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Reliable IoT Systems for Improving Quality Of Life Through The Exploitation of Cloud, Mobile and BLE Based Technologies Case Study: SunProtect UV

Orges Cico,
Department of Software Engineering,
Canadian Institute of Technology, Engineering Faculty,
Tirana, Albania

Abstract— **This paper presents the integration of mobile, cloud and embedded device communications based on existing internet infrastructure. Connecting various smart objects within an intelligent ecosystem provides high capability. Moreover the trend of Internet of Things (IoT), addressing health, quality of life, smart cities etc. has been presented.**

We described similar aspects with a proper case study (Sun Protect UV), relying on Nordic Semiconductors in which a health related mobile cloud application interconnected with a wearable device are presented. The research undertaken shall represent not just the technological innovation, exploiting state of the art technology, but also the health benefits related to this smart system.

Keywords. Internet-of-Things; IoT; Smart Devices; Fall detection; Energy eﬃciency; Wearable devices; Sun UV

I. INTRODUCTION

Internet of Things (IoT) concept and paradigm brings together existing internet infrastructure with everyday embedded devices such as smartphones or other microcontrollers in a common playground to improve people everyday life and provide smart innovative services.

Information technology relying on Internet has widely grown during the past decades. Thus all services and information are exchanged on World Wide Web (www). However a new concept arises with the need to provide interconnection not just between web browsers and cloud based servers / clusters with robust ISO protocols, but also between smart embedded devices.

The latter might rely on independent protocols with respect to the ones used for interconnecting Web applications. The main goal of the IoT is to bring together both paradigms of the 21st Century to collaborate in creating larger grids of intelligent services and devices.

Thus a mobile / cloud / embedded device interconnection through existing state of the art technologies shall be presented along this paper work. A development approach and methodology will be described and adopted to real case study addressing primarily health related issues.

Thus a system monitoring the UV through a mobile application and BLE device is unfolded in the coming section. The main purpose of the SunProtect Application is to control, predict and suggest the best UV dosage for its users, providing not just useful tips but also health benefits.

After results have been gatheredin the last section outcomes and challenges related to technological restrictions and decisions undertaken will be evaluated together with future proposals of improving existing approaches.

II. BACKGROUND

World Wide Web services are obviously the primary source and model of interconnection between services and information. Several existing embedded devices can become part, interact or controlled from existing web technologies. This would result into a combination between the previous two thus deriving the concept of Physical Web = Web Technology + IoT. [2]. Figure 1 represents an overview of the possible physical web architecture to be adopted.

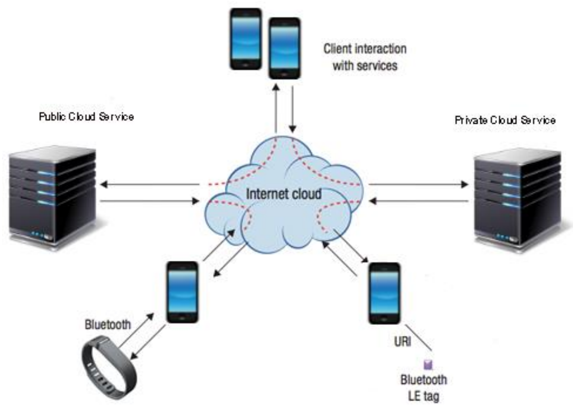

Fig. 1. Possible Architecture adopted to interconnect the existing cloud infrastructure with embedded devices relying on Bluetooth Low Energy (BLE) communication protocol

Existing concepts in web/cloud protocols will be extensively exploited along having a stable and robust infrastructure in storing data, sharing/retrieving information as well as guaranteeing high availability and scalability. Thus URI (Unique Resource Identifiers) and RESTful API (REST standing for Representational State Transfer) will be part of the system architectures.

Moreover further protocols are required in order to fill the communication gap between smartphones and embedded devices relying on state of the art microcontrollers.

One of the largely adopted technology is the one based on Nordic Semiconductors, which has a built-in BLE embedded inside its System on Chip (SoC) microcontrollers. Also the Bluetooth communication protocol relies on Generic Access Profile (GAP) and Generic Attribute Profile.

GAP covers the usage model of the lower-level radio protocols to define roles, procedures, and modes that allow devices to broadcast data, discover devices, establish connections, manage connections, and negotiate security levels, GAP is, in essence, the topmost control layer of BLE. This profile is mandatory for all BLE devices, and all must comply with it.

GATT deals with data exchange in BLE, GATT defines a basic data model and procedures to allow devices to discover, read, write, and push data elements between them. It is, in essence, the topmost data layer of BLE.

Both protocols assure a stable communication of data and services with SmartPhones having BLE technology built-in. (Integrated from Bluetooth vs. 4.0). This has result the most promising standard starting from 2010.

III. LITERATURE REVIEW

The paper addresses not just concerns related to technology but also the health benefits related to the exploitation of BLE embedded devices.

Many publications concerning UV (Ultraviolet) dosage intake have been a major concern related to skin health issues. One of the major risk being skin cancer.

While several articles during the past two years have been published related to development of embedded devices based on different microcontroller technologies. One of the most promising ones seems to be Nordic Semiconductors where BLE integration as a communication protocol has been made easy.

Several authors have presented the possibility of integrating into the Physical Web approach Cloud/Mobile and Embedded Devices, with high proficiency, security, availability and easiness of usage [7-9].

IV. METHODOLOGY

Development of an integrated environment of Cloud / Mobile and Embedded wearable devices consists in the following steps:

1. Development of the Wearable Device (Dongle)
2. Firmware Development providing the communication protocol between the mobile
3. Mobile App Development (Android / iOS)
4. Google Cloud Communication

The wearable device microcontroller is based on Nordic Semiconductor technology with nRF51 Development Kit, from which a firmware development in C programming language is made possible.

A Client / Server (C/S) Architecture is adopted for broadcasting services and exchanging data between the Mobile Application and the Wearable Device.

Firmware acts primarily as the Server while the mobile application developed in Android/iOS etc. shall act as a client communicating with the services offered from the server based on the GAP/GATT protocol.

Decision made from the mobile application shall also be based on communication with the Google Cloud Application. The overall architecture is described in Figure 2.

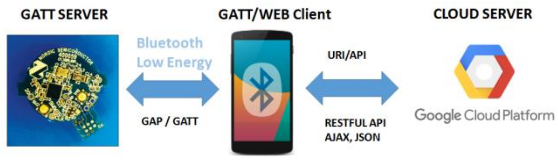

Fig. 2. IoT System Architecture

V. CASE STUDY

The chapter describes the actual implementation and development of the earlier described IoT Architecture. A developed wearable device has been implemented and shown in Figure 3 and 4, representing also the implemented service GATT table. The device is in charge of measuring sun UV. Alongside the wearable device a mobile application directly communicating with it has the capability of proposing suggestion for users best sun exposure throughout a day. The latter is providing the highest source of UVR for most people. However different skin types react differently towards solar radiations (UVR exposure) due to metabolic, genetic reasons or other types of skin abnormalities. Making long term exposure a health related issue not just due to sunburn but other more serious health concerns such as skin cancer (melanoma) or photosensitivity.

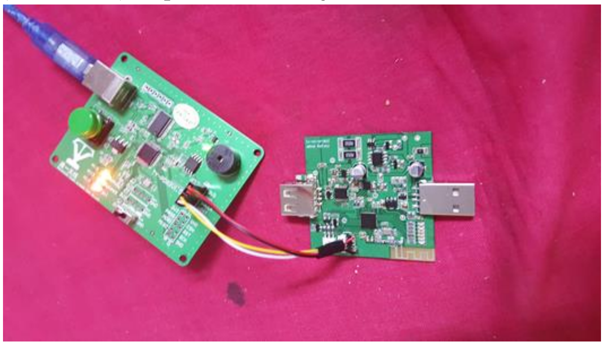

Fig. 3. Programming the device with Nordic Semiconductor Development Kit

Service	Handle	UUID	Permissions	Value	Length	Description
CG Service	0x0090	0x2800 - Primary service declaration	Read	0xC6C6 (Charge Guard)	2 bytes	Sunsense Service Description
Request Attr.	0x0091	0x2803 - Request Sun UV declaration	Read	0x0092	2 bytes	Request for Sun UV Factor
Charger value	0x0092	0x0111 - Set UV User Values	Read/Write	0x00 | 0x01	2 bytes	0x00 = OFF ; 0x01 = ON
Request Attr	0x0093	0x2803 - Voltage Characteristic declaration	Read	0x0094	2 bytes	Request for Data
Volt. target val.	0x0094	0x0112 - Set Skin Type	Read	0x00 | 0x01	2 bytes	Skin Health

Fig. 4. GATT service table

Since the background for such concerns is not at the knowledge of everyone, than it comes of good use to have an easy way to address this issue on daily basis. Benefits of Sun exposure such as vitamin D intake or immune system strengthening especially during childhood have been observed. But larger doses of exposure don't provide any further benefit. Thus a software system should be developed that controls and manages the maximum UVR exposure so the above mentioned health issues don't become a concern. It should monitor UV predictions and based on complex algorithms should provide estimates about sun exposure based on:

1. weather conditions
2. skin type
3. current skin tone
4. eye color etc.

If the health issues are not a concern the app can still be used for every day tips so that best sun exposure for best skin tanning, vitamin D intake etc. is guaranteed. The best portable system that can solve the problem nowadays would be a mobile application connected to device offering UV measurements. However a reliable data storage and sharing as well as computation of results has been implemented based on the Google Cloud Infrastructure.

Figure 5 and 6 represent the architecture of the developed mobile Application as well as the different implemented interfaces.

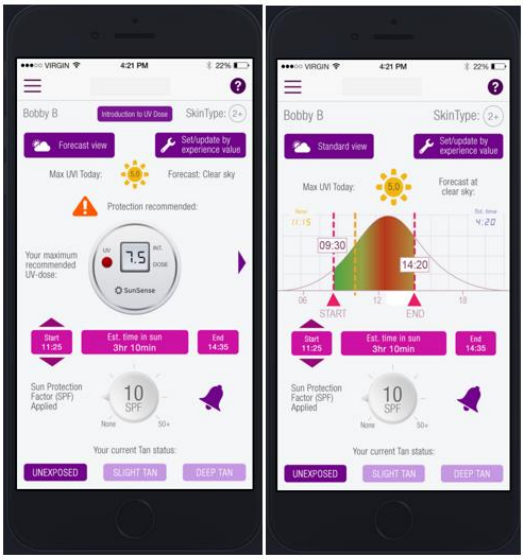

Fig. 4. SunProtectUV Mobile Application Architecture

While in Figure 5 is shown the Google Cloud Application architecture for storing/sharing and performing computations.

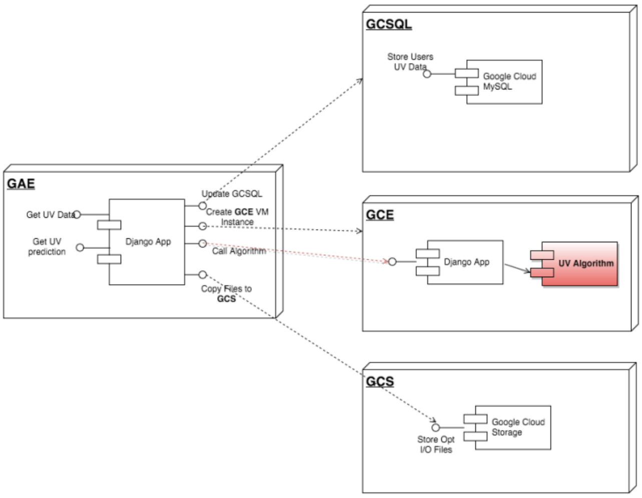

Fig. 5. Google Cloud Application architecture

The cloud infrastructure offers a reliable way of developing storing and sharing information for different users. It also offers more cost effective, and other benefits such as security or privacy, with little latency drawback. Thus providing the possibility of a personalized UV protection plan. The end user also has little or no knowledge at all about the system behind the scenes but it's offered a robust yet easy to use and comprehensive skin protection and health oriented service. And everything is estimated and based on high computation power offered from the cloud platform with very little computational power required from the wearable devices or smart phones.

VI. CONCLUSSIONS

In this paper we have shown the possibility of combining Cloud / Mobile / Wearable devices into IoT grid offering health benefits to the end users. The system can have two operational modes, online and offline, but also a well-structured synchronization logic.

Main benefits are related to easy to use, robust, reliable, secure and scalable system, yet with very little latency concerns.

However still practical issues remain to be addressed such as device proximity awareness, pairing and handshake protocols, centralized vs. peer to peer (p2p) approach, low latency and real time concerns and integration of devices with very low computational power.

A possible continuity could be evaluation of the systems on big scale and data analysis on long term basis.

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