GPS AND SENSOR-ENABLED RFID TAGS

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ABSTRACT

By combining GPS, environmental sensors, RFID tagging (passive and active) ORNL researchers are supporting total asset visibility for the military. Systems based on these technologies with this architecture can be used to provide programs such as FCS with persistent knowledge of the location and status of every asset. This will provide commanders the assurance they need to verify logistics and plan missions.

INTRODUCTION

The long-term vision of program managers for the Defense Logistics Agency (DLA), other military entities such as the Army's Future Combat Systems (FCS) and commercial ventures is to have total asset visibility (TAV) for all of their resources as shown in Figure 1. That is, they need to have actionable information available to them at all times about the location, quantity and state of their material assets and personnel. Researchers at Oak Ridge National Laboratory (ORNL) have performed test and evaluation support for DLA [5]; R&D support for DLA, Department of Energy (DOE) and other customers; and system integration analysis for FCS in the area of radio frequency identification (RFID) tagging and tracking and are working with the Natick Soldier Center on the combat feeding program pilot. Furthermore, they are maturing low-power sensor technologies such that the status and history of the tagged assets can be recorded.

They are bringing together hybrid architectures (active and passive tags), specialized sensor suites (including the new 6-D sensor), novel RF waveforms, precision timing protocols, low-power electronics and multi-band antennas to provide prototypes of the networks that will enable the military to fight more effectively both next year and next decade.

TAV Architectures

TAV Scenario

The long-term vision for TAV may best be described by discussing a hypothetical scenario using the systems shown in Figure 1. We assume that a battle is in progress on a remote continent from the US. On one of the vehicles supporting the battle, a weapon system is starting to demonstrate degraded performance. First, the vehicle's tag and/or hardware status database is programmed with information that the weapon system needs to be fixed. Next, this information is propagated

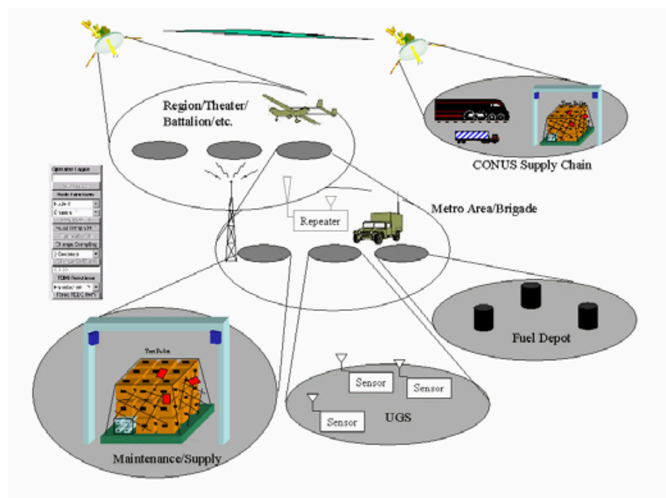


Figure 1. TAV Vision

through the communication networks to the commander level. This information can be passed through conventional networks or specialized communication means such as the digital radio-frequency tag (DRaFT) system being developed by DARPA. (This would combine the functions of combat ID and sustainability by simultaneously establishing the location of friendly forces and their operational state).

From the commander's database a message goes out to logistics support entities that this particular weapon system needs to be replaced by the following day. Logistics entities can send queries back through the communication networks requesting specific model numbers and histories of components on the degraded weapon system. Once the state and history of the system to be replaced has been established, the logistics entities then send out requests for the necessary replacement parts. Some of the parts may be stored in depots in the US, while others will be in the rear area of the battle. By having real-time location data (part of RTLS standards) on all of these assets, the logistics entities can demand emergency shipping and maintenance scheduling such that all the parts and technicians arrive at the maintenance area near the battlefield. Thus, the vehicle can be removed from the battle for a minimum amount of time, repaired and returned to the battle.

Architecture Development

The above scenario becomes a reality if all assets are "tagged" with a unique identifier when they are manufactured, an updateable database about the features of the asset is associated with this identifier [see transducer electronic data sheet (TEDS) discussion], and the asset enters a communication grid that can communicate periodically with the tag. This "grid" might consist of fixed infrastructure systems in the US, portable infrastructures near the rear of the battlefield and mobile infrastructures on the battlefield.

A detailed description of a seven-layer architecture for the Global Grid (GG) was presented at MILCOM 2000 [1]. While this provides the "backbone" or infrastructure grid for asset tracking data, other components must be developed to provide efficient communication of asset related information. Also, administrative protocols must be in place to assure that exactly the right users have exactly the right asset data available to them. Thus, security issues and data dissemination issues must also be addressed by systems engineers developing TAV systems.

One key element in realizing this scenario is the development of a communication architecture that brings together all of the necessary technologies in a seamless fashion. The Internet is comprised of many different hardware and software solutions utilizing common protocols and layer definitions. In the same fashion, we must have common protocols, layer definitions and interface definitions that allow various technologies to support TAV. The architecture definition must include a description of how data about a particular part is requested and reported from a remote entity. This could involve leveraging the activities of the Auto-ID Center, a not-for-profit partnership between more than 87 global companies and three of the world's leading research universities, founded in 1999 at the Massachusetts Institute of Technology (MIT). The Center's mission is to [2] "design the infrastructure and develop the standards to create a universal, open network for identifying individual products and for tracking them as they flow through the global supply chain." The Auto-ID Center's vision is [3] to "revolutionize the way we make, buy, and sell products by merging bits (computers) and atoms (humans) together for optimal mutual communication. Everything will be connected in a dynamic, automated supply chain that joins businesses and consumers together to benefit global commerce and the environment."

In our case, particular components (objects) could be identified by an electronic product code (ePC) or universal unique identification (UUID). An Object Name Server (ONS), a network directory service that is similar to the domain name server (DNS), could be used to link ePCs to databases with up-to-date information about the components. The ONS redirects requests for information on a particular ePC to servers/databases containing the requested information described using the Physical Mark-up Language (PML). PML is an extensible markup language (XML)-based language used in databasing information about physical objects. MIT and the Auto-ID Center have been developing protocols and standards related to enable this type of system since 1999.

ORNL is also participating in the Smart Active Label Consortium (SAL-C) as part of their RFID program. SAL-C [6] is "an international interest group, established in 2002, intended to develop the use of smart active label technologies in a number of industries and to demonstrate new and improved solutions targeted at the specific needs described by end user participants. Smart Active Labels are defined as thin and flexible labels that contain an integrated circuit and a power source." By participating in these consortia, ORNL is helping to bring together

TAV.

Standards Are Key To Leveraging

One key to capturing the full potential of ongoing science and technology efforts around the globe--both military and commercial--is to define a TAV architecture that leverages a diversity of information sources, hardware and communication methods while maintaining flexibility for future growth. This architecture includes broad scope issues such as global connectivity as well as details such as common data formatting.

Adherence to international standards is vitally important in efficiently bringing together these disparate systems. For instance, many military and commercial entities are requiring the near future communication systems be Internet Protocol version 6 (IPv6) compliant. While this imposes some protocol overhead on systems, it allows components from multiple vendors to communicate without the burden of writing specialized software drivers.

Other standards focus on RFID and RTLS issues, such as the unique identification of every component in the world and the reporting of its current location. Many asset tracking systems utilize the global positioning satellite (GPS) system put in place by the US government to establish precise location. However, these standards augment GPS-derived data as necessary with location information generated by other systems. As this standard matures, it can provide the common data formatting and reporting mechanisms for both unique identification and real-time location data.

Yet another body of standards focuses on sensor communications. This type of standard is typified by the IEEE 1451 family. It provides an object model that enables generic data networks to communicate with transducers (both sensors and actuators). It also provides a TEDS definition that is key to associating a database of features with a uniquely identified transducer.

A fourth type of standard involves the synchronization and transport of precise time. One member of this family is IEEE 1588. This standard defines a data format and protocol for transporting accurate time across diverse networks. Other standards as well as some R&D efforts are tackling the problem of synchronizing clocks across vast distances.

By combining the features of these types of standards, logistics entities can establish the equivalent of the common operating picture (COP) that military units use for situational awareness/understanding (SA/SU). Furthermore, employment of the real-time tracking features means that systems supporting logistics can also support combat identification (CID) on or near the battlefield, since the knowledge of a platform's state is combined with knowledge of its location.

RFID Testing at ORNL

As discussed in last years briefing, a battery of testing, designed to evaluate the effectiveness of tracking assets via RFID intelligent tags, has been performed at ORNL [5].

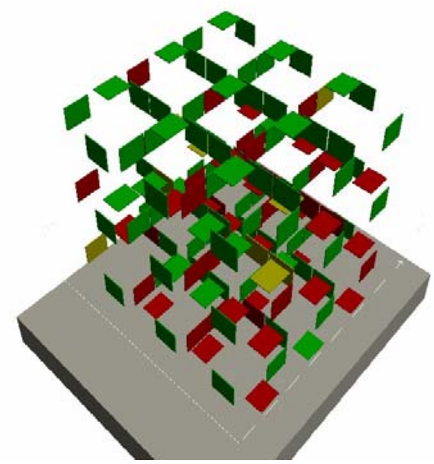


Figure 2. Package Tags Accessed by Portal Reader

As a continuation of that program, further testing of the newer generation of tagging technologies has been carried out in FY03. This testing involves real-life in-situ testing at user facilities. While much of the data is proprietary, general trends can be noted here. The effective ranges of the tags have increased, as well as the efficacy of the anti-collision protocols. However, some vendors tend to overstate the capabilities and/or maturity levels of their products and care must be exercised when developing a total integrated system to obtain real test data.

One specific pilot program is being carried out as part of the Natick Soldier Center Combat Feeding Auto-ID RFID Demo. The partners include: Alien, OatSystems, DLA, ORNL, NAVY AIT, Navy Science Advisor (ONR) and LMI. Preliminary testing began in Feb 03, with "shakedown" testing in March 03 and Class 1 demonstrations slated for 4QFY03 – 1QFY04. The ultimate goals of a deployed system would include

- Real-time supply point inventories
- Inventory unit issues for vehicles or pre-built inventory (on the ground)
- Visibility of supply point node data via the web
- Sensor integration, track/capture Class I temperature data
    - Insure food safety/LFFO
    - Determine remaining shelf life
- Inventory/tally container contents as loaded at source
- Update container inventories as items removed/added
- Determine container contents/locate specific items
- Generate item supply point demand rates
- GS to DS re-supply or Class I push packages

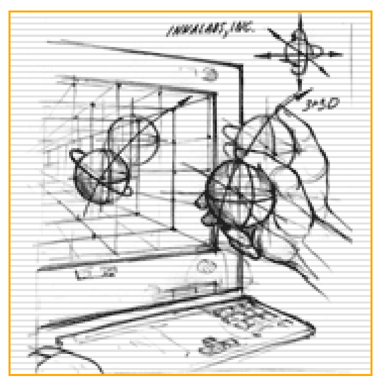
RFID R&D Efforts

R&D efforts at ORNL involve improving methods and designing hardware to perform improved RFID tagging/tracking and are currently being funded by DLA, DOE and other entities. The DLA efforts are focused on merging standards and technologies that will truly bring about global-wide TAV such as described in the opening scenario. This involves designing multi-band tags that can operate in any part of the world. It also involves developing, influencing and/or tracking protocol standards to ensure that the data from disparate systems can be brought together to form usable (actionable) information.

One particular effort involves development of multi-band antennas using fractal geometries. Antennas and antenna arrays based on fractal shapes have been shown to produce resonant structures that are approximately 15% to 35% smaller in volume than their equivalent linear implementations [4]. Additionally, the use of multiple fractal dimensions can lead to designs that provide multi-band capabilities.

Follow-on efforts involve development of printable antenna designs for GTAG. An evolutionary algorithm is being utilized to design antenna structures optimized to provide superior performance in both Europe (~870 MHz) and North America (902-928 MHz). This antenna will be optimized for each of the bands rather than the less efficient approach of employing a wide band antenna.

ORNL researchers are also conducting simulation and modeling efforts in cooperation with three different commercial entities to produce prototype quantities of printable antennas for characterization and further refinement of simulation/models. The goal is to have working prototypes for use with existing passive RFID chips/straps from Alien, Intemec and Matrix by 4th quarter of this year.



A DoD-funded effort has been initiated at ORNL to mature a novel six-dimensional sensor technology originally developed in Russia and recently patented in the U. S. [7]. The unit, initially developed as a "3-D" computer-input device for gaming, virtual-reality applications, and dexterous robotic-control systems, consists of an insulating sphere or ellipsoid suspended in a ferromagnetic fluid which is contained in a roughly spherical enclosure. The enclosure has six coil and/or magnetic structures mounted biorthogonally around the perimeter, so as to produce three perpendicular magnetic field orientations which act on the ferromagnetic fluid and the central inertial body. By appropriately generating the six coil drive signals and processing the electrical output signals from the coils (as variable-reluctance readouts), three linear (X, Y, and Z) and three rotational (roll, pitch, and yaw) acceleration signals can be developed via either analog, digital, or hybrid circuit techniques for use in assembling a very small, low-power, low-drift six-dimensional inertial sensor unit. Although the unit is presently only in a prototypic form, it holds significant promise as a highly effective, rugged, inexpensive substitute for ring-laser and conventional MEMS gyros.

Yet another project involves combining improved waveform technologies with standardized sensor interfaces and GPS to achieve TAV of the now ubiquitous shipping containers. ORNL in conjunction with Navigational Sciences, Inc. and Tarallax Wireless, Inc. is developing an active "tag" that will initially be used to track refrigerated shipping containers on-board ships, in shipping terminals and over the road. A suite of sensors utilizing IEEE 1451 interfaces will be used to assure product quality and security. A novel hybrid spread-spectrum waveform will be used to ensure tag to network communications and radiolocation in the highly reflective RF (multipath) environments both in the shipping terminal and on the ship. Initial over the road communications will utilize digital cellular phone technology with GPS position tracking.

Another area of research involves miniaturization of power source technologies. Development of long-life miniature power sources will enhance both handheld readers and active tags to fit a smaller footprint and/or operate longer without maintenance.

SUMMARY

The vision of global TAV will be achievable in the near future. Some of the programs and findings presented in this paper are important in accomplishing that vision. Specifically, standards involvement, forward-looking architecture developments, consortia participation and sensor development will ensure that future technology improvements move us toward that vision.

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