Mindful Oversight: A people-tracking application of the Internet of Things

Manuel E. Bermudez, Ph.D.
University of Florida, USA, manuel@cise.ufl.edu

Abstract– We present the design and on-going implementation effort of a people-tracking platform for wearable devices to promote safety, productivity, and compliance in various industry environments. By exploiting the characteristics which make the IOT such a revolutionary concept, it is possible to improve business performance through real time location and threat analysis.

The project is being developed by a group of undergraduate students at the University of Florida, under our IPPD (Integrated Product and Process Design) program, a highly successful University-Industry Cooperation program. Our project is sponsored by MindTree, Inc. a high-technology company based in India and the US. We describe the current status of the design and software/hardware that has been produced, and describe the educational program (IPPD) under which they are being developed.

Keywords—People tracking, Internet of Things.

I. Introduction

The author's IPPD project [1] this year at the University of Florida consists of developing a hardware/software system based on the concept the Internet of Things [2], meant to be used in an industrial setting by managers and owners of businesses to track their employees throughout the day for safety, productivity, and rules compliance. If there happens to be an emergency in the workplace, knowing where all the employees are located can prove to be very useful. Or in such a case where there are restricted areas in the workplace only accessible by a handful of employees, Mindful Oversight would aid in ensuring that only the appropriate personnel are in these restricted areas throughout the day. Also, looking back through days and weeks of movement patterns, information such as most frequently traveled paths by employees could be discerned. Knowing this information could allow the managers, if so desired, to optimize that path for faster movements – enhancing employee production.

The major objectives of this project are as follows:

- In real time, track employee indoor movement.
- Perform analysis on employee movement
- Dislay results in a user-friendly graphical user interface (GUI) via a web application.
- Enable the addition of "Geo-fences", or restricted areas, for certain employees.

To accomplish efficient tracking indoors, wearable devices will be communicating through the ZigBee [3] protocol with strategically placed beacons. Each beacon will then broadcast information about the signal strength received from the wearable to a gateway processor which will calculate the location and send it to cloud storage.The system design requires both hardware and software components:

<u>Hardware:</u>

The tracking system will use a circuit board with a microprocessor and Zigbee module to broadcast radio signals in the Sub-GHz range. The radio signals will be received by an array of Zigbee routers set up for accurate location detection. These routers will relay information regarding each wearable device to a gateway connected to the internet. The gateway will run algorithms based on the known location of the routers and the received signal strength (RSS [4]) of the wearable signal. The resulting location determined from the algorithms will be sent to the cloud to be stored. The Mindful Oversight software will access the locations of the wearables assigned to different employees for analysis and display purposes.

<u>Software:</u>

Each beacon will send a unique ID to identify itself, a unique ID for the wearable it is referencing in signal transmission, and the received signal strength (RSS) from the wearable. The location determination algorithm will use this information to determine the wearable's location, which will then be sent to the database for storage and analysis as well as to the user interface for display.

II. Sponsor needs and system specifications

The sponsor's (i.e. customer's) needs appear in Table 1. The needs are broken down into three categories: cost, features, and quality. Each customer need has been given an importance rating, from 1 to 5, with 1 being lowest, and 5 being the highest.

The Mindful Oversight system is intended to encompass wearable tracking devices and an easy-to-use software interface displaying information retrieved by the device. The system specifications, including units and target information, appear in Table 2.

TABLE I
CUSTOMER NEEDS AND IMPORTANCE

	Category	Customer Need	Imp
Product	Cost	Affordable (2000$ Baseline)	4
	Features	Wearable	5
		At least 10 Hrs battery life	4
		Heart rate monitor	3
		Aethetics	2
		Comfortability	4
		Show battery level	1
		User friendly interface	4
		Reliability	5
		Reusable	5
		Readable/Well Documented	4
		Interconnectivity	2
		Geographic fences	5
		Transportable (charging station incuded)	5
	Quality	Durable	4
		Weighted Column Totals (Product	
		Rank	
		Importance Range 1 to 5	
		Correlation: 1=Low,3=Medium,9=High	

TABLE 2
SYSTEM SPECIFICATIONS AND TARGETS

No.	Specification	Units	Target
1	Device (or beacons?) must hold up to hour worth of locations	Bytes of memory	8k Bytes of RAM
2	Battery life	hours	10 hours
3	Location tracking	GPS coordinates	+- 3ft
4	Registration/Deregistration	y/n	y
5	Geo fences / timing	y/n	y
6	Cost	$	2000
7	Batch Analysis	y/n	y
8	List employees	y/n	y
9	Search for specific employee	y/n	y

System features are expressed in the stakeholder's language. The features and their descriptions listed in Table 1 are measurable engineering characteristics of the product, as described in Table 3.

III. SYSTEM ARCHITECTURE

Tracking employees in an indoor setting requires a few hardware components. These components include one component worn by the employee (the "wearable") that will continually transmit signals, multiple components (the "beacons", at least 3) to receive the signal broadcast by the wearable and transmit information about the wearable's signal to a central device, and a central component (the "gateway") that receives signal information from the beacons, and performs calculations to estimate the wearable's location. Using ZigBee devices in the sub-GHz range, our beacons will have a range of approximately 100 meters. This will be considered when setting up the beacons in the workplace. There must be a minimum coverage of 3 beacons for any given area to calculate the location of a wearable.

There are several technical challenges in the development effort. Challenges with the hardware side include accounting for environmental factors such as walls blocking line of sight, potentially crowded areas where people will always be moving in front of the beacons, timing issues regarding signal transmission/reception, and the timing of the algorithm to update the wearables' location. Challenges on the software side include displaying a map of the workplace that can be dynamically changed to account for additions or subtractions to the work environment, efficiently displaying updated locations, conducting batch analysis on all employee's paths traveled, and providing an easily extensible program for Mindtree to continue further development of the Mindful Oversight system.

IV. HARDWARE DESIGN DESCRIPTION

A significant portion of the time spent on this project has been dedicated to determining the best hardware components to use. Many different options for wireless communication have been considered, include LoRa (Low Power Wide Area Network) [5], Bluetooth, and WiFi but eventually the Zigbee wireless standard was settled upon as the best option for the purposes of People+. The hardware of the Mindful Oversight project can be split up into three separate, standalone objects: the wearables, the beacons, and the gateway module. The wearable will be made of an Adafruit Trinket Mini Microcontroller [6] (shown in Figure 1) along with an Xbee SX module [7], also shown in Figure 1.Together these will be programmed to send out a signal to be received by nearby beacons.

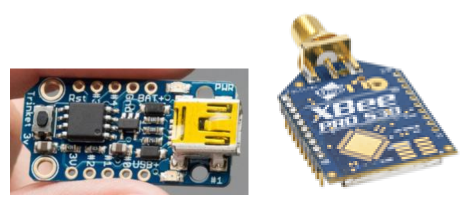

Fig. 1 Adafruit Trinket Mini Microcontroller, and Xbee SX Module.

The beacon will be made of the same hardware but different coding will allow it to have a different function; which will be to receive and send RSSI values to the gateway module, a Raspberry Pi 3 processor [8]. The gateway module will consist of the Raspberry Pi 3, a shield connection bridge, and an Xbee Wireless Shield, all three shown in Figure 2. This module will receive RSSI values from all the nearby beacons, calculate the location of the wearable (using a location algorithm) and then send the data to a cloud site for data storage. The Xbee Wireless shield will give the Raspberry Pi the ability to transmit the location data over the Zigbee wireless network.

Fig. 2 Raspberry Pi 3, Connection Bridge, and Xbee Wireless Shield.

As of this writing, the various hardware components are being sourced from various vendors. We will be receiving products from Raspberry Pi, Arduino, XBee, and Digi International. Assembly will take place on the UF campus, and the components will be soldered together and programmed. If any PC (printed circuit) boards are required, they will be designed and printed locally.

V. Software design Description

The project specification includes the design and implementation of a new user interface to allow efficient and ample access to all the Mindful Oversight platform's functionality. The software platform uses HTML, CSS, and AngularJS on the front-end, handling all the back-end implementation in C#. The software communicates with the tracking system over an IoT cloud platform, storing and pulling information from a central database as needed. This will allow the user to analyze data seamlessly, and in real time. Figure 4 shows the flow and access of both data and services.

The front-end web application accesses the data access layer through the back-end API. Our data storage segment will be divided into several layers. The IoT Cloud Platform encompasses all of the technologies which allow for communication not only between the hardware devices themselves, but also the translation of data between hardware and software. For time efficiency purposes, the database portion of the Mindful Oversight platform will be divided into a central cloud base database, and a local database. The local database will greatly improve access times for frequently accessed data such as employee credentials and shift information. The cloud server will provide the hardware gateways with a platform on which to dump results without waiting for a connection socket to receive any previously sent packets. This will free the software interface to query results only when necessary rather than continuously waiting for input. All data will be stored using a relational database model to allow for relationships to be created between entities.

The Mindful Oversight back end will offer the user access to the platform's functionality. Aided by Microsoft's Entity Framework, the People+ API will divide the application's relational data into domain specific objects, such as a list of assets, employee information, wearable properties, and so on. The API will also abstract all data manipulation capabilities, requiring only that the user specify the necessary parameters, and encapsulating all data access and operations. Data manipulation functions include creating employee activity reports, path travel frequencies, and asset distribution.

The front end will be written as a web application using HTML5 [9], CSS [10], and AngularJS [11] to allow for simple yet responsive dynamic views. They are dynamic in the sense that data displayed can be updated in real time without reloading the frame with the use of AngularJS directives. The interface is intended to be intuitive and require no formal training to operate. The built-in help guide will aid users in solving any anticipated complications. The front-end alongside the back-end will serve as an interface between the software and hardware sub-systems of the Mindful Oversight platform functionality. The data access layer will serve as a pipe between the subsystems, allowing them to efficiently share any necessary information.

VI. Operating Environment and Installation Considerations

The Mindful Oversight system is intended to be used in an office/indoor environment. These environments should be a locations in which employees would be moving around with some frequency. Some considerations regarding environmental factors include:

- People walking in front of the beacons, and interfering with the signals
- Walls or other obstacles inside a building interfering with the signals
- Expanding building sizes
- Adding new hardware to a previously deployed system

In preparation for testing of our forthcoming prototype, a series of tests have been designed, specifically for testing the signal strengths with a variety of interfering factors, including people, walls, machinery, etc. The housing of the wearable device will deal with the typical wear and tear of working environments, as well as the comfort of the employee. We intend to use a 3D printer to produce the initial housing prototype, to ensure the housing is as small as possible while still providing some protection, for example, from accidentally dropping the wearable, or any type of bumping. The material of this housing needs to be comfortable, durable, and affordable. More research is still required to find the best material for this portion of the project.

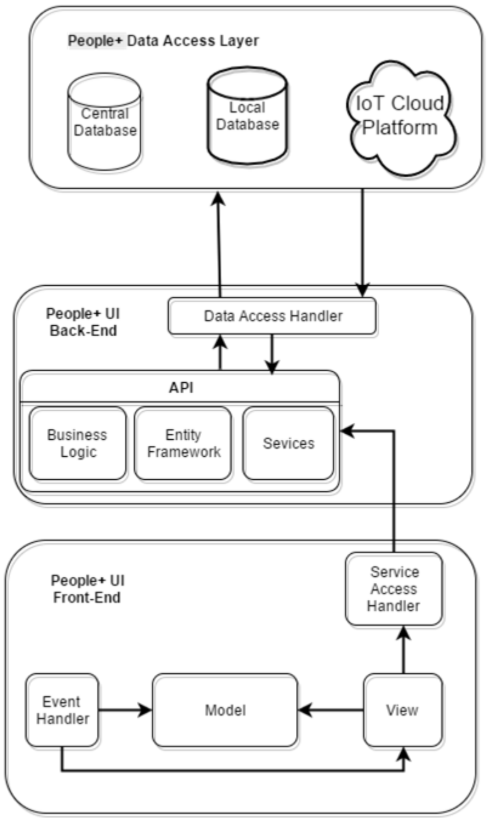

Fig. 4 Software Data Flow Diagram.

Various factors must be taken into account regarding the installation of this system. The main issue is the number of beacons and their placement. Some other factors include the number and nature of obstructions within the environment, the number, length and location of walls within environment, and the amount of electronic interference. Adjustments will have to be made due to these factors, by increasing the number of beacons, and by spacing them more closely. Of necessity, this will have to be done on a trial-and-error basis.

VII. DEVELOPMENT PLANS

The current development stages of the Mindful Oversight platform and connected hardware prototypes appear in Table 5. The table lists the primary milestones to be reached, along with a description of each one, and the projected date.

TABLE 5. PROTOTYPE DEVELOPMENT PLANS

Milestone	Description	Projected Date
Hardware/Software Interaction	Connection established between the wearable device and the platform, and complete data transmissions between them.	November, 2016
Server Implementation	Complete data storage of data sent from the device to the platform onto a local server or cloud.	December, 2016
Triangulation Basis	Algorithm available for triangulation based on RSSI from the gateway.	February, 2017
Final Prototype	Complete, working, debugged prototype developed and implemented. Goal: least 3 assets to track and the full system implemented to show functionality.	May, 2017

VIII. CONCLUSIONS

We have described an on-going project at the University of Florida, involving the design and implementation of a people-tracking platform for wearable devices to promote safety, productivity, and compliance in various industry environments. The project is being developed by a group of undergraduate students at the University of Florida, under our IPPD (Integrated Product and Process Design) program, a highly successful University-Industry Cooperation program. Our project is sponsored by MindTree, Inc. a high-technology company based in India and the US. We have described the current status of the design and software/hardware that has been produced, and expect to have comprehensive results soon.

REFERENCES

[1] The IPPD Program at the Unniversity of Florida: http://www.ippd.ufl.edu/
[2] The Internet of Things: Business Insider. http://www.businessinsider.com/what-is-the-internet-of-things-definition-2016-8
[3] The Zigbee Wireless Standard: Digi.com. https://www.digi.com/resources/standards-and-technologies/rfmodems/zigbee-wireless-standard
[4] RSSI: Received signal strength indication: https://en.wikipedia.org/wiki/Received_signal_strength_indication
[5] LoRA Alliance: https://www.lora-alliance.org/
[6] Adafruit Trinket Mini Microcontroller: https://learn.adafruit.com/introducing-trinket/introduction
[7] Xbee SX modules: Digi.com. https://www.digi.com/pdf/ds-xbee-xbeepro-sx-modules.pdf
[8] Raspberry Pi 3: https://en.wikipedia.org/wiki/Raspberry_Pi
[9] HTML5: https://en.wikipedia.org/wiki/HTML5
[10] CSS: Cascading Style Sheets: https://www.w3.org/Style/CSS/Overview.en.html
[11] AngularJS: https://angularjs.org/

Digital Object Identifier: (to be inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).