Bluetooth Low Energy (BLE) technology for asset tracking – application in manufacturing industry.

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ABSTRACT

In post covid scenario where remote working is the new normal digitalization and use of IoT is the need of the hour. In most manufacturing environment now focus will be to increase the competitiveness and productivity. Optimum use of men and material requires improved production/assembly line management and information about location of resources. Automatic asset tracking in production/assembly line empowers manager to take data driven decisions. Bluetooth Low Energy (BLE) is one such technology for effectively monitoring resources movement and improving performance and safety of production/assembly line.

Since BLE technology is not popular in manufacturing environment the aim of the study is to prioritize most critical waste in production/assembly line and showcase the use of BLE technology for asset tracking. A framework is proposed to leverage the technology and to reduce the waste

Keywords

Lean manufacturing, gateway, Bluetooth Low Energy (BLE), waste, indoor positioning, asset tracking

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Introduction

Production/assembly line involves various operations relate to material handling. Improving production efficiency is always the priority. Right material in the right quantity at right workstation can help in improving the efficiency. Lean concept is widely accepted principle for removing waste.

Asset tracking is important for management of data in a production environment. Recently advancement in technologies is shift focus from manual tracking of assets to automatic asset tracking which can help in reducing waste and cost.

There are many Indoor positioning system (IPS) technologies available to track the indoor location information like GPS, BLE, Wi-Fi. Each technology has it own advantage and disadvantage.

Various wireless technologies are available for indoor asset positioning. Technologies like Radio Frequency Identification (RFID), Wi-Fi, Global Positioning System (GPS), Bluetooth Low Energy (BLE) helps facilitate tracking objects in indoor and outdoor environment. While GPS technology is preferred in outdoor application.

Wi-Fi

Wi-Fi stands for Wireless-Fidelity and is based on IEEE 802.11 technology. In Wi-Fi transmission of data takes place over the air through radio frequency. Wireless signals are sent out by hubs and these signals are accessed by devices within specified range. According to (Woo, S. & Heo, J. ,2011) they investigate the feasibility study of a Wi-Fi based indoor positioning system for construction site, along with precision of the Wi-Fi technology in indoor application. According to (Olevall & Fuchs, 2017) major challenge while implementing Wi-Fi technology is high power consumption. Also, while connecting with smartphones, scan duration is longer for Wi-Fi. This makes it difficult to position the moving devices accurately.

RFID

In this technology radio waves are used to identify and track the objects. Object information is stored in RFID tags having an integrated microchip and antenna, which transmit data to interrogator or RFID reader. This transmitted is decoded into format which can be understood by computer. RFID tags can be attached to different objects of production line to track the location of the asset.

According to (Haddud et al., 2015), RFID technology can be used in manufacturing environment for asset tracking. A study done by (Zhu & Xu, 2019) to give over view of RFID-Based indoor positioning technology, various challenge one face during implementation are privacy concerns, data interference, one way communication and unstable Received Signal Strength (RSS).

GPS

According to (Hameed & Ahmed, 2019) GPS is one of the widely used technology in outdoor application. But when it comes to indoor tracking of assets, GPS shows lot of inconsistencies. This is because of the unpredictable closed environment. This makes the visual communication with the GPS satellite challenging and thus makes GPS technology an inadequate tool for determining object positions in indoor locations

Infrared

According to (Hameed & Ahmed, 2019), Infrared system used for indoor asset tracking uses Active Badge. The Active Badge is responsible for sending unique infrared signals to infrared receivers after fixed interval of time. The receiver then transmit data in database. Major disadvantage of using this technology is high power consumption. Also signals gets easily blocked by hinderance/obstacle in path due to some object or wall.

BLE

The paper by (Gomez et al., 2012) describes Bluetooth Low Energy (BLE) as emerging wireless technology for short range communication developed by Bluetooth Special

Interest Group (SIG). There are few reasons which led to choosing of BLE over other technologies. According to (K., 2018), Firstly, BLE asset tracking is cost effective and high Return on Investment (ROI). Secondly, BLE beacons and tags are easy to install and can be integrated with existing network. Thirdly, BLE beacons are very energy efficient technology.

Literature Review

Lean manufacturing is nothing but a set of tools and methods to eliminate wastes from manufacturing environment. According to Sobek, Durward & Lang, (2010) any activity which do not add value to the end customer is considered as waste

According to Ohno (1988), the seven deadly waste are Overproduction, Waiting, Transporting, Extra processing, Inventory, Motion, Defects. (Krafcik, 1988) summarized that lean plants are more capable of achieving productivity and quality simultaneously.

Adoption of BLE technology on production/assembly line for data collection and asset tracking can help in identifying waste and helps in analyzing how these wastes can be eliminated

Bluetooth Low energy (BLE) is a new concept in production/assembly line, but as a technology it has been widely accepted in various application

(Yoo et al., 2018), the paper discusses about implementing the real time asset tracking based on Bluetooth Low Energy (BLE) in a tertiary care hospital. Active tags and BLE beacons were used to track the assets.

(Stavrou et al., 2019), this paper addresses about customer's indoor positioning in a two-floor grocery retail store and discuss the framework and implementation of technology. According to the paper major advantage of using BLE technology in retail environment is one to one tracking of customer and identification, which is not available with other technologies like Wi-Fi and RFID.

According to (Bloch & Pastell, 2020), BLE technology can also be used for localization in barn environment and monitoring the location of cow. The purpose of using this technology is low cost and long battery life. Apart from locating the cow, the technology also helped in recognize long distance walking, cow's preferred location and crowded areas in barn.

(Giuliano et al., 2020) implemented the technology for museum application. Information about the location of the visitors within the premises of museum can be used by the museum operator to advance communication services, so as to improve overall cultural experience of the visitor.

According to (Lee et al., 2019) the aim of the study was to propose a framework for asset tracking in warehouse application. This paper provides a useful insight to use cost effective BLE technology in manufacturing environment.

A paper by (Ramakrishnan et al., 2016) aimed to understand the feasibility and efficacy of using BLE beacon on shop floor for inventory management.

The main aim of this research is to investigate the impact on BLE technology on production line for reducing waste and propose a frame work for asset tracking

Research Methodology

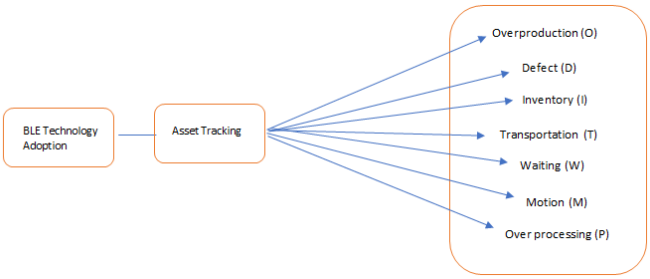

Figure-1 Seven types of waste

To identify the major cause of waste in production line/assembly line two methods were used. Firstly, In-Depth Interviews and brainstorming sessions were conducted for three managers and in charge of production line. The main objective to conduct one-to-one interviews was to gain experience-base information from the respondent and practically what all challenges they faced in tracking of asset on assembly/ production line. Also, they were asked what according to them is the major source of waste on a production line which can be eliminated by adopting BLE technology.

Secondly, various researchers work was analysis and compared to find the relative importance of the seven waste.

According to the in-depth interviews following are major challenges

- Manual tracking of material and operators
- Large waiting time and unnecessary movement of resources
- Lack of data availability on actual time consumed for a work
- Manual signal for material requirement from warehouse and suppliers

Analytic Hierarchy Process (AHP) is used to make a decision for prioritizing alternatives and to identify the critical criteria for the solution idea. The objective is to find the most critical waste in a production/assembly line and then proposing Bluetooth Low Energy (BLE) technology framework to tackle the same.

Step-1: Setting of goals

First step is to define the objectives to meet the goal. The goal of using AHP analysis is to prioritize which waste is most critical in a production/assembly line

Step-2: Pair wise comparison matrix

A table is created to show pair wise comparison matrix. Importance of each factor is indicated by their relative score. Relative importance is determined as per the outcome of the interviews. Decision making is done as per the fundamental scale of AHP as shown below. Each waste is denoted by letter (as O = Overproduction, D = Defects, I = Inventory, T = Transportation, W = Waiting, M = Moving, P = Over processing)

1.0 = Equally important, 1.25 = Slightly more important, 1.75 = Moderately more important, 2.0 = Highly Important, 2.5 = Extremely high important

	O	D	I	T	W	M	P
O	1.00	0.67	0.67	1.33	0.40	0.50	1.33
D	1.50	1.00	1.00	2.00	0.67	1.33	2.00
I	1.50	1.00	1.00	2.00	0.67	0.80	1.33
T	0.75	0.50	0.50	1.00	0.50	0.57	0.80
W	2.50	1.50	1.50	2.00	1.00	1.33	2.00
M	2.00	0.75	1.25	1.75	0.75	1.00	2.00
P	0.75	0.50	0.75	1.25	0.50	0.50	1.00
	10.00	5.92	6.67	11.33	4.48	6.04	10.47

Table-1 Pairwise comparison matrix of seven waste

Step-3: Normalized matrix and Priority vector
Matrix is normalized by taking column sum of pair wise comparison matrix and then dividing every cell value by its column sum. Then sum row wise of this normalized matrix is taken. This column is Priority vectors denoted by PV. Based on the Priority vectors ranking is done as shown in Table 2 & 3.

	O	D	I	T	W	M	P	Total	PV
O	0.100	0.113	0.100	0.118	0.089	0.083	0.127	0.73	0.10
D	0.150	0.169	0.150	0.176	0.149	0.221	0.191	1.21	0.17
I	0.150	0.169	0.150	0.176	0.149	0.132	0.127	1.05	0.15
T	0.075	0.085	0.075	0.088	0.112	0.095	0.076	0.61	0.09
W	0.250	0.254	0.225	0.176	0.223	0.221	0.191	1.54	0.22
M	0.200	0.127	0.188	0.154	0.167	0.166	0.191	1.19	0.17
P	0.075	0.085	0.113	0.110	0.112	0.083	0.096	0.67	0.10

Table-2 Normalized Matrix

MUDA	**Priority score**	**Rank**
Overproduction (O)	0.104248365	5
Defect (D)	0.172298078	2
Inventory (I)	0.150580601	4
Transportation (T)	0.086476692	7
Waiting (W)	0.219991862	1
Motion (M)	0.170379503	3
Over processing (P)	0.096024899	6

Table 3: Ranking as per Priority vector

Step: 4 To check consistency of scores

- Consistency Index, Random index and Consistency Ratio is calculated to check if the consistency is there in the score provided.

CI	0.0090
RI	1.34000
CR	0.0067

If CR is less than or equal to 0.1 then it is acceptable. Here we get CR as 0.0067 which validates the consistency in scores given to the 7 wastes.
Now to confirm the validity of AHP analysis and In-depth interviews various research papers were referred and their ranking given to the seven waste is compared to identify which the most important waste. Average was taken to come up with final ranking as shown in Table 5

	Overproduction (O)	Defect (D)	Inventory (I)	Transportation (T)	Waiting (W)	Motion (M)	Over processing (P)
(Rawabdeh, 2005)	6	2	4	7	5	1	3
(Arunagiri & Gnanavelbabu, 2016)	3	6	4	2	1	5	7
(Arunagiri & Gnanavelbabu, 2014)	6	7	4	1	2	3	5
(Rayate & Khairnar, 2018)	7	5	2	1	4	3	8
(Henny & Budiman, 2018)	5	1	3	6	2	4	7
(Marifa et al., 2018)	7	1	3	5	2	6	4
(Ramkumar et al., 2019)	7	1	6	5	3	4	2
(El-Namrouty, 2013)	5	3	1	6	2	4	7
Average Ranking	5.75	3.25	3.375	4.125	2.625	3.75	5.375
Final Ranking	7	2	3	5	1	4	6

Table 5: Ranking based on various researchers

From the above two methods we understand that waiting, defects and motion time are the major sources of waste in production/assembly line which needs to be dealt with and instead of manual asset tracking, BLE technology can help in reducing the waste
To tackle the above waste an architecture using Bluetooth Low Energy technology is proposed

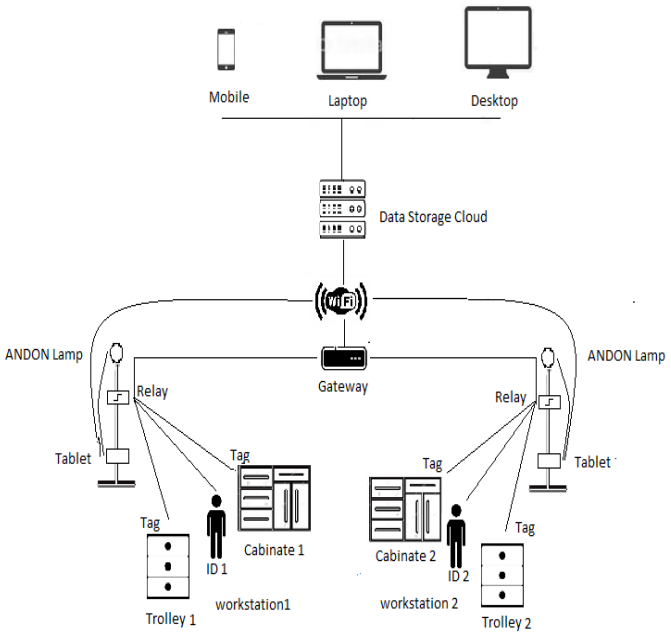

Figure-2: Framework of asset tracking in assembly line

The proposed asset tracking system consists of different component like Beacons, Bluetooth signal receiver, Wi-Fi network, database, application.

Beacons are small devices which are applied to the object to be traced. They transmit particular information at particular interval of time in a given radius. Here in this architecture tags are applied on all the cabinets, manpower working on the cabinet, KANBAN trolleys etc. to establish a coordinate system. These tags are powered by coin battery which has a long life. The data transmitted by BLE beacons is captured by BLE receivers. We are using Bluetooth enabled Tablets, which are located on specific locations. The gateway scans the area for BLE receivers to collect and read the data transmitted by the BLE receivers and send the information to data storage cloud through Wi-Fi. The cloud software stores the data in the server and result is displayed on a web-based application through an application programming interface (API).

This web application is run on devices like mobile, laptop and production line managers can track the movement of goods in real time on a production/assembly line on these devices.

ANDON alert is provided to automatically indicate the material shortfall on production/assembly line.

Result

As per initial research 7 waste were identified in production/assembly line. To under the relative importance of the seven waste, AHP analysis is performed. As per the AHP analysis waiting time is the most critical waste in production/assembly line. Defect, inventory and move time are another critical waste. Here we get CR as 0.0067 which validates the consistency in scores given to the 7 wastes.

The same result is support and validated by the comparison of various research papers.

Framework has been suggested using Bluetooth Low Energy (BLE) technology for real time asset tracking of man and material. Instead of manual tracking now using BLE technology the production manager will be in better position of identifying the major reason for large waiting time in the system. It will help in better coordination and communication among line workers and production manager and manpower can be reallocated to reduce waiting time. This technology can also help in tracking the defects more seamlessly and accurately, hence reducing the time in identifying the defective item. By tracking the movement of man power, motion time can be analyzed and unnecessary motion time can be optimized.

Conclusion and Future work

This paper addresses the problem of manual asset tracking in production/assembly line through BLE technology. Prioritization and criticality of waste in production/assembly line is identified through AHP analyzes. This work concludes that production line managers need to monitor three major MUDA i.e. wait time, defects and moving time.

The action plan suggests that to use Bluetooth Low Energy (BLE) technology. Though this technology is not implemented in production/assembly line but many of the used cases are discussed in literature view which indicated the reliability and flexibility of this technology in asset tracking. Also, low cost and long battery life are other major advantage of this technology.

This study is not without limitations. Implementation of framework requires coordination between managers and work force. Another issue can be strategically locating the BLE receivers as their will be distortion of signals due to multiple reflection and absorption.

The future work can be developing the framework using hybrid technology. Using the best practices of BLE technology and Wi-Fi technology asset tracking mechanism can be improved.

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