An Analyze Movement Path of Employees in Fire Drill by Indoor Location System Using Bluetooth

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***Abstract*— Fire drill is a practice of the emergency procedure to be used in case of fire. The key success factor of this practice is evacuation time which start since the fire alarm rang until the last person left the building. Another factor is the evacuation path. The safety regulation requires person inside building to go to the nearest fire exit during the emergency. However, during practice we never know the real evacuation path. Therefore, in this paper, we present indoor location system using Bluetooth to track movement path of employees during fire drill. This system records the path of employee during evacuation and analyzes each employee. The experiment found that there are 40% of all employees who do not go to nearest fire exit according to safety regulation. In addition, 92% of employee who did not got to nearest fire exit are the employee who the starting point is at the back of the building. One observation is that the assembly point is in the front of the building.**

Keywords*— *An Analyze Movement Path in Fire Drill, Indoor Location System, Bluetooth Indoor Location System.

I. INTRODUCTION

Fire is one of the most malicious incidents in the city because it causes loss both human life and asset. The security agency of the building have a policy to reduce the fire occurrence and reduce the loss caused by fire such as fire safety training, fire drill etc. Nowadays, with technology advancement, there are many systems to reduce the loss caused by fire. Bahrudin and Buniyamin [1] proposed fire alarm system. This system is a real-time monitoring system that detects the presence of smoke in the air and captures images via a camera installed inside a room when a fire occurs. The embedded system consists of Raspberry Pi, Arduino, gas sensor and webcam. When smoke is detected, the system displays an image of the rooms status in a webpage. The system required the administrator to confirm and report the event to the firefighter using Short Message Service (SMS). Gupta *el.al.* [2] proposed automatic alert system. This system divides into 2 units, transmitter and receiver. The transmitter consists of temperature, infrared sensors and radio frequency module. The receiver consists of micro-controller, GPS and GSM module. If fire is detected, transmitter module transmit 433 MHz signal to receiver. After that micro-controller sends information via SMS and Multimedia Messaging Service (MMS) to administrator. The information includes URL address of latitude and longitude which shows in Google map. Mohd Fuzi *el.al.* [3] presents fire alert detection system using ZigBee wireless network**.** Heat sensor and buzzer have been installed in Arduino. If this system detects heat from fire, the buzzer alarm is triggered and the system sends temperature information via Zigbee to server. This system will alarm when temperature is higher than 92.04 Celsius. Islam *et. al.* [4] designed and implemented fire detection system with indoor localization using ZigBee. Sensors, smoke, smog, temperature and Infra-Red-light radiation have been installed in Arduino. These sensors send data via WI-FI to server. If fire is detected this system calculated position of fire by trilateration from Infra-Red-light sensor. Imteaj *et.al.* [5] propose fire alarming and authentication system using Raspberry Pi 3. The light intensity sensor, gas sensor and camera have been installed in Arduino board. When Arduino board detects fire, it sends command to camera to snap image and also sends data to Raspberry. The Raspberry sends a message along with the image to the administrator. An administrator can confirm or deny, if the administrator confirms the system will immediately alarm and send message to the nearby fire brigade. Muheden *et.al.* [6] designed and implemented fire alarm system using wireless sensor network. This system installed sensor nodes flame, gas, temperature and humidity in Androino. If fire is detected the system send the notification alarm message via Wi-Fi to mobile application of users. [1]-[6] are related to fire alarm system. Tabbakha *et.al*.[7] presents an indoor positioning system and motion tracking system for the elderly, who are staying alone. The system is able to track the elderly location based on the room that they are currently situated and recognizes whether the elderly is moving or sitting. This system consist of 3 part. The first part has Raspberry Pi Zero featuring accelerometer, gyroscope and beacon. The data from motion sensor and beacon will publish to *Message Queuing Telemetry Transport* (MQTT) server. The second part is Raspberry Pi 3 and Bluetooth scanner. It scans signal strength from beacon and publish it to MQTT server. The third part is server, it contains machine leaning software which is used to evaluate and determine the most suitable classifier. This system can detect what room is elderly living. Although, papers [1]-[6] is related to fire detection but it is not related to tracking people. [7] works on tracking people but cannot records exactly X-Y position and only records approximate distance between beacon and Bluetooth scanner. So, this paper presents indoor localization system

using Bluetooth to monitor evacuation path during fire drill which can locate exact location of employee in the building.

The rest of the paper is organized as follows: section 2 provides system structure. In section 3, the implementation steps of the setup system. In section 4, the results of the experiment are explained in detail. In section 5 and section 6, are discussion and conclusion.

II. System Structure

This paper presents an implementation of the indoor localization system using Bluetooth as show in Figure. 1. The Bluetooth tags broadcast signal, then anchors (Bluetooth scanner) receive signal strength of Bluetooth tags. After that, the anchors publish data using MQTT protocol to MQTT broker. The cloud server (Amazon Web Service) receives tag data by subscribing from MQTT broker. The position of tag is computed at server using Geo-n localization algorithm [8] and recoded to the database. The administrator can monitor statistics data via web application.

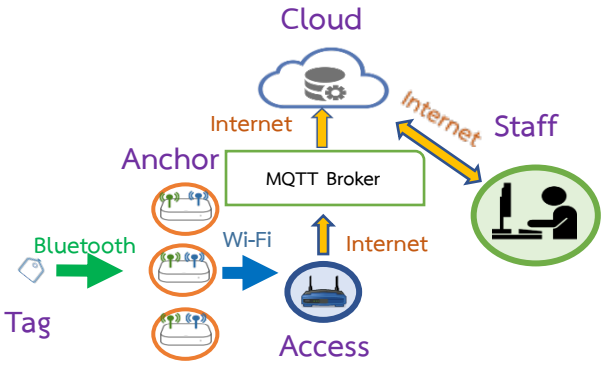

Fig. 1. System Architecture

A. Hardware

Hardware separates into 2 parts: anchor and tag as shown in figure 2 and 3, respectively. These anchors have been developed by Location and Auto ID Lab, NECTEC. The anchor installs Bluetooth Chip Nordic model nRF52832 and Wi-Fi module model LinkIt Smart 7688 Duo. The cost of anchor about $71. This experiment, we use Minew company [9] tag which is easily obtained from market. The cost of tag is about $6-$9 depends on quantity.

Fig. 2. Anchors.

Fig. 3. Tags.

B. Software

We use Amazon Web Service (AWS) to subscribe data from MQTT protocol and compute location of employee by the Geo-n localization algorithm. This algorithm uses a two-stage filtering technique to obtain the most representative intersection points between every pair of circles induced by anchor coordinates and distance measurements and uses these to estimate the position of unlocalized nodes. If no intersection exists between two circles [8]. Location information is displayed real time on web application and is recorded to a NoSQL database using Node.js. The Figure. 4 presents real time location of employees during fire drill. The big points (orange) are anchors and the small points (blue) are employees.

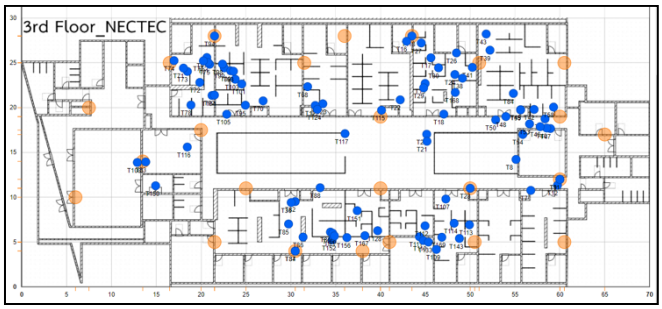

Fig. 4. Show real time location of employees.

III. Implementation

This experiment took place in NECTEC building, a 6 storied building. However, we tested only on the 1st and 3rd floors. The size of each floor is 70×30 square Meter. There are 25 anchors installed on the 1st and 3rd floors, total of 50 anchors. Another 9 anchors are installed at the assembly point. The installation of Bluetooth anchors bases on of Maneerat [10] method. The Figure. 5 shows installation of Bluetooth anchor where the points in the figure. are anchors.142 tags are the employees on the 1st and 3rd floors.

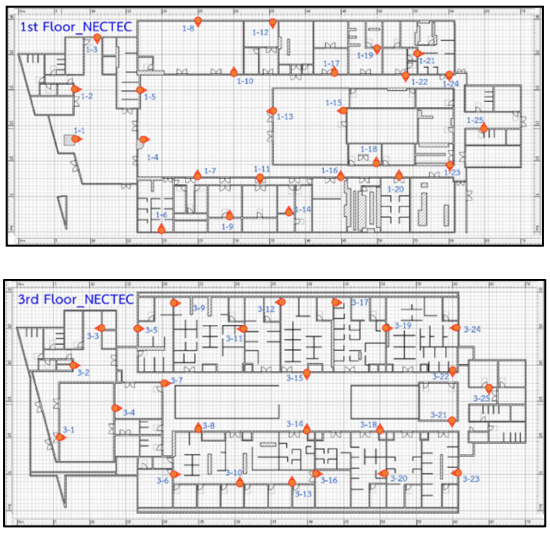

Fig. 5. show installation of Bluetooth anchor.

Normally, safety staff notify schedule of fire drill but they do not notify specific day. So, A week before fire drill, we distribute tags to employees who work on the first floor and the third floor. Furthermore, we request employees to carry tag all time when they are in building. According to fire drill regulation, the employee must go to nearest fire exit as soon as possible. The starting point position of employees is significant key to analysis. The length of building is divided into 2 parts: front of building and back of building according to the evacuation plan in the Figure 7. If the starting point of employees are at the back of building, then they should go to fire exit at the back of building. If the starting point of employees are at the front of building, and they should go to fire exit at the front of building. This behavior is considered to be safe action according to safety regulation. However, if the starting point of employees are at the back of building, and they go to fire exit at the front of building. Or if the starting point of employees are at the front of building, and they go to fire exit at the back of building. This behavior is considered to be risky action according to safety regulation. The Figure. 6 presents detail of building. However, dividing zone is depending on evacuation plan of building.

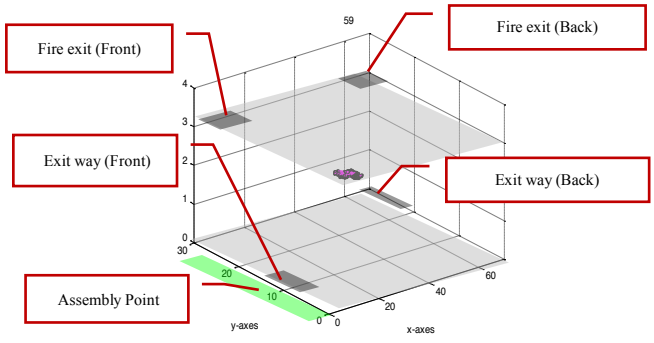

Fig. 6. The position of fire exit on each floor.

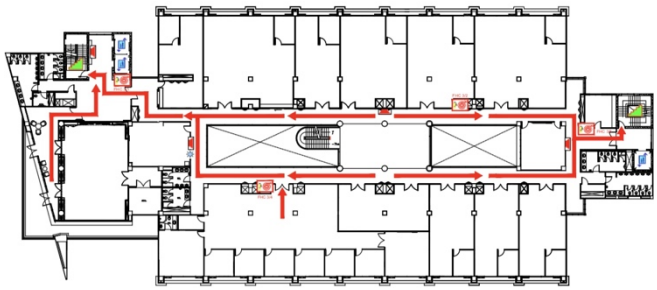

Fig. 7. The evacuation plan.

Figure. 8 is our algorithm that detects movement of employees. The starting point and the ending point on each floor is a key point for detect movement of employees.

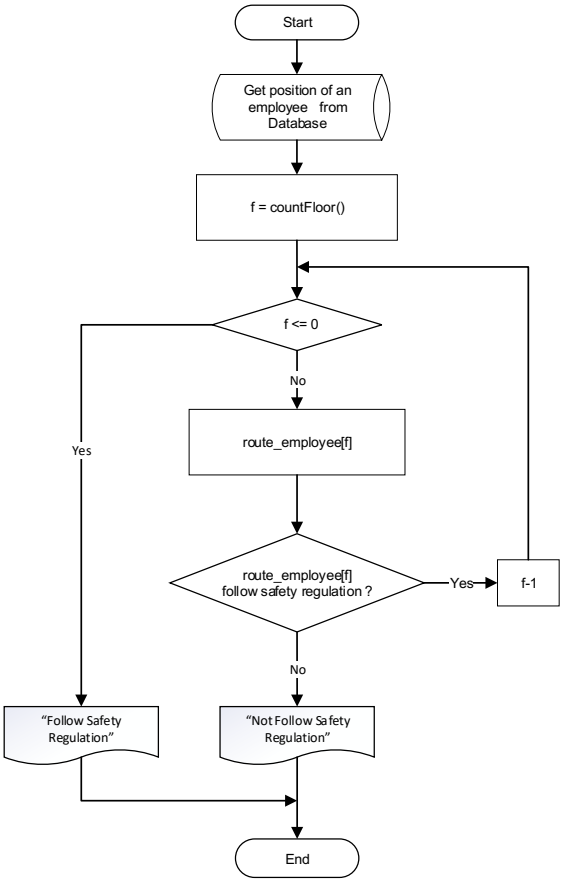

Fig. 8. flow chart of detecting of employee's movement.

IV. Result

This experiment is tracking and analyzing movement of employees during fire drill by indoor localization system using Bluetooth. According to fire drill regulation, the employees must go to nearest exit way as soon as possible. The total cost of this implement is $2,627. The cost of anchors is $1,775 per floor (25 ×$71) and the cost of tag is $852 (142×$6).

TABLE I. SUMMARY OF MOVEMENT

Floor	Number of Tag	Follow safety regulation	Not Follow the safety regulation	Follow the safety regulation (%)
1st	31	17	14	54.83%
3rd	62	29	33	46.77%
Other	49	-	-	
Sum	142	56	47	60.21%

From table 1, there are 31 employees on the 1st floor, and 62 employees on the 3rd floor. On the test day, 30 employees were not in the building. Another 19 employees did not carry tag. In this experiment 17 employees from the 1st floor went to the nearest fire exit, while the other 14 employees did not go to the nearest fire exit. Therefore 54.83% of the employee on the 1st floor follows the safety regulation. 29 employees from the 3rd floor went to the nearest fire exit, while the other 33 employees did not go to the nearest fire exit. Therefore 46.77% of the employee on the 3rd floor follows the safety regulation. In summary, 56 employees from 1st floor and 3rd floor went to nearest fire exit, while the other 47 employees did not go to the nearest fire exit. Therefore 60.21% of the employee on the 1st floor and 3rd floor follows the safety regulation.

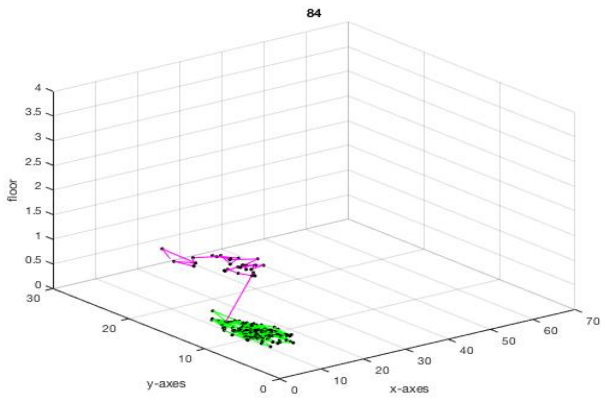

Fig. 9. The movement of employee on the 1st floor who goes to the nearest fire exit.

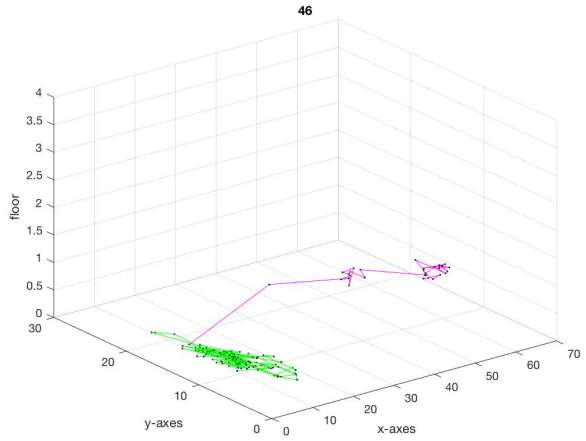

Fig. 10. The movement of employee on the 1st floor who does not go to the nearest fire exit.

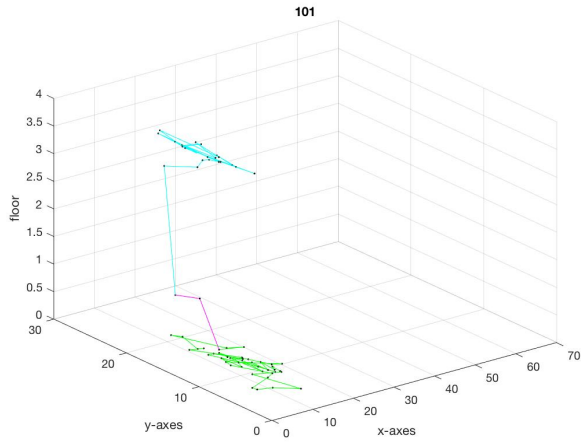

Fig. 11. The movement of employee on the 3rd floor who goes to the nearest fire exit.

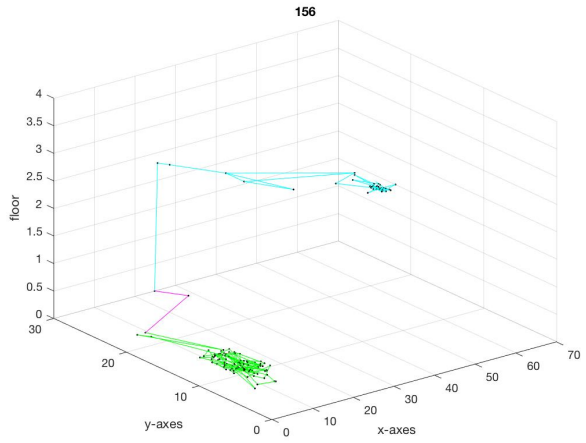

Fig. 12. The movement of employee on the 3rd floor who does not go to the nearest fire exit.

The figure 9-12 show example movement of employee which each color has difference meaning. The green line is the employee who is at the assembly point. The purple is the employee who is on the 1st floor. The blue is the employee who is on 3rd floor or 2nd floor. From the experiment we found

that, there are 40% of employee did not go to the nearest fire exit. So, we investigate more on the starting point of employees. The result of analysis represents in table 2.

TABLE II. ANALYSIS OF STARTING POINT 'EMPLOYEES

Floor	**Total**	**Starting Point**			
		Front of building		***Back of building***	
1st	31	17		16	
		Follow the safety regulation	***Not Follow the safety regulation***	***Follow the safety regulation***	***Not Follow the safety regulation***
		17	0	0	16
3rd	62	25		37	
		Follow the safety regulation	***Not Follow the safety regulation***	***Follow the safety regulation***	***Not Follow the safety regulation***
		25	0	4	33

From the table 2, it demonstrates starting point of employee when the fire alarm starts. On the 1st floor, there are 17 employees are at the front of building and 16 employees at the back of building. On the 3rd floor, 25 employees are at the front of building, and 37 employees who are at the back of building. 92% of employee who did not go to the nearest fire exit are the employee who are at the back of the building when the fire alarm rang.

TABLE III. COMPARISON STATISTICS OF FIRE DRILL AT NECTEC BUILDING IN 2016-2018

Fire drill at NECTEC building (Year)	**2016**	**2017**	**2018**			
Last employee out from building (Goal lass than 5 minute)	*Max*	*Max*	*Floor*	*Avg*	*Max*	*Min*
	5	4.18	1st	2.16	3.36	1.21
			3rd	3.24	4.38	1.24

The advantages of applying indoor location tracking system using Bluetooth in fire drill is that the safety staff can receive more insight statistics information. From table 3 in 2018 (applying indoor location tracking system in fire drill) can show the difference maximum, minimum and average evacuated time of each floor. But in 2016-2017 (without applying indoor location system in fire drill) show only maximum evacuated time of employee in this building. Other advantages of this system, safety staff can monitor real-time route of employees and predict emergency case from their movements.

V. DISCUSSION

In this paper, we present indoor location system using Bluetooth for analyzing movement path of employees during fire drill at NECTEC building. From the experiment, there are 40% of employees did not go to the nearest fire exit. 92% of employee who did not got to nearest fire exit are the employee who the starting point is at the back of the building. One speculation is that the assembly point is the front of building. With the heatwave outside, they might prefer to walk inside the building to the assembly point. Since we cannot force employees to carry tag at all times, only 65% of tag shows in database. The cost of anchor is about $1,775 (56,000 Bath) per floor and the cost of tag is $7 (220 Bath) per a user. This system is considered cheap compare to the price of human life. In this experiment, we collected the exact position (X-axis, Y-axis, Z-axis) of employee from fire drill start until stop.

VI. CONCLUSION

This paper proposes indoor location system using Bluetooth during fire drill at NECTEC building to analyze the movement of employees. we divide the length of building into 2 parts: front of building and back of building according to the evacuation plan. If the starting point of employee is at the front of the building. The employee should go to the nearest exit, which is at the front of the building. Same rule applies to the starting of employee when it is at the back of the building. The result found that, there are 40% of employees did not go to the nearest fire exit. 92% of employee who did not got to nearest fire exit are the employee who the starting point is at the back of the building. Before this implementation, the safety staff have no idea how the employee evacuated from the building. Therefore, they only focus on the evacuate time. With this system, now the

safety staff can educate the employee about the proper evacuation path. In addition, the cost of this system is expensive if it can save human life.

This system is an indoor location real time monitoring system that can apply to indoor location real time tracking system for people or devices such as indoor location monitoring system for elder, patient or children as well as inventory monitoring system. Future work, we are interested in applying machine learning to increase precision of position of interested object using Bluetooth.

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