User Requirements for Indoor Geo-Localization System for Manufacturing Shop floor and Selection of Appropriate Product

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Abstract. This work is derived from an industrial consultancy work where the researchers surveyed the market to find most appropriate indoor localization server for use in digital shop floor initiative at a manufacturing company. Here we describe requirements of indoor Geo-localization for manufacturing shop floor. Then we evaluate various technologies to suit the business use cases. Finally, we provide reasons for selection of Wi-Fi finger printing based open source Geo-localization server.

Keywords: Indoor Geo-localization Server, Location Tracking, Digital Factory, Industry 4.0, IOT, Fingerprinting, Wi-Fi based indoor Geo-localization.

1 Introduction

In a connected world where machinery, plant, parts, inventory, vehicles and people are ever connected, knowing their positions invariably becomes a key business aspect. GPS devices are commonly used for outdoor localization but sparse availability of GPS signals in indoor environment poses challenges for its indoor usage. In this study, a manufacturing company with multiple factories and offices around the world wanted to scan the market to identify a geo-localization server for localizing IOT devices in indoor environments. Implementation cost and maintenance were to play a vital role in the solution identification. This market study consisted of three parts

- Identifying the business use cases to get an idea of accuracy, latency and scalability needs.
- Understanding available technologies from existing literature.
- Selection of appropriate product from the selected technology.

Finally, after evaluating multiple solutions against business needs, one of the Wi-Fi fingerprinting based open source product was selected. This product, ANYPLACE [1], was initially developed at University of Cyprus [2]. We implemented a few use cases on the product. In this paper, we present the results of this business study for search of an appropriate indoor localization server

2 The Business Use Cases

In consultation with experts of Digital Factory following use cases are identified.

2.1 Connected Worker

The Connected Industrial Worker uses field-tested mobile, sensor, asset-tracking, analytics and wearable technologies to help execute the daily work activities of an industrial or field worker more effectively. In hazardous and large industrial work environments, the worker would also wear location and hazmat sensors that can monitor, for example, levels of environmental toxin exposure, as well as the worker's location.

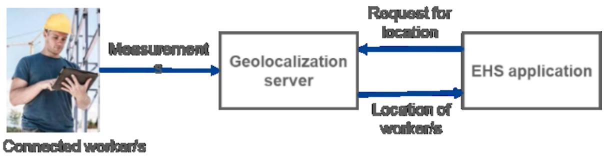

Fig. 1. Connected Worker

The location of workers can be persisted in a separate data store by the geolocation application. The monitoring applications to be used by supervisors should get last available location. Movement of workers should also be available on demand.
Accuracy- 5-10m; Scalability - 5000 wearable devices; Latency- 1-2 seconds

2.2 Connected Parts: part positioning and part tracking

In a manufacturing environment supply chain can be more effective if parts can be traced at the shop floor. For example- some job cards are generated on daily basis based on manufacturing planning and scheduling. Some job card may define attaching or fixing of some item/part to another. Before any worker starts the job, the concerned part should be available on the shop floor near the workplace.

Accuracy- 5-10m; Scalability- 1000 parts; Latency- 1-2 seconds.

2.3 Connected Tools

Connected screw driver, connected portable welding machine, connected fork lifter, etc., have Wi-Fi and these devices can be detected in a wireless network. If their location on the shop floor can be computed and visualized. It can save a lot of time otherwise spent in locating these items on the shop floor. The supervisor may want to know location of all forklift trucks or location of all portable welding machines. There may be an application which may automatically check that the tools have come back to their normal place after the shift.

Accuracy- 2 m; Scalability - 10000 movable tools; Latency- 2-3 seconds

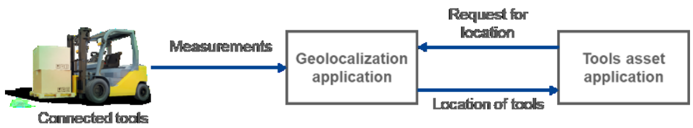

Fig. 2. Connected tools.

2.4 Connected Building

Connected Buildings refers to a kind of office infrastructure where building components are connected (wired or wireless) and they report their status through applications and can be monitored centrally. Office and factories have many fixed devices. They may share some data regarding their status. Based on the condition/status a person visits the place for repair, cleaning or for any other maintenance activity. If we can also get the location of the device on the map, it helps. The location of building connected fixed devices like CCTV, projectors do not change frequently. Once an hour update might be enough.

Accuracy- 5-10 m, Scalability- 1000 fixed devices, Latency- Variable

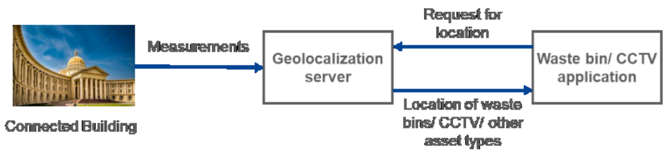

Fig. 3. Connected buildings

2.5 Wrong-place Tracking

Sometimes a person may visit a prohibited area (say, a high voltage yard) or an equipment may be lying at a wrong place. Such incidents should be reported in near real time. A geo-fence can be defined and tracking can be put in place for IOT enabled devices. This can ensure movement of such devices in and out of defined fences.

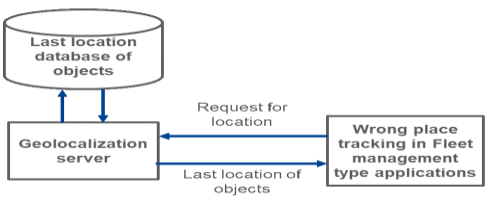

Fig. 4. Wrong place tracking

Accuracy- 2-5 m, Scalability- 100 request in an hour. Latency- 1-2 seconds.

2.6 Navigation

There are two aspects to Navigation feature. One, suggesting a route between two locations and second traversing the route as the object is moving along the route. Navigation is required for a worker to go from place A to place B with or without a vehicle. Thus navigation will be guiding in nature where a human being will make final decision. The application should help users through a mapping application and guide to the desired destination. There are two key elements to this, visibility of origin and destination locations and the path or route from origin to destination. The navigation functionality will need that indoor maps are stored and points of interests and paths can be marked on it. In online or query phase user will ask for destination and path which should come from the stored data.

This may need 2 m Accuracy, with 100 requests per hour, while location updates may be every few milliseconds while on the path.

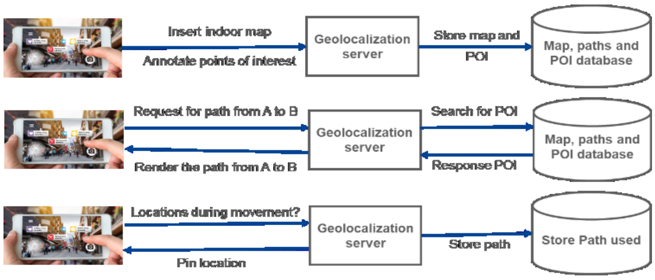

Fig. 5. Navigation functionality- store map, render path and traverse the path

2.7 Mission Tracking

When someone is going from place A to B then the path and its location should be tracked on the map. This refers to a series of locations with corresponding timestamps. The data of the movement can be kept in another database. This need is covered in the last section of the navigation.

2.8 Lifecycle management

Following items have lifecycle related needs

Fingerprinting lifecycle management.

Crowd sourcing will be a critical feature to manage life cycle of the finger printing exercise. Fingerprint will change with change of Wi-Fi AP, change in the orientation of a AP, and change in the direction of antennas of AP.

Crowdsourcing will help in increasing the accuracy. Some devices do not move say doors etc. This may assist to reverse calibrate and update the Wi-Fi fingerprints with respect to observed data from fixed location of some of the Wi-Fi objects.

Fingerprinting will also provide boundary of dark zones, or no Wi-Fi zones. Presently users do not know if the access point is not working or it is a dark spot. After finger printing of entire area, we will know this aspect.

Life cycle of position of Access Points/ direction of Antennas.

Sometimes routers may be replaced and relocated. Sometimes the direction of directional antennas may be changed. This will affect fingerprint of RSS of access points in a given area. The method of finger printing or the triangulation algorithm should detect this and take appropriate corrective action. Some antennas may stop working or their alignment may also get changed.

2.9 Frequency of localization of an object/ refresh rate

All objects need not be localized at same interval. Some objects which are relatively fixed, such as doors, door locks may need localization once a day while other objects like movable tools, connected workers etc. can be localized more frequently say every 5 seconds. While for some services it may be localization on demand, when an application sends a request to locate an object, its last known location is sent. Refresh rate of objects should depend on object type.

2.10 Multi floor support

The localization in buildings will need multi-floor support. The area map should be converted to Map of points with Latitude and Longitude. Ultimately the application should provide postman type address.

2.11 Mapping

Mapping is a critical need with Geo-localization. The area map will contain some indoor and some outdoor points. Outdoor points will have GPS signals. There may be some Wi-Fi signals also in outdoor areas. The application should work smoothly indoor and outdoor.

2.12 Intranet of things

The application will not use internet. The cellphone app will use intranet to connect to Geo-localization server. The IOT Objects will send the data over intranet. Other application will also use the service over intranet.

2.13 History of locations

The historical data of locations should be kept. This is needed for tracking till the mission of taking an object from point A to point B is complete. Last known location of an object is sufficient for most applications, such as location of inventory. But Historical information of movement and path may be required later for some kind of analysis.

The following figure summarizes the important business needs

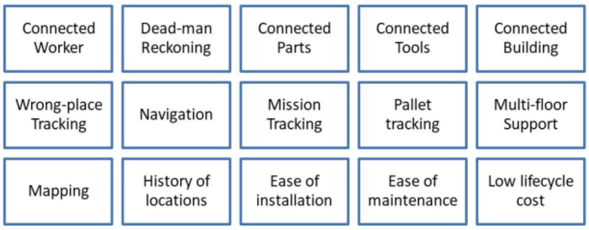

Fig. 6. Summary of important business needs

3 Wi-Fi Infrastructure at the Manufacturing Company

3.1 Routers

There are approximately 2000 CISCO routers at manufacturing company's offices and factories. These are company managed access points. In addition, canteen, labs and other company offices within the same premises also have their own fixed access points which can be used for Geo-localization. Portable hotspots, and mobile hotspots should not be used. Thus the solution should provide selection of access points to be used where RSS fingerprints from selective access points can be considered and rest can be disregarded.
Best devices can connect up to 20 Wi-Fi objects for data transfer and can hold up to 50 objects where all are not using data.

3.2 Edge Devices

There are three Wi-Fi controllers in the company. They maintain life cycle of access points. These controllers control, configure and manage all the access points. All are CISCO access points in 2.4 G Hz single band and 2.4 and 5.0 G Hz dual band. The Geo-localization server will be used by all company locations worldwide.

4 Comparison of position technologies

There are many technologies available for localization. We studied Bluetooth Low Energy (BLE) technology, passive and active RFID technology, Ultrasound technology, Earth Magnetic Field, Radio Frequency, Laser Ranging, and Ultra Wide Band (UWB) Technology. Detailed survey of such technologies is available in [3] [4] Smart phones based indoor localization is available in [5] Wireless localization is discussed in [6] and [7]. There are some data sets for testing the algorithms as in [8].

Criteria of comparison should be selected based on intended use. In present case, accuracy, ability to localize thousands of objects at multiple locations, need for extra infrastructure and tags, low cost, and ease of maintenance were important.

For localization of parts two options are possible. Either the part has a Wi-Fi tag or a person with Wi-Fi enabled barcode scanner scans the part and sends Wi-Fi footprint and barcode to central server. Where part location and barcode both can be stored in database.

Association of barcode with part type can be done at part or job-card related application side.

5 Selection of Technology

After due consideration of all the positioning technologies it is observed that, Bluetooth Low Energy is more accurate but costly as many beacons are needed to cover an area. While Wi-Fi based methods are least costly as no additional infrastructure is required. UWB is most accurate but it will need extra infrastructure and can't be used on cell-phones.

Accuracy of 2-5 meters is possible with Wi-Fi based fingerprinting techniques. Scaling for 100000 plus devices is possible with parallel architecture. Multi-floor support, mapping and navigation is possible with Wi-Fi based methods.

Wireless Technology	Range	Dedicated Infrastructure	Power Consumption	Disadvantages
Earth Magnetic Field	5 km	No	Low	signal changes little in small distance
Wi-Fi	35 m	No (for most places)	High	high variance signal
Laser Ranging	30 ~ 60 m	Yes	Low	Need dedicated infrastructure
Bluetooth	10 m	Yes	Low	Cover range is limited
Ultrasound	20m	Yes	Low	Cover range is limited
Radio Frequency	1m	Yes	Low	Cover range is limited

6 Discussion and Selection of Product

Three open source initiatives provide Wi-Fi fingerprinting based solutions, Anyplace, Redpin, and Find3. Out of the three Anyplace has active users and active support group.

After going through all technologies and available products and business needs we concluded to recommend ANYPLACE open source tool. Scanner can be used to geo-localize barcoded devices which do not have Wi-Fi sensor. Following was also noticed during the course of exploring indoor Geo-localization which needs further research.

- The Indoor Geolocation problem is a complex research problem which needs more research [9],
- Low cost Wi-Fi based Geo-localization is the only long lasting solution due to its widespread use and availability across the world in the form of access points and availability on mobile devices and IOT devices.
- New Wi-Fi measurement based techniques are claiming sub meter accuracy [10], which needs further demonstration and proof.

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