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6Lo Bluetooth Low Energy for Patient-Centric Healthcare Service on the Internet of Things

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***Abstract*—In this proposal, we suggest the Internet of Things connectivity for patient-centric healthcare based on Bluetooth Low Energy (BLE). According to population aging, the career-centric healthcare change to patient-centric healthcare to manage excessive older people. A smartphone and BLE sensing devices are widely used as infrastructure of patient-centric healthcare. However because BLE cannot support IP communication with Internet devices, the smartphone wastes additional resource for application to communicate with Internet devices. Because of wasted resource, the smartphone may occur performance degradation and shutdown. To solve this issue, we support IP communication on BLE. We uses 6LoWPAN standard which provides IPv6 communication over Low power Wireless Personal Networks (6LoWPAN) to enable IPv6 communication over BLE.**

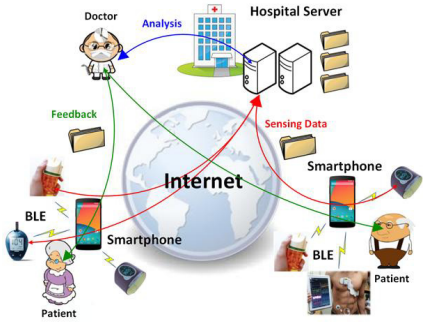

Fig. 1. The Internet of Things connectivity for the patient-centiric healthcare model.

I. Introduction

The proportion of older people over 60 has been rising steadily. Since the number of older people increases, who need the healthcare, the resource of healthcare has to be concurrently increased to handle them [1]. The way to manage excessive older people is changing the career-centric healthcare to the patient-centric healthcare [2]. To do change, the Internet of Things (IoT) is required. The IoT enables integration of sensors, patient identification, and network infrastructure which any body uses anytime, anywhere through any device and media [3]. A smartphone can be used, as the IoT healthcare device, to provide the IoT connectivity, because patients always carry the smartphone as a personal device and access the Internet anytime and anywhere.

In addition, in order for the patient to carry the IoT healthcare sensing device, which sends sensing data to smartphone for integration of sensors, the IoT healthcare sensing device is required to be small and light, and guarantee low energy consumption for long lifetime. To satisfy requirements, Bluetooth Low Enegy (BLE) can be a proper candidate because BLE is enough to small and light, and it is specially designed for reducing energy consumption. Additionally, lots of the BLE IoT healthcare sensing devices are widely distributed in healthcare market.

As shown in Fig. 1, patient often uses the multiple IoT healthcare sensing devices for accurate feedback from doctor. Unfortunately, since BLE cannot support direct communication with Internet devices, each IoT healthcare sensing device needs one application to convert a BLE packet to an Internet packet and send it to server. If patient uses the multiple IoT healthcare sensing devices, the smartphone runs multiple applications for them. When multiple applications occupy smartphone's resource too much, the smartphone occurs performance degradation and shutdown caused by shortage of battery.

To avoid performance degradation and shutdown, BLE has to directly transfer sensing data to the Internet without additional running application on the smartphone. Fortunately, IETF IPv6 over Low Power Wireless Personal Area Network (6LoWPAN) working group defines standard for providing interoperability with IPv6. IETF 6Lo working group also propose draft for transmission of IPv6 packets over BLE [4]. To implement the IoT connectivity for the patient-centric healthcare without performance degradation and shutdown of the smartphone, we propose a 6LoWPAN over BLE (6BLE) that features direct connectivity between BLE and IPv6. We designed 6BLE protocol stack, autoconfigured address, neighbor discovery and header compression based on draft of 6Lo. Also, we designed fragmentation & reassembly, unit and multicast address mapping, and routing in local network which are not define in draft yet. Besides, comparing to 6Lo draft, we also include original BLE protocol stack in 6BLE stack to offer compatibility between 6BLE and original BLE.

II. 6LoWPAN over BLE

The 6BLE consists of software and hardware platform for an end-device and a gateway. As shown in Fig. 2, the end-device protocol stack includes lightweight transport, lightweight network layer on the adaptation layer. The stack also has both original layer of BLE and additional layer

This work was supported by the IT R&D program of MSIP/IITP. [10041313, UX-oriented Mobile SW Platform], This work has been supported by National GNSS Research Center program of Defense Acquisition Program Administration and Agency for Defense Development.

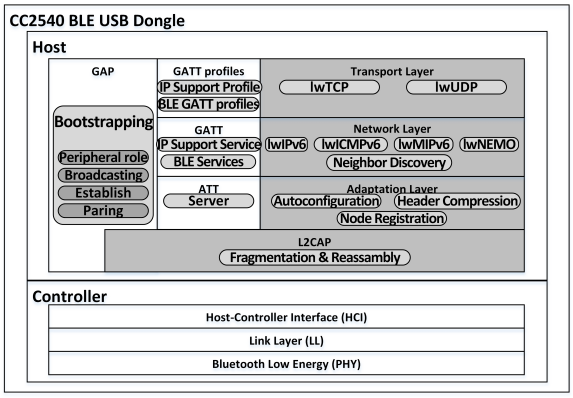

Fig. 2. The 6LoWPAN over BLE End-Device protocol stack

for 6LoWPAN in the Host part. Comparing to 6Lo working group proposed protocol stack [4], our proposed protocol stack includes GAP, BLE GATT profile, and BLE service in GATT, which are original components of BLE, to provide not only 6BLE also BLE communication. The reason why the proposed BLE protocol stack supports the BLE and the 6BLE layer is that user can selectively choose the BLE or the 6BLE communication depending on situation and compatibility. For instance, if patient transfers data to only smartphone, IoT healthcare sensing device do not need to send data via the 6BLE, because the original BLE is enough to do that. In addition, since IPv6 packet is much heavier than original BLE packet, a user can save data traffic to keep performance of network.

Fig. 3 shows the prototype stack of a gateway, which includes full transport, network layer in the Raspberry Pi. Similarly to end-device, the gateway also supports dual protocol stack for providing original BLE communication as well as 6BLE communication. However, we implement 6LoWPAN stack and BLE stack in different devices;Raspberry Pi, CC2540 BLE dongle. In doing so, users do not need to modify their own device software. They only need to put the CC2540 BLE USB dongle into their own device and install gateway sofware which includes adaptation layer for 6LoWPAN.

III. Implementation and 6LoWPAN over BLE Architecture and Platform

The proposed 6BLE platform is built on our SNAIL [5] platform. As shown in Fig. 4a, the 6BLE end-devie consists of CC2540 BLE USB dongle and E-health sensor platform v2.0. CC2540 performs to interact data between application layer to BLE PHY layer. E-health sensor platform performs as healthcare sensing element to gather patient's statement and receive data&commands from server/the other devices. In implementation, we use four sensors, which are electrocardiogram (ECG), eletromyograph (EMG), galvanic skin response (GSR), and body temperature sensor and etc.

As shown in Fig. 4b and 4c, the 6BLE gateway consists of CC2540 BLE USB dongle and Raspberry Pi. CC2540 performs as bridge between 6LoWPAN gateway software in Raspberry Pi and BLE network through USB connection. Because it works as bridge, CC2540 of gateway does not contain tranport, network, and adaptation layer comparing

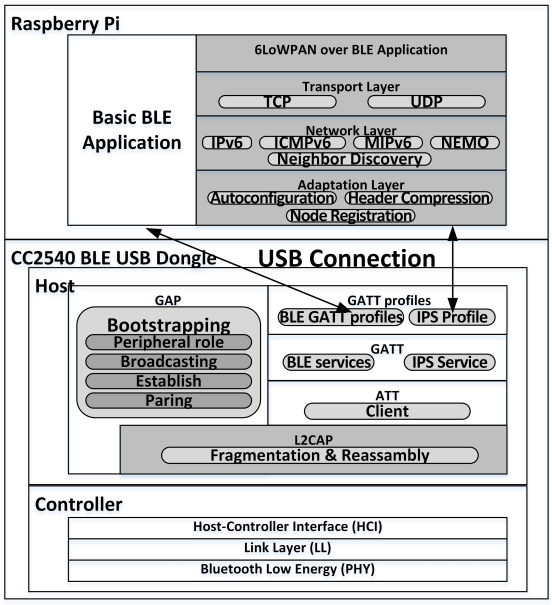

Fig. 3. The 6LoWPAN over BLE Gateway protocol stack

(a) (b) (c)

Fig. 4. The hardware platform for 6LoWPAN over BLE (a)End-device (b)CC2540 Bridge (c)Gateway

to CC2540 of end-device. In the Raspberry Pi, it forwards IPv6 packets from the Internet to CC2540 with 6LoWPAN functionality such as header compression. And it also manages the connection handlers of BLE end-devices to exchange profiles to switch between original BLE and 6BLE.

IV. Conclusion

This proposed 6BLE stack provides interoperability between IPv6 and BLE through smartphone as gateway. By using 6BLE, the IoT healthcare sensing devices directly communicate with Internet devices, such as hospital server, without performance degradation and shutdown. We suggest solution to take care of healthcare issues occurred by population aging by using the Internet of Things connectivity for patient-centric haelthcare based on Bluetooth Low Energy.

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