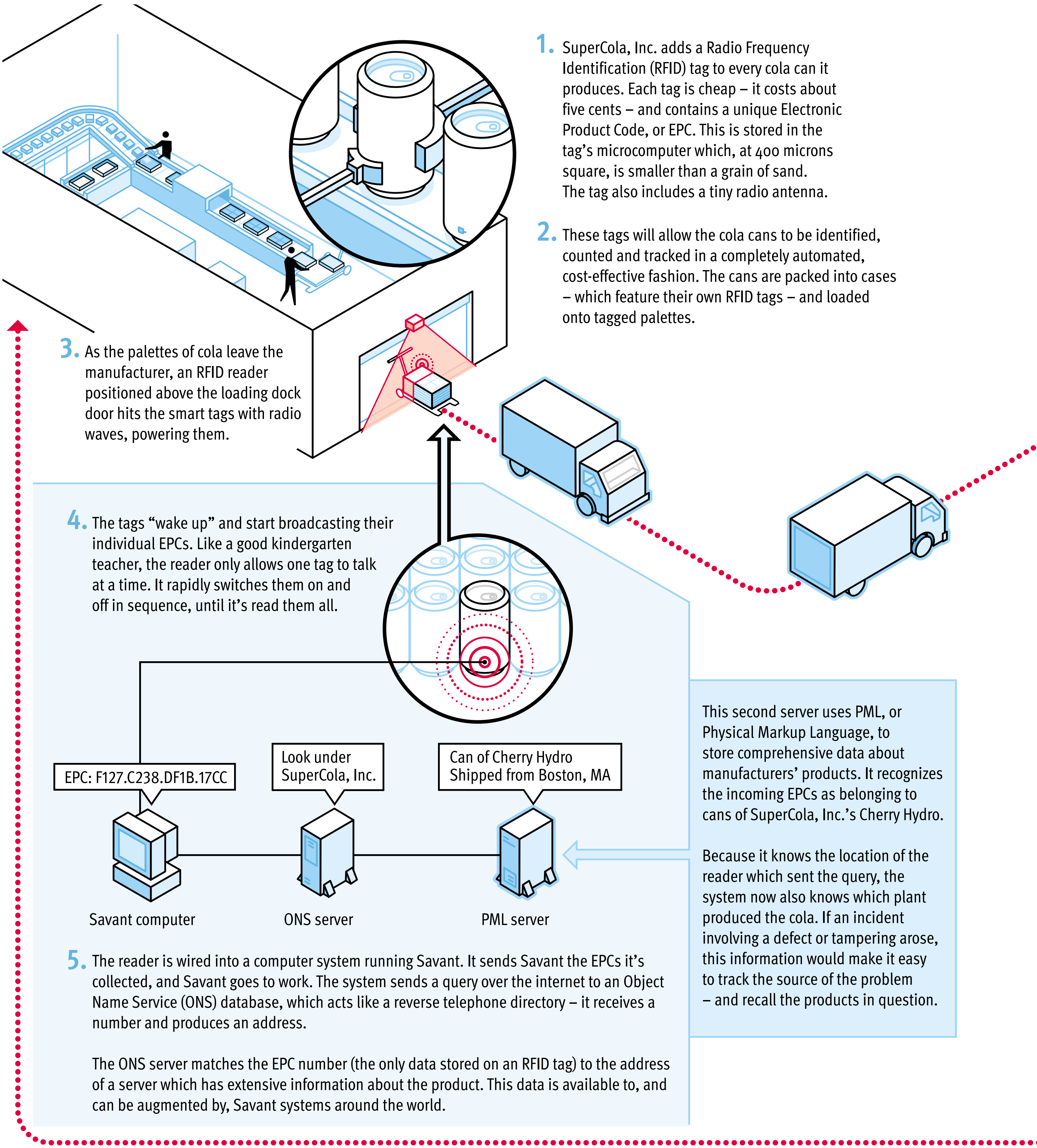
AUTO-ID CENTER

TECHNOLOGY GUIDE

HOW THE AUTO-ID SYSTEM WILL AUTOMATE THE SUPPLY CHAIN

With Auto-ID technology, physical objects will have embedded intelligence that will allow them to communicate with each other and with businesses and consumers. Auto-ID technology offers an automated, numeric system of smart objects that revolutionizes the way we manufacture, sell, and buy products. Here's how it works:



1. SuperCola, Inc. adds a Radio Frequency Identification (RFID) tag to every cola can it produces. Each tag is cheap – it costs about five cents – and contains a unique Electronic Product Code, or EPC. This is stored in the tag's microcomputer which, at 400 microns square, is smaller than a grain of sand. The tag also includes a tiny radio antenna.

2. These tags will allow the cola cans to be identified, counted and tracked in a completely automated, cost-effective fashion. The cans are packed into cases – which feature their own RFID tags – and loaded onto tagged palettes.

3. As the palettes of cola leave the manufacturer, an RFID reader positioned above the loading dock door hits the smart tags with radio waves, powering them.

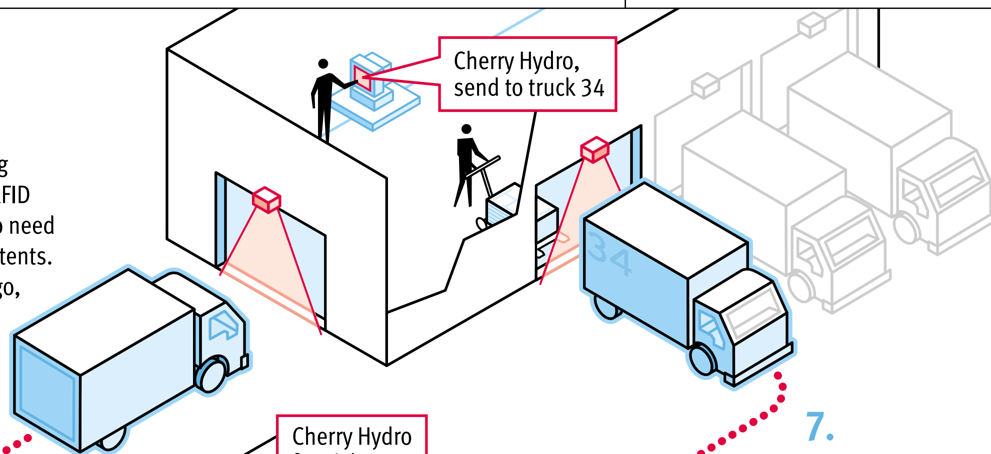
4. The tags "wake up" and start broadcasting their individual EPCs. Like a good kindergarten teacher, the reader only allows one tag to talk at a time. It rapidly switches them on and off in sequence, until it's read them all.

5. The reader is wired into a computer system running Savant. It sends Savant the EPCs it's collected, and Savant goes to work. The system sends a query over the internet to an Object Name Service (ONS) database, which acts like a reverse telephone directory – it receives a number and produces an address.

The ONS server matches the EPC number (the only data stored on an RFID tag) to the address of a server which has extensive information about the product. This data is available to, and can be augmented by, Savant systems around the world.

This second server uses PML, or Physical Markup Language, to store comprehensive data about manufacturers' products. It recognizes the incoming EPCs as belonging to cans of SuperCola, Inc.'s Cherry Hydro.

Because it knows the location of the reader which sent the query, the system now also knows which plant produced the cola. If an incident involving a defect or tampering arose, this information would make it easy to track the source of the problem – and recall the products in question.



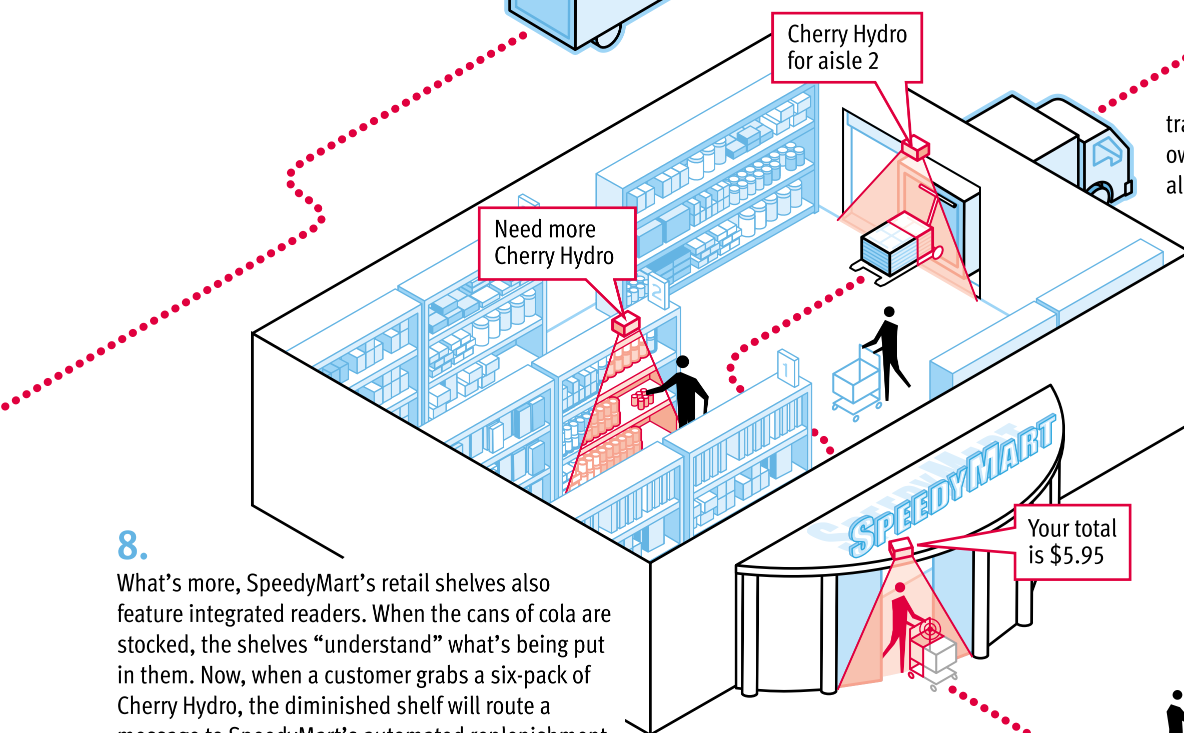
6.

The palettes of cola arrive at the shipping service's distribution center. Thanks to RFID readers in the unloading area, there's no need to open packages and examine their contents. Savant provides a description of the cargo, and the cola is quickly routed to the appropriate truck.

7.

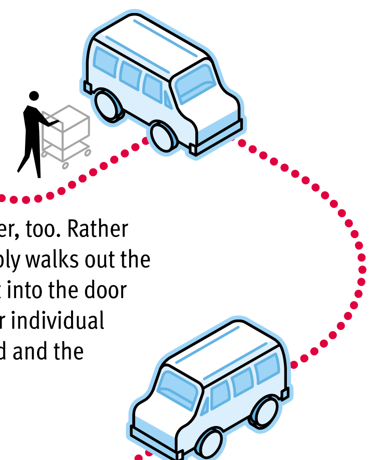
The delivery arrives at SpeedyMart, who has been tracking the shipment thanks to its own Savant connection. SpeedyMart also has loading dock readers.

As soon as the cola arrives, SpeedyMart's retail systems are automatically updated to include every can of Cherry Hydro that arrived. In this manner, SpeedyMart can locate its entire Cherry Hydro inventory automatically, accurately and without incurring cost.



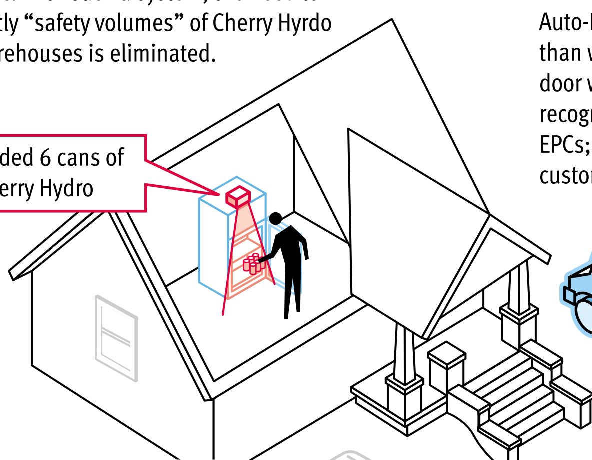
8.

What's more, SpeedyMart's retail shelves also feature integrated readers. When the cans of cola are stocked, the shelves "understand" what's being put in them. Now, when a customer grabs a six-pack of Cherry Hydro, the diminished shelf will route a message to SpeedyMart's automated replenishment systems – which will order more Cherry Hydro from SuperCola, Inc. With such a system, the need to maintain costly "safety volumes" of Cherry Hyrdo in remote warehouses is eliminated.



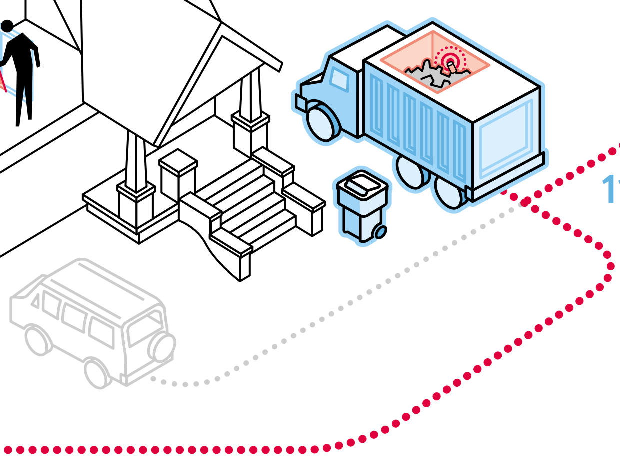
9.

Auto-ID makes the customer's life easier, too. Rather than wait in line for a cashier, she simply walks out the door with her purchases. A reader built into the door recognizes the items in her cart by their individual EPCs; A swipe of the debit or credit card and the customer is on her way.



10.

At home, the refrigerator updates its records to reflect the influx of Cherry Hydro. As the cola is depleted, the fridge will add the beverage to its automated grocery list.



11. When the cola cans hit the recycling center, RFID readers will automate the process of sorting them into the appropriate recyclable category – eliminating expensive manual sorting. The cans can even be routed to their manufacturer for reuse at the plant.

Front Cover: Work in progress, RFID Testing at the Field Test Lab, Arkansas
This Page: Professor Sanjay Sarma, MIT Auto-ID Center

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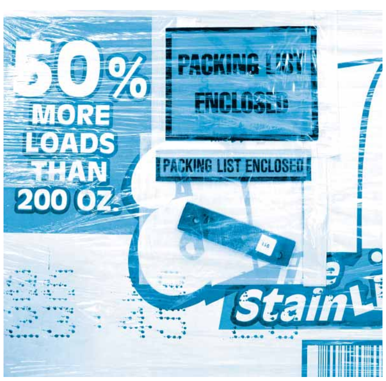
"RFID has the potential to radically alter the way we do business. The strategic insights we get from participating in the Auto-ID Center's efforts are invaluable."
Stephen David, CIO, The Procter & Gamble Company

INTRODUCTION

The Auto-ID Center aims to change the world. By creating an open global network that can identify anything, anywhere, automatically, it seeks to give companies something that, until now, they have only dreamed of: near-perfect supply chain visibility. The system, if widely adopted, could eliminate human error from data collection, reduce inventories, keep product in-stock, reduce loss and waste, and improve safety and security. The possibilities seem limitless.

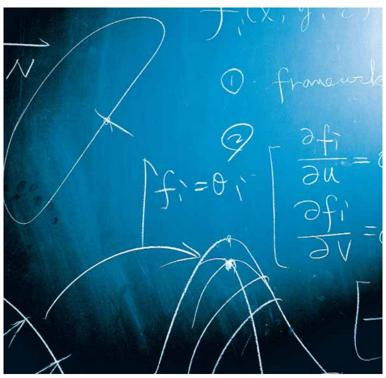
This guide describes the technology the Center and its sponsors are creating to make this vision a reality. It is meant for everybody, not just people with technical backgrounds. To keep things clear we have simplified our explanations and avoided unnecessary detail. Technical Research Papers, which give fuller accounts of our work are available from our web site at www.autoidcenter.org.



Section One deals with the basics of auto identification and data capture. It explains the shortcomings of existing technology and shows how an open, global network for identifying goods with RFID tags has the potential to make companies vastly more efficient and profitable. Section Two explains broadly how the Auto-ID Center is addressing each of the technical challenges involved with uniquely identifying every product made everywhere in the world. In Section Three, we go into greater depth about the standards we are proposing and the infrastructure elements we are designing to make our vision a reality. And Section Four spells out how we are turning our research into a full-scale system that companies can take advantage of. It describes the current, large-scale field test of our technology and lays out a general timetable for project elements we aim to complete by the end of 2003. Our goal is to have a system ready by that time, so vendors can develop new products and companies can begin deploying them with confidence.

We have tried to explain the Auto-ID Center's standards and technology in a way that's easy to understand. But there are technical terms that can't be avoided, so we've included in the appendix a glossary of terms (see back inside flap). Words that appear in the glossary are highlighted in blue throughout the text. The appendix also includes a list of frequently asked questions.

AUTOMATIC IDENTIFICATION – THE BASICS



Facing Page: Work in Progress, RFID Testing at the Field Test Lab in Arkansas
This Page: ThingMagic, Cambridge, MA; Blackboard, MIT Auto-ID Center; Work in Progress, RFID Testing at the Field Test Lab in Arkansas

What Is Automatic Identification?

Automatic identification, or auto ID for short, is the broad term given to a host of technologies that are used to help machines identify objects. Auto identification is often coupled with automatic data capture. That is, companies want to identify items, capture information about them and somehow get the data into a computer without having employees type it in. The aim of most auto-ID systems is to increase efficiency, reduce data entry errors, and free up staff to perform more value-added functions. There are a host of technologies that fall under the Auto-ID umbrella. These include bar codes, smart cards, voice recognition, some biometric technologies (retinal scans, for instance), optical character recognition, radio frequency identification (RFID) and others.

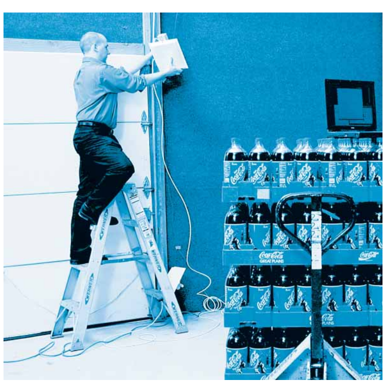
RFID is a generic term for technologies that use radio waves to automatically identify individual items. There are several methods of identifying objects using RFID, but the most common is to store a serial number that identifies a product, and perhaps other information, on a microchip that is attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves returned from the RFID tag into a form that can then be passed on to computers that can make use of it. This is the technology the Auto-ID Center has chosen to focus on.

Why Focus on Radio Frequency Identification?

Bar codes have been the primary means of identifying products for the past 25 years. During that span, they have served their purpose well. But bar codes have one big shortcoming: they are line-of-sight technology. That is, a scanner has to "see" the bar code to read it, which means people usually have to orient the bar code towards a scanner for it to be read. Radio frequency identification, by contrast, doesn't require line of sight. RFID tags can be read as long as they are within range of a reader.

Bar codes have other shortcomings as well. If a label is ripped, soiled or falls off, there is no way to scan the item. And standard bar codes identify only the manufacturer and product, not the unique item. The bar code on one milk carton is the same as every other, making it impossible to identify which one might pass its expiration date first.

RFID is a proven technology that's been around since the Second World War. Up to now, it's been too expensive and too limited to be practical for many commercial applications. But if tags can be made cheaply enough, they can solve many of the problems associated with bar codes.



The Importance of Tracking Individual Items

At the Auto-ID Center, we believe there is a very strong business case for being able to identify unique products using a technology that doesn't require line of sight. The new network we are developing has the potential to give companies something they've never had before: near-perfect supply chain visibility. That is, companies will be able to know exactly where every item in their supply chain is at any moment in time. How they take advantage of that capability will be up to them, just as it is up to each company to figure out how to leverage the Internet.

A REVOLUTIONARY APPROACH TO AUTO-ID

Creating an Internet of Things

The Internet connects computers to one another. What the Auto-ID Center aims to do, in effect, is develop a network that connects computers to objects – boxes of laundry detergent, pairs of jeans, airplane engines. We are not creating just the hardware (RIFD tags and readers) or just the software to run the network. With the help of our sponsors, we are developing everything that is needed to create an "Internet of things," including affordable hardware, network software and protocols, and languages for describing objects in ways computers can understand. The system will be based on existing standards. It will be open to anyone, and it will be entirely free – just like the Internet.

Why is this necessary?
Well, it's not, any more than the creating the Internet was "necessary." But just as the Internet has made companies vastly more efficient by enabling them to share data, we believe that the ability to track individual items as they move from factories to store shelves to recycling facilities will make companies vastly more efficient. Companies, in fact, have long realized that capturing data about goods automatically and accurately would be a great boon to their business. Billions of dollars have been invested worldwide in bar code technology.

Many companies are investing in RFID systems today to get the advantages they offer. These investments are usually made in closed-loop systems – that is, when a company is tracking goods that never leave its own control. That way, they don't have to worry about their tags being read by other companies. But most companies don't have closed-loop systems. Since all existing RFID technology is proprietary (meaning there are no standards), if Company A tags a widget and sends it to Company B, Company B can't identify the product unless it has invested in the same technology from the same vendor as Company A.

Another problem is cost.
RFID readers typically cost $1,000 or more. Companies would need thousands of readers to cover all their factories, warehouses and stores. Readers typically operate at one radio frequency. If tags from three different manufacturers used three different frequencies, a store might have to have three readers in some locations, increasing the cost further.

RFID tags are also fairly expensive – 50 cents or more – which makes them impractical for identifying millions of items that cost only a few dollars.

Creating one, open global network for RFID means that companies can invest in systems and have confidence that the tags they put on their products can be read by retailers and other business partners. It means companies can share information about products and develop systems that automate many of today's labor-intensive operations. For example, when shipments arrive at a store from a factory, the computer systems of both companies can be updated automatically and an invoice can automatically be sent. It also means that manufacturers of RFID equipment can make equipment in vast quantities, since it will work with anyone's system, which will help bring down the price of both tags and readers. (There are other issues related to cost that we'll tackle later.)

Jargon Alert

Proprietary
Technology that's exclusively owned by one vendor and therefore doesn't work with technologies from other vendors.

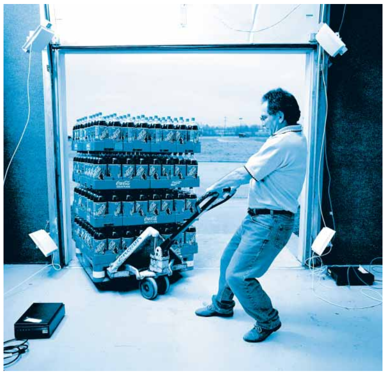
Protocol
A set of formal rules describing how to transmit data, especially across a network.

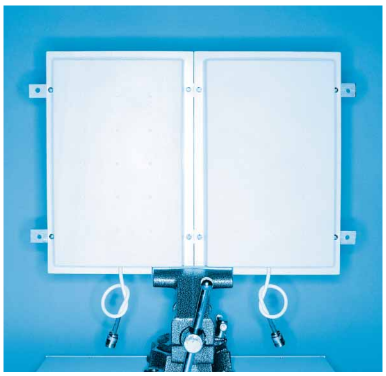
Specification
A detailed statement prescribing materials, dimensions, and other aspects of something to be built, or manufactured.

Standard
A practice that is widely accepted or employed. In computing, standards relate to common ways to build hardware and widely accepted means of communicating over a network.

Identifying Trillions of Items

When we say we are creating an Internet of things, we aren't suggesting that we plan to build another global network. Rather, we plan to build on top of the Internet. We are developing only those elements that will enable RFID systems to track items and share information over the Internet. Still, making it possible to uniquely identify every item manufactured everywhere in the world is a huge and complex undertaking. Let's break down each aspect of the challenge and explain how we are tackling it. (The illustration on the front inside flap provides a graphic interpretation of how all the elements of the system will work in practice.)





Facing Page: Work in Progress, RFID Testing at the Field Test Lab in Arkansas
This Page Top & Bottom: Work in Progress, RFID Testing at the Field Test Lab in Arkansas
Middle: An example of a reader or interrogator

How do you distinguish between one can of Coke and another?
There are a number of ways, but the best solution we've found is to give each item a unique number – a license plate, if you will. The Auto-ID Center has proposed a universal standard for product "license plates" – the Electronic Product Code. Like a bar code, the EPC is divided into numbers that identify the manufacturer, product, version and serial number. But the EPC uses an extra set of digits to identify unique items. The EPC is the only information stored on the RFID tag's microchip. This keeps the cost of the tag down and provides flexibility, since an infinite amount of dynamic data can be associated with the serial number in a database.

How do you track the item using the license plate?
The answer is to create a network of RFID readers (sometimes called interrogators). In a warehouse for example, there could be readers around the doors on a loading dock and on every bay. When a pallet of goods arrives, the reader on the dock door picks up its unique license plate. Inventory systems are alerted to its arrival. When the pallet is put in bay A, that reader sends a signal saying item 1-2345-67890 is in bay A.

How do you know what item 1-2345-67890 is?
The EPC by itself tells you no more about a product than a car's license plate tells you about a car. Computers need a way to associate the EPC with information stored somewhere else about the unique item. To help computer systems find and understand information about a product, the Auto-ID Center has developed some new technologies and standards. The first key element is called the Object Name Service. ONS points a computer to an address on the Internet where information about a product is stored. The concept is based on the Domain Name Service, which points computers to the address of particular Web sites on the World Wide Web. ONS basically tells a company's computer systems: "Everything you need to know about product 1-2345-67890 is stored in a file on a computer located at the following Internet address…"

How does a computer act on information about a product?
The point of automatic identification, of course, is to take people out of the loop, to enable computers to gather information and act on it. For that to happen, computers must be able to not just identify a product, but interpret some basic information about it. To make this possible, the Auto-ID Center has created a new computer language called the Physical Markup Language. PML is based on the widely accepted eXtensible Markup Language (XML), which is used to describe common types of data (addresses, dates, invoice numbers and so on) and transactions (purchases, requests for quotes and so on) in a way computers running different proprietary applications can understand. PML files will be stored in PML servers, dedicated computers that deliver information over a network. (The Object Name Service, described above, points computers to the PML server.)

Some information about each product will be stored in a PML file, such as a product's name and broad category (soft drink, auto part, clothing and so on), when it was made and where, its expiration date, its current location, even its current temperature, if that's important. PML files will provide information to existing enterprise applications or new yet-to-be developed applications. The PML file could contain instructions for where a pallet should be shipped. It could contain instructions for a point-of-sale display to lower the price of an item when its expiration date approaches. Or it could contain instructions for how long your microwave needs to cook a particular brand of frozen pizza.

How do you avoid having all this data about individual products overload existing networks?
The Auto-ID Center has created software technology called Savant to manage and move information in a way that doesn't overload existing corporate and public networks. Savant uses a distributed architecture, meaning it runs on different computers distributed through an organization, rather than from one central computer. Savants are organized in a hierarchy and act as the nervous system of the new EPC network, managing the flow of information. At the edge of the network, Savants gather data from readers. They pass on only relevant information to existing business applications, such as which products are about to expire. A Savant running at a distribution center might determine when product needs to be reordered from manufacturers, and so on.

How do companies use the EPC data to become more efficient and more profitable?
How companies use EPC data and the network we are creating will be up to them, just as it's up to them to decide how they want to use the Internet. But the Auto-ID Center is providing some basic tools that will help them take advantage of the network. Savant will have a Task Management System that will enable companies to set triggers. A Savant running in a manufacturing plant might send a message to a parts replenishment system indicating which station on an assembly line is running low. A Savant running in a store might signal an existing inventory system to delay a shipment of diapers because there are already too many pallets in stock.

The Importance of Standards

It's worth stressing here again that the adoption of standards for identifying products, communicating with tags, and describing products and their status are vital. Without standards, the cost of RFID tags will take years – perhaps decades – to fall to a point where they can be put on individual products. And even when they are cheap enough, companies will not be able to read each others' tags. This will cripple this industry before it's even born and prevent companies from reaping the enormous benefits RFID can bring. All companies benefit from an open system. Competitive advantage goes to those who use the system in the most innovative and effective ways.

This Page Top: Prasad Putta, Consultant Systems Architect and CEO, Oats Systems with members of his team
Bottom: Work in Progress, A robotics demonstration in the lab at the Cambridge Centre

SECTION 3

AN IN-DEPTH LOOK AT THE NEW NETWORK

The Auto-ID Center and its sponsors are working to develop flexible tags and readers and to bring the cost of the hardware down to a level where RFID can be used to track individual items. And we're working to create a new, open, global network that will allow companies to take advantage of low-cost RFID tags. Below, we explain the key elements of our approach to automatic identification in greater depth.

The Electronic Product Code

The Auto-ID Center has proposed a new Electronic Product Code as the next standard for identifying products. Our goal is not to replace existing bar code standards, but rather to create a migration path for companies to move from established standards for bar codes to the new EPC. To encourage this evolution, we have adopted the basic structures of the Global Trade Item Number (GTIN), an umbrella group under which virtually all existing bar codes fall. There's no guarantee that the world will adopt the EPC, but our proposal already has the support of the Uniform Code Council and EAN International, the two main bodies that oversee international bar code standards. We're also working with other national and international trade groups and standard bodies.

Electronic Product Code or EPC

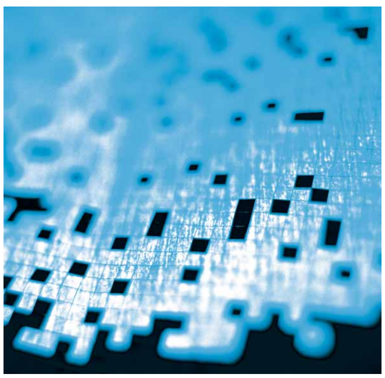
ELECTRONIC PRODUCT CODE TYPE I

01.0000A89.00016F.000169DC0

Header	EPC Manager	Object Class	Serial Number
8-bits	28-bits	24-bits	36-bits

How it works
The EPC is a number made up of a header and three sets of data, as shown in the above figure. The header identifies the EPC's version number – this allows for different lengths or types of EPC later on. The second part of the number identifies the EPC Manager – most likely the manufacturer of the product the EPC is attached to – for example 'The Coca-Cola Company'. The third, called object class, refers to the exact type of product, most often the Stock Keeping Unit – for example 'Diet Coke 330 ml can, US version. The fourth is the serial number, unique to the item – this tells us exactly which 330 ml can of Diet Coke we are referring to. This makes it possible, for example, to quickly find products that might be nearing their expiration date.

Types of EPCs
The Auto-ID Center has proposed EPCs of 64- and 96 bits. Eventually, there could be more. The 96-bit number is the one we think should be most common. We chose 96 bits as a compromise between the desire to ensure that all objects have a unique EPC and the need to keep the cost of the tag down. The 96-bit EPC provides unique identifiers for 268 million companies. Each manufacturer can have 16 million object classes and 68 billion serial numbers in each class, more than enough to cover all products manufactured worldwide for years to come. Since there is no need for that many serial numbers at this time, we propose an interim 64-bit code. The smaller code will help keep the price of the RFID chips down initially, while providing more than enough unique EPCs for current needs.



Facing Page from Top to Bottom: A vial containing thousands of speck of dust size microchips from Sponsor Alien Technology; Tiny microchips or 'nanoblocks'
This Page from Top to Bottom: Auto-ID Center test tag from Sponsor Alien Technology; Chips on a Silicon Wafer; RFID tag with barcode from Checkpoint

The Basics of RFID Tags

An RFID tag is made up of a microchip attached to an antenna. There are different kinds of tags for different applications, and we'll explain these in this section. One of the keys to making RFID useful for tracking individual items is dramatically reducing the cost of the tags. The section below explains how we plan to do that.

Active vs passive

Active RFID tags have a battery, which is used to run the microchip's circuitry and to broadcast a signal to a reader (the way a cell phone transmits signals to a base station). Passive tags have no battery. Instead, they draw power from the reader, which sends out electromagnetic waves that induce a current in the tag's antenna. Semi-passive tags use a battery to run the chip's circuitry, but communicate by drawing power from the reader. Active and semi-passive tags are useful for tracking high-value goods that need to be scanned over long ranges, such as railway cars on a track, but they cost a dollar or more, making them too expensive to put on low-cost items. The Auto-ID Center is focusing on passive tags, which cost under a dollar today. Their read range isn't as far – less than ten feet vs. 100 feet or more for active tags – but they are far less expensive than active tags and require no maintenance. We also research other tag types, however, and they are not excluded from our system.

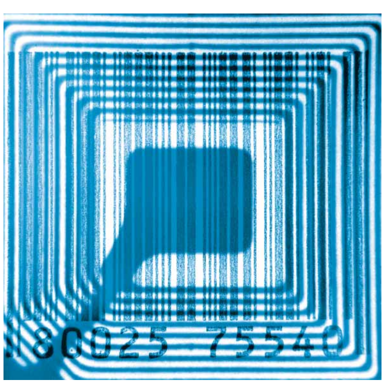
Read-write vs. read-only

Chips in RF tags can be read-write or read-only. With read-write chips, you can add information to the tag or write over existing information when the tag is within range of a reader, or interrogator. Read-write tags are useful in some specialized applications, but since they are more expensive than read-only chips, they are impractical for tracking inexpensive items. Some read-only microchips have information stored on them during the manufacturing process. The information on such chips can never be changed. Another method is to use something called electrically erasable programmable read-only memory, or EEPROM. With EEPROM, the data can be overwritten using a special electronic process.

The Auto-ID Center's spec

We are not creating RFID tags or even telling vendors what types of tags to make. Our only concern is that tags carry an EPC, communicate in an open standard way, and meet some minimum performance requirements so they can be read by readers anywhere. However, because very low-cost tags are a key component of our system, we have been working on designs for chips that will cost around 5 cents when produced in bulk and can be read from at least four feet. The first tags are ultra-high frequency; that is, they operate at 915 MHz. They use EEPROM, so companies can write an EPC to the tag when the item is produced and packaged, but other memory technologies could also be used.

Bringing Down Tag Costs



The high-cost of RFID tags has been one of the biggest inhibitors to wide-scale adoption of the technology. Today, the cheapest RFID tags sell for about 50 cents in large quantities. At the Auto-ID Center, we aim to bring down the price of a tag to 5 cents. We have devised several strategies for doing that.

Simple is better

Under the Auto-ID Center's scheme, a 96-bit or 64-bit Electronic Product Code will be the only information stored on the chip in an RFID tag. That's because chips with less memory cost less money. Consider that a single gate of silicon logic – the fundamental building block for digital microchips – costs about one thousandth of one cent. The Auto-ID Center's members produce more than 500 billion units a year, so each additional logic gate on a tag would cost them more than $5 million in lost profit.

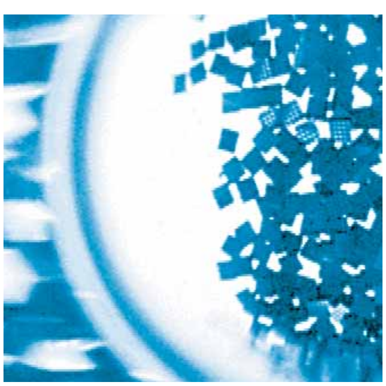
Shrink the chip

One key to bringing down the cost of passive, read-only tags is the size of the microchip used. The price of an 8-inch silicon wafer is relatively stable, but by cutting the wafer into smaller pieces, the price of each chip falls. Today, most wafers are cut with a diamond saw. This process yields a maximum of about 15,000 microchips that are one millimeter square. A process called wet etching – laying down a thin line of acid to eat through the wafer – can yield upwards of 250,000 chips that are about 150 microns square, or about three times the width of a human hair.

Chips that are small are much cheaper than traditional microchips. But working with them has always been a problem. Pick-and-place robots that handle most silicon chips are unable to deal with anything that tiny. Auto-ID Center sponsor Alien Technology, a startup based in Morgan Hill, Calif., has developed a process called fluidic self-assembly to put the chips in a base, so the antennas can be added. The chips have beveled edges because of the way the acid eats through the silicon crystal. Alien creates a base with holes that look like molds for these chips. It then flows thousands of tiny chips, which Alien calls "nanoblocks," in a special liquid over the base and some fall perfectly into place. The rest are collected and reused. The base is cut into straps with metal pads so an antenna can be mounted on the chip to create a tag. The antenna and chip are sandwiched between two layers to create a finished tag. When Alien's new production facility is fully operational, it will turn out 80 billion chips a year. Other methods of assembling small chips are also being developed, as are improvements to existing approaches. One promising approach is vibratory assembly, which is being researched by MIT and also by Auto-ID Center sponsor Philips Semiconductor.

A new antenna

Another key to creating low-cost tags is reducing the cost of the antenna. Rafsec, an Auto-ID Center sponsor, is developing an innovative antenna that will be attached to Alien chips to make tags that, at high volumes, could cost around 5 cents. Today, most RFID antennas are made by removing elements from conductive metals like copper and aluminum with acid and then shaping them. Rafsec, a subsidiary of Finland's UPM-Kymmene Corp., one of the world's largest manufacturers of printing papers, has pioneered a high-speed plating technology, where an antenna is printed using conductive ink and then a layer of metal is stamped on top. Using this technology, Rafsec can produce antennas for about a penny when manufactured in bulk, compared with 5 to 15 cents for a typical antenna made with existing technology. Other innovative approaches to low cost antenna manufacturing are being developed by other Auto-ID Center sponsors.

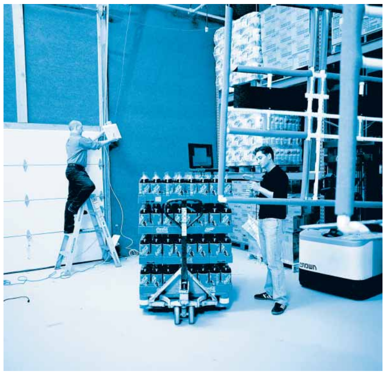


Silicon alternatives

Several companies are working independently of the Auto-ID Center on RFID tags that use cheaper alternatives to silicon, and even "chipless tags," that are purely magnetic. These efforts hold great promise, and the Auto-ID Center supports them. The system we are developing does not exclude these technologies or any other. Our vision is of an evolving world where any tag, silicon or not, can talk to any reader, provided that both speak the right language, and meet some basic performance requirements. Chips made of synthetic polymers or special crystals may turn out to be less expensive than silicon chips, and they may have other applications, such as in complementary sensors for detecting temperature or vibration. By creating a global network companies can use to identify products, we are also creating a new market in which such innovations can flourish.

Understanding Radio Waves

Tags communicate with readers using radio waves. Before we explain how readers work, it's useful to explain a little bit about radio waves and their properties. Radio waves are part of the electromagnetic spectrum, the broad name that scientists use to cover all frequencies of energy emitted in the form of waves. At one end of the spectrum are low-frequency waves, such as those used by AM radio and communication systems for ships at sea. At the high end are x-rays and gamma rays.



Government regulation

Governments around the world regulate much of the electromagnetic spectrum. FM radio stations in the United States, for instance, must operate between 88 and 108 MHz. (If you listen to 91.5 FM, it means your radio is tuned to receive waves repeating 91.5 million times per second.) One problem with RFID is that countries around the world have assigned parts of the spectrum for different uses. With the exception of special ISM bands, which are set aside for industrial, scientific and medical use, there is almost no part of the spectrum available everywhere in the world. That means a tag operating at 915 MHz in one country might not be readable in another where that area of the spectrum is used for another purpose.

One frequency doesn't fit all

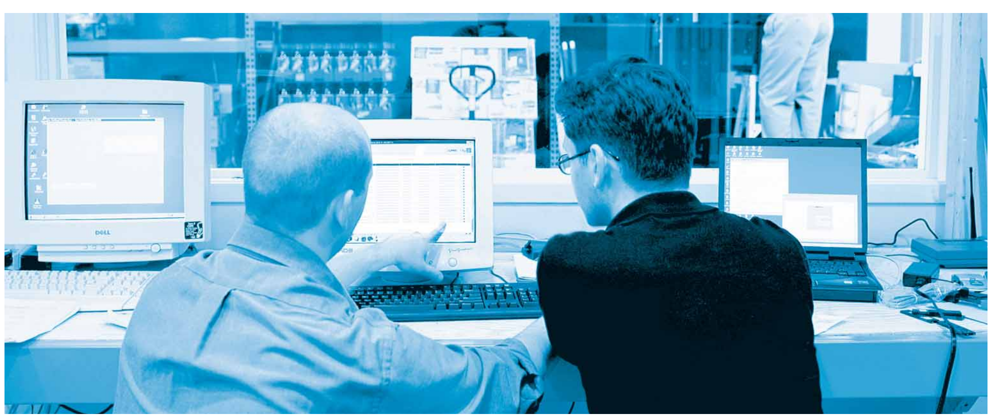
Even if there were one band of the spectrum available in every country around the world, it might be counterproductive to restrict all RFID tags to that band. That's because different frequencies have different characteristics that make them more useful for different applications. For instance, low-frequency tags are cheaper than ultra high frequency (UHF) tags, use less power and are better able to penetrate non-metallic substances. They are ideal for scanning objects with high-water content, such as fruit, at close range. UHF frequencies typically offer better range and can transfer data faster. But they use more power and are less likely to pass through materials. And because they tend to be more "directed," they require a clear path between the tag and reader. UHF tags might be better for scanning boxes of goods as they pass through a bay door into a warehouse.

Some of the key frequencies the Auto-ID Center is considering.

Frequency	Common Name
125 KHz	Low frequency
13.56 MHz	High frequency (HF)
915 MHz	Ultra-high frequency (UHF)
868 MHz	Ultra-high frequency (UHF)
2.45 GHz	Microwave

Water and metal

Many people have heard that radio waves are absorbed by water and are distorted by metal, making RFID useless for tracking products with high water content or packaged in metal containers. The way radio waves are affected by water and metal does make tracking metal products or those with high water content more problematic, but we have found that good system design and engineering can overcome these shortcomings of RFID. This is one reason why our approach is not to constrain vendors and users by promoting a system that relies on just one frequency. Instead, our goal is to create a system in which any tag can be used to identify a product, as long as it has an Electronic Product Code and communicates using some basic communication standards we have established.



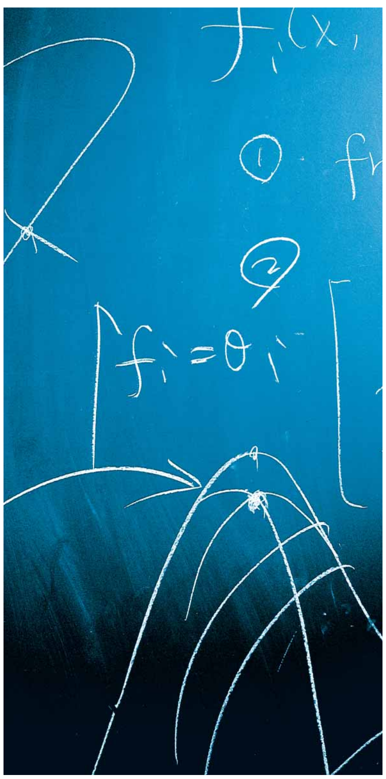
The Reader

RFID readers use a variety of methods to communicate with tags. The most common method for reading passive tags at close range is called inductive coupling. Simply put, the coiled antenna of the reader creates a magnetic field with the coiled antenna of the tag. The tag draws energy from this field and uses it to send back waves to the reader, which are turned into digital information – the tag's Electronic Product Code.

Affordable agile readers

Today, readers cost $1,000 or more. Most can only read chips using a single frequency. The Auto-ID Center has designed reference specifications for agile readers that can read chips of different frequencies. That way, companies can use different types of tags in different situations and not have to buy a reader for each frequency. Since companies will need to buy many readers to cover all the area of their operations, readers must be affordable. Our spec will enable manufacturers to produce agile readers for around $100 in volume.

Facing Page: Work in Progress, RFID Testing at the Field Test Lab in Arkansas
This Page: Black Board, MIT Auto-ID Center



Avoiding reader collision

One problem encountered with RFID readers is the signal from one can interfere with the signal from another where coverage overlaps. This is called reader collision. The Auto-ID Center uses an anti-collision scheme called time division multiple access, or TDMA. In simple terms, the readers are instructed to read at different times, rather than both trying to read at the same time. This ensures that they don't interfere with each other. But it means any RFID tag in an area where two readers overlap will be read twice. So we've developed a system for deleting duplicate codes.

Avoiding tag collision

Another problem readers have is reading a lot of chips in the same field. Tag collision occurs when more than one chip reflects back a signal at the same time, confusing the reader. The Auto-ID Center has adopted a standard method for solving the problem. The reader asks tags to respond only if their first digits match the digits communicated by the reader. In essence, the reader says to the tags: "Respond only if your EPC begins with 0." If more than one chip responds, the reader then says: "Respond if your EPC begins with 00." It keeps doing this until only one tag responds. But it happens so quickly that a reader can read 50 tags in less than a second.

Read range

The read range of a tag depends on the power of the reader and the frequency the reader and tag use to communicate. Generally speaking, higher frequency tags have longer read ranges but they require more energy output from the reader. A typical low frequency tag has to be read within a foot. A UHF tag can be read from 10 to 20 feet.

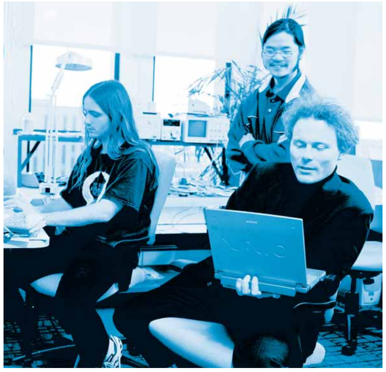
Range can be a critical issue in some applications, such as identifying train cars as they roll down the track. But longer range isn't always an advantage. If you had two readers in a warehouse the size of a football field, you might know what's in inventory, but the readers wouldn't help you find it. For the supply chain, it's better to have a network of readers that can pinpoint precisely where a tag is. The Auto-ID Center's design is for an agile reader that can read tags from around four feet.

Savant

In a world where every object has an RFID tag, readers will be picking up a continual stream of EPCs. Managing and moving all this data is a difficult problem and one that must be overcome for any global RFID network to be of value. The Auto-ID Center has designed software technology called Savant to act as the nervous system of the network.

Distributed architecture

Savant is different from most enterprise software in that it isn't one overarching application. Instead, it uses a distributed architecture and is organized in a hierarchy that manages the flow of data. There will be Savants running in stores, distribution centers, regional offices, factories, perhaps even on trucks and in cargo planes. Savants at each level will gather, store and act on information and interact with other Savants. For instance, a Savant at a store might inform a distribution center that more product is needed. A Savant at the distribution center might inform the store Savant that a shipment was dispatched at a specific time. Here are some of the tasks the Savants will handle.



Data smoothing

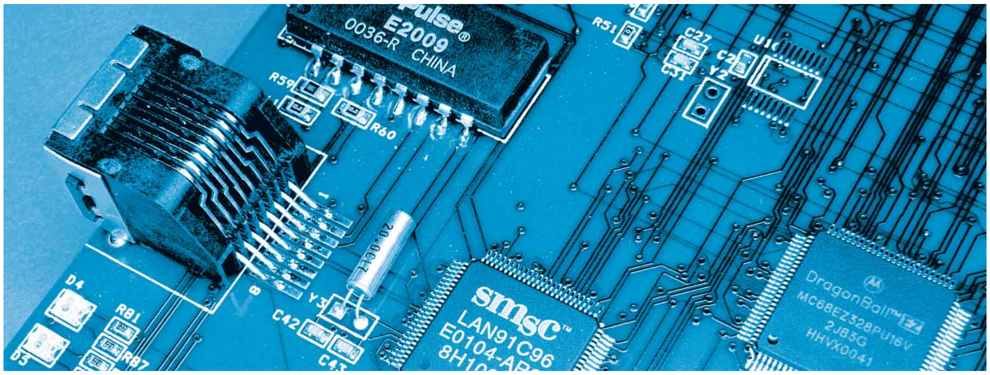
Savants at the edge of the network – those attached to readers – will smooth data. Not every tag is read every time, and sometimes a tag is read incorrectly. By using algorithms Savant is able to correct these errors.

Reader coordination

If the signals from two readers overlap, they may read the same tag, producing duplicate EPCs. One of the Savant's jobs is to analyze reads and delete duplicate codes.

Data forwarding

At each level, the Savant has to decide what information needs to be forwarded up or down the chain. For instance, a Savant in a cold storage facility might forward only changes in the temperature of stored items.



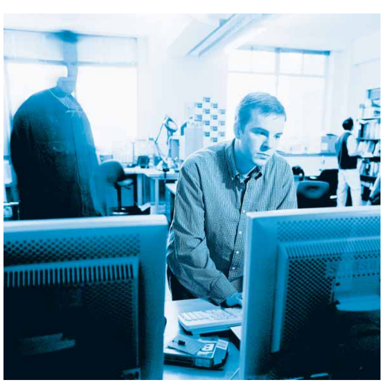
Data storage

Existing databases can't handle more than a few hundred transactions a second, so another job of the Savants is to maintain a real-time in-memory event database (RIED). In essence, the system will take the EPC data that is generated in real time and store it intelligently, so that other enterprise applications have access to the information, but databases aren't overloaded.

Task management

All Savants, regardless of their level in the hierarchy, feature a Task Management System (TMS), which enables them to perform data management and data monitoring using customizable tasks. For example, a Savant running in a store might be programmed to alert the stockroom manager when product on the shelves drops below a certain level.

Facing Page Left to Right: ThingMagic, Cambridge, MA; A circuit board from a prototype Auto-ID Center reader
This Page Top to Bottom: Work in Progress, RFID Testing at the Field Test Lab in Arkansas; Tim Milne, PhD Candidate and Brendon Lewis, Graduate Student, MIT Auto-ID Center



Object Name Service

The Auto-ID Center's vision of an open, global network for tracking goods requires some special network architecture. Since only the Electronic Product Code is stored on the tag, computers need some way of matching the EPC to information about the associated item. That's the role of the Object Name Service (ONS), an automated networking service similar to the Domain Name Service (DNS) that points computers to sites on the World Wide Web.

When an interrogator reads an RFID tag, the Electronic Product Code is passed on to a Savant (see above). The Savant can, in turn, go to an ONS on a local network or the Internet to find where information on the product is stored. ONS points Savant to a server where a file about that product is stored. That file can then be retrieved by the Savant, and the information about the product in the file can be forwarded to a company's inventory or supply chain applications.

Special requirements
The Object Name Service will handle many more requests than the Web's Domain Name Service. Therefore, companies will need to maintain ONS servers locally, which will store information for quick retrieval. So a computer manufacturer may store ONS data from its current suppliers on its own network, rather than pulling the information off the Web site every time a shipment arrives at the assembly plant. The system will also have built-in redundancies. For example, if a server with information on a certain product crashes, ONS will be able to point the Savant to another server where the same information is stored.

Physical Markup Language

The Electronic Product Code identifies individual products, but all the useful information about the product is written in a new, standard computer language we call Physical Markup Language (PML). PML is based on the widely accepted eXtensible Markup Language (XML). Because it's meant to be a universal standard for describing all physical objects, processes and environments, PML will be broad and will cover all industries. Our aim is to start with a simple language to encourage adoption. PML can evolve over time, just as HTML, the basic language of the Web, has become more sophisticated since it was introduced.

Standards for describing objects
PML will provide a common method for describing physical objects. It will be broadly hierarchical. So, for instance, a can of Coke might be described as a carbonated beverage, which would fall under the subcategory soft drink, which would fall under the broader category food. Not all classifications are so simple, so to ensure that PML has broad acceptance, we are relying on work already done by standards bodies, such as the International Bureau of Weights and Measures (Le Système International d'Unités – SI) and the National Institute of Standards and Technology in the United States.

Types of PML data
In addition to product information that doesn't change (such as material composition), PML will include data that changes constantly (dynamic data) and data that changes over time (temporal data). Dynamic data in a PML file might include the temperature of a shipment of fruit, or vibration levels from a machine. Temporal data changes discretely and intermittently throughout an object's life. One example is an object's location. By making all of this information available in a PML file, companies will be able to use information in new and innovative ways. A company could, for instance, set triggers so the price of a product falls as its expiration date approaches. Third party logistics providers could offer service-level contracts indicating that goods will be stored at a certain temperature as they are transported.

PML Server
PML files will be stored on a PML server, a dedicated computer that is configured to provide files to other computers requesting them. PML servers will be maintained by manufacturers and will store files for all of the items a manufacturer makes.

Facing Page: Work in Progress, A robotics demonstration under construction at the lab at the Cambridge Auto-ID Centre
This Page: Yun Kang and Brendon Lewis, Graduate Student, MIT Auto-ID Center

Control

Once Auto ID data is linked to related PML information via a network, the next important issue relates to what decisions should be made on the basis of this information and to what extent the actions that drive physical operations might be influenced. Whether it is in manufacturing, distribution, retail or domestic use, the process of adjusting operating conditions in order to meet desired requirements is known as "control". For example, in manufacturing, this might refer to the optimal maneuvering of a robot to achieve the best packing sequence for a packaging line.

The Auto-ID Center's vision is of a world where smart products can interact with machines without human involvement, and hence can influence the manner in which they are produced, moved, sold or used. For instance, a smart washing machine of the future might read a tag sewn into the collar of a shirt, learn directly from a related web site that the shirt is made of a delicate fabric and adjust the wash cycle and amount or type of soap accordingly. Auto ID will enable a new generation of highly distributed and intelligent control systems. For this to happen, however, there has to be a formal process.

Decisions
The first step, of course, is for a computer or other machine to recognize an object. Our core technology – the EPC, ONS and PML file – make that possible. The PML file may also contain instructions, or rules, about how a shirt should be washed. But there has to be a set of protocols to follow in order that the shirt and machine can "converse" effectively. The washing machine may be incapable of executing certain instructions for example, because it doesn't have a specific feature or is washing other clothes at the same time. The protocols can provide a set of steps to go through to reach a decision, and can even support a "negotiation" between shirt and machine if needed.

Execution
This refers to the ability of a machine to carry out a set of customized instructions in a suitable manner. Recall that the machine may be washing more than one shirt at a time. There are two basic elements which influence the effectiveness of control execution: physical control and physical operation. Physical control refers to the computer control hardware and software required to execute decisions within the physical world. The physical operation is where digital instructions become real-world actions. Physical operations can include warehouse conveyors, factory robots and smart appliances.

The Holy Grail
The Auto-ID Center's control research group at the University of Cambridge is focused on the fundamental issues associated with control and is considering various novel applications in inventory management, production control, domestic functions, and product distribution. Creating some standard rules, protocols and guidelines for decision making and execution will enable software engineers to develop a new breed of enterprise software that allows managers to set some basic parameters and have machines act on them automatically.

SECTION FOUR

MAKING IT REAL

The Field Test

From 1999 to 2001, the Auto-ID Center's research teams were focused on designing the prototype system software and hardware for a new network that would allow companies to track goods using low-cost RFID tags. Field research with a number of sponsors, including Gillette, Procter & Gamble, Sun Microsystems, Unilever and Wal-Mart took place during 2000 and 2001. This work formed the foundation for a large-scale field test, which began in the fall of 2001.

On Friday, September 28, 2001, the Center achieved a major milestone. Electronic Product Codes on pallets of Bounty paper towels in a P&G factory in Cape Giradeau, Missouri, were read remotely in the MIT Lab, using scalable architecture developed and installed for the field test. Phase 1 used commercially available tags and readers that were modified as required for our needs. The aim was to test the software and system design only. It was a success. We were able to look into and search P&G's facility's inventory remotely, in real time. On Monday, October 1, 2001, a shipment of Bounty was sent to a Sam's Club in Tulsa, Oklahoma, and the EPCs were read as the pallets left the factory. Over the following months, we added pallets of goods from other vendors, including Gillette and Unilever.

In February 2002, we moved into Phase Two of the field test: putting tags on cases. Companies like Unilever, Proctor & Gamble, Kraft, Coca-Cola, Gillette, Wal-Mart, and Johnson & Johnson shipped tagged cases to and from selected distribution centers and retail store in over 8 US states. Despite the significant increase in the amount of data created by moving from the pallet level to the case level, the system continued to function well. Phase Three, planned for the end of 2002, will test the system's ability to scale even more, when we begin to tag individual units. For this phase, we plan to introduce new, scalable low cost tags and readers.

Auto-ID Center labs in other regions are also planning field tests. We expect to be live in Europe and Asia during 2003. These tests will enhance our understanding of performance requirements of the new EPC network and will provide further opportunity to stress test the system we have designed.

What's next?

The Auto-ID Center is focused on creating standards and the basic software needed to create a new network for tracking items using low-cost RFID tags. Through the end of 2003, we will be publishing a series of detailed technical specifications and documentation to enable vendors to create and develop related products and services. We will also be developing some of the network architecture to the point where it is ready to be used and commercialized by industry. By the end of 2003, we will have enabled vendors and users to start investing in EPC-related technology with reasonable assurance that the technology works, that there are compelling commercial reasons to do so, and that the public will be comfortable with the technology.

Our Web site (www.autoidcenter.org) has Research Papers and other information that anyone can download for free. There is also a Sponsors Only area of the site, which includes information and materials not available to the public at large. We encourage you to visit our site frequently to stay up to date with the Center's many activities.

APPENDIX

Frequently Asked Questions

What is the difference between auto-ID and RFID?

Automatic identification, or auto ID for short, is the broad term given to technologies that are used to help machines identify objects. There are a host of technologies that fall under the auto-ID umbrella, including bar codes, smart cards, voice recognition and so on. Radio frequency identification (RFID) is one type of Auto-ID technology. It uses radio waves to automatically identify individual items.

What about the integration of EPC data into legacy systems?

The Auto-ID Center has developed network software called Savant, which will manage the flow of data. Savant is based on open standards and will be freely available to all companies. Companies need only create an interface between their existing systems and Savant to take advantage of the data from electronic product codes. Moreover, some members of the Auto-ID Center, such as SAP, are working on systems that will take advantage of EPC data in new ways.

Why is item-level tracking important?

Standard bar codes identify only the manufacturer and product, not the unique item. The bar code on one can of diet soft drink is the same as every other, so it's impossible to identify which one was just made and which one is about to pass its expiration date. With standard product bar codes, it's impossible to tell which package of razors was paid for and which was stolen, or which shipment of running shoes should be sent to Venice, Italy, and which one to Venice, California. (Shippers like UPS had developed special bar codes for indicating were a specific item should be sent.) RFID tags with EPCs, on the other hand, makes it easy to identify specific items, so companies can automatically marked down items nearing their sell-by date, identify potential shoplifters and avoid misdirected shipments. In fact, the benefits of item-level tracking haven't really been explored, because up to now it has never been possible.

What can the EPC network do that existing bar code systems can't?

Bar codes are a line-of-sight technology. That is, a scanner has to "see" the bar code to read it. That means people usually have to orient the bar code towards a scanner for it to be read. Also, if a bar code label is ripped, soiled or falls off, there is no way to scan the item. Radio frequency identification, by contrast, doesn't require line of sight. RFID tags can be read as long as they are within range of a reader. And since radio waves pass through plastic, tags can be protected from damage.

Because RFID tags can communicate with readers without line of sight in most cases, RFID also has the potential to reduce out of stocks. Studies show that, on average, products are not on the store shelves 7 percent of the time. Every time a customer leaves a store without buying what they came for because it wasn't on the shelf, the retailer and the manufacturer lose out. RFID has the potential to dramatically reduce out of stocks by providing real-time visibility into what's on the store shelves. It also has the potential to dramatically reduce theft by alerting store employees to unusual activity at the shelves. It may also reduce employee theft, counterfeiting, administrative errors, and mass recalls. And there are some unique benefits associated with the ability to track individual items (see previous questions).

Why isn't the Auto-ID Center developing applications?

The Auto-ID Center is an independent, non-profit organization. Our aim is not to build and market hardware or software. We are creating a network that is akin to the Internet – an open, universal platform companies can use to do business. It is up to companies to leverage the network in whatever ways they see fit, just as they leverage the Internet today.

What will the Center actually deliver and when?

The Auto-ID Center is focused on creating standards and the basic software needed to create a new network for tracking items using low-cost RFID tags. Through the end of 2003, we will be publishing a series of detailed technical specifications and documentation to enable vendors to create and develop related products and services. We will also be developing some of the network architecture to the point where it is ready to be used and commercialized by industry. By the end of 2003, we will have enabled vendors and users to start investing in EPC-related technology with reasonable assurance that the technology works, that there are compelling commercial reasons to do so, and that the public will be comfortable with the technology.

Who owns the intellectual property created by the Auto-ID Center?

The Auto-ID Center is a unique partnership between industry and academia. Strictly speaking, the intellectual property belongs to the universities where our research is conducted. However, the intellectual property will be licensed free of charge to any company that wants to use it.

What makes the Auto-ID Center unique? Is there any competition?

Companies have long formed groups to promote the interests of a particular industry or to lobby governments for changes to particular laws. But the Auto-ID Center may be the first time in history that companies from different industries and different regions of the world have come together to develop technology they feel would benefit their businesses – and their competitors' businesses. There are groups of RFID vendors that have come together to propose standards or to foster the development in the RFID industry in other ways. These are not, however, the Auto-ID Center's competitors. None are focused on developing an open, global network for tracking individual items with low-cost RFID tags and readers.

A

Active tag: An RFID tag that uses a battery to power its microchip and communicate with a reader.

Address: A unique number that identifies a computer on a network.

Agile reader: Generic term for a reader that can read different types of RFID tags, such as those made by different manufacturers, or those that operate at different frequencies.

Amplitude: The maximum height of a radio wave.

Analog data: Information that is represented by continuously changing physical quantity, such as length or height of an electromagnetic wave (see below).

Antenna: A device for sending or receiving electromagnetic waves.

Anti-collision: A technique used to prevent several tags in the field of a single reader, or readers with overlapping fields, from interfering with one another. Anti-collision algorithms typically work by ensuring that the tags or readers don't transmit at the same time.

Automatic data capture (ADC): Methods of collecting data and entering it directly into computer systems without human involvement (see also automatic identification and data collection).

Automatic identification and data collection (ADC): A broad term that covers methods of entering data directly into a computer system without using a keyboard. These include barcode scanning, radio frequency identification, voice recognition and other technologies.

B

Bandwidth: The amount of data that can be passed along a communications channel in a given period of time. Also, the size of the communications channel available.

Bar code: A standard adopted to make it possible for machines to automatically identify labeled objects. The barcode was adopted because the bars were easier for machines to read than characters that humans could read. The main drawbacks of the bar code system in common use are that it can't distinguish one can of soup from another and scanners have to have line of sight to read the label.

Bit: The smallest unit of digital information – a single one or zero. A 96-bit EPC is a string of 96 ones and zeros.

C

Cache: Memory for storing and quickly retrieving recently accessed data.

Chip: See microchip.

Collision: Radio signals interfering with one another. Signals from tags or readers can collide (see below).

Coupling: The transfer of energy from one electronic circuit to another. Inductive and capacitive coupling are two methods used to transfer energy (and also data) between a reader and a tag.

D

Die: A tiny square of silicon with an integrated circuit etched on it – more commonly known as a silicon chip.

Distributed architecture: Software that runs simultaneously on different computers distributed throughout an organization, rather than on one central computer.

Domain Name Service: A service used on the Internet to help the network route information to the correct computers.

Dynamic data: Data that can change constantly, such as the temperature of an item.

E

EAN International: The international group that administers bar code standards in many parts of the world.

Electrically Erasable Programmable Read-Only Memory (EEPROM): A type of electronic memory that retains its contents even when the power is cut off and which can be reprogrammed.

Electromagnetic interference (EMI): The effect one wireless systems or product has on neighboring systems or products.

Electromagnetic compatibility (EMC): The ability of a system or product to function properly in environment where other electromagnetic devices are used and not be a source itself of electromagnetic interference.

Electromagnetic ID (EMID) tag: A memory device with circuitry for communicating wirelessly with an external tag reader. An RFID tag is one type of electromagnetic ID tag.

Electromagnetic spectrum: The entire frequency range of electromagnetic waves.

Electromagnetic waves: Energy that is emitted in the form of waves. Types of electromagnetic waves include radio waves, gamma rays and x-rays.

Electronic article surveillance (EAS): Simple electronic tags that are either "on" or "off." When an item is purchased or borrowed legally, the tag is turned off. When someone passes a gate area holding an item with a tag that hasn't been turned off, an alarm sounds.

Electronic data interchange (EDI): A widely accepted method of sharing data over a business network.

Electronic Product Code: (EPC): The Auto-ID Center's coding scheme that will identify an item's manufacturer, product category and unique serial number.

European Article Numbering (EAN): The bar code standard used throughout Europe, Asia and South America. It is administered by EAN International.

eXtensible markup language (XML): A widely accepted way of sharing information over the Internet in a way that computers can use, regardless of their operating system.

F

Fluidic Self-Assembly: A manufacturing process, patented by Alien Technology, that involves flowing tiny microchips in a special fluid over a base with holes shaped to catch the chips.

Frequency: The number of repetitions of a complete waveform in a specific period of time. 1 KHz equals 1,000 complete waveforms in one second. 1 MHz equals 1 million waveforms per second.

Frequency Shift Keying (FSK): A method of switching between different frequencies to transmit digital data. Often, one frequency represents a one, the other a zero.

G

Global Trade Item Number (GTIN): A superset of bar code standards, which is used internationally. In addition to manufacturer and product category, GTIN also includes shipping, weight and other information. The EPC is designed to provide continuity with GTIN.

H

Hardware: The physical, touchable, material parts of a computer or other system. Hardware for RFID systems consists of tags and readers, along with the computers required to collate, process and communicate the data generated.

High-frequency tags: Tags operating in the 13.56 MHz range.

Holonic Manufacturing System (HMS): A method for manufacturing goods based on the cooperation of autonomous, functionally complete entities with diverse and often conflicting goals. Holonic manufacturing is still in the early stages of development, but can be greatly enhanced by RFID technology.

I

Inductive coupling: A method of transmitting data between tags and readers that relies on interactions between the magnetic field that exists between the two devices.

Industrial, Scientific, and Medical (ISM) bands: A group of unlicensed frequencies of the electromagnetic spectrum. It isn't necessary to buy a license from the government before using communications equipment that operates at an ISM band frequency.

Integrated circuit (IC): This is another name for a chip or microchip. ICs make up the brains of computers.

Internet Protocol (IP): The network layer for the TCP/IP protocol suite widely used on Ethernet networks. It routes packets of data among computers connected to a network.

The Internet Engineering Task Force (IETF): An open, international group of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture.

Interrogator: An RFID reader.

L

Logic gate: Tiny switches on microchip circuits that enable the chip to perform certain operations.

Low-frequency tags: RFID tags that communicate with readers at 125 KHz.

Line-of-sight technology: Technology that requires an item to be "seen" to be automatically identified by a machine. Bar codes and optical character recognition are two line-of-site sight technologies.

M

Microchip: A microelectronic semiconductor device comprising many interconnected transistors and other components. Also called a chip or an "integrated circuit."

Micron: A unit of length equal to one millionth of a meter or one thousandth of a millimeter.

Modulation: Changing the frequency, phase or amplitude of a wave to transmit data.

Multiple access schemes: Methods of allowing several radio transmitters to operate simultaneously within the same frequency spectrum.

N

Nanoblock: The term Alien Technology uses to describe its tiny microchips, which are about the width of three human hairs.

Network: Any system that transmits voice, video and/or data between users.

O

Object Name Service (ONS): An Auto-ID Center designed system for looking up unique Electronic Product Codes and pointing computers to information about the item associated with the code. ONS is similar to the Domain Name System, which points computers to sites on the Internet.

P

Passive tag: An RFID tag that does not use a battery. The tag draws energy from an electromagnetic field created by the reader.

Phase Shift Keying (PSK): A method of communicating information by switching transmission between different phases of the waveform to represent digital data.

Physical Markup Language (PML): An Auto-ID Center designed method of describing products in a way computers can understand. PML is based on the widely accepted eXtensible Markup Language used to share data over the Internet in a format all computers can use.

PML Server: A dedicated computer that will respond to requests for Physical Markup Language (PML) files related to individual Electronic Product Codes. The manufacturer of the item may maintain the PML files and servers.

R

Radio Frequency Identification (RFID): A method of identifying unique items using radio waves. The big advantage over bar code technology is lasers must see a bar code to read it. Radio waves do not require line of site and can pass through materials such as cardboard and plastic.

Radio waves: Electromagnetic waves that fall within the lower end of the electromagnetic spectrum.

Read range: The distance from which a reader can communicate with a tag. Range is influenced by the power of the reader, frequency used for communication, and the design of the antenna.

Reader: Also called an interrogator. The reader communicates with the RFID tag and passes the information in digital form to a computer system.

Reader collision: A problem that occurs when signals from readers with overlapping fields interfere with one another.

Read-only memory (ROM): A form of storing information on a chip that cannot be overwritten. Read-only chips are less expensive than read-write chips.

Read-write: The ability to read and overwrite stored information. Chips for read-write RFID tags are more expensive than equivalent read-only chips.

Real-time In-memory Event Database (RIED): A method of storing frequently used data so it can be made available quickly.

RFID transponder: See transponder.

S

Savant: Distributed network software that manages and moves data related to Electronic Product Codes.

Semi-passive tags: RFID tags that use a battery to run the chip's circuitry, but communicate by drawing power from the reader.

Server: A computer that processes and fulfills requests for files, Web pages or other digital information.

Smart cards: A broad term used for a plastic card (usually the size of a credit card) with an embedded microchip. Some smart cards contain an RFID chip so they can identify the holder without requiring any physical contact with a reader. RFID smart cards are often called "contactless" smart cards.

Software: Also called a "computer program" or "program." Software is essentially the instructions that tell the physical computer – the hardware – what to do. Software can be written in different computer languages and generally falls into two categories: system software and application software or application programs. System software is any software required to support the production or execution of application programs but which is not specific to any particular application. Examples of system software would include the operating system and network software that directs traffic or checks passwords. Application software is the programs that run on top of the system software and perform specific functions, such as record keeping.

Static data: Data that doesn't change, such as facts relating to the material composition of a product.

Synthetic polymers: Man-made compounds that make up plastic-like materials. Special types of synthetic polymers may one day offer an inexpensive replacement to silicon in microchips.

T

Tag: The generic term for a radio frequency identification device. Tags are sometimes referred to as smart labels.

Tag collision: Interference caused when more than one RFID tag sends back a signal to the read at the same time.

Task management system: A method of organizing and customizing software to execute a set of tasks automatically.

Transmission Control Protocol (TCP): A set of formal communications rules developed to internetwork dissimilar types of computers. TCP is the connection-oriented protocol built on top of Internet Protocol (IP) and is nearly always seen in the combination TCP/IP. It adds reliable communication and flow-control. TCP/IP has become the de facto standard for communicating over the Internet.

Temporal data: Data that changes discretely and intermittently throughout an object's life, such as its location.

Time Division Multiple Access (TDMA): A method of solving the problem of the signals of two readers colliding. Algorithms are used to make sure the readers attempt to read tags at different times.

Transponder: A radio transmitter-receiver that is activated when it receives a predetermined signal. RFID tags are sometimes referred to as transponders.

U

Ultra-high frequency (UHF): The term generally given to waves in the 300 MHz to 3 GHz. UHF offers high bandwidth and good range, but UHF waves don't penetrate materials well and require more power to be transmitted over a given range than lower frequency waves.

Unified Modeling Language (UML): An open, standard method of modeling large, complex computer systems.

Uniform Code Council (UCC): The nonprofit organization that overseas the Uniform Product Code, the barcode standard used in North America.

Universal Product Code (UPC): The barcode standard used in North America. It is administered by the Uniform Code Council.

User Datagram Protocol (UDP): A set of communications rules that govern the transmission of data over a network. UDP doesn't require a connection or guarantee the delivery of data, so all error processing and retransmission must be taken care of by the application program.

W

Wafer: A small thin circular slice of a semiconducting material, such as pure silicon, on which an integrated circuit can be formed. Silicon wafers are usually eight to 12 inches in diameter.

X

XML: See eXtensible Markup Language.

XML Query Language (XQL): A method of querying a database based on XML. Files created using the Auto-ID Center's Physical Markup Language can be searched using XQL.

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