Whitepaper

Real Time Location Systems – WiFi or BLE

Real Time Location System (RTLS) technology is delivering significant benefits in many healthcare settings. Next generation RTLS systems, along with wide scale deployment of smart devices, present challenges and exciting opportunities. RTLS systems are increasingly finding a place in healthcare enterprise technology strategies.

Rauland AUSTRALIA

A new perspective on care.

Executive Summary

This white paper lays out the key considerations that a health care information technology executive needs to be aware of when selecting a real time location system for health care use. While narrowing the technology platform to WiFi or Bluetooth Low Energy (BLE) based solutions, the paper presents an in-depth review between the two and makes the case for selecting a BLE solution based on a cost per outcome comparison.

Globally, healthcare organisations are under continuous pressure to deliver excellent clinical outcomes while utilising minimal resources. Efficient use of capital and operational budgets is of the highest importance for a sustainable clinical care organisation. The intelligent use of technology is a significant point of leverage which healthcare leadership teams are striving towards.

Many clinical care organisations are looking to (RTLS) to boost staff and patient safety, save staff precious time in locating critical equipment, enhance clinical care outcomes, and increase medical device utilisation.[2, 5]

Overall, RTLS use cases in healthcare can be summarised into the following categories:

- Personal safety or duress
- Patient tracking
- Asset tracking
- Staff tracking

Clinical care organisations generally look for the following benefits when deploying an RTLS solution:

- Higher return on investment for medical equipment, through increased utilisation and elimination of lost equipment
- Robust contact tracing of patient and staff members during outbreak events
- Workflow automation tied to staff presence
- Patient and visitor wayfinding
- Higher utilisation of nursing staff time, as less is spent locating critical assets

Research shows that many healthcare RTLS projects fail to deliver the expected outcomes and have faced significant adoption challenges.[4, 6]

There are a variety of technologies discussed in conjunction with location services, some of which can be used to enable RTLS. These include WiFi, Bluetooth (including BLE), ultra-wide band (UWB), radio frequency identification (RFID), sonar, visual, magnetic field strength fingerprinting, infrared, near-field communication (NFC), and ZigBee. Many of these technologies have great theoretical promise, with significant practical drawback to their successful implementation in the real world environment. After a thorough review is undertaken, most organisations find themselves looking at a choice between a (BLE) or a WiFi based solution.

Open standards for RTLS do not exist. This has led to many RTLS deployments that fulfil a certain limited use case but are not suitable as part of an economical enterprise-wide strategy. Other RTLS deployments have focused on designing an overarching service definition for location aware applications, only to lack the flexibility to meet the evolving needs of next generation use cases.

A BLE approach to solving the healthcare RTLS puzzle is emerging as a winning choice. As this paper will explain in more detail, BLE for RTLS enables flexibility in deployment options, great interoperability with existing infrastructure investments, lower capital and operational costs and superior full-lifecycle costs when compared to other solutions.

This paper outlines the key considerations decision makers need to review when making a healthcare RTLS investment. This is followed by a comparison between the WiFi and BLE approaches, then highlights some advantages for a BLE approach.

Components of an RTLS Solution

WiFi Solutions

Wireless Access Points – Fixed infrastructure components that interface between the wired and wireless network; provide low level data needed to compute location

Accuracy Augmentation Devices – Additional hardware devices needed to enhance accuracy

Location Tags – Battery powered location targets

BLE Solutions

Location Tags – Battery powered location targets

Bluetooth Sensors – Fixed location infrastructure that listens for specific Bluetooth devices and sends digital messages to the targeted devices.

Considerations

Investment decision makers can group their considerations into the following groups: RTLS Design, RTLS Equipment Lifecycle and RTLS Operational Approach.

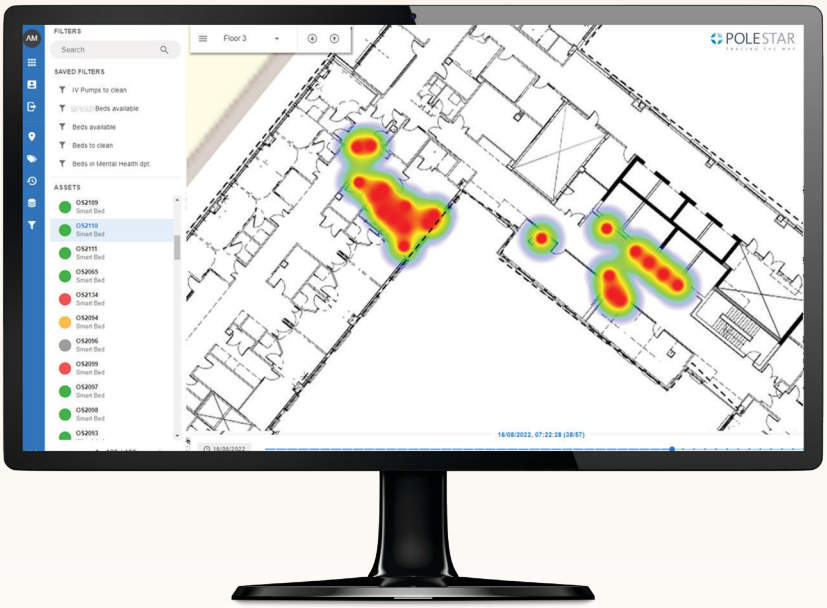
Design Considerations

Electromagnetic Interference: The healthcare operational environment has a wide variety of equipment that either emits or is sensitive to electromagnetic waves. This includes critical care therapeutic devices such as cardiac pacemakers. The choice of RTLS equipment must neither interfere with nor be disrupted by other equipment, including devices patients or relatives are likely to carry.

Infrastructure Equipment: Equipment for the RTLS solution needs to be cost effective, reliable, and easy to install and manage. The clinical needs of a specific care location are likely to change over time as the needs of the patients served by the facility change. These changes are unlikely to coincide with existing capital budgets for IT infrastructure. An RTLS approach that enables location accuracy to be increased in specific clinical locations for minimal additional costs, is essential for long term success.

Special consideration should be given to adding RTLS to a brown-field site with existing BLE compatible devices such as smart locks, wireless access points and multi-sensors. The RTLS equipment vendor selected should have a demonstrable track record of interoperability to ensure the existing investment can be leveraged.

Equipment Transmission Power: All other things being equal, lower powered equipment is preferred. Low power equipment is less likely to interfere with other equipment, is more cost effective to operate, and if battery powered, require fewer batteries.



RTLS asset tracking:
This image shows a real-world example of RTLS asset tracking in a healthcare setting. The hot spots in the image show where the asset has spent significant amounts of time.

RTLS Solution Accuracy Classifications in a Clinical Setting

Floor – a target is anywhere on a given floor
Ward – a target is somewhere within a specific care ward
Area – further specificity to an area within a ward
Room – a target is known to be in a specific care delivery room
Subroom – the system can differentiate between different areas in a specific room, such as in the bed, in a chair, or in the ensuite

Battery Life: RTLS solutions typically use battery powered tags for locating targets and some solutions augment fixed (wired) infrastructure with battery powered equipment for enhanced location accuracy. Battery life expectations for mobile tags should be several years and for beacon infrastructure, battery life approaching a decade should be the target.

Device Form Factor: Equipment and personnel (both staff members and patients) will likely end up with location tags attached, so it is important that aesthetics and utility are considered. For patient tags, the logistics around assignment and infection control should be factored in.

System Scalability: Within a clinical care facility, specific care needs evolve over time as patient populations change and variations in clinical conditions occur. The RTLS solution should be able to scale up without the need for costly infrastructure upgrades.

Building Materials: The types of building materials in place will have a significant impact on the RTLS solution. In general, older building materials absorb electromagnetic waves much more readily. Building materials also come into play when we consider the future technologies that are likely to be deployed. Newer wireless networking technology like sub-millimetre 5G is more likely to be attenuated by walls, leading designers to value flexibility and use diverse technologies to meet evolving needs.

Equipment Lifecycle Considerations

Infrastructure Capital & Deployment: When selecting equipment for an RTLS solution, it is important to consider both the capital cost of the equipment itself and the deployment costs, such as installation labour and interruption to clinical service during installation activities. Since clinical use cases often evolve more quickly than capital budget allocations, retrofit costs to uplift location accuracy should also be considered.

Electrical Cabling: In addition to capital costs for equipment, the costs for cabling and use of shared networking infrastructure such as switch ports should be considered.

End of Life Costs & e-Waste: A wholistic consideration of factors must include a provision for dealing with decommissioning of equipment. RTLS solution equipment with a longer life span generates less e-waste. Equipment with life spans exceeding one decade is becoming more accessible and represent a wiser choice.

Operational Considerations

Infection Control: With any system that will be deployed in a patient care setting, infection control is a key consideration. System components that come into contact with patients, visitors, or care team members should meet the infection control standards with respect to cleaning and disinfection, or be designed to be single-use and disposable.

Integration with Other Major IT Investments: RTLS solutions must fit in well with an organisation's overall IT investment strategy to be successful over time.

Location Accuracy: Accuracy targets are usually broken down along the following: floor, ward, area, room, subroom. These requirements are likely to vary from one clinical location to another based on care needs. The key operational consideration is around how to classify these needs and adjust to changing requirements over time.

WiFi & BLE Comparison

WiFi based, and BLE based RTLS solutions are the most popular choices available in the healthcare sector. As such, we'll compare WiFi and BLE from several perspectives.

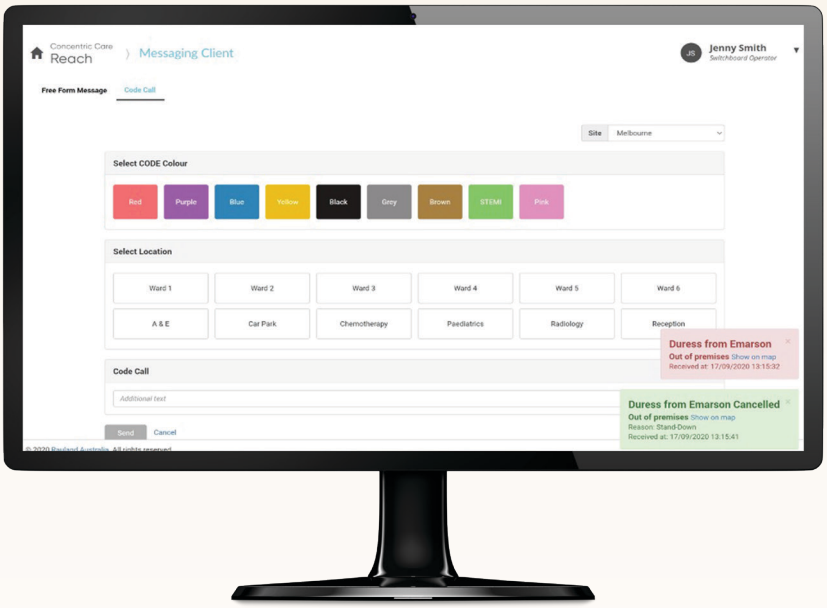
Accuracy

The accuracy of the RTLS solution is critical to the successful adoption of the solution. Many post-implementation interviews with clinical users of RTLS solutions, remark on poor accuracy leading to poor outcomes and lack of trust in the system.[4,6] It is also likely that the accuracy requirements of an RTLS system are likely to change over time as the facility's clinical case mix changes and new location aware use applications are deployed.

Both WiFi and BLE RTLS systems are capable of subroom accuracy. WiFi based solutions either need to be augmented with additional types of devices to achieve room level accuracy, or a cost-prohibitively high number of wireless access points must be deployed. WiFi based systems that are not carefully considered can run into significant accuracy problems, especially misidentifying the floor that an RTLS target is located on.

BLE based RTLS systems rely on fixed location BLE sensors. These use well known standards such as iBeacon or Eddystone and can be dedicated devices powered by structured cables, built into other infrastructure devices (such as wireless access points) or battery powered.

BLE based RTLS solutions can achieve Subroom level location accuracy at lower price points and lower operational management burdens when compared to WiFi based approaches.



Concentric Care Command Centre:
A view of the Concentric Care Command Centre with real time alerts for RTLS events in the bottom right. Clinicians preserve situational awareness whilst using the Command Centre.

WiFi & BLE Comparison

Latency

Latency is the measure of time between a location tag movement and the location change is then reflected in the system. Most systems have configuration options that can impact latency by controlling the transmission or polling intervals. This configuration setting trades latency for battery life or energy usage.

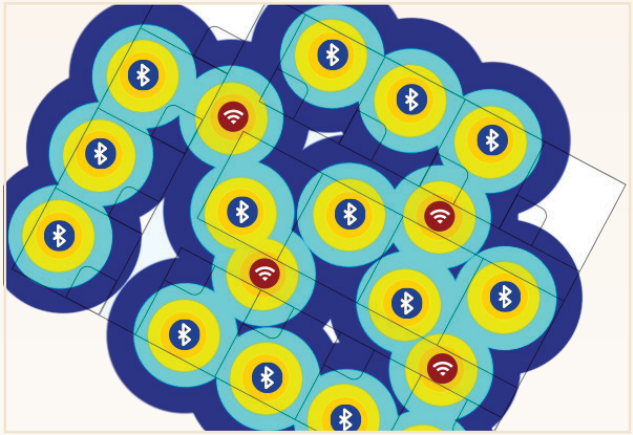
WiFi solutions without accuracy augmentation devices typically have a latency greater than one minute. WiFi solutions with accuracy augmentation devices measure latency results in under 15 seconds. BLE based solutions with optimised settings, can also reach 15 second latency.

WiFi based solutions are generally computationally heavy as they do all the computational analysis at a central processing node. BLE solutions on the other hand, have the capability of using a decentralized computational model for some use cases to calculate location, leading to lower latency and lower centralised compute costs.

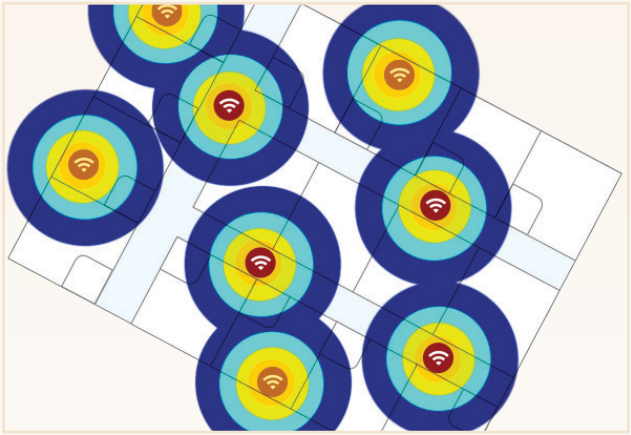
Tag Battery Life

Location tags are battery powered and effective management of location tags is a key part of successful RTLS implementations. The graphics on the following page include images of several location tags.

WiFi uses significantly more power than BLE. WiFi tags generally have a battery life of less than 10 weeks, whereas many BLE tags are available that have a battery life of several years.



Solutions deployed using BLE:
BLE based location can afford to place sensors where ever needed to achieve optimal location for RTLS. Cost is far reduced, and installation and management is simplified.



Solutions deployed using WiFi only:
WiFi access points are typically installed only in corridors, which *cannot* provide room level accuracy. Adding many more WiFi access points at the edges of the facility as required for RTLS to be accurate, is extremely costly.

WiFi & BLE Comparison

Types of WiFi Accuracy Augmentation Hardware

- Infrared Sensors
- Low-Frequency Exciters or Low-Frequency Choke-Points
- Sonic Sensors

Infrastructure Density

RTLS solution accuracy is heavily dependent on the density of infrastructure devices. WiFi based systems without augmentation hardware generally have the lowest infrastructure density but suffer from low accuracy. BLE based systems require slightly more (lower cost) infrastructure devices than standard WiFi, to achieve room or subroom accuracy. Finally, WiFi devices with accuracy augmentation hardware require both the highest number and widest variety of infrastructure devices.

In addition to higher costs, the increased infrastructure density requirements of WiFi based solutions leads to issues with WiFi RF channel contention. This is exacerbated by the need to run WiFi access points used for RTLS systems at fixed and high transmission power states. The use of automated power levels in wireless access points generally must be disabled for use with RTLS solutions, resulting in performance impacts in certain situations, such as real time communication (VoIP and video conferencing). High density WiFi access point deployments struggle to achieve economical use of the WiFi RF spectrum.

Infrastructure Interoperability

Interoperability between equipment from heterogeneous vendors is an important way to achieve cost savings, and generally leads to better solution outcomes.

Android Clinical Mobile Device

Android Clinical Mobile Device – has both WiFi and BLE capabilities. Using BLE means WiFi is required less, and device power use is less

Battery powered BLE sensor

BLE sensor – with multi year battery life

BLE based location tag

BLE based location tag – lifetime ~ years without battery change

WiFi solutions without augmentation hardware can interoperate with location tags made by different vendors. When accuracy augmentation hardware is added to the WiFi solution, interoperability is sacrificed – because endpoint devices require additional (and often bespoke) sensor equipment. BLE is a clear winner when it comes to interoperability as a wide variety of compliant BLE tags from different vendors are available. BLE has the added benefit of many network vendors including compliant BLE beacons in their wireless access point devices.

WiFi only deployments suffer from interoperability challenges unless homogeneous hardware procurement is strictly enforced. This also leads to vendor lock-in and decreased flexibility.

Leveraging the BLE sensors built into wireless access points leads to vendor interoperability.

Prospective network equipment vendors should have a demonstrable track record of supporting customers regardless of networking infrastructure choices.

Cost

BLE has clear cost benefits, that can be broken down into capital and operational expense areas.

Capital expense is lessened with the BLE approach as less hardware is needed to achieve the required accuracy levels. BLE RTLS hardware can achieve service lifespans exceeding a decade. BLE hardware is easy to retrofit into an existing deployment with reduced switch port needs, reduced structured cabling needs, and excellent battery powered beacon options. Battery powered BLE beacons can reach decade long battery life, and are therefore much more energy efficient, leading to less tag and battery waste. The benchmark for BLE location tag battery life is 4 years.

BLE RTLS solutions have lower operational expenses due to reduced operational complexity of a single type of technology (BLE beacons) available in multiple reliable formfactors for the operational team to manage. Additionally, the extreme energy efficiency of BLE technology leads to less operational cost for power and less management overhead for battery replacement.

Comparison Table

Overview	WiFi (stand-alone)	WiFi (w/accuracy augmentation)	BLE
Accuracy	Ward / Area	Room / Subroom	Room / Subroom
Latency	High	Low	Medium
Tag Battery Life	Short	Short	Long
Infrastructure Density	Medium	High	Medium
Infrastructure Interoperability	Medium	None	Good
Cost	$$	$$$	$
Energy Efficiency	Low	Low	High
Scalability / Ease of Extension	Medium	High	Low

Key Advantages of BLE for Healthcare RTLS

Single Device Strategy – User Experience

Modern healthcare technology platforms should be focused on user experience to support improved clinical outcomes. Users have an expectation that technology platforms used in the delivery of clinical care will be integrated, providing a seamless user experience. A single mobile device that powers a clinician's digital workflows is the expectation for a modern workforce.

Using a BLE based RTLS system is a particularly good approach for organisations that are pursuing a single device strategy, in which users are encouraged to run as many functions as possible from a smartphone form factor device. Since there are good low level standards (such as iBeacon and Eddystone) for device agnostic location services on top of BLE, and BLE has superior energy usage characteristics, the single device issued to staff members can have many location enabled apps running on it efficiently and can also serve as a location tag, to be tracked by the RTLS solution.

Optimisation of WiFi Investment

WiFi access points are usually deployed in corridors and open spaces – with rooms within the facility running parallel or adjacent, to gain the best possible coverage and availability for users. This is very effective for wireless networking return on investment; however, this approach can adversely impact the accuracy of WiFi based RTLS solutions. To address this deficiency, additional WiFi access points need to be deployed into each room. Doing so presents significant additional expense.

Flexible Applications

Unlike technologies wholly reliant on WiFi networks for location services, BLE utilises standard protocols that are widely available in devices such as mobile phones, healthcare compatible smart phones, wristbands, ID badge like tags and waterproof tags that can be attached to equipment.

This has resulted in a widespread variety of manufacturers providing differing BLE tags and devices suitable for adding value, safety, and efficiency in the healthcare environment. The microform factor of BLE chips and their highly efficient power consumption supports many use cases.

Many consumer products contain BLE compliant hardware, such as smart phones, smart watches and even televisions. The same BLE beacons deployed for clinical purposes can be leveraged for other applications, such as tracking of areas attended to by cleaning contractors, and patient wayfinding (using their own device).

Battery Life

BLE was designed with minimised battery and energy consumption at front of mind – the technology uses a tiny amount of energy in comparison to WiFi (802.11) networking technologies. This design means that small form factor tags used on assets, equipment, and wristbands are highly efficient with battery life that is fit for purpose. Additionally, the use of BLE reduces the battery consumption on smart devices and wireless telephones – CPU usage times are shorter, WiFi radios are not active as often and the net result is that there is a negligible impact on battery life on handsets when delivering critical solutions like duress, using BLE. Power usage for mobile devices is drastically less for BLE based solutions, saving batteries and tag lifetime. Extended battery life also decreases the amount of battery waste produced and lowers the operational burden of replacing batteries.

Deployment Efficiency & Cost Reduction

BLE sensors eliminate the need for high density WiFi and dedicated structured cabling back to Power over Ethernet switches for many use cases. Therefore, additional network switch ports and related licencing for this infrastructure is not required. BLE beacons that are deployed in individual rooms and areas requiring increased accuracy for location services, are an affordable and effective technology innovation that reduces the overall total cost ownership, as wireless access point densities do not need to be increased to achieve granular location services.

This has further positive impacts in relation to ongoing costs including refresh cycles, power consumption, and WiFi management. The level of reliance on the WiFi network for life critical services such as mobile duress is also greatly reduced.

Building and network infrastructure investments are expected to provide value over long periods of time and changing the deployed design can be extremely costly. The use of inexpensive battery powered BLE hardware for RTLS is a game changer when it comes to deployment flexibility. Battery powered BLE devices allow for targeted use of RTLS solutions without a network redesign or uplift, and without the need to perform capital works.

BLE can stand alone to a WiFi deployment, meaning that flexibility in relation to WiFi vendor, access point model, or change in vendor for commercial or other needs can be completed without adversely impacting the RTLS solution.

Healthcare workers at risk require highly accurate and responsive location services that can be delivered across a wide range of devices including location tags and mobile devices - both corporate and personal. BLE technology can empower facilities to deploy these solutions promptly, and to any worker with a smartphone.

Conclusion

When selecting an RTLS solution, the decision of which technology platform to build upon will have a significant impact on the success of the initiative. BLE based RTLS systems can better enable a seamlessly connected and care focused workforce through the support of a wide range of end user devices. BLE based RTLS systems are easier to fit into a dynamic enterprise technology strategy because they provide granular RTLS coverage in a wider variety of situations, with less whole of life management complexity. BLE based RTLS systems are less costly to purchase, install, expand, and maintain, as they have lower capital costs, require less network cabling, and have a lower impact on network infrastructure. The flexibility, cost effectiveness and openness of BLE based RTLS solutions makes them the clear winner for use in a healthcare environment.

References

1. Asaad, Safar M., & Maghdid, Halgurd S. (2022). A Comprehensive Review of Indoor/Outdoor Localization Solutions in IoT era: Research Challenges and Future Perspectives. Computer Networks, 212 (2022) 109041. doi: 10.1016/j.comnet.2022.109041
2. Shen, Lester & Sui, Di & Plum, Christopher & Kirk,. (2020). WiFi LOCATION-BASED SERVICES (LBS) FOR OCCUPANCY SENSING IN BUILDINGS: A TECHNICAL OVERVIEW Center for Energy and Environment WiFi Location-Based Services (LBS). 10.13140/RG.2.2.25469.31204
3. Pancham, J., Millham, R., & Fong, S. J. (2017). Evaluation of Real Time Location System technologies in the health care sector. 2017 17th International Conference on Computational Science and Its Applications (ICCSA). doi:10.1109/iccsa.2017.7999645
4. Fisher, J. A., & Monahan, T. (2012). Evaluation of real-time location systems in their hospital contexts. International Journal of Medical Informatics, 81(10), 705–712. doi:10.1016/j.ijmedinf.2012.07.001
5. Kamel Boulos, M. N., & Berry, G. (2012). Real-time locating systems (RTLS) in healthcare: a condensed primer. International Journal of Health Geographics, 11(1), 25. doi:10.1186/1476-072x-11-25
6. Bazo, R., da Costa, C. A., Seewald, L. A., da Silveira, L. G., Antunes, R. S., Righi, R. da R., & Rodrigues, V. F. (2021). A Survey About Real-Time Location Systems in Healthcare Environments. Journal of Medical Systems, 45(3). doi:10.1007/s10916-021-01710-1