game. If any business is going to “win the game of tag” they must first understand how RFID can help their business and select RFID hardware and middleware that is not only applicable to their business but scalable for future growth. This project aimed to develop a middleware application that handled data persistence, system integration and statistical analysis of data in order to make RFID valuable to small business. Through the use of program APIs the middleware was able to handle these tasks. There still lies a tremendous opportunity to even further develop this research area. For example, the software robustness would increase if the middleware would be tested in a small business environment. In that environment, the customer would be able to give recommendations for improvement as well as give real-world values to the cost-benefit analysis model development that would determine if the project satisfies the company’s IRR (internal rate of return). There can also be development of coding that will allow for seamless integration between the RFID hardware, database software and statistical analysis software (SPSS, SAS, etc.) Though each business and supply chain is very different, this project proves that there is an opportunity to supply small business the capability to integrate RFID technology to improve their business processes.

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