Application for Automated Inventory Management of Weapons and Related Assets

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ABSTRACT

The Oak Ridge National Laboratory (ORNL) is developing a system that uses a new inductive communication technology called RuBee™, to manage and inventory weapons housed in Department of Energy (DOE) armories. RuBee™ is under consideration as an IEEE Standard (P1902.1), and is being used on this project primarily because of its high performance when used in, on, and around metal; typical of an armory vault environment. The primary objective of this project is to supply sustainable technology that provides timely information on the status and location of weapons and related assets. This paper will focus on the design of the system, including software, hardware and field implementation. Various design choices will be discussed as they relate to the challenge of implementing this type of system in a working DOE armory.

INTRODUCTION

For many years, laboratories around the world have been working on technologies and methods that can provide improved diversion detection and accountability for protected assets. In many cases, the lack of technologies that support the real-time tracking has hindered progress. There have also been concerns and restrictions on using technologies that transmit signals, especially for protected and accountable assets located or stored in secure areas. However, significant resources since the late 1970s have been invested in barcode-based technologies for inventory. These technologies have proven themselves as reliable, beneficial approaches for maintaining inventory. Unfortunately, they have not been very effective at providing timely information or much, if any, security benefits.

Today the market is flooded with several types of radio frequency (RF)–based technologies that are designed to support timely monitoring and tracking of assets. Some of these technologies are designed primarily to support inventory functions, and some of the newer products are being built with security functions in mind. However, RF technologies in the past have had limited success when used on metallic objects, especially small metallic objects that are densely arranged. With the development of technologies such as the RuBee™ radio tags, it is now possible to use RF tags for inventory (and other functions as well,) even for these 'hard to tag' items. One of the first applications is for the automated inventory of weapons and related assets at DOE armories [1,2].

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The use of RuBee™ radio tags for automated inventory comes after the result of thorough testing of many versions of radio frequency identification (RFID) devices. Tested devices include 900 MHz passive, 13.56 MHz passive, 2.4 GHz passive, 2.4 GHz active and Ultra Wide Band active. Each of the tested devices was not suitable for deployment on weapons because of at least one of the following: size limitations (tags were too large,) operational difficulty near metal, limited read range, short (<1 year) battery life, not able to survive repeated shock or simply unreliable performance. In addition, the target deployment locations include secure government areas with stringent radio frequency restrictions. RuBee™ radio tags are the only tags tested able to meet both the performance requirements and operate at a frequency which is suitable for deployment in secure facilities. In addition, RuBee™ tags feature a 4-bit microprocessor and embedded power supply, which gives them the flexibility to incorporate sensors and/or handle additional processing tasks such as encryption. In the case of weapons, an additional sensor has been added to facilitate counting rounds fired.

Currently, a large number of man-hours are spent on the daily, weekly, monthly and yearly inventories of weapons and other high-valued assets within DOE armories. This time is spent doing visual inspection (from a simple there or not there check to a full serial number validation) and recording this inventory data on paper based systems or manually into software systems. Additionally, unplanned man-hours and costs are incurred as the result of a lost asset; most notably a lost weapon. An automated inventory system provides a return on investment by eliminating the timely manual inventories. Lost asset reconciliation costs can be greatly reduced by examining the system logs and recognizing a chain of events that may help explain what happened to that asset. In other cases, lost asset reconciliation costs can be completely eliminated by showing that the asset is still 'on the grid' but has simply been placed in an incorrect storage location.

The recent advances in radio tags are fundamentally necessary for this type of system. However, the system software, its architecture and its features ultimately fulfill the needs of the end-user. It can even be argued that the stringent rules associated with networked deployments at DOE and other secure sites make the software and network architecture design even more important to the success of a deployment. The ORNL developed Automated Weapon Inventory System (AWIS) software, its architecture and features will be discussed in this paper.

P1902.1 (RuBee™) BACKGROUND

RuBee™ is a low frequency radio protocol developed by Visible Assets Inc. The original design goal for RuBee™ was to fill a gap in the radio frequency identification (RFID) market related to tracking high valued assets. In recent years, overzealous marketing and technical misunderstandings have led to a number of failed RFID deployments. The popular back-scatter RFID systems working at frequencies of 900MHz or 2.4GHz are easily blocked by metal, liquids and are quite sensitive to orientation. These constraints lead to systems that rarely provide read rates of 100%. As an example, if we examine Walmart, which may be the largest current user of Ultra High Frequency RFID (UHF

900MHz), their published read rates vary from 98% down to 66% for reads on loaded pallets [3]. While this may be acceptable read rates for low-cost commodities, it is not acceptable for high valued assets.

The RuBee™ protocol operates at a low frequency of 131kHz. At this frequency, the signal energy is composed of a magnetic field, which has very different properties from the electric field signals of other back-scatter UHF RFID systems. Most importantly, the magnetic field is an omnidirectional sphere, it easily penetrates water and metal, and the field strength falls of at a rate of $\frac{1}{r^3}$ where r is the radius of the field. By being omnidirectional, the orientation issues of UHF RFID systems are eliminated. The ability to penetrate water and metal makes the tags much more useful for personnel (humans are about 62% water) and in applications where metal is in close proximity or the tagged item itself is metallic. The rate of signal strength falloff is important from a security standpoint. The fast non-linear falloff means that the signal cannot be monitored remotely. This is in contrast to UHF RFID that relies on a strong carrier signal that can be monitored from long distances and can potentially cause interference with other systems operating at the same frequency.

RuBee™ is not completely without downsides. The use of low frequencies has benefits as discussed, but these come at a cost of bandwidth and reliance on a battery. Practical bandwidth for RuBee™ tags varies from 2 tag reads per second per reader to 7 tag reads per second per reader based on the install configuration. In contrast UHF RFID systems have been tested at up to 265 tag reads per second [4]. Additionally, the RuBee™ tags are not powered by the readers, but rely on an on-board button cell battery to power a receiver and 4-bit microprocessor. In normal operating environments, the battery is expected to last 7-10 years.

SOFTWARE BACKGROUND

The Automated Weapon Inventory System (AWIS) software application and underlying architecture is based on extensive feedback from armorers, end users, and other administrators from the Department of Energy protective force contractors. The architecture of the software is also heavily influenced by the software and network restrictions common at the planned deployment locations, which include highly secure government sites. Design choices are also based on the software and database that is provided by Visible Assets Inc. as part of the Dot-Tag server.

An emerging theme in secure computing environments is to remove reliance on user hardware in order to process and save sensitive data. The reasoning behind this is that client computers that don't process or store data can be kept in more vulnerable locations and are less sensitive to attack from malicious software (viruses, trojans, etc.). There are several methods used to accomplish this, including the use of thick and thin clients or by simply relying on software methods that maintain data and processing on a central server as much as possible, but don't discriminate on the type of client that connects. The latter method (usually called web-based software) is typically accomplished using hypertext transfer protocol (http) and associated protocols to run applications on Internet browsers or Java applications loaded from an Internet browser. The use of web applications is extremely powerful because no software is stored on the client computer. Software updates can be made on the server and will immediately become effective on the client side. Additionally, user privileges can be kept low on the client computer as well since they are only required to run a standard Internet browser. Based on these benefits, the AWIS application uses a web-based architecture.

Web-based applications have various benefits, but the tradeoff is that they have traditionally provided users with a substandard user interface. The reason for this is that programmers have had limited tools to work with – resulting in programs that provide only snapshots of data, long load times and difficult to use interfaces. However, recent advances in software combined with increases in network bandwidth have opened doors to more interactive web applications with easy to use, fast interfaces and dynamic data content.

The key to providing an enhanced web interface is the use of background asynchronous data retrieval. In other words, the application must be able to retrieve data from the server asynchronously from user inputs or interactions. In this way, data can not only be kept current, but can also be buffered so that when a user requests new data, that data can have already been downloaded, and can now be displayed quickly to the user. The group of web development software used to accomplish this has been coined Asynchronous JavaScript and XML, or AJAX. The term is somewhat misleading as it has come to represent the technique of asynchronous data retrieval instead of the specific use of JavaScript and XML. Web applications can actually include scripting or markup languages in addition to or in place of JavaScript and XML, but are still referred to as AJAX applications. Perhaps the most well known AJAX applications are Google Maps (maps.google.com) and Google Gmail (gmail.google.com).

SYSTEM ARCHITECTURE

The AWIS system architecture is shown in Figure 1. Starting from the left side of the diagram, antennae are deployed in appropriate locations. The antennae are available in different form factors to suit various install configurations. The wireless communication between the antennas and the tags is based on the emerging IEEE P1902.1 standard. The next layer is composed of the Visible Assets Inc. readers (sometimes called routers.) These network devices perform the functions of controlling the system antennas, talking to tags, collecting data and passing the data to a central server. The readers run embedded Linux (FreeBSD) on an ARM computer board. An ARM computer board is a reduced instruction set computer that is compact, uses little power and yet has plenty of processing power for the required application. Using the Visible Assets Inc. readers, tag data is collected and passed to a central Dot-Tag server via standard CAT5/6 network infrastructure, using TCP/IP protocols.

The Dot-Tag Server is a rack mountable Linux (Cent OS) server running an Apache web server with the Apache Tomcat application server. Apache Tomcat implements the Java

Servlet and JavaServer Pages (JSP) specifications from Sun Microsystems [5]. This application layer of the architecture is split into two parts to separate the manufacturer (Visible Assets Inc.) code and the code developed by ORNL. The manufacturer code is written as a Java Servlet. This application communicates with each reader via TCP/IP and collects tag information. Data is maintained in a PostgreSQL database. The AWIS software is hosted by the same Dot-Tag server, and shares the same PostgreSQL database. As discussed previously, the AWIS software is a web application. It is hosted by the Apache web server which has been configured to provide support for the PHP scripting language.

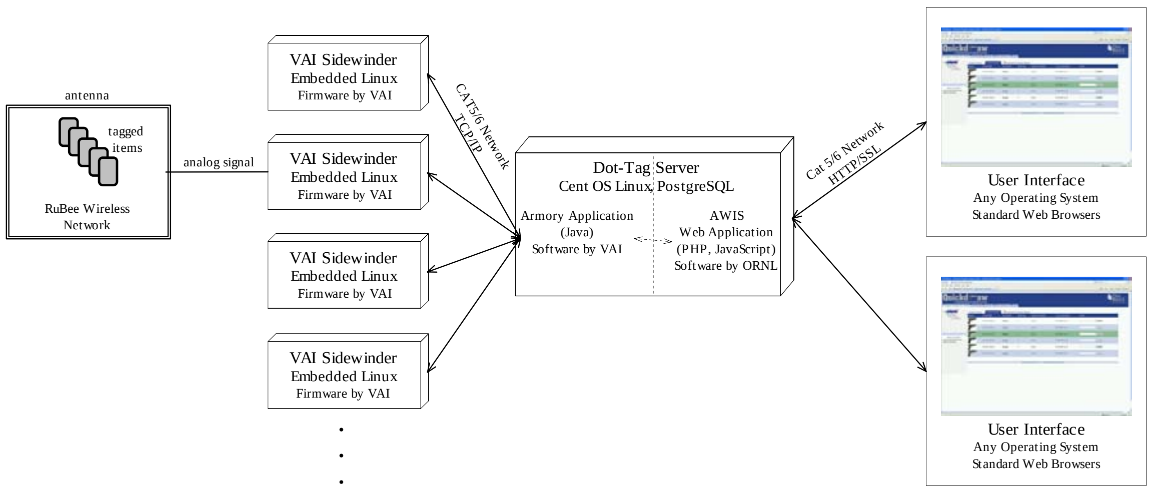

Figure 1. System Architecture

HARDWARE INTEGRATION

RuBee™ tags are embedded or attached to each asset that is to be tracked. The first asset to be tagged was a Sig Sauer P226 handgun. A custom tag was developed which is embedded inside the grip area of a Sig Sauer P226 handgun as shown in Figure 2.

Figure 2. RuBee tag embedded in Sig Sauer P226 Grip

An early RuBee™ weapon rack prototype is shown in Figure 3. In this configuration, antennae are embedded into each side of the shelf structure. While this will be a common configuration for new installs, it should be possible to retrofit existing rack/storage configurations by employing a wide range of RuBee™ antennae and embedding or attaching them to existing storage racks.

Figure 3. RuBee™ Weapons Rack Prototype

SOFTWARE FEATURES

The AWIS software application works in conjunction with the Visible Assets Inc. Dot-Tag server and reader systems to provide near real-time inventory via embedded or attached RuBee™ radio tags. AWIS also supports management functions including detailed data records for each asset, past event history, maintenance records, maintenance tracking based on date and/or shots fired and disposition control.

The system uses various types of trigger inputs to initiate inventory update scans. These trigger devices are typically infrared motion detectors, pressure mats or light beams. When a trigger occurs, an ORNL developed device called a SideArm interprets the input and sends a message to the Dot-Tag server causing an inventory update scan to begin. By strategically placing trigger devices in a facility, the system is assured to fully account for all tag activity while avoiding unnecessary RF scanning that would prematurely drain the tag batteries.

The AWIS user interface is split into two main sections, the data viewing section and the administrative section. The data section provides the user with a simple interface for viewing inventory data and generating inventory reports. The administrative section provides methods for registering new assets, updating asset information, managing maintenance, etc.

Data Viewing Section

The data viewing section provides four ways to view inventory and asset data. These data views include “Weapon Inventory By Location,” “Search By ID,” “View All Assets,” and “View Transaction Log.”

The “Weapon Inventory By Location” view allows the user to limit data on the screen to a specific location. The weapon inventory system can be composed of up to 100 readers, deployed at various locations throughout a facility (or even across facilities). This view lets the user select a specific location for viewing current inventory status. An adobe PDF compatible report can also be generated by selecting an area, then clicking the “Generate Inventory Report” link. This report contains an inventory snapshot at the time of creation. The report is suitable for printing or saving to disk. A screenshot of the AWIS application is shown in Figure 4.

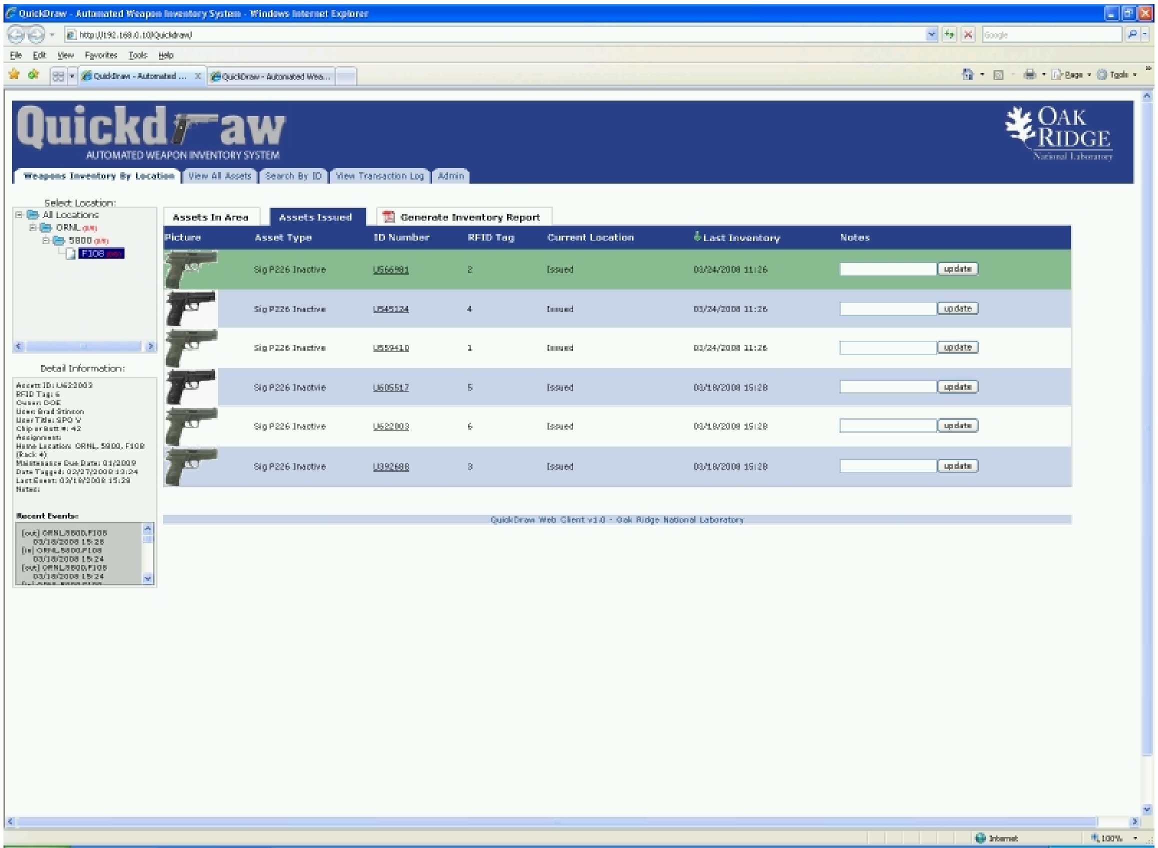

Figure 4. Inventory By Location View

The additional data views provide the ability for the user to search for a specific asset by its serial number, RFID tag number or assigned user. The user can also view a transaction log that includes the last 300 transaction events.

<u>Admin Section</u>

The admin section is password protected and is meant for access only by armorers, supervisors or other management staff. Admin functions include asset management/registration, rack/reader management, disposition management, user management and database backup functions.

Asset management provides administrative staff with the tools they need to register new assets into the system, edit existing assets or remove assets from the system. The interface is easy to use and provides real-time error checking to help avoid data entry mistakes. A typical asset management screen show in shown in Figure 5.

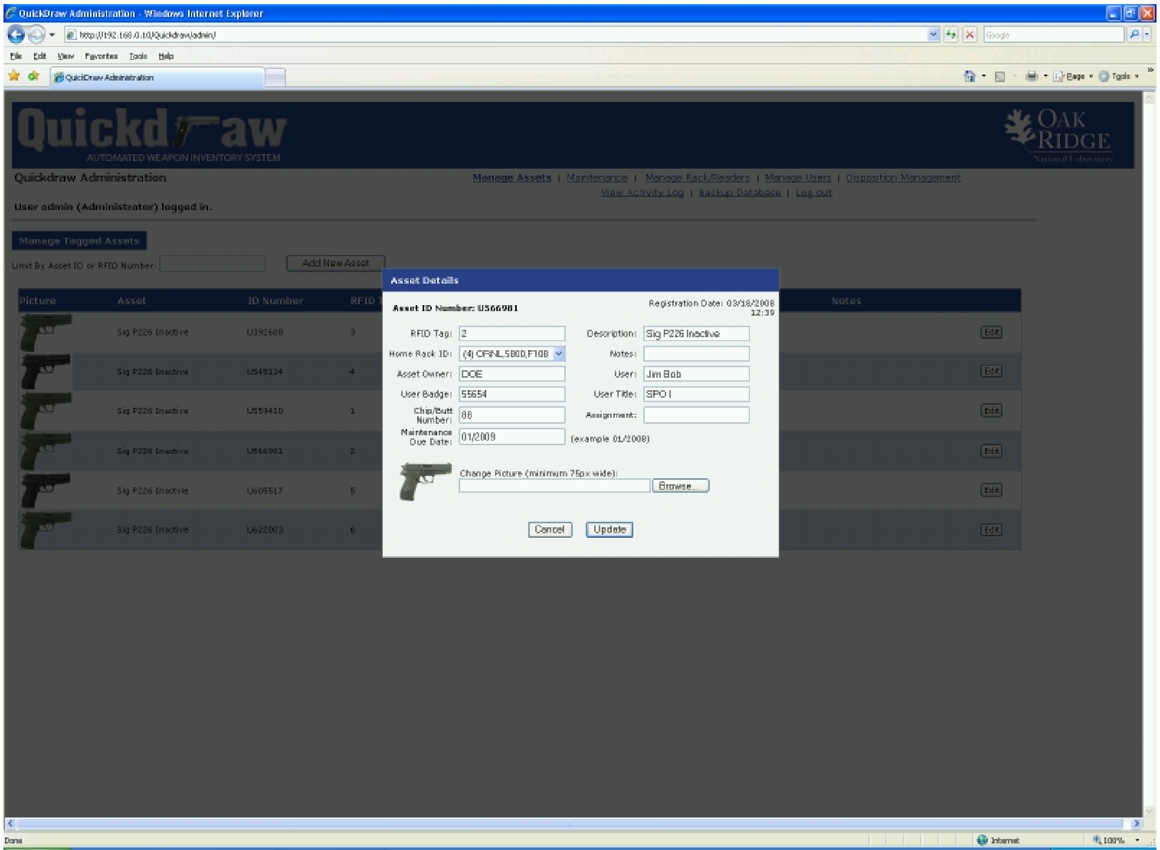

Figure 5. Admin - Asset Management

Other administrative functions include rack/reader management, user management, disposition management and weapon maintenance search functions. Rack/reader management allows administrators to add new readers to the system or edit existing racks/readers. User management allows the administrator to add or edit users. There are two levels of administrative users in the AWIS system. An armorer can manage tags and view maintenance search results, but cannot manage users, racks/readers or disposition assets. Disposition management provides a way to remove assets from the AWIS system, but maintains a full record of why the item was dispositioned and where it is located. Weapon maintenance functions allow administrators or armorers to search for weapons by maintenance due date, or to quickly identify weapons that are past due for maintenance. Finally, each administrative event is logged, including the event, the user that performed the action and the date/time.

CONCLUSION

This AWIS software along with the RuBee™ radio tags and other Visible Assets hardware provides a robust and scalable method of performing automated inventory of weapons and related assets. This is a groundbreaking application. Never before has a system been capable of wirelessly tracking densely arranged, small metallic objects with this type of performance, security and scalability. The fact that the system has been designed from the ground up for deployment at secure facilities makes it truly unique in the world of RF-based inventory systems.

ACKNOWLEDGMENTS

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