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TWO WAY ARCHITECTURE BETWEEN IOT SENSORS AND CLOUD COMPUTING FOR REMOTE HEALTH CARE MONITORING APPLICATIONS

Research in Progress

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Abstract

This research presents an intelligent two way IoT (Internet of Things) architecture that uses IoT sensors and cloud-technology for data collection, monitoring and alerting strategies. This approach can enhance development of support systems which are useful for patients and aging individuals who want to remain in an independent living environment. Such an architecture can be used for early detection of anomalies and reduce medical costs. In this paper we present a technical architecture called SMMC - Sensors, Micro Controller, Machine to Machine Protocols and Cloud. The technical architecture proposed will firstly collect data from IoT sensors at the point of care. Secondly, the data collected by sensors is usually an analogue signal, this is processed by the micro controller. Thereafter the data is sent to the cloud, where clinical decision support algorithms can be applied to check for any clinically alarming anomalies in the data. Finally using machine to machine protocols can be used to activate sensors for feedback or alerts. We present this architecture along with a smart bed scenario, and describe further research in progress.
Keywords: Remote Health Care Monitoring, IoT Health Care, MQTT, ThingSpeak, AAL

1 Introduction

IoT technology is utilized widely in developing health care solutions, especially in applications such as remote health monitoring and in-home care. IoT-based health care applications have received compelling attention in recent years, especially for solutions that enable independent living. Existing research has focused on the design and implementations of IoT-based health care systems that provide remote and continuous monitoring and support early detection and timely care for those people who need special attention such as chronic disease patients, people with disabilities, and the elderly. The motivation of these applications is to reduce health care expenses while providing better quality of life for people.

In this paper we present a technical architecture called *SMMC* - Sensors, Micro Controller, Machine to Machine Protocols and Cloud. The technical architecture proposed will firstly collect data from IoT sensors at the point of care. Secondly, the data collected by sensors is usually an analogue signal, this is processed by the micro controller. Thereafter the data is sent to the cloud, where clinical decision support algorithms can be applied to check for any clinically alarming anomalies in the data. Finally using machine to machine protocols can be used to activate sensors for feedback or alerts. For example a weighing sensor measures weight of an elderly individual in their bed. The data is processed by a micro controller and sent

to the cloud. The individuals weight data is not being received & it is late night, therefore the sensor in next of kin's room is activated (led light and an alarm) prompting to check on the older patient.
The structure of the paper is as follows - we present the literature on health monitoring systems in IOT in section 2. Then we articulate the SMMC architecture in section 3. The SMMC is applied to a scenario of weight sensor, this is presented in section 4 followed by conclusions and plans for further work in section 5.

2 Literature Review

This section focuses on a review of smart healthcare applications based on IoT including remote health monitoring applications and ambient assisted living (AAL) applications.

2.1 Remote Health Monitoring Applications

Numerous studies have attempted to focus on remote health monitoring, especially continuous monitoring, which is very important in chronic diseases such as heart failure, diabetes, and asthma. Chang et al. developed a context-aware and interactive m-health system for diabetics, consisting a blood glucose monitor and a cloud server platform (Chang et al., 2016). Patient's blood glucose values and measurement scenarios are collected and sent to a cloud server by an Android-based device. Patient's health status obtained by analyzing the collected information is used for performing appropriate interventions such as sending instruction messages to the patient or generating notifications to the patient's caregivers if necessary.
In the research developed by (Fanucci et al., 2013), H@H platform is described using biomedical sensors for daily collecting parameters of Chronic Heart Failure (CHF) patients, including Electrocardiography (ECG), SpO2, blood pressure and weight. The collected data are automatically sent to the hospital's database and monitored by physicians, allowing patients to take timely interventions in case of necessary. A smart shirt which is a wearable ECG system has been designed and implemented by (Jeon, J. Lee, and Choi, 2013), using an ECG sensing device for real-time monitoring and self-diagnosis for CHF patients. The measured data are transmitted wirelessly to a smart phone using Bluetooth. In case of emergency, the system can make an automatic call to the Emergency Rescue Center. Suh et al. developed a weight and activity with blood pressure monitoring system called WANDA (Suh et al., 2011) which consists of sensors, web servers, and back-end databases. The weight, blood pressure and physical activity of CHF patients are measured and sent to the web server's database. Simultaneously, 12 most common signs and symptoms of CHF are daily checked through questionnaires using a smart phone-based application. When the obtained values are out of the acceptable range, alerts are sent to healthcare providers via text message or e-mail.

2.2 Ambient Assisted Living (AAL) Applications

Providing personalized care for the elderly or the disabled based on their profile and the surrounding context, which is well-known as Ambient Assisted Living (AAL), is one of the key solutions that brings sustainable care for those people, and supports them to live more independently in their homes without worrying about losing their independence (Al-Shaqi, Mourshed, and Rezgui, 2016).
In the research carried out by (Chuang et al., 2015), a system called SilverLink is proposed which is a home-care solution for seniors. It uses multiple object sensors placed in-home for tracking users' activities as well as their health status based on their preference and lifestyle. Simultaneously, a human sensor is attached on each users' body all the time for recording their motions such as walking, sitting or falling. The sensed data are transmitted to the data center and processed by the advanced analytic engine for checking and triggering alerts to the emergency response team if there is any abnormalities in users' activities or movement patterns.

A similar system called Help to You (H2U) is developed by (Basanta, Y.-P. Huang, and T.-T. Lee, 2016) that makes use of wearable devices, biosensors and wireless sensor networks for providing applications including emergency calls, medication reminders and symptom checks based on monitoring real-time activities and health status of the old aged. Medical adherence solutions such as a drug management system based on RFID technology (Parida et al., 2012), or an intelligent pill box (S.-C. Huang et al., 2014) are useful for elderly people who have high risk of suffering from dementia.

In (Santos et al., 2016), authors proposed a system that integrates an IoT-based mobile gateway with an Intelligent Personal Assistant (IPA) platform for providing services including location monitoring, heart rate monitoring, and fall detecting. The user's information about location, heart rate, and possible fall detection is collected by the gateway and sent immediately to the caregiver's IPA for generating alarms or appropriate interventions. In addition, the capability to interact with other smart objects enables IPAs to obtain new knowledge and awareness about their users. The experiment results indicate that the location monitoring service is more accurate in outdoor locations than at indoor locations. In the meanwhile, the heart rate monitoring accuracy depends on the accuracy of the used sensors. The falls detection algorithm accuracy achieves 100% with still, walk, sit down, stand up and lay down activities, while achieves 96.7%, 86.7% and 93.3% with three activities including jump, run and fall, respectively. Another real-time falls detection system was introduced by (Cheng, Jiang, and Shi, 2015) using wearable sensors for tracking the motion and location of the body. The system has 96.4% of fall detection accuracy based on total 150 experiments with 10 intentional falls and 5 daily life activities.

2.3 Research Gap and Future Opportunities for IoT Health Care applications

Our review on recent IoT applications in health care found that existing studies focus on vital sign monitoring and activity monitoring for detecting abnormal situations, fewer of them concentrate on *integrating environmental factors* for analytic and *decision-making support* (Al-Shaqi, Mourshed, and Rezgui, 2016). Moreover, most of the systems are designed for tracking physical health status of individuals, while mental health status has considerable impact on human well-being. Solutions for monitoring and detecting both physical and mental health changes need to be further developed. For example, authors in (Mirza et al., 2016) suggest to use a smart bed with an embedded weight sensor for collecting data and identifying any indications in physical or mental health changes. In addition, future IoT-based health care applications should empower effective self-care for individuals, especially for people with chronic conditions or the old aged, to help them optimize their outcomes and quality of life. On the other hand, research performed by (Al-Shaqi, Mourshed, and Rezgui, 2016) also indicates that IoT-based systems in AAL field experience several limitations including: the lack of sufficient clinical evidence showing that AAL systems improve the patients' quality of life; the shortage of detailed research related to users' acceptance of AAL systems; the deficiency in solving the needs and demands of end-users; and the slightness of information about the implemented AAL system that users' caregivers are educated. Such limitations should be solved in future AAL applications in order to achieve sustainable and holistic solutions for supporting the old and disable people to maintain their health and live independently in their own homes.

Therefore, monitoring weight is a key elment of care. "sudden elderly weigh loss" is an early indicator of critical health changes, for instance: cancer, depression, forgetting to eat or drink. The challenge for home care of elderly or ill compared to the hospital environment is, that even the simple task of consistent weigh monitoring is challenging for family or care personal. They have to move the patient to the scale daily and record data consistently. The described solution, apart from anomalies around behaviour (time spend in bed/ absence), can help with such tasks and detect health condition changes early on. Furthermore, the system will be able to solve the problem of consistent and accurate weigh monitoring of elderly or ill in a home environment where there is no stringent process in place like in hospitals. Weight progression as an early indicator of health status changes can be monitored without a care taker having to conduct this routine daily. Warnings and patient history can be provided to clinicians instantly. This enables independent living of patients especially such with memory issues. The system also enables occupancy, fall and behaviour monitoring without the need of wearing a wrist band (which patients are sometimes inclined to remove/ take off) or fitting the house with an array of PIR sensors or sensor mats. The solution supplies one more element in the tool kit of home and health monitoring reducing worries of family members for their independent living elderly. With an aging society and less care personal this solution addresses the problem of efficiently monitoring people at risk and enables aging with dignity.

3 SMMC Model for IoT

Based on the gap analysis in our literature review, we focus on proposing an architecture which facilitates design and development of IoT solutions that not only collect and monitor consistenly data, but are able to respond, alert and inform in real time for clinical decision support. In the IoT monitoring solutions, a typical setup consists of smart sensors, micro-controllers, networks, ubiquitous devices and underlying software services. Thus, we name the model as SMMC, in which sensors, micro-controller, MQTT and cloud computing are utilized to build IoT. Each component in SMMC will use the most effective hardware and software. Each component is replaceable and can be substituted based on alternatives available.
The SMMC model being specifically considered is made up of the following components:

1. World of Sensors

   Sensor nodes to *measure or monitor* basic vital signs of people, such as people's weight or temperature. On the other hand, sensors used to *remind or alert*, such as light sensor or buzzer.

2. Micro-controller Platform

   Micro-controllers connect with sensors allowing sending and receiving of data. The micro-controller converts the analog signal to digital values and controls all the devices and sensors. Arduino and Raspberry Pi are two popular choices to connect with IoT sensors.

3. Machine-to-Machine Protocols

   Different IoT devices are connected by special type of IoT protocols, in other words, Machine-to-Machine (M2M) is to use a sort of IoT protocols to support real time communication. Popular M2M protocols include MQ Telemetry Transport (MQTT) and Constrained Application Protocol (CoAP) are in use (Zubov, 2016). MQTT is designed as an extremely lightweight publish/subscribe messaging transport with TCP. It is useful for connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium. CoAP is a specialized web transfer protocol for use with constrained nodes and constrained networks in the IoT with UDP protocol.

4. Cloud Computing

   Cloud computing can be utilized for storing IoT data remotely, and this extends the scope of IoT solutions to deal with real world things in a more distributed and dynamic manner (Botta et al., 2016). Cloud servers can be setup using proprietary needs. However packages such as Pachube, Nimbits and ThingSpeak offer direct APIs, can be consumed by micro controllers to post data. Data storage on the cloud enables leveraging clinical decision support algorithms, to detect anomalies, and build in triggers to send warnings, alerts, or information. This can occur either by using 3rd party services, or using the M2M protocols to trigger actions on the sensors. For example using a HTTP web service - a text message or automated phone call can be generated, to inform family members of the person at risk, alternatively send a M2M signal back to patient's home, reminding them about medical adherence or any other medical activity that needs to be conducted.

4 Scenario of IoT Health Care using SMMC

In this section, a scenario of continuous weight monitoring is proposed. Figure 1 shows a visual representation of SMMC, with a weighing sensor. The data from weight sensor is captured continuously. Then, all data is aggregated through micro-controller by WIFI module and are stored at Cloud platform.

On the other hand, MQTT Machine-to-Machine protocol plays a significant role in IoT framework. It can communicate with micro-controller and other IoT devices, which could be a control command to micro-controller or a trigger to other IoT devices. Meanwhile, other IoT devices can communicate with micro-controller directly using MQTT protocol. This example used *ThingSpeak* as an IoT Cloud platform that stores, classifies and analyzes data. The following sections describe each component in the SMCC architecture for this scenario.

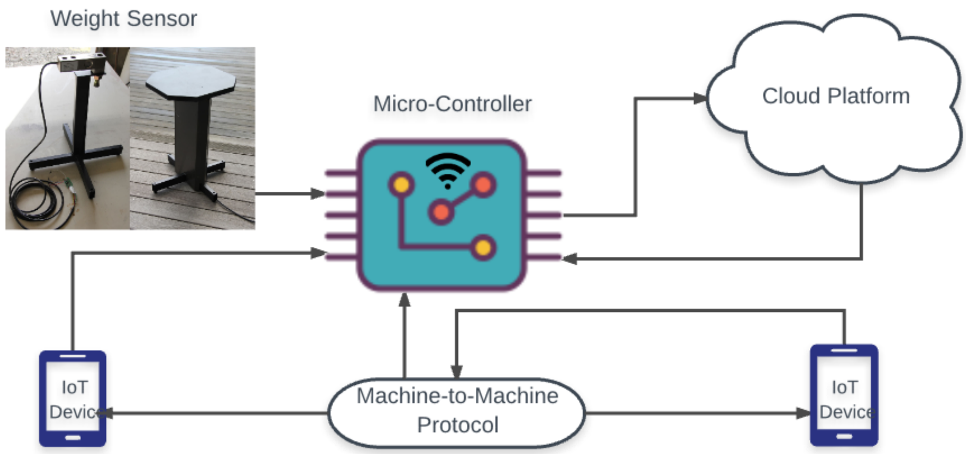

Figure 1. SMMC Framework of IoT for Health Care

4.1 Sensor to Micro-controller

In terms of the SMMC IoT framework, an experiment would be verify the effectiveness of this architecture. we first use prototype to measure weights, which includes weight load sensor and an amplifier HX711. According to the requirement of the health care monitoring, real time analogue weight data would be read. We used Arduino Uno as micro-controller because it can read real time data and convert analogue signals to digital signals, as summarized in the pseudo-code below.

Input: Weights W
Output: Weights W at Arduino
Method
1. Receive Analogue W from weight sensor
2. Convert Analogue W to Digital W
3. For accuracy, Average W after receiving five W.
4. Send W from '*WeightSensor*' $\Rightarrow$ Arduino

However, the standard Arduino Uno micro-controller does not have WIFI module. Either WIFI shield or external WIFI module would be utilized to send Arduino data to be stored at Cloud. CC3300 WIFI Shield is an Arduino shield which has CC3000 WIFI chipset developed by Texas Instruments. It uses SPI for communication. It has no AP mode so that it can connect to access points but cannot be an access point. Moreover, there is a library of CC3000 WIFI shield for Arduino. Therefore, Arduino Uno with CC3000 WIFI shield is used in the scenario to read and send weight data to Cloud in this experiment. Weights data has to be encrypted before sending because weights data is private and personal information. In this case, MD5 is to be used to encrypt data even though the data is not a data file.

4.2 Two Way Communication Between Micro-controller and Cloud Platform

For this scenario we used *ThingSpeak*, it is an IoT cloud platform that allows to collect, store, analyse, visualize, and act on data from sensors or actuators in the cloud and develop IoT applications. Sensor data can be sent to ThingSpeak from Arduino, Raspberry Pi, BeagleBone Black, and other hardware. The primary element of ThingSpeak activity is the channel, which contains data fields, location fields, and a status field. We installed ThingSpeak library from Arduino IDE and configure the parameters, such as myChannelNumber and myWriteAPIKey variables. Next, we create a ThingSpeak channel and write data to the channel. Finally, the weighs data is send to ThingSpeak periodically at configurable interval times. The method is summarized in the pseudo-code below:

Input: Average Digital Weight W at Adruino
Output: Averae Digital Weight W at Cloud Platform
Method
1. Receive W
2. WIFI CONNECT
3. If WIFI is connected Then Set up HTTP
4. Send Encrypted data to Cloud
5. Else if WIFI Reconnect ⇒ Exit

4.3 Machine-to-Machine Protocol

The machine to machine protocol can be accessed via cloud or micro controller. For instance if the anomaly in data is detected by the cloud application (line 4 in pseudo code in section 4.2) based on clinical decision support algorithms, then it will trigger *feedback or alert* originating from the cloud. Figure 2 depicts a concept for setting up the escalation process visually for reminding relevant people who may need this information. The medium for alerts can be text message, email or calls as well as turning on/off sensors. For example, the weight of a patient dropped constantly over a week an alert is triggered to next of kin. However another alternative is to detect these anomalies at the micro controller level and instantiate a machine to machine request. For example the person wakes up at night, which turns on the LED lights.

MQTT is a Client/Server publish or subscribe messaging protocol on IoT health care system, and provides an Arduino library to adapt. Specifically, MQTT client publish or subscribe message with other devices by MQTT tool, and Arduino with WIFI module can receive message as well from publishing, which means it can control Arduino. To use MQTT protocol transfering data, the MQTT and SMS services have been building in CentOS at Cloud platform as well in the experiment. The sms service is from Nexmo by sms API and to alert users who are relevant to health care system. Figure 3 shows a free mobile app for MQTT client, which includes subscribe and publish features. All clinical rules can be set up at decision support web application on Cloud Server CentOS, where MQTT server, decision support web application and other external services are installed. In the meanwhile, we use buzzer and LED light sensor for testing in this scenario.

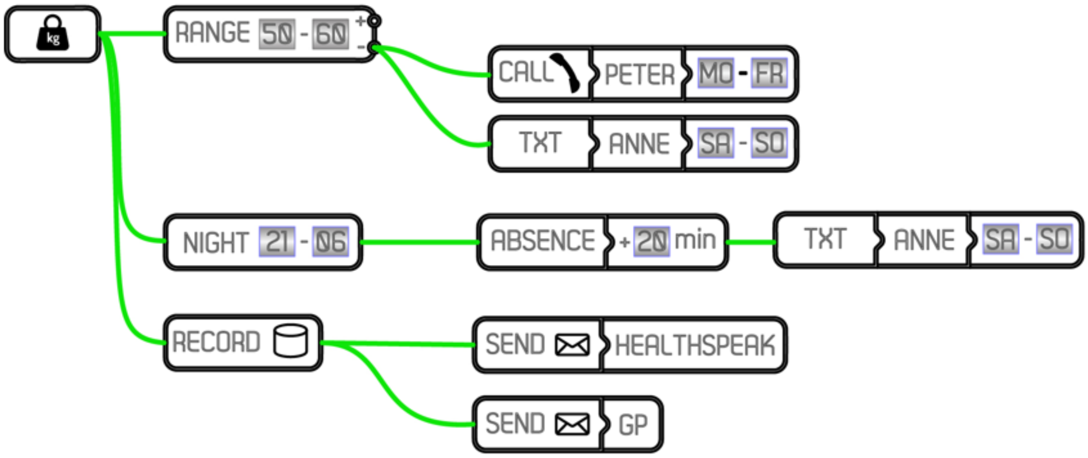

Figure 2. Concept of a Configurable Visual Escalation Process

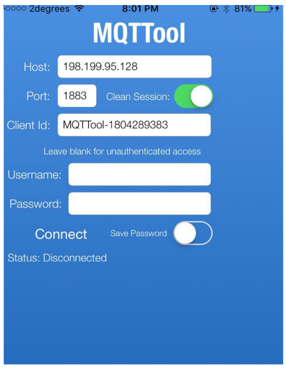

Figure 3. MQTT Client Mobile Application

5 Conclusion and Future Work

This article focused on solutions using IoT for health care, and proposed a framework called SMMC. The article also presented scenario which monitors weights and sends data to ThingSpeak and triggers alerts via M2M and HTTP. The aim of this research is to improve patient experience when living independently, while engaging relatives and caregivers through a low cost, commercial 'app-cessory' leveraging cloud based services. However, this study was time consuming for seamless and consistent gathering the accurate weight data. The future work involves testing this framework in an actual bed in AAL living environments, as well as with pressure sensors, which would be measure movements. This testing will show the usability, utility and quality of such approach in the real world.

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