Improving Motorcycle Anti-Theft System with the use of Bluetooth Low Energy 4.0

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***Abstract*—This paper proposes the improvement of motorcycle anti-theft system (MATS) utilizing Bluetooth Low Energy (BLE) 4.0. In the our previous work, the couple RFID passive tags were installed on motorcycles to detect the larceny conditions. The main problem was found in the last experiments that the RFID tags attached with the ignition key cannot be hung flexibly. Therefore, the BLE4.0, which is the low-power- consumption device, is dangle on the motorcycle's key and the RFID tags is installed on the bike's hidden body. The anti lost devices have been applied for responsibility of BLE-tags slave mode, installed on a key. The HM-11 BLE 4.0 module combination with an Arduino board has a function as the master mode, reading the MAC address (called ID) of BLE slave devices. The results show that the maximum distance, in which the BLE master module can detect the BLE slave's ID, is approximately 18 meters. The proposed method is reliable because the BLE devices can be hung on the key together while the motorbike is running on the speed not over than 80km/hr. Finally, the experimental results guarantee that, when relatively compared with the previous method, accuracy of the MATS is improved efficiently; moreover, this proposed system can actually be used in the real situation at the Prachinburi province, Thailand.**

Keywords—Bluetooth Low Energy; Motorcycle Anti-Theft; RFID;

I. INTRODUCTION

Nowadays, there is a huge of motorcycles over than 300 thousand in Thailand, and this is directly proportional to a considerable number of stolen motorcycles. It is the social issue that why the development of the motorcycle anti-theft system is required. In the previous version, the motorcycle anti-theft system consisting of the two UHF RFID passive tags has been demonstrated [1]. The first one is located on the body of motorbikes hidden from seeing (called the *bike tag*). The second one is attached with the ignition key (called the *key tag*). However, thefts still unlock motorcycles if the RFID reader is unable to scan the key tag, if else the bike tag is removed or discovered. The key idea of the previous system is shown in Fig.1. The RFID tag is scanned when the key tags are only installed in front of bikes. The weak point of the previous system is observed that the key tags cannot completely be installed on the motorcycle's key. This seems not practical in real-life situations. Moreover, there is inaccuracy if the passive RFID key tags are positioned more than 9 meters

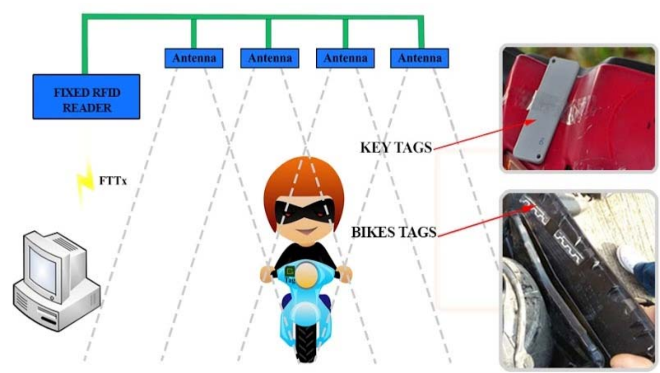

Fig. 1. The motorcycle anti-theft system

away from the reader. Accordingly, this paper utilizes the BLE 4.0 devices rather than the RFID key tags.

The Bluetooth low energy 4.0 has been introduced by the Special Interest Group (SIG) in 2010 [2]. The BLE wireless technology has the key feature that plays the vital role with a standard coin cell battery for a few years of consumption time due to ultra-low peak, average and idle mode power consumption [3]. The various papers [4],[5], for examples, guarantee that the BLE consumes low energy with the effective range (50m). Furthermore, the BLE provides the flexible communication mechanism including the low-cost option, relatively compared with other wireless technologies [3]. Therefore, many researchers have presented their works involving the BLE 4.0 in the last couple of years. Ting Zhang, et al[6] has proposed the wearable sensor-based healthcare system using the Bluetooth low energy. Similarly to the paper offered by Chinese researcher [2], they designed and implemented the heart-rate monitor system on iOS with the help of BLE 4.0 for data communication. Moreover, the papers [3], [7]-[9] have presented the indoor localization utilizing BLE 4.0 based on the

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received signal strength indication (RSSI). The BLE 4.0 is attractive and widely used in the different fields, mobiles, entertainments, home automations, sports, consumer electronics, and automobile, for examples. However, the development is far from applying the BLE 4.0 as a part of the anti-theft system. The similar work presented in [10]concerning with using the BLE 4.0 for anti-theft system has been presented. This work has applied the BLE 4.0 for data communications between smart phones when the magnetic sensor detects an unauthorized removal of the container, and also including measurements of temperature, moisture, vibration and other abnormal conditions. This is a long-time communication because the BLE 4.0 has to concurrently transmit and receive data. It is not convenient for a real-time processing. Hence, only utilizing BLE 4.0's ID address for the MATs is demonstrated in this paper with improving the accuracy of key-tag detection when the BLE 4.0 instead of the RFID-tag card is made attachable for the ignition key. In addition, the BLE-tags reader is implemented and added on the proposed system as well.

The description of this paper is organized as follow. In section II, the overview concept of improving system is presented. In section III, the BLE devices applied to the key tags and the BLE tags reader is explained, while in section IV the experimental results are reported. Finally, the conclusion and future work plans are concluded in section V.

II. Overview Of The Concept Brhin Improving theSystem

The improvements made to the motorcycle anti-theft system are shown in Fig. 2 where the block of reading BLE tags is added to the device. This block has the responsibility to read the BLE's ID of a key tag, suspended on the key's bike due to the usage of the passive RFID. The reading of the BLE tags comprised of 2 important parts: the reader which works in master mode and the BLE tags, operating in slave mode (This process is described in greater detail in the next section). However, the RFID tags which is installed on the bike's body had not been changed because its detection accuracy is already good, as shown in our previous paper [1]. The anti-theft system decides the RFID's ID and BLE's ID which is already registered on the database. In a normal case, the RFID's ID of bike tags and the BLE's ID of the key tag must be detected simultaneously, whilst in the case of stolen bikes only the RFID's ID can be detected. Both normal and abnormal conditions can save the information such as a time and license plate number to the database but the alarm is notified when the abnormal case happens. According to Fig. 2, the RFID reader and BLE reader must be installed at the pole beside the road to detect the bike tags and key tags which are equipped on the motorcycle and its key, respectively, whilst the processing unit which is responsible to judge the abnormal case and saves the data has been install in the room at the command center. The data communication between the pole and the center utilize the FTTx (Fiber to the x) likes a previous work, illustrating in Fig. 1.

III. BLE tags Reader And BLE Tags

A. BLE tags reader

The one of the main ideas to improve a MTAS is nothing changed for a software at the command center. Solely place some devices on a pole to search the ID of the BLE tags and send them back with TCP/IP protocol to the processing unit at a center. This software has a duty to identify some abnormal conditions, by receiving the ID of key tags and bike tags, then alarm and saving the data to a database. The bike tags 's ID is capable of getting by the fixed RFID reader, same as the

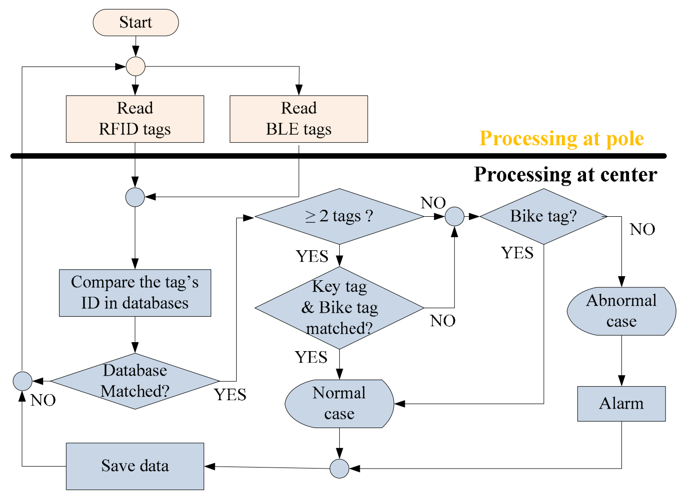

Fig. 2. The flowchart of the improving system

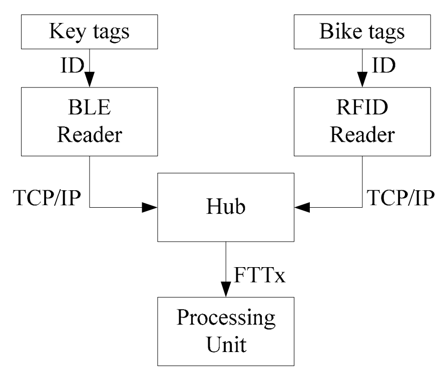

Fig. 3. The block diagram of improving system by adding the BLE technology

previous version, while the ID of key tags are replaced by the BLE technology and they need other readers. Therefore, a BLE-tags reader is produced to competent the ID of BLE tags when tags are in the range. A block diagram of the improving system is demonstrated in Fig. 3.

The previous system employs a RFID reader to detect the ID in both of the key tags and bike tags which are the RFID passive devices, while the improved system enlarges a BLE reader. A BLE tags reader consists of the popular BLE 4.0 module HM-10, Arduino UNO R3, Ethernet shield W5100, DC adapter 5V 3A and 5VDC fan. The block diagram of BLE tags reader is shown in Fig. 4.The HM-10 module is connected to an Arduino board with RS-232 protocol and using *AT command* to communicate the data between them. In addition, the 3.3V low power is also supplied by Arduino. The HM-10 must be set to the master role and is able to detect the 6 maximum ID of slave BLE devices in simultaneously, appearing in its datasheet. However, a standalone Arduino cannot send the tags 's ID to the far away processing unit. An Ethernet shield W5100 allows the Arduino board to connect to a command center using TCP/IP protocol.

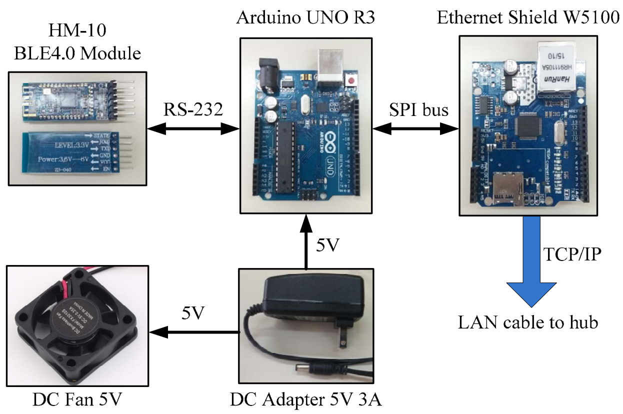

Fig. 4. The block diagram of BLE tags reader

By using this shield, a BLD tags ID is immediately sent to the center after an Arduino is processed successfully. The W5100 communicates with an Arduino using SPI bus on the digital pin 10-13 of UNO and the SD card is never used because it share the SPI bus and only one can be active at a time. Moreover, its standard RJ-45 connection making the BLE tags reader is also easily connected to the processing software by LAN cable. Since a BLE tags reader is installed at the pole where in an outdoor environment, supplementing a fan to reduces the temperature is strongly recommend.

Although the Ethernet Shield offers the power over Ethernet (PoE) but the addition of DC adapter 5V 3A makes all devices work more effectively because the placing of a fan is established according to desire supplied current.

B. BLE Tags

A role of BLE tags presents their MAC address (or ID), when it is the range of the reader, the difference of BLE devices has the difference of ID. The anti-key lost devices demonstrating in Fig. 5has been utilized as a BLE tags, operating in the slave role. Its model is GS-BKF01 which is the products from Shenzhen Gotrich Technology company, China. Since the anti-key lost devices is designed to hang on a key, making them suitable to be used in this research, because it can be immediately applied to the system without modifying anything, while their appearances is also slight. Furthermore, the BLE tags dispense to the user greater than 1000. A purchase from the company or factory is the best alternative in this situation. The important specification of the BLE tags can be expressed in Table I. It can be seen that the power consumption in the standby mode is only 0.4uA and 0.079mA in the normal mode, resulting a tags able to be running for years. In our last work, the RFID passive tags are needless to maintain for a long time. With this reason, the BLE tags are an available device as similar as possible in the lifetime but its performance is extremely increased.

Fig. 5. The anti-key lost device work as BLE tags

TABLE I. THE SPECIFICATION OF BLE TAGS

Bluetooth version	4.0
Chip	AMICCOM
Static standby power consumption	0.4μA
Voltage	3V
Current	0.079mA
Battery	220mAh CR2032
Bluetooth range	10m
Size	38*38*7.2mm

IV. EXPERIMENTAL RESULTS

The experiments carried out on this paper was divide into 3 parts:1. a measurement of RSSI of BLE tags while the inactive motorcycle mode, 2. BLE tags detection in the running mode and 3. the testing of the whole of the improving MATS. Full explanation of the results will be detailed in turn.

A. RSSI of BLE tags in the motorcycle in an inactive mode

Although the BLE model GS-BKF01 has the BLE range of around 10 meters (shown in Table I) but to guarantee that this device is capable of hanging the key of the motorbike, including the read range is sufficient to use in a MATS. A RSSI of BLE tags while the motorcycle is not running must be measured, the tags was attached to the key similar to the image illustrated in Fig. 6. Then the BLE tags reader measured the RSSI of a tag and calculates the average 5 times measuring in each difference distances. Thus, the averaging of RSSI versus the distances between reader and tags are shown in Fig. 7. The measuring result demonstrated that the maximum distances that the reader can competently receive the signals from the BLE tags was about18meters and the average of RSSI is -81dBm.In this experiment, the results confirmed that BLE technology has enough reading range to use in the motorbike anti-theft system due to its range was longer than the width of a general roads in Thailand.

Fig. 6. The BLE tags isattached to the key.

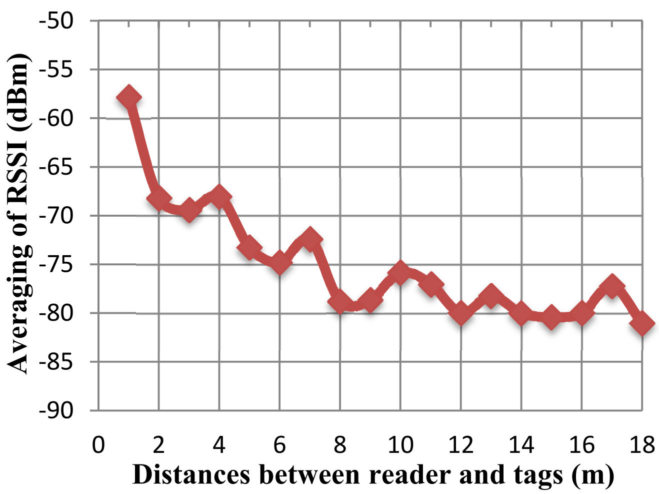

Fig. 7. An averaging of RSSI vs distance between BLE reader and BLE tags

B. BLE tags detection in the motorcycle is running mode

This anti-theft system set off the alarm when the motorcycle was stolen. The alarm was installed in the bike tags and no key tags was running pass the detection pole. However, the alarm was not be activated if the bike has the both its bike tags and BLE key tags. So, the experiment to analyze the capability of a BLE key tags detection is necessary. In this part, the RSSI of the BLE tags suspended on a key same as the earlier testing was measured, but in this section the motorcycle was in a running mode. The BLE reader has been placed on the equipments box at the detection pole, illustrated in Fig. 8. Consequently, the testing bike would drive pass the pole with varying speeds, starting from 60 km/hr to 90 km/hr by increasing of 10km/hr in each step. furthermore, the bike must run in all of three lanes, the left lane was called lane no.1. In addition, the number of the reader detected a tags for every bike running was record and each experimental case was evaluated for 10 times to compute the averaging. The experimental result of this part can be shown in Table II.

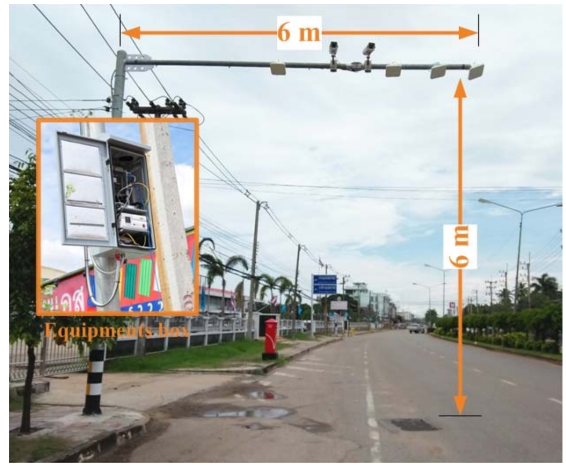

Fig. 8. The detection pole.

TABLE II. THE EXPERIMENTAL RESULTS OF BLE-TAGS DETECTION IN THE MOTORCYCLE IS RUNNING MODE

Lane no.	Speed (km/hr)	The no. of test	The no. of success	Average of RSSI (dBm)	Average of the no. of detection
1	60	10	10	-70.2	4.3
	70	10	10	-68.5	3.6
	80	10	10	-71.1	3.8
	90	10	9	-65.3	2.2
2	60	10	10	-71.2	3.2
	70	10	10	-66.5	3.6
	80	10	10	-69.4	3.4
	90	10	9	-72.1	2.4
3	60	10	10	-64.3	2.0
	70	10	10	-69.2	1.5
	80	10	9	-73.4	1.3
	90	10	8	-70.1	0.9

The results in Table II shows that the BLE reader was able to detect the key tag 100% of the time whilst the bike was running at the speed within 70 km/hr. However, an increase in speed show a decrease in detection accuracy of 98.8% and 95.8% with the speed of 80km/hr and 90 km/hr, respectively. On average the RSSI in each case was satisfactory with adequate signal strength. The only time the average number of detection was less than 1 was when the bike was travelling at speeds of 90 km/hr in lane 3. This experiment proves that the reader was capable of detecting the BLE tags attached to the key while the motorbike is in motion.

C. The accuracy of the improving MATS

The accuracy of the improving MATS was evaluated in this part. The bike tags was fitted inside the main body of the motorbike, as per the image shown in Fig. 1. While the BLE tags had been attached to the ignition key as shown in Fig. 6. The bike was then driven through the path of the detection pole both of stolen case and normal case while all other experimental condition remained the same as the previous part. The result of this test is shown in Table III.

It can be seen that the normal case of the improvements made to the motorcycle anti-theft system has increased its accuracy to 100%. It can be used on all part of the road when the bike was running with the velocity smaller than 70km/hr. But in speeds of 80km/hr and 90km/hr, the accuracy was reduced to 94.4% and 90% respectively. The comparison of an error between the stolen case and the normal case show that an error of the stolen case was quite similar because its depends on the accuracy of RFID key tags detection and its lower than a BLE detection. The pole's arm was bowed and the RFID antenna was added to increase the accuracy of RFID detection.

TABLE III. THE MEASURING OF THE ACCURACY OF IMPROVING MATS

Lane no.	Speed (km/hr)	The no. of test	The no. of success (Normal)	The no. of success (Stolen)
1	60	10	10	10
	70	10	10	10
	80	10	10	10
	90	10	9	10
2	60	10	10	10
	70	10	10	10
	80	10	8	8
	90	10	8	8
3	60	10	10	10
	70	10	10	10
	80	10	7	8
	90	10	6	6

V. CONCLUSION

In this paper, the concept of improving the motorcycle anti-theft system utilizing the Bluetooth Low Energy 4.0.was presented. We used the anti key lost device to work as the BLE tags and implement the BLE tags reader to detect the MAC address of the tags. The results of the experiment shows that we were able to successfully latch the BLE tags to the key. This is a new feature not implemented in our previous work. The MATS is 100% accurate in all parts of the road, in speeds of up to 70km/hr, 94.4% for up to 80km/hr and 90% for up to 90km/hr, respectively. This device is currently being piloted by the Prachinburi provincial police in detecting stolen motorcycles within their province. They have already erected four detection poles in the process. Our next project will be to focus on ways to reduce production costs of the key tags.

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REFERENCES

[1] W. Koodtalang, and W. Wongsaroj, “Experimental of RFID Application in the Motorcycle Anti-Theft System,”*The 26th Thaksin University National Academic Conference*, May 2016.

[2] L. Guo-cheng and Y. Hong-yang, "Design and implementation of a Bluetooth 4.0-based heart rate monitor system on iOS platform," *Communications, Circuits and Systems (ICCCAS), 2013 International Conference on*, Chengdu, 2013, pp. 112-115.

[3] A. Arvanitopoulos, J. Gialelis and S. Koubias, "Energy efficient indoor localization utilizing BT 4.0 strapdown inertial navigation system," *Proceedings of the 2014 IEEE Emerging Technology and Factory Automation (ETFA)*, Barcelona, 2014, pp. 1-5.

[4] J. Liu, C. Chen, Y. Ma and Y. Xu, "Energy Analysis of Device Discovery for Bluetooth Low Energy," *Vehicular Technology Conference (VTC Fall), 2013 IEEE 78th*, Las Vegas, NV, 2013, pp. 1-5.

[5] M. Siekkinen, M. Hiienkari, J. K. Nurminen and J. Nieminen, "How low energy is bluetooth low energy? Comparative measurements with ZigBee/802.15.4," *Wireless Communications and Networking Conference Workshops (WCNCW), 2012 IEEE*, Paris, 2012, pp. 232-237.

[6] T. Zhang, J. Lu, F. Hu and Q. Hao, "Bluetooth low energy for wearable sensor-based healthcare systems," *Healthcare Innovation Conference (HIC), 2014 IEEE*, Seattle, WA, 2014, pp. 251-254.

[7] M. E. Rida, F. Liu, Y. Jadi, A. A. A. Algawhari and A. Askourih, "Indoor Location Position Based on Bluetooth Signal Strength," *Information Science and Control Engineering (ICISCE), 2015 2nd International Conference on*, Shanghai, 2015, pp. 769-773.

[8] Z. Jianyong, L. Haiyong, C. Zili and L. Zhaohui, "RSSI based Bluetooth low energy indoor positioning," *Indoor Positioning and Indoor Navigation (IPIN), 2014 International Conference on*, Busan, 2014, pp. 526-533.

[9] Y. Wang, Q. Ye, J. Cheng and L. Wang, "RSSI-Based Bluetooth Indoor Localization," *2015 11th International Conference on Mobile Ad-hoc and Sensor Networks (MSN)*, Shenzhen, 2015, pp. 165-171.

[10] C. T. Lee *et al.*, "Smart Insulating Container with Anti-theft Features by M2M Tracking," *Internet of Things (iThings), 2014 IEEE International Conference on, and Green Computing and Communications (GreenCom), IEEE and Cyber, Physical and Social Computing(CPSCom), IEEE*, Taipei, 2014, pp. 140-147.