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The development of IoT-based non-obstructive monitoring system for human's sleep monitoring.

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***Abstract*— During the past few years, Internet of Things (IoT) has unprecedentedly become a buzz word in most areas of business and industry. In this paper, we have developed an IoT solution for human's sleep monitoring based on a data pillow system over the internet via 3G/4G LTE or internet router. A private java application server displays the sleeping information via graphs and widgets together with Node-Red which is a platform on android and iOS mobile apps. To observe sleep information, we have adopted force sensitive resistors (FSRs) installed under the pillow for collecting breathing data. A small single board computer, LattePanda, was used as data acquisition and management system. Initial test results showed that the data pillow successfully to upload sleep data to the server smoothly. The analysis of raw sleep data shows that the IoT data pillow can detecting difference breathing signals between normal respiration, hypopnea and apnea. The integration of sensors, wireless technology, and IoT could improve the data pillow system in terms of facilitating the users to measure their own sleep quality at home while the doctor can access to sleep data of patients over the internet.**

Keywords*— *IoT Data pillow, Smart home, Sleep monitoring, Smart pillow

I. INTRODUCTION

A great number of people suffers from sleep disorders. In Thailand, more than 5 million people suffer from insomnia [1]. Moreover, the Thai Society of Neurology estimates the number of people with sleeping disorders between 30% and 40% of the population [2]. Sleep disorders can be caused by other illnesses, stress, changes in the environment or as a consequence of the medication of the patient [3]. Insomnia, sleep apnea, sleepiness during daytime, snoring, restless legs syndrome or periodic limb movement disorder are some of the illnesses and symptoms related to poor sleep quality and sleep disorders, being insomnia one of the most common. In order to diagnose these disorders, a one-night constant monitoring of the patient must be performed in a specially designed room. These sleep monitoring rooms are not available at all hospitals and these having them only have one or two. Due to the shortage of sleep monitoring rooms and the time required to perform the procedure, patient waiting lists are very long. Thai patients wait up to half to 1 years in order to be diagnosed. Due to this problem, many patients with sleep disorders do not know which disorder they have nor can they receive the correct treatment [4]. However, technology can be employed to improve sleep quality until a professional diagnose is performed.

In this publication, we present an IoT-based non-obstructive monitoring system for human's sleep monitoring that monitors breathing patterns to evaluate the sleep quality and sleep efficiency of the user.

II. MATERIALS AND METHODS

A. IoT Data pillow configuration

The IoT data pillow system consists of twelve force sensitive resistors sensors (FSRs) distributed under the pillowcase to detect the body movement. The sensors cover the area of pillow as shown in Fig. 2. For collecting the sleep data, a single board computer called LattePanda was used as the mainboard for this work. The board consist of Intel Quad Core 1.8GHz processor, 2-4GB RAM and 32-64GB onboard flash memory which enough for develop an IoT Data pillow system. It is also includes Wi-Fi and Bluetooth 4.0 module for data communication. The open source Arduino code was developed to capture sleep data at 4 Hz and sending data to server. When the user begins to sleep, the sensors start measuring. IoT data pillow will measure and send data to server all night until user wakes up. In this case, Node-Red server, which is a service that allows to publish and subscribe IoT elements like sensors or other devices, is utilized.

B. Experimental validation testing.

To evaluate the IoT-based data pillows system. Three devices have been created and tested with 3 volunteers at different place and conditions. The sleep data signal are collected for use in calculating sleep efficiency and also the efficiency of uploading data to the sever when compared with the data obtained from text file on Lattepanda.

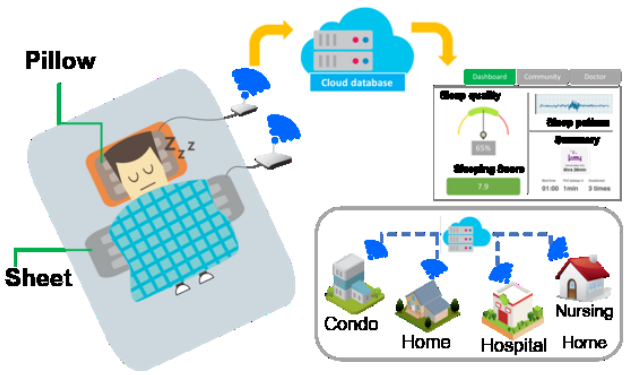

Fig. 1. The concept of non-obstructive monitoring system for human's sleep monitoring.

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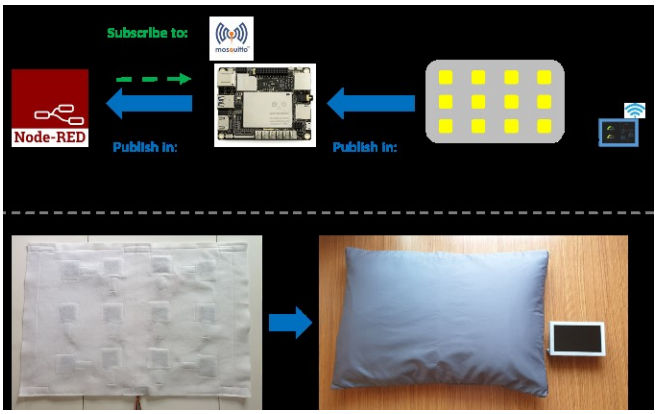

Fig. 2. Architecture of non-obstructive monitoring system for human's sleep monitoring.

III. RESULTS AND DISCUSSION

To evaluate the performance of uploading data to the server of IoT data pillow system. Three devices have been installed and tested at volunteer's bed for 1 week continuously as shown in Fig. 3. The comparison result between recording data on SD card and the storing data on the server are presented in Table 1. It was shown that our IoT data pillow can communicate with the server very well. In the case that the internet is stable, the efficiency of the device for uploading sleep data to ther server is 100%. However, in the case of actual use that sometime the internet signal is not always stable. The efficiency of data uploading may be decrease and affect the calculation of sleep quality. This problem also needs to be improved to increase the efficiency of the device.

To evaluate the capabilities of the data pillow device to distinguish the quality of sleep of the user. The raw sleep data

TABLE I. THE COMPARISION OF THE AMOUNT OF DATA BETWEEN RECORDING INTO SD CARD AND DATA ON THE SERVER

Date of experiment	No. of data in Sd card	No. of data in Node-Red server	Efficiency (%)
09/12/2018	90,312	90,312	100
10/12/2018	85,054	85,054	100
11/12/2018	74,626	74,626	100
12/12/2018	70,080	70,080	100
13/12/2018	91,854	91,854	100
14/12/2018	87,412	87,412	100
15/12/2018	89,006	89,006	100

Fig. 3. The installation of IoT data pillow at the voluntees's bed.

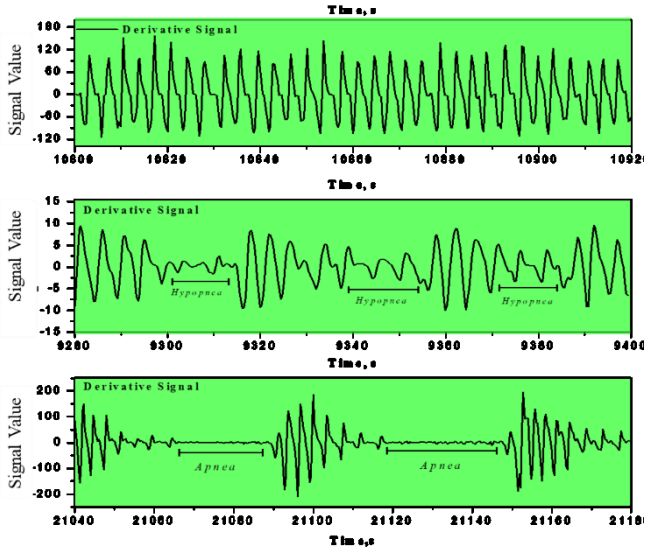

Fig. 4. Comparison of sleep signal from the data pillow for normal respiration, hypopnea and apnea.

from the server were downloaded and analyzed. As shown in the Fig. 4. IoT data pillow was successful in detecting difference breathing signals between normal respiration, hypopnea and apnea. This primary result is a confirmation that the IoT Data pillow can be used to measure sleep quality at the initial level.

IV. CONCLUSION

The IoT-based data pillow were successfully developed and tested. This system comprises force resistive resistance sensors (FSRs) embedded under the pillow, the data acquisition based on a single board computer called LattePanda, wireless communication and the MQTT broker. Three devices has been created and tested with the volunteers for 1 week continuously. Initial test results showed that the data pillow successfully upload sleep data to the server smoothly. From the initial analysis of raw sleep data, the results show that the IoT data pillow can detect different breathing signals between normal respiration, hypopnea and apnea.

V. ACKNOWLEDGMENT

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