A Comparison of RF Tag Location Products for Real-World Applications

A Ubisense White Paper

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Introduction

There are many RF tagging systems on the market, and most provide some kind of location capability. But different systems differ hugely in capability and cost.

Ultimately it's the applications, and the benefits they provide in the short term and longer term that count. The measure of a location tagging system is the applications that it enables.

In this paper we consider a representative set of RF tagging and location systems. We describe how they each measure up to a set of generic requirements for location systems and we outline some of the costs of the systems.

We then describe some specific location-aware applications in healthcare. For each application we list the requirements that it places on the underlying location technology.

Finally, we bring together the applications and systems to see which systems can implement which applications.

The conclusion of this paper is that there are two main classes of location-aware application for RF tag systems:

- simple 'finding' applications that do not require significant accuracy or system performance, and
- 'Smart Space' applications, that require very high levels of accuracy, real-time response, support for tag communications and platform support for programming and integration.

The simple 'finding' applications provide a relatively low level of benefits, while the 'Smart Space' applications offer much more value and do not limit future expansion of benefits.

The application analysis in this paper makes it clear that the Ubisense tracking technology is the only one capable of supporting 'Smart Space' applications and delivering the benefits they provide.

This paper concentrates on low-level tagging and tracking hardware and systems, but Ubisense also provides a software platform and tools to enable fast, low-risk development of large-scale Smart Space installations. This complete package makes Ubisense the only choice for implementing real-world Smart Space.

RF Tag Location Systems Considered in this Paper

RFID Proximity Cards

Example: Bewator Cotag, Wavetrend

RFID proximity cards are in widespread use. They are active or passive devices activated by proximity to a fixed reader. They are often used in access control systems. Location can be deduced by considering the last reader to see the card.

An IEEE802.11 System

Example: Ekahau/NSC

This system uses a WLAN network to track tags equipped with WLAN access cards. It works by measuring signal strength data which is correlated with location.

A Bluetooth System

Example: Bluetags

This system is like the IEEE802.11 system but in this case works in a Bluetooth environment.

A Dedicated Conventional RF System

Example: WhereNet

This system uses the same 2.4GHz band as the IEEE802.11 and Bluetooth systems, but it uses a dedicated standard protocol (ANSI 371.1) optimized for low-power spread-spectrum location. It works by timing signals transmitted from tags to a network of receivers.

A Unidirectional UWB System

Example: Parco PAL

This system is a unidirectional location system utilizing UWB. Tags transmit UWB to networked receivers and are located using Differential Time of Arrival (DTOA).

Ubisense

Ubisense is a unidirectional UWB location platform with a conventional bi-directional TDMA control channel. Tags transmit UWB signals to networked receivers and are located using Angle of Arrival (AOA) and Differential Time of Arrival (DTOA).

General Requirements for RF Tag Location Systems

In this section we consider some general requirements on RF tag location systems, and assess how each of our systems measures up to the requirements.

The systems are marked using a 5 mark scheme: Very good; Good; Average; Poor; Very poor.

Tag size

Small tag size is valuable for asset tags because it allows tags to be fixed to a wider range of equipment, and for tags carried by people because it is easier to carry a small device.

	Small tag size
Proximity Cards	Very good (coin / card)
IEEE802.11	Average (PDA)
Bluetooth	Good (matchbox)
Dedicated RF	Good (matchbox)
Unidirectional UWB	Good (matchbox)
Ubisense	Good (matchbox)

Tag battery life

A long tag battery life is valuable especially for applications such as asset tracking, when the tag is left in the field for an extended period. The maintenance of any location system is an often overlooked cost for long term implementations. When a tag is attached to electrical equipment, a battery life of 6 months (or sometimes 1 year) can ensure that the battery is changed only when the equipment is periodically checked.

Proximity cards are typically either wholly passive or have a sealed battery with a life of many years that never requires changing during the lifetime of the tag.

The IEEE802.11 and Bluetooth systems have relatively high battery consumption because the tags have to engage in protocols (IEEE802.11 and IEEE802.15.1 respectively) that offer relatively little support for power saving.

The Dedicated RF, Unidirectional UWB and Ubisense use various techniques to ensure long battery lifetime. The Ubisense platform dynamically adapts its update rate based on the tags movements to provide greatly increased battery lifetime.

	Long life tags
Proximity Cards	Very good (unlimited)
IEEE802.11	Poor (days)
Bluetooth	Average (2 weeks rechargeable)
Dedicated RF	Very good (years)
Unidirectional UWB	Good (>1 year)
Ubisense	Good (1 year people, >1 year assets)

Accuracy

Accuracy requirements vary from application to application. One application might only need to know which building a person is in, whereas another might need to detect when a person picks up an object.

The proximity card systems provide the lowest accuracy here because they rely on an (unreliable) sensing of tags as they pass through portals in the building. If the portals are far apart, this may result in very large location errors.

Conventional RF systems that use the 2.4GHz band are typically accurate to a few meters. Their accuracy is limited by the high level and variability of multipath distortion experienced in an in-building environment.

UWB systems are less prone to multipath distortion because of their much higher bandwidth and their use of a modulation scheme that makes it easy to reject multipath signals. This leads to accuracy that is typically an order of magnitude better than the conventional RF systems.

	Accuracy
Proximity Cards	Very poor (about 30m)
IEEE802.11	Average (about 3m)
Bluetooth	Average (about 3m)
Dedicated RF	Average (about 3m)
Unidirectional UWB	Very good (< 0.3m)
Ubisense	Very good (< 0.3m)

Real time response

As accuracy increases, so sample rate becomes more important. A person walking fast travels at about 2.5m/s, and can start and stop moving almost instantaneously – so a 1Hz update rate can be equivalent to a transient positioning error of about 2.5m.

When tracking people it is therefore important to be able to use a very high update rate when necessary. However there is a trade-off between update rate and tag power consumption, so a good system will provide mechanisms for varying update rate in response to tag behavior.

Proximity cards provide no support for real-time response.

The conventional RF systems provide little support -- but this is less important for them because of their lower accuracy.

The unidirectional UWB systems support selectable update rates, but because there are no control channels these must be selected by physically changing the tag, so rates cannot be selected automatically in response to tag behavior. Moreover the maximum rate is 1Hz, which could still lead to transient errors in the region of 2.5m.

The Ubisense platform uses its RF control channel to support continuous variation of the tag update rate in response to tag behavior, varying from a fraction of 1 Hz to 10Hz.

	Real time response
Proximity Cards	Very poor (0.001Hz typically)
IEEE802.11	Poor (around 0.1 Hz)
Bluetooth	Average (around 0.4Hz)
Dedicated RF	Poor (selectable to 0.2Hz)
Unidirectional UWB	Average (selectable 0.1 or 1 Hz)
Ubisense	Very good (continuously variable)

Communications support

The ability to send data from the tag can be valuable for some applications. The ability to send data to the tag in order to 'page' it can also be an important feature.

Proximity cards are able to exchange data when they are in contact with the tag reader, but because this contact is so intermittent the support for communications is classed as very poor.

The Dedicated RF system does not support any data transfer involving the tag.

Unidirectional UWB supports data flow from the tag to the sensor infrastructure, but there is no data channel from infrastructure to tag, so it is not possible to 'page' the tag.

The IEEE802.11, Bluetooth and Ubisense systems all support 2 way data transfer between the tag and the infrastructure,

making it possible to send data to/from the tag, and to 'page' the tag.

	Communications
Proximity Cards	Very poor (intermittent at best)
IEEE802.11	Good (2 way data)
Bluetooth	Good (2 way data)
Dedicated RF	Very poor (none)
Unidirectional UWB	Poor (1 way only)
Ubisense	Good (2 way data)

Spatial Programming and integration support

Location-aware systems can be more valuable when supporting many simultaneous services that are integrated with other systems. This requires special support for writing programs that use spatial information and integrate cleanly with other systems and devices.

There is little or no support in proximity card systems for such programming.

The IEEE802.11, Bluetooth, Dedicated RF and Unidirectional UWB provide software for visualizing the positions of tags on a map, and interfaces for extracting positions into other systems.

The Ubisense platform provides a complete suite of tools for developing multiple, simultaneous, real-time location-aware applications, including visual programming of location-aware applications, extensive published API's for integrating to other systems, and simulation tools to support requirements capture and testing for location-aware applications.

	Integration and programming
Proximity Cards	Low
IEEE802.11	Medium
Bluetooth	Medium
Dedicated RF	Medium
Unidirectional UWB	Medium
Ubisense	Very good

Costs of RF Tag Location Systems

The costs of RF tag location systems generally consist of three components: the tag costs, the infrastructure costs, and the installation costs.

Tag cost

Because RF tag location systems are intended to support large numbers of objects and people, large numbers of tags must be used. So a low tag cost is beneficial.

Proximity card systems use cheap components and benefit from their market maturity and volume, leading to costs of a few dollars.

The other tags are much more complex than the proximity card tags, and this is reflected in their costs. Most of the other systems use at least one $10 component in the tag, and they all cost a few 10s of dollars.

	Cheap tags
Proximity Cards	Very good ($1s)
IEEE802.11	Average ($10s)
Bluetooth	Average ($10s)
Dedicated RF	Good (low $10s)
Unidirectional UWB	Average ($10s)
Ubisense	Average ($10s)

Infrastructure cost

The proximity card systems only have readers at portals and so their infrastructure cost tends to be low. However, if there are a very large number of portals, costs will rise proportionally.

The IEEE802.11 system uses an existing WLAN infrastructure and so could lead to very low incremental cost if the accuracy requirements could be achieved with existing infrastructure and the interference was not too great. However in large buildings WLAN installations are likely to make use of leaky feeder antennae which greatly reduce their value for location systems.

For the other systems, cost is generally related to range from tag to receivers: the longer the range the lower the cost. The Bluetooth and Dedicated RF systems have indoor ranges of typically 50-100m, while the UWB systems have shorter

ranges because the higher operating frequency of these systems is more severely attenuated by building materials.

	Low infrastructure cost
Proximity Cards	Very good
IEEE802.11	Very good (if using existing HW)
Bluetooth	Good
Dedicated RF	Good
Unidirectional UWB	Medium
Ubisense	Medium

Installation cost

Installation cost reflects the cost of installing each infrastructure element and so it is generally proportional to the overall infrastructure cost.

	Low installation cost
Proximity Cards	Very good
IEEE802.11	Very good (if using existing HW)
Bluetooth	Good
Dedicated RF	Good
Unidirectional UWB	Medium
Ubisense	Medium

Application Requirements for RF Tag Location Systems

In this section we focus on healthcare applications. For some typical applications of location-awareness, we consider what requirements are placed on the underlying location system.

Example 1: Mobile patient monitoring

Several systems exist for monitoring the vital signs of mobile patients. Monitored data, especially ECG, is sent wirelessly to a central control room where it is observed by an expert. The need for location-awareness arises when the data exhibits some new abnormality: then a visual assessment of the patient's condition has to be made. The location of the patient is a key factor in how this assessment will be made. Depending on the capability of the location system, it is possible to implement various applications. Below are a few of the many examples that could be implemented:

Find the patient. If we can find where the patient is, the expert can telephone a nearby ward or department to request that a suitable member of staff finds the patient and performs an appropriate physical assessment. This feature only requires location of the patient to a few meters' accuracy. In practice this can be a poor solution because it can take a long time to get hold of a suitable member of staff who is actually free.

Page a nearby staff member. If we can find where the patient is, and we can find the locations of members of staff who are qualified to perform visual assessments, then we can locate the nearest member of staff qualified to perform the assessment and page them. This member of staff then finds the patient, performs the assessment and telephones the results to the expert. This feature still only requires location accuracy of a few meters but also requires paging. It works better than the base application because a qualified member of staff is automatically selected, but it still requires that the staff member is not busy, is able to find the patient, and is able to get through to the expert with the visual assessment.

Film the patient automatically. At the other extreme, we could use digital Pan-Tilt-Zoom cameras to film the patient and put video or still footage of the patient on the screen in front of the expert, allowing the expert to make a visual assessment of the patient directly. This feature requires very high accuracy, real-time performance and integration

support. It could potentially be much more effective because it would remove the need for communication between members of staff.

Example 2: Asset management

Asset management is often suggested as an application of location tagging, the idea being that it is possible to keep an inventory of assets and their locations to make it easier to find assets when needed. Again, various levels of provision are possible, of which these are some examples:

Find the asset. If we know where an asset is, then we know where to go to look for it. A member of staff who needed to find an asset could look for it on a map before going to get it. This does not require a very high degree of location accuracy – a few meters is adequate. But it does require good tag battery lifetime of about 1 year.

Detect when the asset is being used. Simply finding an asset is not very valuable if we find it only to discover that it is already in use. By using much more accurate and real-time location information, especially if staff members wear tags, we can detect when an asset is being used. If we have 2 way tag communications we can add protocols to support use assertion and so make use detection more reliable. This is valuable for two reasons: firstly, use detection makes it easier to find a free asset; secondly, it becomes possible to measure asset utilization levels and optimize asset provision accordingly, thereby saving costs.

Page staff when the asset is free. In a system that detects asset use, we can use a paging feature on the tag to alert a member of staff when an asset has become free. If a member of staff is looking for an asset that is in use, we could enable them to select an option that would notify them when the asset became free. This would add extra value by decreasing the duration of periods of non-use, and thus optimize asset provision. This can be especially powerful if we consider applying the same general approach to a wider consideration of 'assets', such as consulting rooms, or even some people.

Example 3: Smart Space Applications

The application examples above display a general trend. Location tracking itself has a certain value, but when accurate location tracking is combined with real-time behavior and tag communications and integrated with other systems, much more value is created.

We use the term 'Smart Space' to describe platforms that incorporate accurate location, real-time response, and support for 2-way communications, spatial programming and systems integration. The value of Smart Space is that it allows software systems to react automatically to what happens in their surroundings in order to simplify work for people, whether it be pointing a camera at a patient with an abnormal heart rhythm, or detecting when a piece of equipment is unused and paging somebody who wants it.

For many of the complex logistical and communications problems that occur in a healthcare environment, there are Smart Space solutions. Below are some examples:

Configuration of resources. Many items of medical equipment are able to display their user interfaces on remote displays. There is also increasing interest in the use of portable displays. Smart Space can be used to simplify the process of configuring where the interfaces get displayed. By bringing equipment together at the same bed a user can ensure that all appropriate interfaces get displayed together; by then subsequently moving to another screen in another part of a hospital the user could see the same configuration of interfaces. Applications like this require very accurate location, in real time, integrated with equipment and display protocols.

Workflow. Ambulatory care hospitals are designed to maximize the throughput of elective surgical patients. This can be aided by workflow management systems that monitor process flow within the building. But these systems typically require user intervention to assert that certain physical events have occurred (e.g. patient X is now in the recovery room) – this user intervention tends to be forgotten in the heat of the moment, leading to incorrect operation of the workflow system. Smart Space can solve this problem by automatically detecting physical events without any user intervention. Applications like this require very accurate location, in real time, typically integrated with 2 way communications.

EPR generation. Creation of records is a time-consuming job for medical staff, and one which frequently occurs some time after the event. Smart Space can simplify this problem by detecting interactions between staff, patients and equipment and thereby creating skeleton records for the medical staff to fill in later. Applications like this require very accurate location, in real time, integrated with equipment.

Summary of application requirements

The table below contains the collated requirements for all the applications described above. A requirement for 'Average' performance in the given category is represented by 'x'; 'Good' is represented by 'xx'; 'Very good' is represented by 'xxx'.

		Small tags	Long life tags	Accuracy	Real time	Comms	Programming
Patient Monitoring	**Find patient**	xx		x			
	Page nearby staff	xx		xx	x	xx	
	Film patient	xx		xxx	xxx		xx
Asset Management	**Find asset**	x	xx	x			
	Detect use	x	xx	xxx	xxx		xx
	Page when free	x	xx	xxx	xxx	xx	xx
Smart Space Applications	**Configuration**	xx	xx	xxx	xxx		xx
	Workflow	xx	xx	xxx	xxx	xx	xx
	EPR	xx	xx	xxx	xxx		xx

Measuring the Systems by Application Requirements

The table below shows how the individual systems measure up to the requirements created by the applications described above.

There are some important points to note:

- Tag size and battery lifetime are important. Failure to reach suitable standards on these categories can make a tagging system unusable for any application.
- 'Average' levels of asset location (to around 3m) can be valuable for simple 'finding' applications. But there is not a great deal of value in locating assets above a certain level of precision, especially if you do not know whether or not the asset is in use.
- There are lots of valuable applications for Smart Space but they need more than just location: without real time response, communications from and to the tag, and simple programming and integration, it is hard to implement Smart Space applications.

		Prox. Cards	802.11	Bluetooth	Ded. RF	Uni. UWB	Ubisense
Patient Monitoring	Find patient			x	x	x	x
	Page nearby staff			x	x*	x*	x
	Film patient						x
Asset Management	Find asset				x	x	x
	Detect use						x
	Page when free						x
Smart Space Applications	Configuration						x
	Workflow						x
	EPR						x

* when used with a separate paging system

Ubisense is the only RF tag system available that enables Smart Space. This is because Ubisense is the only system to combine high accuracy with real time performance, 2-way tag communications and simple support for programming and integration.

Summary

There are many RF tagging technologies available today that add a certain amount of location capability to the basic identification facilities offered by swipe cards and low-range proximity cards.

The obvious application for such technologies is in locating assets and people. But such applications place other requirements on the tracking technology, such as long battery life or integration with paging, and some available technologies do not measure up event to those requirements.

Moreover the future of location technology is not in low-value applications such as asset tracking, it is in creating high-value Smart Space applications and environments that deliver multiple benefits to users by enabling software to interact with the real world.

These applications require real-time, high accuracy location, support for tag communications, and platform and tool support for programming and integration.

Low accuracy, non-real time, hard-to-integrate systems may meet some of today's location demands but such systems severely limit the range of applications which can be implemented, and hence the benefits that can be delivered to users.

Ubisense is the only system that combines the right underlying tracking technology with a complete package of platform, tools and integration support, to deliver systems that extend without limit to provide ever-increasing levels of benefit for customers.