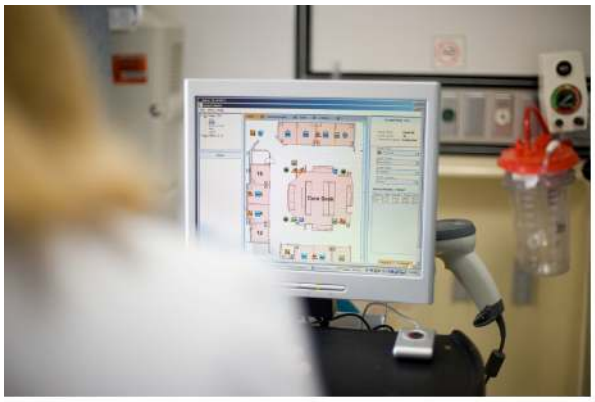
How to Choose the Right Location Solution



Location solutions have received more attention over the past few years as technology matures and more deployments flourish. Businesses are increasingly interested in leveraging location information on assets and people to streamline their business processes. However, business processes are very specific to each company, and as a result it has proven difficult for companies to choose among the multiple technologies available when it comes to location solutions.

This white paper introduces important location solution concepts so that you can make informed choices. The objective is to help you avoid some common misconceptions, such as equating a location solution with a radio frequency ID (RFID) system, or believing that each technology excludes all the others or that the location solution is independent from the network in place.

Indeed, a location solution is much more than simply an RFID system because it includes:

- Multiple applications
- Middleware
- A network
- An RFID system composed of
  - Locatable devices
  - Readers

To have a performing location solution, all these components are required and should integrate with each other. In addition, several RFID technologies can complement each other. For complex business processes, it's common to deploy multiple technologies based on the existing network, the accuracy or range needed by the applications, or the type of locatable devices.

Introduction

More and more articles are published about companies deploying location technology to streamline their business processes. Monitoring the location of shipments in supply chains, real-time update of inventory for manufacturing or retail companies, prevention of equipment losses in offices or in hospitals, and automatic alerts or upload of relevant information based on the user location are all possible now thanks to the progress made in location technology. The adoption rate will increase in the coming years as access to these technologies becomes easier and as more and more business partners deploy location services concurrently to tighten their collaboration.

In order to benefit from location technology and make informed choices, customers need to:

- Acquire the necessary vocabulary to read more material on this topic.
- Understand the different components of a location solution and their impact on the final result.
- Measure the level of control they need for each component of the solution.
- Assess the benefits and ease of deployment of each type of technology, as well as the complexity and limits of each.
- Familiarize themselves with different use scenarios in which the complementarities of these technologies are showcased.

This white paper will help you achieve these goals by providing:

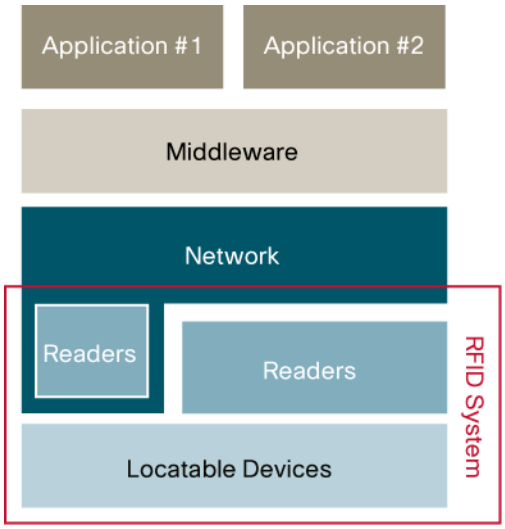
- A clear definition of a location solution and explanation of the role of each component.
- An overview of the most frequent technologies used and the associated benefits and shortcomings.
- Examples of deployments or applications in multiple industries and environments using multiple location technologies.
- Recommendations on how to choose and deploy the right location solution.

Definition of a Location Solution

A location solution enables relevant and timely location information to be included into business applications and decisions. A location solution is composed of multiple components, as shown in Figure 1:

- Multiple applications: either location applications or vertical business applications where the location information needs to be more accurate or automatically updated as the location information changes
- Middleware: to allow the applications to share and retrieve the location information in the right format, as well as to enable network functions such as access rights to business applications depending on the user location
- A network: to connect all these elements together and enable location information to be collected wherever it is needed in an efficient and reliable manner
- An RFID system composed of
  - Locatable devices that are the mobile assets whose location needs to be known
  - A reader that captures the information sent wirelessly by the locatable devices

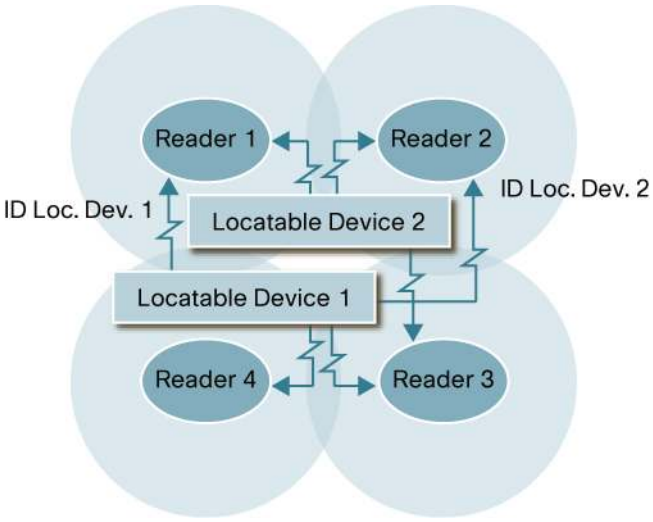
Figure 1. The Different Components of a Location Solution



RFID System

An RFID system uses wireless technology to exchange ID information between a reader and a locatable device, as shown on Figure 2.

Figure 2. RFID System



Readers and Locatable Devices

The communication between the locatable device and the reader has to be wireless since, by definition, the locatable device is a mobile asset. Note that we use the word locatable device and not tag. A tag is a locatable device but not all locatable devices are tags. There are two types of locatable devices.

Locatable devices

Any wireless device is natively a locatable device because to connect to the network, these devices transmit their credentials over the wireless network. When wireless devices are the locatable devices a company wants to track, the reader that receives this information is often integrated in the wireless network that provides connectivity. Examples of such networks are Wi-Fi, cellular, or Global Positioning System (GPS) networks. In this case, Wi-Fi laptops or cell phones are native locatable devices.

However, these native locatable devices are designed to perform multiple tasks, and the location function is seldom their primary function. For instance, the primary use for cell phones is for voice calls. As a result they are often turned off at night, and thus stop sending their ID information to the cellular network; in other words, they stop being locatable. But depending on the final application, not receiving the location information at night is not necessarily a limitation. If the information is used to locate the user during his working hours when he is on the road, the locatable device could be a cell phone. On the other hand, if the application is to monitor if a patient is back at the hospital at night, another locatable device is needed.

Cell phones can also be advanced locatable devices, sending more information than simply their ID; they also transmit call information that can be used by applications along with their location. For example, a cell phone can notify you that the person you are trying to call is 100 meters away.

Mobile assets that are not wireless represent a second type of locatable device. Tags can be added to these devices to wirelessly transmit information to RFID readers. Although tags are often designed simply to contain ID information, they can also transmit additional information fields, such as temperature, pressure, and so on. An example is an infusion pump in a hospital. This asset is mobile but is not a wireless device. A Wi-Fi tag could be fixed on it to track its location, and can even include a button to indicate the pump status as clean or not, depending on the final use case.

Readers

The reader's function is to receive the information sent by the locatable devices. When you choose an RFID system, it is important to verify that all the fields needed for the final use (such as ID, temperature, or other fields) and sent by the locatable devices are captured by the reader. Some readers only understand ID information and will ignore the rest of the information sent by the locatable device. More advanced reader devices like Wi-Fi access points allow you to change the fields they can read and can consequently play a broader, more adaptable role than collecting location information.

Passive and Active RFID Systems

In addition of the distinction between native or made locatable devices, there are passive and active RFID systems. In an active RFID system, the locatable device has a battery and uses it to send messages to the readers continuously, whereas in a passive RFID system, the locatable device has no battery and sends messages only after it receives energy coming from a chokepoint. Table 1 shows a comparison between active and passive RFID systems.

Table 1. Comparison between Passive and Active RFID

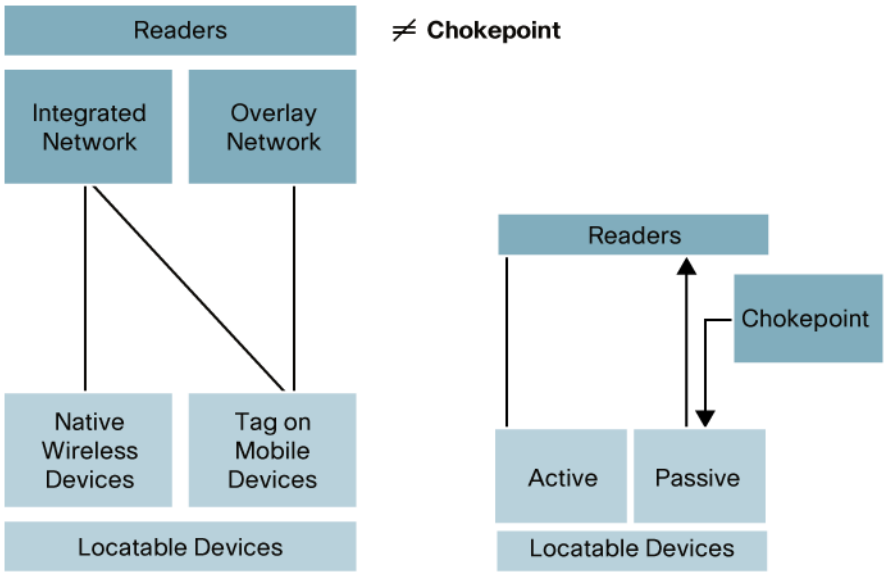
	Active RFID	Passive RFID
Power source	Internal to locatable device	Energy transferred from chokepoint over wireless
Battery	Yes	No
Availability of power	Continuous	Within chokepoint proximity
Required signal strength from reader to locatable device	Very low	Very high
Available signal strength from locatable device to reader	High	Very low
Read range1[1]	Long range (>100m)	Very short range (<3m)

It is common to confuse a reader with a chokepoint device. While a reader captures the wireless information sent by the locatable device, a chokepoint sends energy to passive locatable devices so they can, in turn, send their ID information to the reader. Both functions can be integrated in the same hardware or they can be provided separately.

As shown in Figure 3, native locatable devices often communicate with readers that are integrated within the network infrastructure, such as Wi-Fi laptops connecting to WLAN access points, whereas made locatable devices often (but not always) use an overlay network. This is especially true of passive RFID tags with their own reader and their own management system. The advantage of the integrated network is that it can use not only existing wireless devices as locatable devices but also add tags as needed. Integrated readers are ideal for environments with a mix of native and made locatable devices.

[1] Distance between the locatable device and the reader

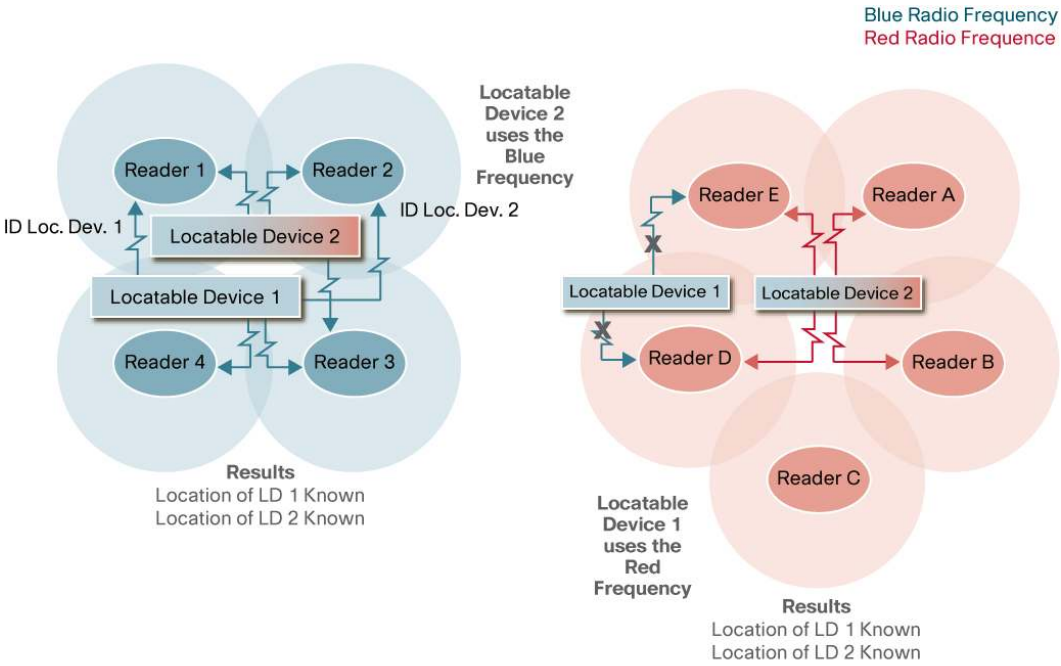
Figure 3. Possible Combinations of Locatable Devices and Readers



Multiple-Frequency Locatable Devices

The final variation in RFID systems is multiple-frequency locatable devices. The communication between a reader and a locatable device happens over a certain frequency, but some locatable devices can support multiple frequencies, as illustrated in Figure 4. These devices can be recognized by any reader supporting these frequencies. The information transmitted can be different from one frequency to the other, as the associated readers can relate to different applications. In the scenario shown in Figure 4, locatable device 1 supports only the green frequency and is not recognized when moving to the environment where the orange frequency is used. In contrast, locatable device 2 supports both frequencies and is recognized in both environments. An example of multiple-frequency locatable devices is a Wi-Fi laptop where the location information is sent over several channels but each reader, in this case, each access point, will read the information available on the channel it is configured for (in order to avoid interference with the surrounding readers, that is, access points).

Figure 4. Multiple-Frequency Locatable Devices



Calculation Methods

Once the information sent over wireless network from the locatable device to one or more readers is captured, some calculation is necessary to transform the captured ID information into a location.

Several methods are available:

- Nearest reader: where the location of the closest reader receiving the ID information will be the proxy for the location of the device
- Cell of origin: where the zone covered by the reader is the proxy for the location of the device. Note that in this case the accuracy of the solution will be equal to the size of the cell covered by the reader.
- Received signal strength (RSS): This is a more sophisticated method. The received signal strength at the locatable device or at the reader will be used to calculate the distance between them. This process is reproduced for at least three readers and then the location information is deduced by correlating these data points. Some high-end systems using this method can also dynamically integrate information on the attenuation and/or multipath affecting the wireless environment.
- Time of arrival (ToA): With this method, the distance between the reader and the locatable device is calculated based on the absolute time when the signal is received by the reader. Just as with RSS, this process is reproduced for at least three readers and then the location information is deduced.
- Time difference of arrival (TDoA): This method offers the same logic as ToA, but instead of absolute time of arrival, it uses a relative time.
- Angle of arrival (AoA): In this method, the distance between the reader and the locatable device is calculated based on the angle of incidence at which the signal is received. Again this process is reproduced for at least three readers and then the location information is deduced.

Things to remember about RFID Systems:

- Locatable devices can be native or made.
  - Native locatable devices (for example, Wi-Fi phones) are not designed for location only and can perform advanced tasks that can be coupled with location.
  - Made locatable devices (for example, tags) are mainly designed for location and often offer a limited set of features besides location.
  - It is important to verify that readers can capture all the information sent by the locatable devices for advanced applications.
- An RFID system can be active or passive. Passive RFID systems require the use of chokepoints in addition to readers.
- Some locatable devices can support multiple frequencies.
- Readers can be integrated in the network or deployed as an overlay network.
  - Readers integrated in the network can often support both native and made locatable devices, where as overlay networks are often limited to made locatable devices.
  - As a result, readers integrated in the network can also support more advanced features supported by native locatable devices.
- Several calculation methods exist for location. The most sophisticated ones can dynamically adapt to the characteristics of the wireless environment.

Network

As shown in Figure 1, the network is where the RFID system gets connected to the rest of the location solution. The role of the network is to retrieve the location information and deliver it to the middleware in an efficient and reliable manner. Most companies deploying location solutions already have a network in place to provide connectivity to employees.

Wired LANs

If a company only has a wired LAN, the RFID system will be deployed as an overlay network, and the IT manager will have to configure and maintain the wired network as well as the wireless RFID system. Most of the time, the connection between the LAN and the RFID system is over Ethernet or USB.

In this configuration, the devices used by the employees, which we cannot assume are all wireless, will be made locatable through to the use of wireless tags. Overlay RFID systems are often passive, and the chokepoint function often resides within the reader for the following reasons:

- It is costly to deploy an overlay network of readers everywhere in the facilities. Companies therefore deploy readers only in places where the location information is really needed such as the entrance in a building or a room, every 100 meters on an assembly line etc.
- Since the reader coverage is not pervasive, the location information is received only where readers are installed to capture the signal sent by the locatable device. As a result, it is useless for the locatable device to send information in a continuous way (that is, when far away from a reader). Most of the tags used in this situation are thus passive tags and send information only when excited by a chokepoint.

- Because readers are in a limited number of places, the chokepoints have to be in these same places and thus are often integrated within the reader.

In this case, a simple calculation method is needed, the nearest reader, as a proxy for the device location. The accuracy then depends on the read range, or in other words on the frequency used by the RFID system. The location information is only received when triggered by an event (proximity of a chokepoint/reader) and can belong only to a finite set of locations.

Applications that require a continuous location (in terms of time and place) cannot be supported. For instance, if a locatable device is on an assembly line and moves from point A to B, the location information will be captured at each point (assuming A and B have a chokepoint/reader). But if you want to know at a certain instant where the locatable device is and if at this time the device is not close to a chokepoint/reader, your request will not be answered. Also if the locatable device is removed from the assembly line and lost, this location solution does not allow finding where the device is within the facility.

Requirements for higher flexibility and accuracy will proportionally increase the acquisition and maintenance cost of the system. Using the previous illustration, a chokepoint/reader can be added at the entrance of the building to know if the locatable device is still in the building or not. If the company wants to know at the room level where the device is, it must add chokepoints/readers at the entrance of every room in the building, thus significantly increasing the cost.

LAN coupled with an RFID system is mostly used in environments where location is highly controller and predictable (that is, within a finite set of places) and needs to be known at specific moments only.

Wireless LANs

For companies that already have a wireless LAN, several technologies can be concurrently deployed. First, the RFID system can use Wi-Fi technology between the locatable devices and the reader. Thus any Wi-Fi device (laptops, phones, and so on) can be a locatable device, and mobile assets that do not have native wireless capabilities can be made locatable thanks to a Wi-Fi tag. The WLAN access points then have two functions: their regular networking function to provide voice, data, and video over Wi-Fi, and the reader function to collect information sent by the locatable devices.

In this configuration, a mix of native and made locatable devices can exist and communicate with an integrated network of readers. Most of the time, the RFID system is an active one with no chokepoint required because:

- The wireless coverage is already pervasive enough to provide access to users anywhere in the facilities, so there are readers (access points) everywhere.
- In addition, the frequency used in Wi-Fi enables long-range communications (>100m), with the result that Wi-Fi locatable devices should be able to send information to readers from anywhere in the facilities. To do this in a continuous way, they require a battery and not the power of a chokepoint.

Depending on the accuracy needed, several calculation methods can be used, such as closest cell of origin or received signal strength.

Applications like finding a locatable device anytime and anywhere in the building are now possible. This scenario represents several additional benefits:

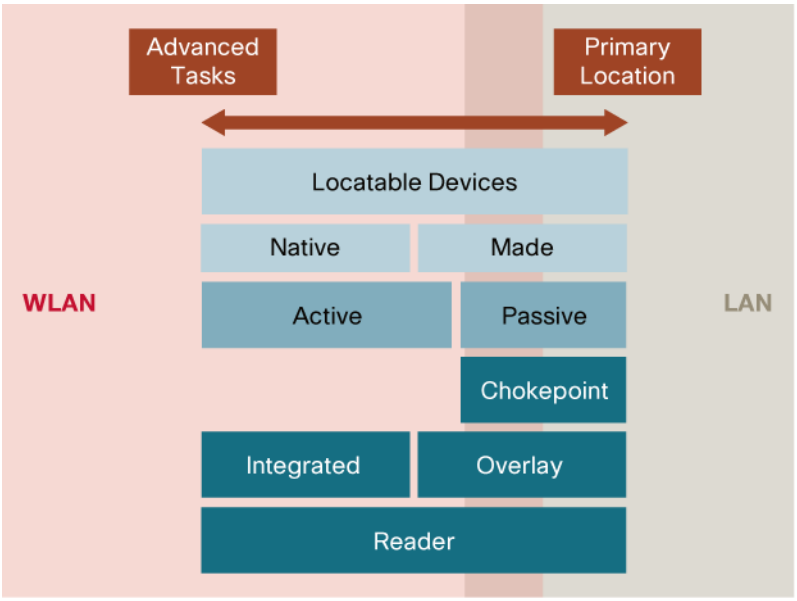
- In terms of capital expenditures (CapEx): No additional readers have to be bought, and most of the Wi-Fi devices like laptops or Wi-Fi phones can become locatable devices at no additional cost. Other nonwireless devices can use Wi-Fi tags to become locatable.
- In terms of operational expenditure (OpEx): The same network becomes multipurpose and thus requires no additional maintenance other than the one performed to ensure user connectivity. is needed. The management tool of the WLAN can be used to manage both the networking capabilities and the location solution along with readers and locatable devices.
- In terms of speed of deployment: With a pervasive WLAN, the readers are already deployed in any place that location information is needed. The addition of the calculation method and Wi-Fi tag is easier and faster than the deployment of an overlay network.
- In terms of advanced features: Several Wi-Fi devices can perform multiple and more advanced tasks and more advanced tasks than simply sending their ID information. For instance, Wi-Fi laptops provide access to multiple applications. Coupled with the location of the device, this configuration can enable the context-aware applications discussed later in the “Applications” section.

Although the WLAN scenario described so far provides accuracy within 10 meters, some applications may require a higher accuracy. You can then deploy chokepoints as described in the LAN section. This will offer accuracy equal to the read range In this case, multiple frequency locatable devices should be used. As they approach a chokepoint, they retrieve energy over a certain frequency and will send information over Wi-Fi to the reader, in this case an access point. The chokepoint function does not have to be integrated in the reader. Chokepoints just need to be placed into a finite set of locations that require accuracy equal or higher than the read range.

As a result, having a WLAN network offers the ability to benefit from the best of both worlds. A Wi-Fi RFID system can be used everywhere and with the existing Wi-Fi devices; in places where better accuracy is needed, some chokepoints working in another frequency can be added along with the associated tags. The cost for the additional chokepoints is lower than that for a LAN coupled with an RFID system purely relying on overlay chokepoints/readers. In addition a single management tool can be used for both the network and the RFID system. Wi-Fi devices can be tracked as well as tags. Advanced applications can be run along with location and a better accuracy can be reached when necessary.

The most frequent scenarios for RFID systems are summarized in Figured 5.

Figure 5. Most Frequently Used Scenarios



Networks Not Owned by the Enterprise

Other configurations are possible especially when the network is not owned and managed by the enterprise using the location solution. Examples include the cellular and GPS networks.

A cellular network is owned and managed by a service provider. Cell phones can be native locatable devices and used as a proxy for the location of their owner. A location application could consist of notifying the cell phone owner when people from his “buddy list” are in a range of 100 meters from him. In this scenario, the base stations act as integrated readers and the cell phone acts as an active RFID system. The location information is continuous.

Figure 6 summarizes the most frequently used location technologies with their associated network configurations and characteristics.

Figure 6. Most Frequently Used Location Technologies

RFID System Frequency

	LF—HF—UHF 125 kHz–915 MHz	WLAN 2.4 GHz	Cellular 800 MHz–2400 MHz	GPS 1176 MHz–1575 MHz
RFID System	**Passive or Active** Easier to transfer energy in low frequencies	**Active**	**Active**	**Active**
Locatable Devices	**Made** Tag	**Native** Wi-Fi laptops, phone or tags	**Native** Cell phones	**Native** GPS phones and Navigator
Calculation Method	**Neaest reader, cell of origin**	**Cell of origin, RSS, TDoA**	**TDoA, EoTD**	**ToA**
Read Range	**Short** Less than 6 feet	**Long** 100 feet indoor 300 feet outdoor	**Long** 35 kilometers	**Long**
Accuracy	**Very High** A few inches to 2 meters indoor	**High** Within 10 meters indoor and outdoor	**Medium** Within 50–300 meters outdoor	**High** Within 5–30 meters outdoor
Readers	**Overlay** Standalone reader	**Integrated** Wi-Fi access point	**Integrated** Base Stations	**Integrated** Satellites
Readers	**High Density** Everywhere location is needed	**Medium Density** Several meters	**Low Density** Several kilometers	**Very Low Density**

Things to remember about networks:

- LANs often use passive overlay RFID systems.
  - Location information is event triggered and belongs to a predefined set of known places.
  - Accuracy depends on the read range.
  - Cost is proportional to the number of chokepoints/readers deployed, and two networks have to be managed.
- WLANs can offer the best of both worlds. Multiple-frequency systems can be mixed for a customized and flexible solution, simple to manage and fast to deploy.
  - Integrated and active RFID system

    Location information is continuous. Advanced applications can be offered.

    Accuracy depends on the calculation method.

    Cost is minimal as readers are integrated in the network and managed from a single point, and most of the Wi-Fi devices can act as locatable devices.

    Overlay RFID system

    Location information is event-triggered and belongs to a predefined set of known places.

    Accuracy depends on the read range.

    Cost is proportional to the number of chokepoints/readers deployed, but only one network has to be managed.

Middleware

The role of middleware is to retrieve the location information from the network and includes a logic to present relevant and understandable information to the applications. Middleware can have different levels of sophistication. This section provides some examples.

One of the simplest middleware is, for instance, to take the location information in longitude and latitude sent by a GPS RFID system and transform it into 3D coordinates in meters (if that what the application using the location information understands). When an application only needs to know or can only understand the building in which a locatable device is currently located, it is the middleware's role to make an informed decision and only present the relevant information to the application.

Additionally, when multiple location formats are collected from multiple RFID systems, it is the role of the middleware to map the right information to right application. Let's assume that a WLAN network supports both a Wi-Fi RFID system, in which Wi-Fi locatable devices move in the whole facilities like finished goods and an overlay RFID system in which locate assets move along an assembly line like in-process manufactured goods. The middleware should send the Wi-Fi RFID system information to the finished good section of the inventory management application and the overlay RFID system information to the assembly line status application or the supplier fulfillment system.

Sometimes the information the middleware sends to the application is not location information. Context-aware middleware is, for instance, a very advanced form of middleware. The applications that are accessible differ depending on the location of the user. For instance, in the back office of a retail store, the user will have access to inventory management applications, but in the store itself, he will have access to customer relationship management applications.

In some location solutions, some applications are triggered based on a location event such as sending an alert via e-mail to all the nurses if a heart monitor exits the hospital. Given the location information, it will also be the middleware role to activate the right application (in this case e-mail) at the appropriate time.

Applications

Location solutions are used to achieve two things: either to streamline existing business processes or to create new business processes, new and smarter ways of doing business.

When business processes are being streamlined, regular business applications are the ones impacted as they have their location field automatically updated. Most the time, these applications, such as inventory management in retail store, are well known and already widely used by the employees. In the past, the location information was entered manually (probably using a bar code reader); the difference is that now, all this is automated. Every time a locatable device crosses the back door, the count down in the inventory is updated. When there are only 10 items left in a category, a replenishment order can be sent to the supplier. All this happens in a fast and transparent way so employees can focus on customer service and not logistics.

When new business processes are being developed, location information can spur development. For instance, in the past cell phones were mainly used to place voice calls or run data applications. But once the location information was made available, cell network operators invented new services, such as locating all your "buddies" and notifying you when they are within

300 meters of you. A new service and application was created, and with it a new source of revenue for carriers.

Here are some examples of the ways in which applications in different environments take advantage of location information.

In Healthcare

Several hospitals have used their WLAN network (already used for voice, data, and video applications) to continuously track wheelchairs using active Wi-Fi tags. When patients are accepted and require a wheelchair, nurses can locate the closest one quickly. Another use is the deployment of chokepoints at the entrance of the Emergency Room and equipping physicians and nurses with multiple frequency tags. These tags receive energy from the chokepoint at a certain frequency and then transmit the information over the Wi-Fi frequency. When a physician enters the ER with his badge, a signal is sent over the WLAN and notifies the nurse that there is at least one physician in the ER and that the physician should not be disturbed by problems that are not life-threatening.

Some Wi-Fi tags can also monitor the temperature, pressure, and other telemetry information in their surroundings. By placing one of these devices into a storage room for medication, alerts can be set up when the room temperature is too high and risks damaging the stored medication or chemicals. The hospital can thus be ensured of the efficiency and quality of their medication and avoid unnecessarily waste.

In Manufacturing

In a manufacturing environment, passive RFID systems can be deployed on the assembly line to monitor production and in-process goods and automatically ask suppliers for replenishment when raw materials are running short. At the same time, finished goods can have an active Wi-Fi tag to monitor their location in a continuous manner anywhere in the facilities as well as to update inventory management applications when they leave the building for shipping. The same network can be used to track forklifts or to provide employees with voice over Wi-Fi capabilities and access to business applications while they are away from their desks.

In Retail

In a retail environment, the same type of inventory management applications can be deployed. An application to alert the store manager if there is no employee in the store can also be implemented. Several supermarkets with pervasive WLAN coverage are also considering equipping shopping charts with Wi-Fi active locatable devices to improve customer experience. The device screen on the chart will list all the promotions available in the department the customer is entering using context-aware middleware and the location information sent by the chart.. Additionally tags can be added into refrigerated areas where temperature needs to be controlled.

In Education

In schools that have a pervasive WLAN, attendance can be tracked using the students Wi-Fi laptops as locatable devices. If a laptop is lost, it can also be located throughout the campus using the WLAN. Professors with Wi-Fi phones can have their calls redirected to their voicemail while they are teaching.

Conclusion

A location solution includes but is not limited to an RFID system. The network, middleware, and the applications are also important in choosing the right technology for the RFID system. These technologies are not mutually exclusive and can be deployed concurrently and in complementary ways, depending on the goal.

Using the same wireless network for location and for connectivity offers multiple advantages in terms of total cost of ownership as well as flexibility and speed of deployment. Using the existing WLAN to perform continuous tracking of native or made locatable devices is a simple step to cross. Deploying chokepoints in places where a specific accuracy is needed is a good and cost effective complement.

For customers new to location solutions, a Wi-Fi RFID system makes sense and allows the customer to get familiar with the range of possibilities that location solutions offer.

To implement a durable and customized location solution, companies should clearly define the requirements the location solution should satisfy. Do they need continuous or event-triggered tracking? How accurate does the solution have to be? What are the locatable devices?

Companies should then look at the network already in place and estimate how much additional equipment is required, how the management of the network and the location solution will integrate, how long the installation will take and how likely it is that the location solution will match your needs. Weighing all these considerations, a staged approach may be appropriate. Especially if a pervasive WLAN is already in place, a Wi-Fi RFID system should be deployed first because it is most economical and simple to deploy.

As a second stage, companies can consider coupling the WLAN with an RFID system using a different frequency. Chokepoints could be deployed and enable users to appreciate the difference between the two systems and the missions they can fulfill.

Once the different location solutions are deployed, customers should try to streamline all the existing business processes making the location field in all the applications dynamically updated, and later on, they should look for new innovative ways to use the location information and maximize their return on investment.

For More Information

For more information on the Cisco Location Solution and to read more on customers deployments, visit http://www.cisco.com/go/location

For more information on the Cisco Unified Wireless Network, visit http://www.cisco.com/go/wireless

For more information technical design and deployment considerations, go to: http://www.cisco.com/univercd/cc/td/doc/solution/wifidesi.pdf

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