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The Potential of Internet of m-health Things "m-IoT" for Non-Invasive Glucose level Sensing

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Abstract—**An amalgamated concept of Internet of m-health Things (m-IoT) has been introduced recently and defined as a new concept that matches the functionalities of m-health and IoT for a new and innovative future (4G health) applications. It is well know that diabetes is a major chronic disease problem worldwide with major economic and social impact. To-date there have not been any studies that address the potential of m-IoT for non-invasive glucose level sensing with advanced opto-physiological assessment technique and diabetes management. In this paper we address the potential benefits of using m-IoT in non-invasive glucose level sensing and the potential m-IoT based architecture for diabetes management. We expect to achieve intelligent identification and management in a heterogeneous connectivity environment from the mobile healthcare perspective. Furthermore this technology will enable new communication connectivity routes between mobile patients and care services through innovative IP based networking architectures.**

I. Introduction

Internet of Things (IoT) is one of the major communication advances in present time that links the internet with everyday sensors and working devices for an all –IP based architecture [1]. Extensive research on using this concept in different applications has been recently reported in [2].
However, the ubiquitous IPv6 based connectivity concept has not been investigated extensively from the mobile healthcare perspective. In recent years there has been major initiatives and work in the area of m-health in different healthcare sectors, e.g. mobile diabetes management systems [3, 4, 5]. More recently, a new concept of m-IoT has been introduced [6]. In principle m-IoT introduce a new healthcare connectivity paradigm that interconnects IPV6 -based communication technologies such as 6LoWPAN with emerging 4G networks for future Internet based m-health services. From the glucose level sensing end, it is well known that real-time/ continuous measurement can provide significant clinical information of the glucose levels and conditions to provide timely intervention of any hyperglycemic episodes of the diabetic patient in real-time compared to non-real time measurements as it is the case currently. In recent years several non-invasive glucose level measurement methods have been addressed [7], and the opto-physiological modeling could provide an approach for effective interpretation of these measurement [8]. These non-invasive glucose monitoring sensors are mainly attached onto the skin, which, as the largest and outermost organ of the body, accounts for 10–15% of the body mass and has one of the lowest metabolic rates, thus having relatively low nutritive requirements. Hence the skin is employed as a blood reservoir by the body, changes in the blood requirements of other organs lead to the changes in the cutaneous blood contents including glucose level. *In-vivo* non-invasive glucose monitoring has the promise of providing great relief to many patients with diabetes mellitus for whom tight glucose control is are directly dependent on the tissue composition and desirable for reducing the effects of long-term complications or helping to avoid the potentially life-threatening condition of hypoglycemia. Currently, the control of the body glucose is performed in a blood sample requiring painful puncture of the skin in order to draw a drop of blood, typically from the fingertip.

The demands from diabetes clinical management and patient self monitoring are moving onto an effective approach when integrating a high performance opto-electronic sensor into state-of-the-art m-Health system. However, to date there is no study to address the potential m- IoT connectivity with non-invasive glucose level sensing.

In this paper we will address such m-IoT based architecture and the potential implementation issues and challenges. Section II describes the methodology adopted to achieve the goals of this work. Section III shows some of the preliminary and evaluation results of a test bed implementation for general m-IoT system. And finally section IV conclude the paper and indicate the ongoing and future work.

II. Method: m-IoT for Real-time Glucose sensing

Fig. 1 shows the m-IoT system based on IPV6 and 6LoWPAN protocol architectures. In this configuration, the non-invasive diabetes sensors from the patients are linked via IPv6 connectivity to the relevant healthcare provider or the diabetes centre. The fundamental role in the architecture is the 6LoWPAN protocol enabling wireless sensor devices for all IP based wireless nodes based on IEEE 802.15.4 standard. The potential of the 6LoWPAN in addition to the IPV6 connectivity is the low power characteristics of these nodes.

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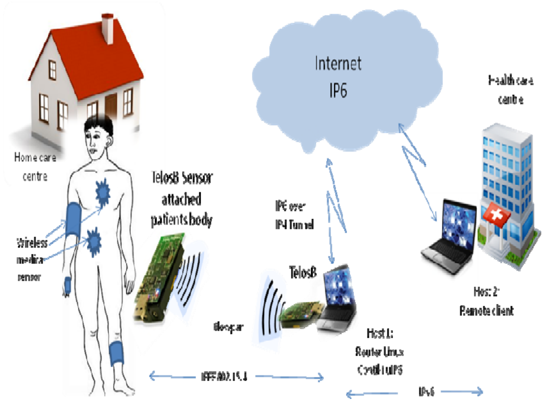

Fig. 1 General 6LowPAN Architecture

An IPV6 access point sends the relevant diabetes clinical data to an IP-based connected healthcare centre. Data can be sent and collected both periodically or event-driven.

Fig. 2 shows the general m-IoT layers architecture based on 6LoWPAN protocol. This model is based on five layers illustrating the combined functionalities of typical IoT layer architecture with 6LoWPAN functionalities.

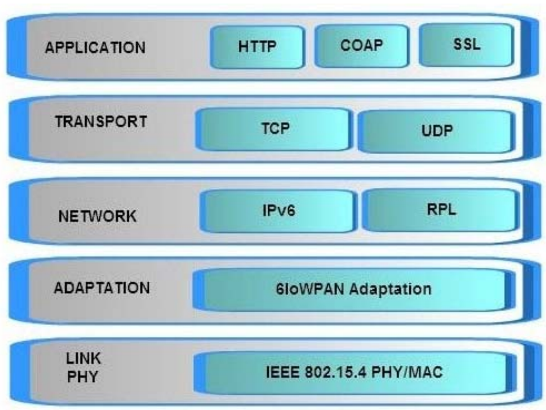

Fig. 2 6LoWPAN based IoT architecture [10]

In this work, the communication interface of the clinical data protocol and clinical sensor node is accomplished by using messaging based protocol over IPv6 connectivity communication layer. Fig 1 illustrates an example of the developed 6LoWPAN system using the layered architecture and implemented using the TelosB sensor motes [9]. This platform is selected for its low power microprocessor (MSP430) and simple USB connectivity issues.

In this platform, the physiological assessment sensor uses IPv6 and 6LoWPAN to establish health data packet transmission over the IEEE 802.15.4 protocol, as well as application specific components that uses proper sockets to interact with the clinical sensor nodes as shown in Fig. (1). These data messages with relevant clinical measurements are responded back by the sensor nodes using the UDP protocol in the Transport layer as shown in Fig. 2.

III. Preliminary Evaluation

The experimental 6LoWPAN based system is shown in Fig.3. The application is implemented using JAVA programming platform. The current evaluation system uses the TelosB mote as the medical sensor node.

In this work a test bed platform is build and tested to verify the m-IoT concept and its related communication setup and requirements in terms of both hardware and software. The sensor used in this experiment is A Body temperature sensor that is build in the TelosB mote used. The next step is to use the non-invasive opto-physiological sensor for glucose level monitoring. The output of this non-invasive sensor can be connected to the TelosB mote. TelosB mote has a built in Analogue-to-Digital convertor that accept an analogue signal of 0-3 Volt and hence we need some signal conditioning interface between the non-Invasive sensor and the 10-pin (U2) and 6-pin (U28) expansion connectors of the TelosB mote as shown in fig. 4.

In real medical scenario each diabetes node (representing individual mobile patient end) can have its own IPv6 address for relevant m-IoT and direct Internet connectivity from any mobile device linked or embedded with these devices. The biomedical information from these opto-physiological sensors is sent in real-time to a central access point where data is collected to special IP linked diabetes management system such as the one described elsewhere [11] for further clinical analysis. Fig. 5 expresses a typical sample of the acquired body temperature variations. The results show the successful implementation of the developed m-IoT system. Work is currently is ongoing to connect the non-invasive sensor within the TelosB node for the real-time glucose data measurement.

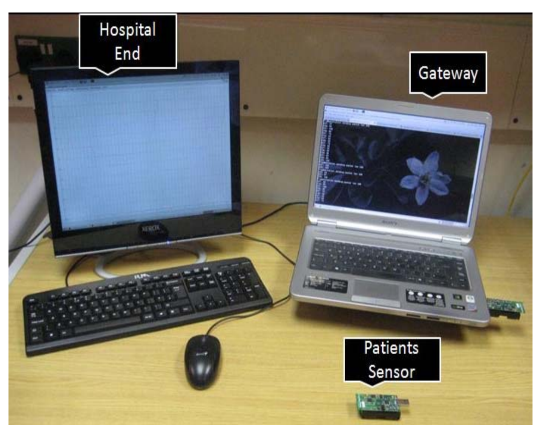

Fig. 3 Experimental m-IoT system

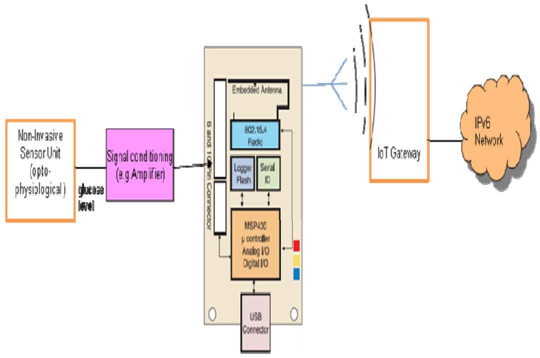

Fig 4 Block diagram of the m-IoT based non-invasive Opto-physiological Glucose sensor.

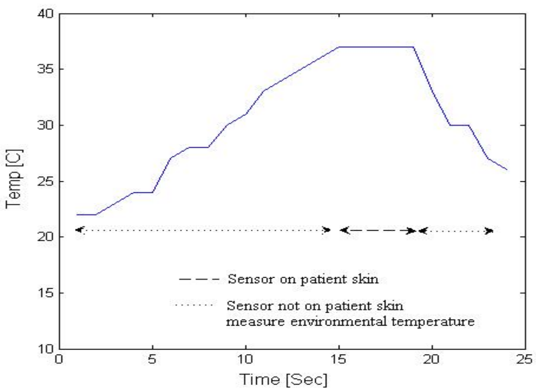

Fig. 5 Sample of m-IoT based temperature data

IV. CONCLUSION AND FUTURE WORK

In this paper we presented a new application concept that links the m-IoT connectivity for real-time non-invasive glucose level measurements in Diabetic patients. An experimental system has been implemented using the 6LoWPAN and TelsoB nodes sensor for verifying the performance of the system. Ongoing work is currently underway to build up and integrate the m-IoT node with the non-invasive opto-electronic sensor for real-time glucose levels and to compare the performance of this new sensor and system set-up with existing off-shelf glucose sensors. Fig 4 above shows a block diagram of the m-IoT based non-invasive Opto-physiological Glucose sensor.

Fig 6 A typical Opto-physiological assessment sensor

A novel non-invasive sensors design and set-up based on opto-physiological modeling as shown in Fig 6, is being considered to integrate with m-IoT and direct Internet connectivity from any mobile devices [9]. To this end, an emerging integrated technique will be explored and investigated towards generating a better performance in the physiological signal capture of the non-invasive glucose monitoring sensor based upon the existing Loughborough University opto-physiological assessment technology. This senor could also combine the accelerometer motion sensor within the integrated sensor cavity. The identical wavelength light sources together with photodiode coupled will be ideally suited for in-vivo and real-time glucose and physical activity measurements and features. Hence the future work will consider to 1) research into performance and reliability of the non-invasive glucose monitoring output, refining and revising of the relevant processes of signal capturing, processing and transferring; 2) comparison with available diabetic assessment device to achieve a stand level of clinical diabetes assessment, and easy-to-operate and routine management; and 3) compliance with the regulations and standards of the applicable UK & Globe health care standards.

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