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Health Wearable Devices in e-Health Vertical via. Internet of Things (IoT) Framework

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Abstract: The advances in wearable technologies are making new data creation easier for the wearable health sensors. The data are distributed from a central gateway to deliver useful, secure and efficient health analytic decision. The suite of technologies comprises of the Internet of Things (IoT) framework is opening new vertical values for the wearable market segment as well as producing new IoT business models. IoT framework provides access and control all kinds of ubiquitous and uniquely identifiable devices, facilities and assets. The framework is flexible in attaching the various vertical (App.). This study discusses the implementation of wearable health devices in e-Health vertical using an IoT framework namely ISEHAT (Intelligent System Environment Health Application and Tracking). The ISEHAT system uses commercial wearable health devices and gateway in developing e-Health applications.

Key words: Health wearable sensor, gateway, IoT, wearable health devices, e-Health applications, framework

INTRODUCTION

The fast growing of networked wearable sensor technologies in many applications is propelling the growing of the Internet of Things (IoT) applications (Koohi, 2010; Pantelopoulos and Bourbakis, 2010; Beltran *et al*., 2013). It includes the design and the development of sensor systems for applications related to the well-being of human health. The attention received from the scientific community and the industry is overwhelming because motivated by the increasing healthcare costs motivate it. The recent technological advances in miniaturization of devices, materials, microelectronics, advanced wireless communications and the continuous advancement of wearable sensor-based systems drive the motivation further. These have high potentials to transform the future of the healthcare by enabling proactive personal health management and ubiquitous monitoring the health condition of patients (Hassanalieragh *et al*., 2015; Ghamari *et al*., 2015).

The IoT offers greater opportunity in the field of e-Health. The main concepts have been demonstrated to improve the access and quality to care and the most important to reduce the cost of healthcare (Lake *et al*., 2014; Yang *et al*., 2014). As part of the IoT framework which includes the hardware components, wearable sensors, actuator, RFID and continuous remote monitoring platform has been rapidly developed to support the healthcare and services for the home environment (Bassi and Horn, 2008).

Wearable technology provides advanced electronic gadgets that can be worn on the body. It can also be part of the clothing and accessory with the ability for data exchange between the devices and the platform. The wearable devices are usually smart sensors utilizing low power Bluetooth wireless communication for connectivity to the smartphone or home gateway. These sensors automatically update the personal data records through a network cloud. The data includes information on the well-being of the body and health parameters with the ongoing activity.

The applications of wearable technologies comprise wearable cameras, smart clothing, wearable application platforms, smart glasses, activity trackers, smart watches as well as health and happiness wearables (Nagtegaal *et al*., 2016). The growth of wearable technology and applications has been widely influenced by the massive market penetration of smartphones. The advancement of longer battery life and smaller battery size contributes a significant percentage (Kewkannate and Kim, 2016).

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The usability, connectivity and capabilities required for applications such as chronic diseases monitoring and health data analytic are achievable when the following characteristics are met for example:

- Ultra-low-power current consumption (e.g., nano-ampere) is essential to keep wearable devices footprint small and has extended battery life. These features provide IoT devices with high usability
- Low-cost devices equipped with useful communication functionalities (e.g., ethernet and wireless connectivity) are the primary factor for IoT's high demand
- Advanced integrated sensor technologies that provide high precision and accuracy at low cost such as the optical sensors implemented on the wearables
- Integrated modules interface for fast device development
- Small packet data protocol that enables fast data rate and low power consumption using Bluetooth's low energy operational mode

The primary motivation behind the growing e-Health applications is to provide a system that offers healthy lifestyles and improves health services with cost effective objective. The system is also capable of handling health-related cases and improving the quality of health service by automating the tasks and processes. The IoT gadgets have increased the growth of e-Health industry with billions of health-related endpoints increasing endlessly. An ISEHAT powered e-Health solution provides the connectivity in a large scale integration of the sensors, information, people, devices, processes, analysis and contexts to health with results that improve the quality of life. ISEHAT is a complete fore-front framework for e-Health.

MATERIALS AND METHODS

ISEHAT architecture overview: Figure 1 shows the ISEHAT architecture layers consists of sensors, gateway, IoT platform, WASP and App. The wearable devices and sensors are responsible for feeding the health data to the ISEHAT framework through an intelligent networked gateway that handles the hardware protocols such as the Bluetooth, Ethernet, WiFi, Zigbee and others for system interoperability among the wearable devices. It also performs device management routine and data processing (pre-filtering) of the raw data from the sensors. The ISEHAT IoT framework performs data formatting for data received from the gateway and passes the formatted data to the ISEHAT's Application Service Framework (WASP) layer for further process. WASP provides the interface for the lower layer communication that also provides the connectivity to the wearable devices, sensors management, data flow and network configuration. WASP provides the process data channel in the ISEHAT system. It also provides the analytic process and database storage before the computing results are passed to the applications in the mobile and desktop version. Apps layer is user interface layer which consists of web portal and mobile App. version.

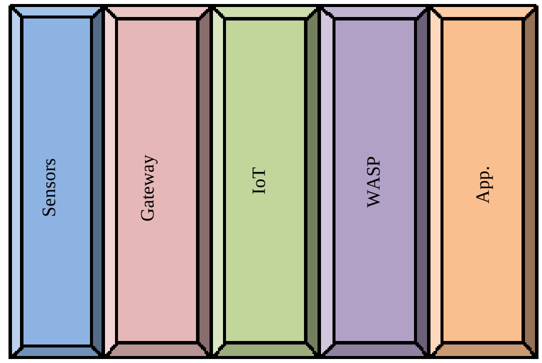

Fig. 1: ISEHAT primary architecture layers

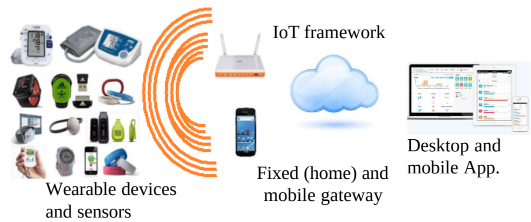

Fig. 2: ISEHAT system illustration

Figure 2 shows the ISEHAT system components consisting the wearable e-Health devices, gateway, IoT framework and applications. Commercial e-Health devices are used in the ISEHAT development. The selection of the devices is based on the robustness, durability, price-wise and accuracy. The selected devices and sensors protect the user's data and enhance privacy and security during data transmission and access to the framework. A home gateway provides data connectivity from the wearable devices to the ISEHAT framework. All data process, analysis and storage are performed directly in the ISEHAT framework. Mobile users can use a mobile agent that provides the internet connectivity to access and pass the e-Health data to the ISEHAT framework.

RESULTS AND DISCUSSION

ISEHAT wearable devices and sensors: Only economic health wearable devices and sensor are used for ISEHAT. The key factors for the selection of the devices are robustness, durability, pricing and accuracy. These devices and sensors provide the high-security level that protects the consumer's data and privacy during data transmission and access. The wearable sensors used in the project came from the brand called iChoice which includes fitness activity sleep tracker, wireless body analyzer (weight scale), wireless blood pressure and pulse oximeter as in Fig. 3.

ISEHAT smart gateway: The gateway is equipped with the latest Bluetooth protocols for IoT applications such as Smart Bluetooth and Bluetooth Low Energy (BLE) provides low power wireless connectivity with the registered wearable and sensors devices as shown in Fig. 4. The gateway initially starts by establishing the Bluetooth connectivity with all e-Health devices within its vicinity. It also actively scans the devices and intelligently determined the type Bluetooth channel and protocol used by the devices. Once a registered device is detected, the gateway initiates data transfer from the device into the gateway using OBEX protocol. The gateway continuously receives, extracts and stores the data from the devices. The data is then matched with the registered user for further processing in the ISEHAT framework. The data transfer to the ISEHAT framework is based on the high layer data transfer protocol such as MQTT or REST and can be associated with the device's preference. The gateway later establishes the internet connectivity before moving the data to the ISEHAT framework using one of the selected high layer data transfer protocol. The gateway continuously repeats the cycle by establishing Bluetooth connectivity and waiting to receive the next data from the same device or other new devices.

Fig. 3: iChoice wearable devices

Sehat IoT framework: Figure 5 shows the vertical layers of ISEHAT framework. The framework plays an important role of the horizontal IoT layers which support multi-vertical applications. One of the main contributions of the frameworks is that user can easily create new applications and publish the Application Program Interfaces (APIs) according to subscribed vertical services. The vertical services in ISEHAT and also from other frameworks consolidated data from bottom layers (gateway, wearable device, sensors) and applied necessary processing to the data. Once the data processing is complete, the framework distributes the process data or analytic result to the user via. the web-based portal or mobile applications.

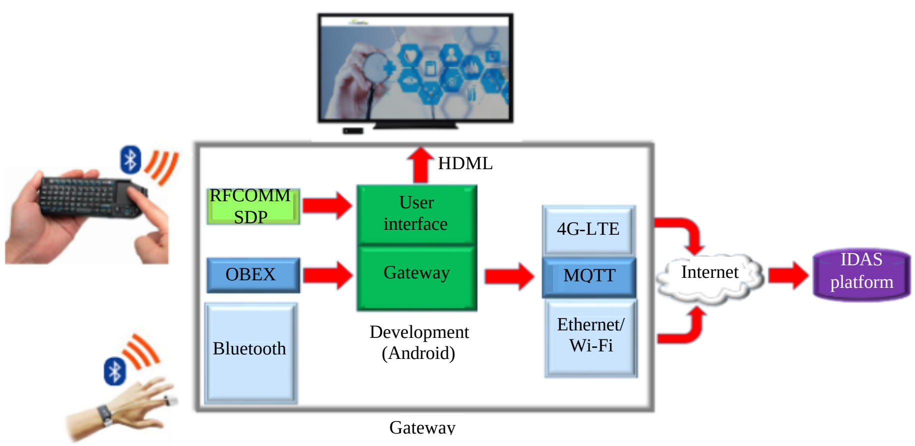

Fig. 4: ISEHAT internal gateway blocks

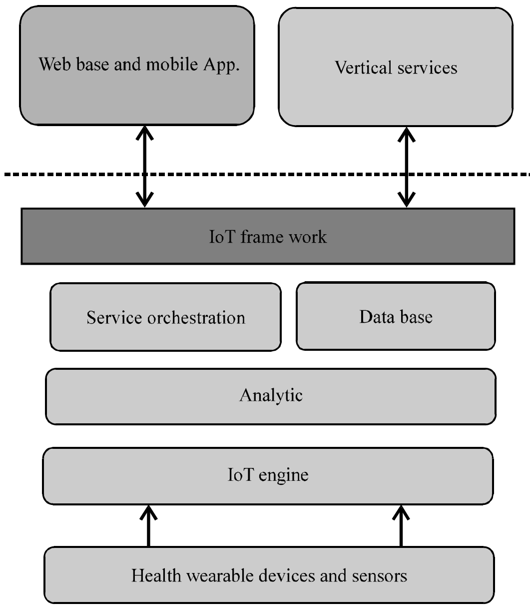

Fig. 5: IoT frameworks illustration

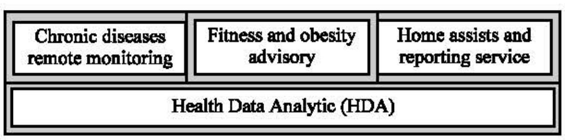

Fig. 6: ISEHAT applications

ISEHAT health components: ISEHAT consists of health framework layer as shown in Fig. 6. The wearable sensors gather health and activities parameters which include:

- Body measurement parameters such as body weight, Body Mass Index (BMI), body fat percentage, body water, bone, visceral fat, skinfold, anthropology BMR, muscle mass, heart rate, blood pressure, blood glucose (before and after a meal), blood oxygen and body temperature
- Routine activity such as exercise, sleep, lifestyle, food and diet pattern

All data are stored in the ISEHAT cloud and can be used by the Health Development Agencies (HDAs), the analytic module in health decision/advisory output for chronic diseases remote monitoring, fitness, obesity report, home assist and information services. Chronic diseases remote monitoring application is a function in ISEHAT system that is dedicated to monitoring chronic conditions based on patient health parameters such as high blood pressure and diabetes. The panel doctor assigned in the ISEHAT can control the patient's health status remotely in an efficient manner and continuously reduces appointments for regular medical checkup. The valuable outputs from this module are the dedicated health plan and alert notification (SMS/e-Mail) when the system detects unusual measurement from the patient's health condition. Health data analytic is also the central health data processing that performs big data analytic from the collected data of routine activities, daily exercise, sleep, food, diet and lifestyle. By using specific algorithms, a predictive health information can be produced with alert notification. The module also provides the health data scoring and trending. Home assist and reporting services is also another module in ISEHAT that provides assistance to patient virtually. It includes medication reminder and statistic reporting. Finally, fitness and obesity advisory that collects inputs from the wearable health sensors for the fitness assessment and monitoring progress.

CONCLUSION

One of the long-predicted IoT revolutions in healthcare is being demonstrated through the examples described in this studies. The ISEHAT continuously becomes the forefront framework for e-Health using use new health cases with cost-effective as well as accessible care services including chronic disease remote monitoring, fitness/obesity advisory and home assist/health reporting service. ISEHAT also provides automation and machine-to-machine communication with deep layers that complete the e-Health applications.

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