2023

Efficacy of Novel BLE Porter Tracking Systems Used in Conjunction with Hospital Freight Drones

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1 Introduction

1.1 Abstract

Hospital porter tracking systems are electronic systems that allow hospitals to track and monitor the movement of their porters who are responsible for moving patients, equipment, and supplies throughout the hospital. These systems provide hospitals with real-time information about the location and status of their porters, allowing them to optimize workflow, reduce wait times, and improve patient care. This paper will examine the benefits and challenges of hospital porter tracking systems, the technologies used in these systems, and the best practices for implementing and maintaining them.

1.2 Introduction

Hospital porter efficiency is important because hospital porters play a critical role in ensuring the smooth functioning of healthcare facilities. Porters are responsible for the safe and timely transportation of patients, medical equipment, and supplies within the hospital. They are also responsible for maintaining the cleanliness and hygiene of patient care areas.

Efficient porters ensure that patients, staff, and equipment move quickly and smoothly throughout the hospital, minimizing delays and disruptions. This helps to reduce wait times for patients, which is essential for providing timely and effective healthcare services. Efficient porters also help to ensure that medical equipment and supplies are available where and when they are needed, reducing the risk of medical errors and improving patient outcomes.

In addition, efficient porters contribute to the overall productivity of the hospital by freeing up clinical staff to focus on patient care. When porters are able to complete their tasks quickly and efficiently, they are able to support the

work of other healthcare professionals, allowing them to focus on their core responsibilities.

One of the primary benefits of hospital porter tracking systems is that they allow hospitals to optimize workflow and reduce wait times. By monitoring the location and status of their porters, hospitals can ensure that patients, equipment, and supplies are moved quickly and efficiently throughout the hospital. This can help to reduce wait times for patients and improve the overall quality of care [1].

Another benefit of hospital porter tracking systems is that they provide hospitals with valuable data that can be used to improve operational efficiency. By analyzing data on porter movements and workload, hospitals can identify bottlenecks in their workflow and make changes to improve efficiency. This can help to reduce costs and improve patient outcomes.

1.3 Literature Review

A study by Khadka et al. [2] examined the use of radio frequency identification (RFID) technology to track hospital porters in a tertiary care hospital in Nepal. The study found that the use of RFID technology improved the efficiency of porter operations by reducing wait times for patients and improving the availability of medical equipment and supplies.

Similarly, a study by Ali et al. [3] investigated the use of a real-time location system (RTLS) to track hospital porters in a large public hospital in Pakistan. The study found that the implementation of the RTLS system led to a significant improvement in porter efficiency, with a reduction in the average waiting time for patients and an increase in the availability of medical equipment and supplies.

Another study by Wang et al. [4] evaluated the use of an indoor positioning system (IPS) to track hospital porters in a Chinese hospital. The study found that

the IPS system improved the efficiency of porter operations by reducing the time needed to transport patients and medical equipment, as well as reducing the number of lost or misplaced items.

In a study conducted by Kondaveeti et al. [5], a novel tracking system was proposed which used Bluetooth Low Energy (BLE) beacons to track the location of hospital porters in real-time. The system was tested in a tertiary care hospital in India and was found to be effective in improving porter efficiency and reducing wait times for patients.

However, it should be noted that the implementation of hospital porter tracking systems may face some challenges. In a study [6], it was found that the implementation of a tracking system in a hospital faced some technical and organizational challenges, such as the need for additional staff training and the need to ensure patient privacy.

Hospital porter tracking systems, such as RFID, RTLS, IPS, and BLE systems, have shown promising results in improving hospital porter efficiency and reducing patient waiting times. While challenges may arise during the implementation process, the benefits of such systems make them a worthwhile investment for hospitals seeking to improve their operations.

These studies are however limited in that they do not study a porter task allocation system in combination with the use of hospital freight delivery via drones. Hospital freight drones are important to healthcare services to deliver limited supplies quickly such as blood.

Drones are more environmentally efficient for delivery due to several reasons. First, they are powered by batteries that produce zero emissions during flight, unlike traditional delivery vehicles that typically use gasoline or diesel fuel [7]. This means that drones have a much lower carbon footprint than traditional

delivery methods [8].

Secondly, drones can be programmed to fly the most direct and efficient route, reducing the distance and time required for delivery. This can result in a significant reduction in fuel consumption and emissions compared to traditional delivery vehicles, which often need to navigate through traffic and make multiple stops [9].

Given the value that drones bring, it can be expected that over time, many hospitals will switch to a drone delivery solution [10] and as such, investigation of the interaction and importance of a porter task assignment system working with a drone delivery system is important to help gauge outcomes for investment.

2 Methodology

For our solution, porters will be tracked using BLE beacons, allowing optimal task assignment based on proximity and availability, so that there are no drones waiting to carry out deliveries. We also aim to make it as intuitive as possible for hospital staff to place a delivery request, in order to reduce patient waiting time. An administrator will have access to a web application to partially automatically assign tasks based on proximity. Below, we will describe how we come to the solution and our design decisions. Following this, we will describe briefly how we came about collecting results.

2.1 Frontend

We evaluated multiple popular frameworks during our frontend implementation and chose React [11] due to its high performance, active developer community, and familiarity to some team members. Our code structure emphasizes modularity and reusability with individual files for each page and reusable components like tables

and forms, reducing duplicate code and promoting consistency [12]. To receive real-time updates about porter locations and status, we utilized websockets and the react-stomp library [13, 14]. We coded the floor plan using Javascript and CSS, overlaying circular markers on each hospital floor image to represent porter, beacon, or delivery locations, and ensured the interactive map scaled correctly using percentage offsets and the 'calculateMarkerPosition' function. We further added functionality to our component to simplify the process of adding physical beacons and delivery locations. Our application allows adding and viewing beacons and locations, receiving real-time updates about porter locations and status, and monitoring deliveries on a scalable and interactive floor plan.

The main page of the final result is shown below:

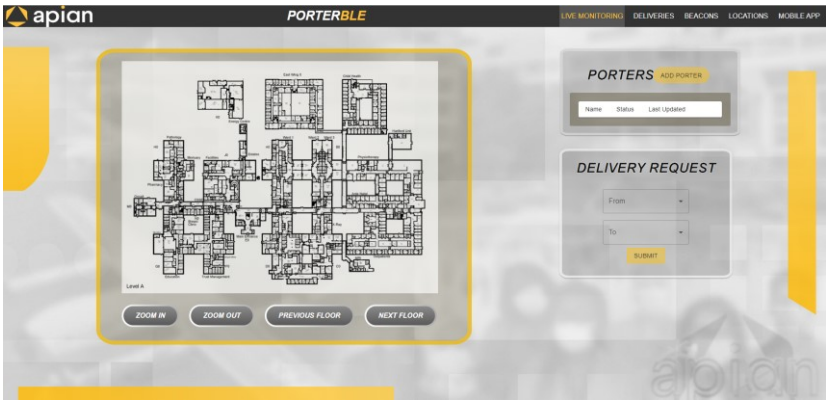

Figure 1 - The main page of our Administrator Web App

2.2 Backend

The backend implementation of the application uses Spring Boot framework, Google Cloud SQL PostgreSQL database, and was deployed using Google Cloud Run. To ensure well-structured code, the application used Spring Boot code structure and separated code into packages [15]. Twilio's messaging API and Firebase Cloud Messaging were integrated to provide real-time updates to porters and push notifications to users' mobile devices, respectively. Beacon pings were used to update a porter's location, and JPA's EntityListeners were used to send live

updates to the frontend via websockets. Cloud SQL PostgreSQL was used for the database, and REST API was implemented for CRUD operations. Authentication was done using OTP via SMS, and Cloud Run was used for deployment. Our choices of tech stack allowed us to build a robust and scalable backend system that processed real-time updates from the frontend accurately [16], we will not go into detail on the decision making that resulted in our choices nor how these technologies function here as this paper is primarily focused on the impacts of a tracking system when used in conjunction with drone freight systems.

2.3 Android App

The app's development began by selecting Kotlin as the programming language of choice, which is now the preferred language for developing Android apps due to its modern, static typing design that enhances the efficiency and accuracy of app development [17]. Kotlin's interoperability with Java proved advantageous for our system as we were able to use existing Java libraries, such as Firebase and Bluetooth Low Energy, while leveraging Kotlin's development features, such as extension functions and coroutines [18].

Since our mobile application required frequent HTTP requests to our backend API endpoint, we heavily relied on Kotlin's coroutine features and HTTP classes for multithreading capabilities. This allowed our application to concurrently run separate HTTP requests as needed.

Moreover, our system depended on Kotlin's BLE API to successfully identify nearby Bluetooth Low Energy beacons. This feature was essential for our solution.

The finished App is below:

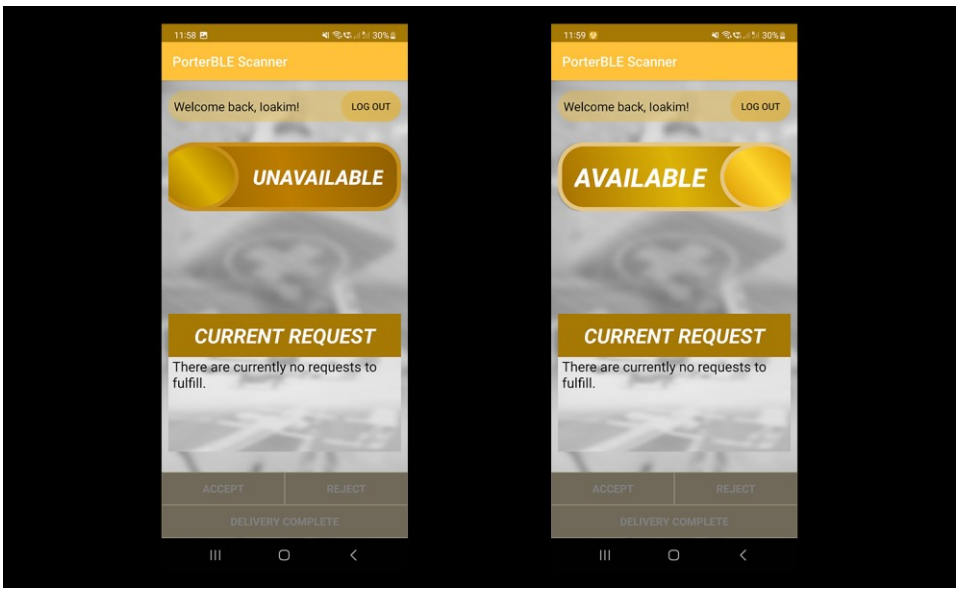

Figure 2 – The Post Login page of the Porter App

2.4 Result Collection

The porter tracking system was trialed in combination with drones at Wansbeck Hospital. During the testing phase of the porter tracking system, the porters were invited to use the application and provide feedback on its functionality, usability, and overall experience. The feedback sessions allowed the development team to identify and address any usability issues and make necessary changes to the application before deployment. We took the opportunity to interview several porters to generate qualitative results on our solution.

To interview porters, we operated on the following principles:

Recruitment: Participants should be chosen based on their experience and expertise relevant to the research question. For example, in this case, porters who have used the porter tracking system would be ideal participants.

Informed consent: Before starting the interview, participants should be informed about the purpose of the research, what their participation will involve, and how their data will be used. They should be given the opportunity to ask any questions they have and to withdraw from the study at any time.

Structured interview guide: The interviewer should have a structured

interview guide to ensure that the same questions are asked of all participants. The guide should cover topics relevant to the research question, and be flexible enough to allow for follow-up questions and probing.

Open-ended questions: The interview questions should be open-ended, allowing participants to provide detailed responses and express their opinions and experiences in their own words.

Neutral tone: The interviewer should maintain a neutral tone, avoiding leading questions or expressing personal opinions that could bias the responses.

Note-taking and recording: The interviewer should take notes during the interview to capture key points and quotes. With the participant's consent, the interview can also be audio or video recorded for later analysis.

Data analysis: The interviews should be transcribed and analyzed using qualitative data analysis techniques such as coding, categorizing, and theme identification. The analysis should be systematic and follow an established method to ensure rigor and accuracy.

3 Results

3.1 Results and Feedback

Once the system was being demonstrated in Wansbeck Hospital, the porters were able to experience any benefits firsthand.

Figure 3 - Interviewing Stuart, a Porter in Wansbeck Hospital who consented their image [19]

As set out in the methodology, we interviewed porters using the product to obtain feedback in order to perform qualitative analysis on the impacts of our product. In a hospital there are not many different porters working usually. In total, 23 different hospital porters were interviewed over the span of two weeks. In order to gather more data from more porters, we interviewed porters taking night shifts too.

Throughout the interviews, we noted down topics that were mentioned by porters and kept note of whether they were repeated by other porters.

We counted how many of the 23 interviews introduced the following topics:

Privacy concern: Porters were concerned about the privacy of the product and

how their location was being logged. Some porters in particular felt heightened sense of pressure to be working as they felt their mistakes and breaks were tracked.

Intuitive Usability: Porters appreciated the system's usability, particularly its intuitive UI.

Improved Efficiency: Porters reported that the system has made their work more efficient by providing a centralized location for tasks and assignments, reducing the need for manual check-ins, and prioritizing urgent tasks.

Less Overwhelming: Porters felt less overwhelmed as they were not being pinged repeatedly for all deliveries.

Beneficial Live Updates: Porters highlighted the benefit of real-time updates and notifications, which help them stay informed about changes to their assignments and tasks.

Other: Miscellaneous topics the porters highlighted which were not repeated

The count of topics is depicted in the graph below:

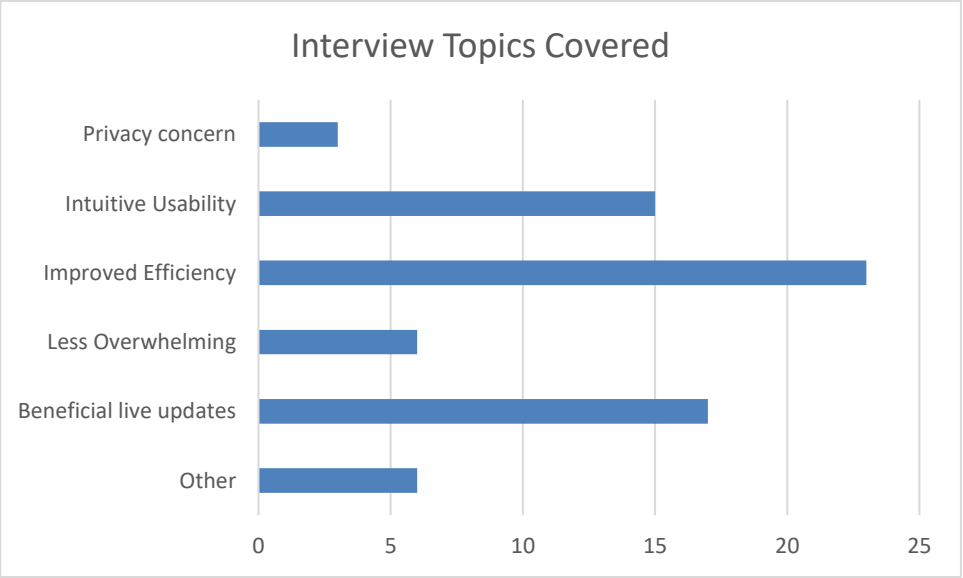

Figure 4 - Graph on Interview Topics mentioned by Porters

Overall, the qualitative analysis suggests that the porter tracking system

has been well-received by the porters, with the majority of feedback being positive. The system's features and functionalities were found to be useful and efficient. The real-time updates and notifications were particularly helpful, as they helped the porters stay organized and informed about their tasks and assignments.

The system provided porters with real-time updates on their assignments, eliminating the need for them to manually track their movements and reducing the likelihood of errors or delays. This resulted in improved efficiency and faster response times, which contributed to an overall increase in productivity and satisfaction among the hospital staff.

Moreover, the porter tracking system helped to ensure that the porters were dispatched to the correct location, which further enhanced the efficiency of hospital operations. By reducing the time and effort required to locate porters and assign tasks, the system allowed hospital staff to focus on their primary responsibilities and provide better patient care.

The large majority of porters mentioned that the service was intuitive and easy to use unprompted, a good indicator that the UI was designed well.

Further to this, one less expected benefit was that the solution benefitted Porter’s mental health. Porters were no longer being pinged for every single delivery and as a result felt more at ease and less overwhelmed with tasks. This was particularly noticeable for porters working in the day shift, when the hospital was more active and more patients were being taken in.

Finally, porters did raise a concern about privacy. In particular, they were concerned that the tracking of their mobile device would make it difficult for them to take breaks and they felt more pressure to perform well and without mistakes. It’s also suspected that more porters felt this way but did not raise the concern

due to worry that it would reflect negatively on their competence.

4 Discussion

4.1 Strengths

BLE (Bluetooth Low Energy) porter tracking systems are effective for several reasons. Firstly, they offer a reliable and cost-effective way of tracking hospital porters' movements and locations in real-time. BLE beacons emit a low-power signal that can be picked up by a smartphone or other device, allowing hospital staff to track the location of porters as they move around the facility [19]. This makes it easier for hospital administrators to manage their resources, optimize staff schedules, and improve patient care by ensuring that porters are available when and where they are needed.

Another advantage of BLE porter tracking systems is that they are highly accurate [20]. The beacons can be placed in specific locations throughout the hospital, and their signal strength can be adjusted to ensure that they only cover a specific area. This means that hospital staff can pinpoint the location of a porter to within a few feet, making it easier to track down hospital porters and prioritize nearby porters to ensure that tasks are assigned efficiently.

Finally, BLE porter tracking systems are also highly scalable [21]. They can be easily integrated with other hospital systems, such as electronic health records (EHRs), nurse call systems, and patient monitoring devices, allowing hospital administrators to create a comprehensive picture of the facility's operations. This makes it easier to identify inefficiencies, streamline workflows, and improve patient outcomes by ensuring that all hospital staff are working together effectively.

The effectiveness of BLE porter tracking systems lies in their reliability,

accuracy, and scalability, which make them an ideal solution for hospitals While BLE porter tracking systems have many advantages, there are also some potential weaknesses and disadvantages to consider.

4.2 Weaknesses

Signal Interference: BLE beacons operate on the same frequency band as other wireless devices, such as Wi-Fi routers and Bluetooth headsets. This can lead to signal interference and cause inaccuracies in the tracking data [22].

Privacy Concerns: BLE tracking systems raise concerns about privacy since they continuously collect data about a person's location. Hospitals must ensure that the tracking data is securely stored, and that patients and staff are informed about how their data is being collected and used.

Initial Investment: Implementing a BLE tracking system can require a significant upfront investment in equipment and software. Hospitals must also train staff on how to use the system, which can add to the cost.

Maintenance and Battery Life: BLE beacons require regular maintenance and battery replacement, which can be time-consuming and costly.

Limited Range: BLE beacons have a limited range, typically up to 100 meters. This means that if a porter moves beyond this range, their location will no longer be tracked [23].

Integration with Existing Systems: Integrating a BLE tracking system with existing hospital systems can be challenging, particularly if the systems were developed by different vendors or are not compatible with one another.

While BLE porter tracking systems offer many benefits, it is important to consider these potential weaknesses and disadvantages before implementing

them in a hospital setting. Hospitals must carefully evaluate their specific needs and ensure that the benefits outweigh the costs and limitations of the system. looking to improve their operations and provide better patient care.

5 Conclusions

5.1 Closing Thoughts

There are several reasons why hospitals are increasingly considering the use of drone delivery for medical supplies and equipment:

Speed: Drone delivery can be much faster than traditional ground transportation, particularly in areas with heavy traffic or difficult terrain. This can be critical in emergencies when time is of the essence.

Cost: Drone delivery can be less expensive than traditional transportation methods since it requires less labor and infrastructure. This can help hospitals save money on transportation costs, which can be significant.

Efficiency: Drones can carry medical supplies and equipment directly to their destination without the need for intermediate stops or transfers. This can help reduce the risk of damage or loss and improve overall efficiency.

Accessibility: Drones can reach remote or hard-to-reach areas that may be difficult or impossible to access by traditional transportation methods. This can be particularly important in disaster areas or other emergency situations.

Environmental Impact: Drones are generally more environmentally friendly than traditional transportation methods since they use less fuel and produce fewer emissions. This can help hospitals reduce their carbon footprint and contribute to a more sustainable future [24].

Overall, the speed, cost-effectiveness, efficiency, accessibility, and

environmental benefits of drone delivery make it an attractive option for hospitals looking to improve their supply chain management and provide better patient care. As drone technology continues to improve and regulations become more favorable, we can expect to see more hospitals shift towards drone delivery in the coming years.

5.2 Recommendations for Extension

Completely automate delivery request system without the need of staff to manually create a request: One of the advantages of using BLE porter tracking systems in hospitals is that they can help automate the delivery request process. Instead of having staff manually create delivery requests, the system can automatically generate requests based on real-time data on the location and availability of porters. This can help reduce the workload of staff and ensure that requests are fulfilled in a timely and efficient manner.

Emergency request. Be able to override current request so porters can now prioritize emergency request: In some cases, it may be necessary to override a current delivery request in order to prioritize an emergency request. BLE porter tracking systems can help facilitate this process by providing real-time data on the location of porters and the urgency of different requests. This can help ensure that emergency requests are given priority and fulfilled as quickly as possible.

More accurate live monitoring of porters. This may only be achieved if and only if privacy measures have been considered: One of the potential benefits of BLE porter tracking systems is that they can provide more accurate live monitoring of porters. This can help hospital staff better understand how porters are being utilized and identify areas for improvement. However, it's important to

consider privacy concerns when implementing these systems. Hospitals should ensure that any tracking systems are designed with privacy in mind and that patients and staff are aware of how their data is being used. This can help ensure that the benefits of tracking systems are realized without compromising privacy and security.

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Appendix

Sample Interview transcripts:

Interview 1:

Interviewer: Can you tell me your thoughts on the new porter tracking system?
Porter: Yes, I really like it. It makes it much easier to keep track of where I am supposed to go and what I am supposed to do.
Interviewer: What do you think are the most significant benefits of using this system?
Porter: I think the biggest benefit is that I don't have to spend as much time trying to figure out where I need to go. The system tells me exactly where I need to be, so I can just focus on getting there as quickly as possible.
Interviewer: Are there any features of the system that you find particularly helpful?
Porter: I really like the real-time updates. It's nice to know when there are changes to my schedule or if there are any urgent tasks that need to be completed.
Interviewer: Is there anything that you think could be improved about the system?
Porter: Honestly, I think it's pretty great as is. I can't think of anything that needs to be changed.

Interview 2:

Interviewer: How do you feel about using the new porter tracking system?
Porter: It's been really helpful. I think it's made my job a lot easier.
Interviewer: Can you give me an example of how the system has made your job easier?
Porter: Sure. Before, I would have to constantly check in with dispatch to see if there were any new tasks that needed to be done. With the system, I can see all of my assignments in one place, so I know exactly what needs to be done and when.
Interviewer: Are there any features of the system that you particularly like?
Porter: I really like the messaging system. It's a lot easier to communicate with dispatch and other porters now that we have a centralized messaging platform.
Interviewer: Is there anything that you think could be improved about the system?
Porter: The only thing I can think of is that the app could be a bit faster. Sometimes it takes a while to load, which can be frustrating when I'm in a hurry. But other than that, I think it's a great system.

Interview 3:

Interviewer: What do you think of the new porter tracking system?
Porter: I really like it. It's much easier to keep track of my tasks and where I need to be.
Interviewer: Have you noticed any changes in your workflow since the system was implemented?
Porter: Yes, definitely. I feel like I'm able to work more efficiently now that I have a better understanding of what's expected of me.
Interviewer: Are there any specific features of the system that you find particularly useful?
Porter: I really like the GPS tracking. It's helpful to have a visual representation of where I am and where I need to go.