mHealth Platform and Architectures to Provide Nutritional Guidance to Children

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Abstract—**Obesity and eating disorders in children are major problems worldwide. To promote their future well-being, it is important to educate children and teenagers about healthy lifestyle choices. Mobile technology offers many opportunities for helping to prevent health problems; however, the sole use of stand-alone applications is insufficient to improve children's health awareness because children require proper orientation from adults. In this paper, we present a mobile platform intended to provide nutrition guidance to children and architectures for implementing this platform in an elementary school environment. These architectures provide data capturing and user interfaces that are especially suited for children, and they permit adults to send and receive notifications and messages to improve results.**

***Keywords*- Internet of Things, mHealth, NFC, QR Codes.**

I. INTRODUCTION

Obesity and excess weight have been recognized as major health problems worldwide because they increase the risk of noncommunicable diseases (NCDs). Through programs based on promoting healthy eating habits and exercise, the World Health Organization (WHO) has sought to help prevent obesity-related chronic diseases [1]–[3]. Children are also affected by excess weight and obesity. Thus, it is important that children gain increased health awareness, particularly regarding nutrition and physical activity.

Today information technology offers a plethora of tools for healthcare [4], among them we consider mHealth as a very effective tool. mHealth comprises the use of mobile technology to provide health solutions. mHealth has been used to offer nutritional guidance to adults with good results. Researchers have developed a wide range of dietary and fitness applications for mobile devices, in some cases using mobile services and wireless sensor networks (WSNs). With these applications, users can improve their health when they suffer from NCDs. These applications generally require that users be aware of the nutritional facts (NFs) of food they are consuming and be able to understand the system information, which is mostly shown as graphics or raw data.

In this work, we describe the development of an mHealth platform intended to be used by children aged 7 to 12 years. Working with children presents unique challenges in terms of providing adequate data-capturing methods in mobile devices and age-appropriate user-friendly interfaces. The functionality to send/receive notifications and messages from adults, including parents and/or teachers, is also important.

In the platform, we used the Internet of Things (IoT) paradigm to provide the necessary features for these applications. The IoT concept [5]–[7] is based on communication among everyday objects, the ability to sense information about our environment, and the implementation of smart objects that can interact with end users and provide benefits in different application areas. The architecture of IoT has three layers [8]–[9]:

1. *Perception Layer*: based on technologies for device recognition, data gathering (in this case, for health-related information), and communication between sensors and mobile devices;
2. *Network Layer*: defines communication protocols and technologies for transmitting information captured in the perception layer; and
3. *Application Layer*: based on end-user requirements for application areas (in this case, focused on health prevention).

We investigated how to implement IoT-based technologies for providing efficient methods to capture health-related information. We considered WSNs for capturing the physical activity information of users. This work was particularly intended to be used by children when they eat away from their homes and parents (i.e., at school). Importantly, we sought to provided architectures with an efficient communication platform between children and related adults (e.g., parents, healthcare providers, nutritionists, etc.), such that adults could remotely receive and send feedback alerts and notifications about the nutritional decisions and health status of the children. This platform would also allow adults to schedule medical appointments, if necessary, to prevent disease development. Through our investigation, we developed a prototype user interface for children to display the health information.

II. RELATED WORK

Emerging mobile device technologies have been used to solve health-related problems in different countries. A clear example of health prevention-related research is SapoFitness [10], which provides a mobile application for dietary evaluation in which patients can record their food intake and physical activities. Medical specialists can remotely monitor the eating habits of their patients; notify patients about their progress, and offer advice about new eating habits. The main advantage of SapoFitness that can be utilized in our research is the implementation of alarm systems to notify patients about their health status. A similar approach is presented in [11]. In this work users are motivated to exercise by using a mobile game called Monster & Gold. A Bluetooth pulse oximeter is used to determine the user's heart rate. In this way the mobile game is used to train and motivate users to jog outdoors at the correct intensity.

Time to Eat [12] is a well example on how mobile phones can be used to promote healthy habits. In this work the authors encourage children to eat well by using a mobile game. This games focus on pet care as part of a child's daily routine, which fits well with behavior change models in which repeated reinforcement is key to success. Although *Time to Eat* is a standalone application, it presents very good clues about developing mobile applications specially intended for children.

A proposal for diabetes prevention, described in [13], implements a sensor network to obtain a patient's health-related information, such as blood pressure and weight. Data are captured by sensors, sent to a sensor gateway, processed, and sent to web services, where medical specialists are available to consult the patient to take preventive measures. Another related project, presented in [14], is a portable device for patients with diabetes to monitor their blood glucose levels and medications. The device also provides general knowledge about the NFs of consumed food, thus informing patients about the best food choices for their health problems.

Some authors, as in [15], have investigated how to implement WSNs and mobile devices to detect suspected arrhythmias in children. Sensor networks are used to monitor ECG signals, temperature, sound, and other parameters, to verify the conditions of the children. In [16], Chapko et al. proposed a health and fitness mobile assistant to investigate the requirements and preferences of end users, presenting technologies, scenarios, and equipment to improve users' experiences of their fitness activities and, thereby, reduce the risk of chronic diseases. In our research we considered using key technologies to promote healthy nutrition and physical activity habits in children. We could observe by the studies presented above [10]–[16] that is crucial the use of wireless sensors and mobile devices to capture specific health- and physical activity-related information from users.

During our preliminary research, we visited several schools in Baja California, Mexico, to obtain an overview of the activities of children and teenagers during their break times. Information regarding the children's behavior and activities was used to generate architecture proposals. We collaborated with medical specialists to identify what health information was required from users to prevent future NCDs. We determined that certain system architectures and technologies would be required for an IoT-based health-prevention platform.

A. *Health Information*

According to healthcare providers from the *Instituto Mexicano del Seguro Social (IMSS)* health institution in Mexico, NCDs can be prevented by promoting healthy eating habits and exercise. Accordingly, some important NFs of food need to be monitored. For our platform, we considered the following NFs: calories (ca), total fat (gt), saturated fat (gs), cholesterol (co), sodium (so), carbohydrates (ch), sugars (az), and protein (pr). We used a JSON structure for handling the NF information. JSON provides simple, rapid data handling and interoperability on mobile devices compared to XML and SGML as alternatives [17]. Figure 1 shows an example JSON structure for the NFs of a chocolate food (with fictitious data).


```
{"NF":{
        "ID":"30015",
        "type":"snack",
        "brand":"herheys",
        "name":"m&m",
        "ca":"299",
        "gt":"19.4",
        "gs":"11.5",
        "co":"15.4",
        "so":"12.5",
        "ch":"34",
        "az":"16",
        "pr":"4.8"
        }
}
```


Figure 1. JSON structure for nutrition facts.

B. *IoT Architecture*

Figure 2 shows the three-layer IoT system architecture, in which IoT technologies and communication protocols are mentioned for each layer.

Figure 2. Levels of our architecture based on IoT.

1. *Perception Layer*. To implement our platform, we considered several technologies in the perception layer. Near-field communication (NFC) is a short-range high-frequency wireless communication technology for exchanging data between devices at distances of less than

10 cm. This technology was designed and marketed by the NFC Forum as an upgrade to Radio Frequency Identification (RFID) technology. NFC provides an efficient method for capturing health-related information, as well as easy and simple interaction with other devices. For these reasons, NFC was used as the main system technology in our platform for the perception layer.

We used NFC tags to read food NFs through smartphones and to process and store the obtained information. After investigating NFC tag characteristics and the information that needed to be managed, we chose Mifare Classic 1K Stickers as the proper tags for this information. Users with smartphones without the NFC feature could alternatively use QR-Code tags. Users can read food NFs with their phone's camera and perform the same process for storing information. WSNs and GPS were used to capture information about the user's physical activities. However, the parameters for these sensors have yet to be defined in detail.

2. *Network Layer*. 3G, IPv6, and Wi-Fi protocols were implemented on this architecture to provide remote communication between mobile devices, servers, and databases containing the health information for each user. Mobile communication protocols also provided the ability to generate alerts and notifications to the users' mobile devices. Zigbee and 802.15.4 provided communication mechanisms between the mobile device and WSNs.

3. *Application Layer*. The main task of the application layer was to provide services to end users through the data processed from the perception layer. Software programs for mobile devices and personal computers were implemented to offer the benefits of IoT to the platform members.

III. PLATFORM DESIGN

Next, we defined the ideal behavior for our mobile health platform, depicted in Figure 3.

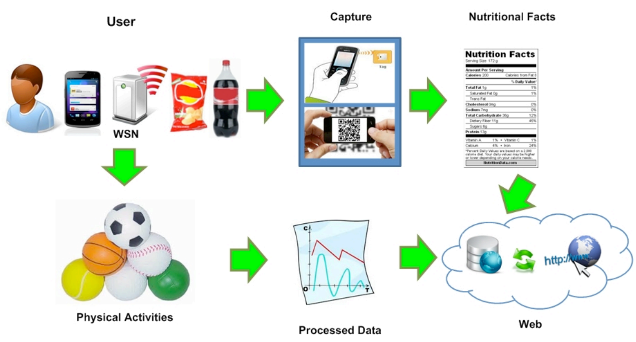

Figure 3. Ideal system behavior

The platform consisted of the following elements, some of them previously defined in [18]:

1. *End User's (Child's) Module*. The end user's module includes the mobile applications required by the child to track his/her food consumption by reading intelligent tags located on the food. This information is sent to the health educator or nutritionist to evaluate food consumption and provide appropriate notifications and messages. Food tags contain nutritional information and provide links to display more information about the food through augmented-reality applications. These applications are appealing to children, as they allow users to obtain information in a recreational way.

2. *Health Educator's (Nutritionist's) Module*. This module consists of a Web-based system that the health educator or teacher uses to collect and analyze the user's information. Data are sent to the system with the available wireless network over the Internet. The health educator's module includes a notification system to send alarms or short motivational messages to the user when required. It also includes a messaging system that can be used to communicate with the authorized user's tutor (or parent) who needs to be informed about the user's habits. The electronic health record of each user is also included in this module.

3. *User's Tutor's (Parents') Module.* This module consists of a mobile application installed on the tutor's device. Tutors can send and receive appropriate feedback and notifications when required. For instance, the health educator may inform a parent that his/her child is consuming too much sugar through a Multimedia Mobile Message (MMS) containing pictures of the items consumed. The parent then can send a warning to the child about these bad choices and take additional interventional measures at home.

4. *Physical Activity Logging Module*. This module is currently being developed. It includes a set of physical devices, such as balls or other toys, equipped with a sensor that logs information about motion related to the user's activity. This information is captured as a set of points and sent to a mobile application or web-based application using WiFi. A game is being developed that will translate the amount of physical activity captured into points to keep children motivated.

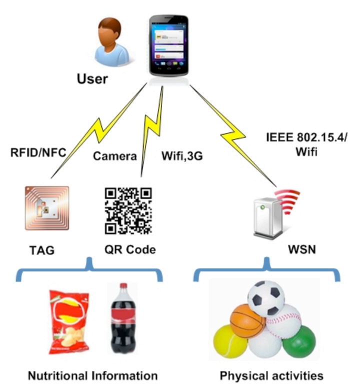

Figure 4. Data-capturing methods using IoT

The ideal dynamic of the platform starts with the children continuously using the mobile apps to store NFs and physical activity (Fig. 4). Information is read with automatic detection techniques, including NFC tags or QR codes for NFs and WSNs for physical activity. Data are stored locally in the mobile device, but are also sent to a web server to be analyzed by a health educator or nutritionist. Information can also be sent to parents. Nutritionists and parents can send notifications or messages to children to help them make appropriate decisions about food intake and physical activity.

IV. PLATFORM IMPLEMENTATION AND ARCHITECTURES

Figure 5 shows the platform components in our mobile health platform, which is intended to be used in elementary schools. The figure shows the interactions among all platform members. The nutritionist is able to visualize data from users and take appropriate measures to prevent health-related problems. Parents and tutors can access data and notifications to verify the health status of users.

To provide the capability of writing intelligent tags, we developed an NFC Application Programming Interface (NFC API), using Java. The NFC API is used to store NFs with the JSON structure (Fig. 2). We used a USB NFC Card Reader/Writer (module ACR122U) and 13.56 MHz Contactless (RFID) Technology. The reader/writer supports NFC, Mifare ISO 14443 A and B cards, and FeliCa contact-less technologies. At present, we only use Mifare Classic 1K Stickers, but we provide the possibly of using QR Codes instead of NFC tags. In this case, we will use a free web service to create the QR Code and an ordinary printer to create the tags. NFs can be obtained from processed food, also a nutritionist provided us with information about food prepared in the school's cafeteria.

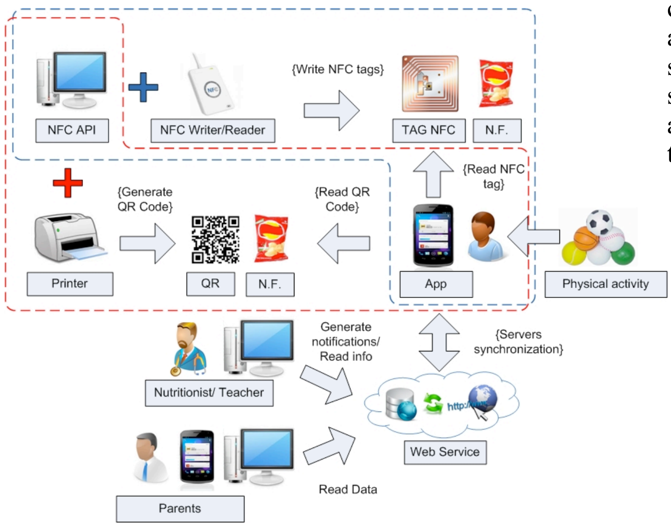

Figure 5. Platform implementation diagram

A. *Platform Architectures*

To develop our platform, we considered two architectures that rely on the technological characteristics of the end user's mobile device. In the first architecture (Fig. 6), the user (child) has a mobile device with the features necessary to implement IoT technologies.

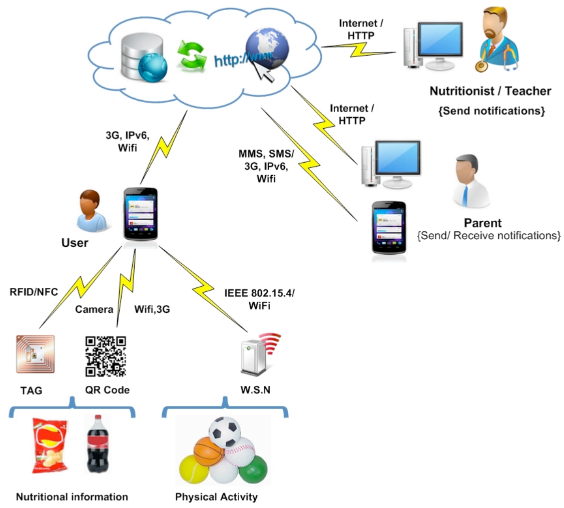

Figure 6. Platform architecture 1

The user stores all of his/her health information on his/her own device. After the data are processed and servers are updated, a nutritionist can access the information for preventive health measures through notifications or medical appointments.

Because most children in elementary school do not have access to mobile phones with NFC technology or equipped with a camera, we proposed a second architecture (Fig. 7), in which the person involved directly with health prevention does not have a mobile device capable of supporting IoT technologies. In this case, a "Global User" performs data entry for one or several children. The Global User may be a parent, teacher, or another student who has a mobile device capable of supporting IoT technologies. Data information can be stored in one mobile device, and the same mobile application can have several accounts to redirect data to the appropriate user.

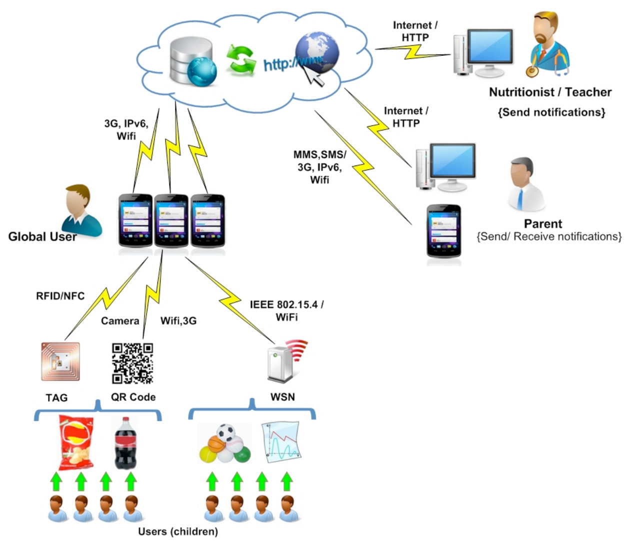

Figure 7. Platform architecture 2

B. *User Interface and Notifications*

To select the most suitable user interface for the mobile application to display health information to children, we performed an experiment with potential end users at two elementary schools in Mexico. There were 43 participants in the user study with ages ranging from 9 to 11 years. Of the participants, 33 own a mobile phone. Children were presented with a prototype application on a mobile device and asked to use its main features. Users were then asked to fill out a survey to verify their understanding of the screens. Note that this is a preliminary user interface; a usability study will be necessary to generate the final user interface.

We used several prototypes, including showing NF with bar and pie charts and using the "Eat Well Plate" graphic. The "Eat Well Plate" ("Plato Sano" or "Plato del buen comer" in Spanish) is a graphic showing the percentage and type of food recommended to be including in a daily menu. It was defined in the Mexican official Norm *NOM-043-SSA2-2005* [19], to provide unified criteria for nutritional guidelines to the Mexican population. The Eat Well Plate divides food into three food groups: fruits and vegetables, cereals and grains, and foods of animal origin (Fig. 8). In our experiments, we found that children best understood the presented information when it was displayed in the form of the Eat Well Plate, probably because schools in Mexico use the Eat Well Plate paradigm for teaching about nutrition.

Figure 8. The Eat Well Plate, as defined in the Mexican legislation.

Figure 9 shows the main screen of the application that we created to be used by the children.

Figure 9. Main screens from the mobile application

This screen presents the application options. The button on the top of the screen is used to read the intelligent tag attached to a food. The button on the middle of the screen has the functionality of providing users a list of the food groups. There is also a screen describing each of the food groups included in the Eat Well Plate. The application is used to read nutritional information on a daily basis.

To inform children of whether they are eating correctly, we present information using stars because this motivational technique is also used at their schools. Once a tag is read, the application uses simple images (Fig. 10) to indicate to users whether they can eat the food group that they have chosen, according to the percentage eaten at the moment. Information is also sent to a web server, where a nutritionist can analyze the data on a daily or weekly basis.

Parents are informed and can send notifications to the child. We defined a set of notifications with several priorities and related communication mechanisms (Table 1). Priority refers to how quickly the notification must reach the user. The nutritionist defines the type of notification to be sent. For instance, if a child has surpassed a maximum calorie intake, he/she may decide to send a priority 0 notification (call) to inform the parents. Parents can also send a priority 1 notification (SMS) to warn the child about this.

Figure 10. Motivational and orientation screens from our mobile application.

After designing the platform architectures, we generated prototypes of the capture modules on the Android O.S. and tested the prototypes with potential end users. NFC was more efficient than QR codes for capturing health information, and users preferred this technology for its simplicity of use. Concerning physical activity, we are currently working on two prototypes using a football equipped with wireless sensors.

TABLE I.

PRIORITIES AND COMUNICATTION MECHANISM FOR NOTIFICATIONS

Priority	Type	Communication
0	Immediately	Call
1	Urgent	HTTP and SMS or MMS
2	Important	SMS or MMS
3	Normal	HTTP

V. CONCLUSION AND FUTURE WORK

In this paper, we have presented the necessary architectures to develop an IoT-based platform for the prevention of obesity- and poor nutrition-related NCDs. Comparing our results with current health-prevention systems; we conclude that our technologies provide more efficient capture mechanisms to end users. As a key to the prevention of health-related problems, our platform also uses an alarm system. Because it is specially designed for children and teenagers, the user interface will improve the end user's experience with the mobile health system. Future improvements will include the development of prototypes based on the proposed architectures, the implementation of different WSNs, and the verification and documentation of the platform's behavior with potential users.

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