Architecture and Design Flow of Tele-Health Monitoring System using STM32 Platform

Sufian Kaki Aslam and Jafar Saniie
Department of Electrical and Computer Engineering
Illinois Institute of Technology
Chicago, Illinois, United States

***Abstract*—In recent years, with the technological advancements in healthcare electronics, we see a number of digital data acquisition devices that can monitor certain body parameters of a patient and alert the concerned person in case of an emergency. However, if one desires to monitor multiple body parameters, they are forced to use multiple data acquisition devices. This determines the need for a platform that will allow users to configure their own digital data acquisition device and monitor their health parameters in real-time. This paper discusses the architecture and design flow of a Tele-Health Monitoring (THM) platform using effective usage of the computation power and various inbuilt peripherals of STM32 microcontroller that will allow users to have a reliable and interactive health monitoring system. The proposed platform provides a channel to interface various health sensors and data acquisition devices such that the individual himself or an authorized health provider can monitor and analyze the physical activity of an individual on regular basis. This platform finds great use in cases where patients are under transportation, homecare or frequent health checkup.**

Keywords— Tele-Health monitoring; STM32 microcontroller; e-Health Sensor Platform; health care; Biomedical sensors

I. INTRODUCTION

Healthcare is becoming expensive each day. With the advancements and innovation in healthcare electronics industry there is a huge possibility of making healthcare affordable without compromising its quality. The rise of telemedicine with which doctors can diagnose/monitor their patients remotely has an important role to play in this Tele-Health system [1], [2]. In this paper we present certain scenarios where Tele-Health monitoring can be used effectively. They are:

- There has always been accidents and patient transportation in which had there been an option to monitor the patient during the travel in ambulance, the doctor/hospital could have prepared for the situation better in order to save the patient's life.
- For patients who live in remote locations and are prescribed to do regular checkup by the doctor, it is very difficult to visit the hospital every time.
- Patients under long term illness who require 24x7 monitoring are taken care by a nurse or a caretaker turn out to be quite expensive for any common man to afford.

Researchers have been designing a number of systems that can make Tele-Health possible using many reliable and affordable technologies. However, majority of the available solutions are based on certain specific body parameters such as Electrocardiograph, Pulse rate etc. [2], [3], [4]. In this paper, we present a platform which has a modular and reconfigurable approach and one can design/configure their Tele-Health monitoring system according to the patient's health requirement. This will allow reusability of monitoring devices thus saving a significant amount of cost and resources.

To address the above discussed situation, we need a system that can facilitate robust and reliable monitoring of multiple parameters of a patient. This system should support interface with various sensors, data acquisition modules and also ensure reusability Thus we use a 32-bit ARM Cortex-M7 microcontroller STM32F746NGH6 [5] using its evaluation board that offers high performance and a number of peripherals to interact with most of the external devices.

II. DESIGN OF TELE-HEALTH MONITORING

The design of Tele-Health monitoring system is classified into three stages: Biometric Data Acquisition; Data Processing and Communication; Notification Panel and User Interface as shown in Figure 1.

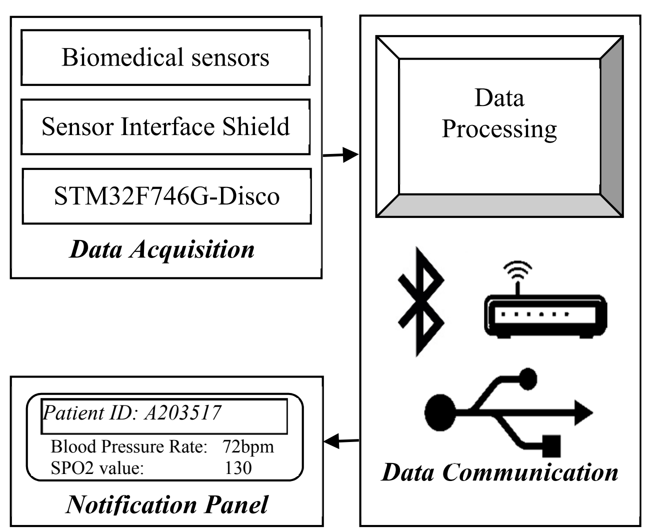

Figure 1. Overview of the Tele-Health Monitoring System

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A. Biometric Data Acquisition

Data from various biomedical sensors and devices that are connected to the patient's body is collected using the microcontroller platform. The Sensor Shield [6] stacked over the STM32F746G-Discovery board [5] makes it easier to interface a number of sensors presented in this paper. Every data acquisition device is mapped to a unique patient ID. However multiple devices can be mapped to a single patient.

B. Data Processing and Communication

Based on the data acquired, the condition of a patient is determined. This involves a dynamic reconfigurable algorithm defined by the doctor or caregiver based on a number of biometric parameters acquired periodically. Also, when the device is connected to an internet enabled PC, Smartphone or a communication module, the data is synchronized with the cloud.

C. Notification Panel and User Interface

This is a dashboard that monitors various physical parameters of the patient and notifies the doctor and/or caregiver about any unusual behavior and emergency situations. It also allows to configure alerts and data synchronization frequency.

III. Biometric Data Acquisition

The data to be acquired depends on the situation of the patient. However, the Tele-Health monitoring platform is designed to support a variety of body parameters to be acquired. In order to exhibit the functionality of Tele-Health monitoring platform, we use 'eHealth Sensor platform' [6] to acquire the biometric data of the subject. This sensor platform is interfaced directly to the STM32F746G-Discovery board.

A. Sensor Platform

In order to demonstrate with a variety of biomedical sensors, we use an open source biometric sensor platform designed for biomedical researchers and developers. In this system, we use eight non-invasive and one invasive (Glucometer) sensor as shown in Figure 2. This system includes the following sensors

- Patient position sensor (Accelerometer)
- Glucometer sensor
- Body temperature sensor
- Pulse and oxygen in blood sensor (SPO2)
- Airflow sensor (Breathing)
- Galvanic Skin response sensor (Sweating)
- Electrocardiogram sensor (ECG)
- Electromyography sensor (EMG)
- Blood pressure sensor (Sphygmomanometer)

All these sensors are connected to the Sensor Shield which provides the necessary connectors and voltage level shifters to each sensor based on its specification. The Sensor Shield used here is primarily designed for Arduino boards [7] to communicate with an Atmega microcontroller developed by Atmel Corporation [8]. In this Tele-Health platform, due to the need for higher performance, we connect it to STM32F746G-Discovery board using its connectors which make it possible to easily connect extension shields. The sensors that are demonstrated here primarily communicates through analog, digital and serial protocols.

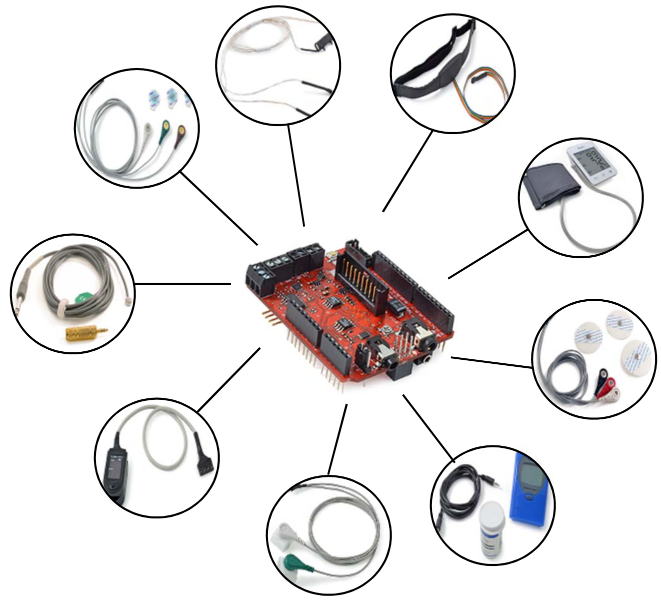

Figure 2. Interfacing Sensors to the Sensor Shield

B. Microcontroller Platform

In this Tele-Health monitoring platform, we use the STM32F746NGH6 microcontroller. For the demonstration purpose, we use STM32F746G-Discovery board which offers an ARM®32-bit Cortex®-M7 microcontroller with high performance and wide range of peripherals built into it. The discovery board offers a 4.3 inch LCD-TFT, Ethernet, USB host, MicroSD card, MEMS digital microphone, etc. In addition to need of processing power, this microcontroller platform satisfies the need of multiple communication protocols to acquire and communicate the data.

The STM32 platform provides a number of ways to program the microcontroller.

1) *uVision Keil* – This software has native developer platform for a wide range of microcontrollers making it easier for the program to port from one microcontroller to another [9]. It interacts with the STM server and allows installation of drivers for the desired microcontroller directly into the software.

2) *mbed* - The ARM mbed IoT device platform provides a developer ecosystem that has an online editor and compiler. It is developed by ARM for embedded developers [10].

3) *Eclipse/Visual Studio* – These are general purpose developer platforms that can be configured to code and compile the STM32 programs using the drivers provided by STM [11], [12].

Figure 3. Interfacing STM32F7 Platform to the Sensor Shield

STM32 platform makes it really easy to upload the program. Once the program is compiled, a .bin file is generated. To upload the program into the controller, it is enough to copy and paste the bin file in the flash memory available in the developer board.

With the specified Sensor Shield, most of the sensors work independently. Due to limited number of GPIOs in Arduino Uno, the shield was designed such that ECG and EMG sensors would not work simultaneously and similarly glucometer and sphygmomanometer would not work simultaneously. But with the large number of GPIOs in STM32F7 microcontroller/discovery board as shown in Figure 3 can not only acquire data from all the available sensors simultaneously but also use rest of the GPIOs for other purposes such as communication.

With the growing demand for fast and reliable biomedical sensors, various manufacturers have been manufacturing the same sensor but with different communication protocols. Table I shows the protocols used by the sensors to communicate with the microcontroller in this THM platform.

TABLE I. COMMUNICATION PROTOCOLS OF SENSORS

S.No	Sensor	Protocol
1	Patient Position Sensor	Digital IO
2	Glucometer Sensor	UART, Digital IO
3	Body temperature sensor	Analog In
4	Pulse & oxygen in blood sensor	Digital IO
5	Airflow sensor	Analog In
6	Galvanic Skin response sensor	Analog In
7	ECG sensor	Analog In
8	EMG sensor	Analog In
9	Sphygmomanometer	UART

IV. DATA PROCESSING AND COMMUNICATION

The Tele-Health platform is designed in a way such that an individual interacting with the system can interface their sensors to the system and have it monitored real-time. Recently there have been many researchers designing algorithms and systems that can monitor a patient remotely using some sensor placed on them or using a smartphone, fitness band, ring etc. [13], [14]. However, this platform intends to bring all such solutions into one platform so that the doctor and/or health inspector can have overall body condition of the patient.

For long term patients who are monitored by the system continuously, it is difficult for a doctor to go over the health conditions of the patient every day. To facilitate this, we come up with functions that define the need for patient's attention. There are a number of ways to determine the emergency of a patient. Most often, the acquired data at that instant shows if the patient is under critical condition. For example, the blood pressure falling under or over the normal range. But there are times when the emergency arises based on certain biomedical parameter over a period of time or a number of parameters put together define the emergency of the patient. Availability of a number of parameters in this platform allows the doctor and caregiver to define emergency for a specific patient and prioritize alerts. The alert can be a tone in the onboard unit, a text message or an email. In general, this method serves the patients under homecare. With the huge amount of health data collected in this system, there is a good opportunity to do data mining and data fusion to provide medical researchers with case studies [3], [15], [16].

Patients who are being transported in an ambulance will be monitored real-time by the doctor/hospital because they have to be prepared to operate. This scenario does not need a long term data processing of the patient. However, this platform allows to log the patient's condition during the travel which can be used later for study or insurance purposes. For patients who use this system for periodic checkups, the data is pushed to the cloud and also sent to the doctor who prescribed periodic checkup. Hence the doctor will analyze the condition of the patient with the current and previous data available in the system.

Figure 4 shows the data acquired by the discovery board communicates with the cloud in three different ways. They are:

1) Communication using the Host USB port available in the microcontroller to interface with a computer. The computer runs a program to collect and store the data. When the computer has an active internet connection, the data gets synchronized to the cloud storage.

2) A wireless Bluetooth connection with a smartphone using the UART port available in the microcontroller. This communication mode is used to monitor the data in a smartphone or a tablet using the android application. Furthermore, the smartphone application

uses the mobile network to alert the caregiver in case of an emergency.

3) A GPRS cellular communication using a GSM module that will allow uninterrupted and seamless data transfer between the data acquisition device and the cloud storage.

Multiple peripherals available in the STM32F746NGH6 microcontroller allow the system to communicate through all the channels simultaneously. In addition to these channels, data can be monitored on the STM32F7 discovery board display.

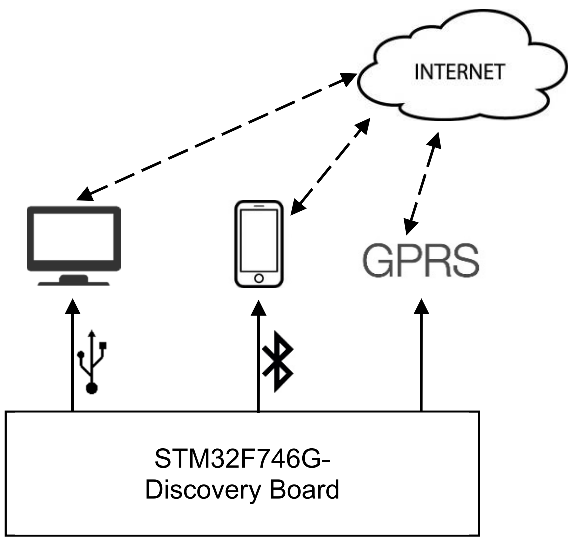

Figure 4. Data Communication Channels

V. Notification Panel and User Interface

The purpose of notification panel is to display the health parameters that determine the patient condition and alert the doctor or caretaker whenever there is an emergency. Since the system eliminates the need for a fulltime caregiver in some cases, the local onboard display is not sufficient for alerts. To solve this problem, the connectivity of PC, mobile phone and GSM is used and the caregiver is alerted through email and text message. The purpose of having the PC and Smartphone channels is to reduce the latency of data which will be caused heavily by the GPRS connection. The various display panels to monitor the body parameters of the patients are as follows.

A. *Onboard Display*

The TFT-LCD display available in the discovery board is used to display the data acquired by the microcontroller locally. The display features a 480x272 pixel size with capacitive touchscreen capability. The touchscreen capability allows a user to navigate various parameters acquired by the microcontroller and view it textually as well as graphically. Figure 5 shows the information displayed on the TFT-LCD. It is refreshed periodically and since every system has its own onboard display, the patient ID, body parameters and connectivity information are displayed in this screen.

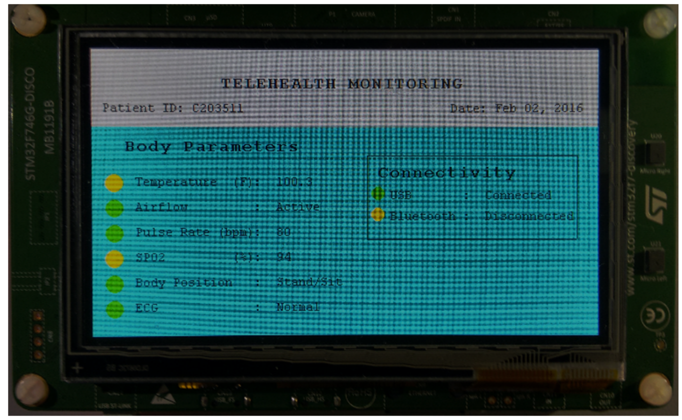

Figure 5. STM32F7 Onboard display

B. *Smartphone Application*

The smartphone application as shown in Figure 6 displays the patient data. The application has been designed using MIT App Inventor that allows a designer to develop the application in graphical user interface [17]. This application is designed to run in an android smartphone or a tablet. In addition to viewing the data, the user can configure settings to make alerts, periodic synchronization, etc. The application in the smartphone communicates with the discovery board through Bluetooth.

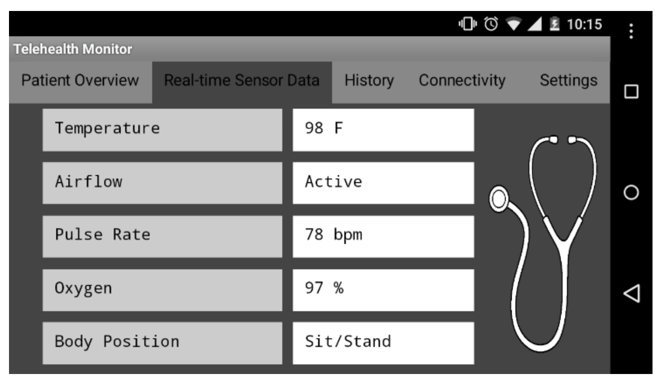

Figure 6. Smartphone Application

When the smartphone is connected to internet and this application is active, it uploads the patient data to the server. If the smartphone is not connected to internet, the application stores the data into the storage and uploads once it has active connection. The 'Run app in background' mode will upload/log the data even when the app is inactive. Figure 6 is screenshot captured when the application was running in a Motorola G2 phone

C. *Computer Application*

This app is developed using Visual Studio to run in a native Windows environment as shown in Figure 7 [12]. Whenever the data is acquired in the STM32 device, it gets pushed to the cloud database if the computer is connected to the internet. When the doctor/user opens the application, it gathers the data from the local database initially and displays in the application but when the user attempts to view the historic data, it gets downloaded from the cloud and is displayed. In addition to display and synchronization of data, the application allows configuring the alerts and maintaining patient enrollment.

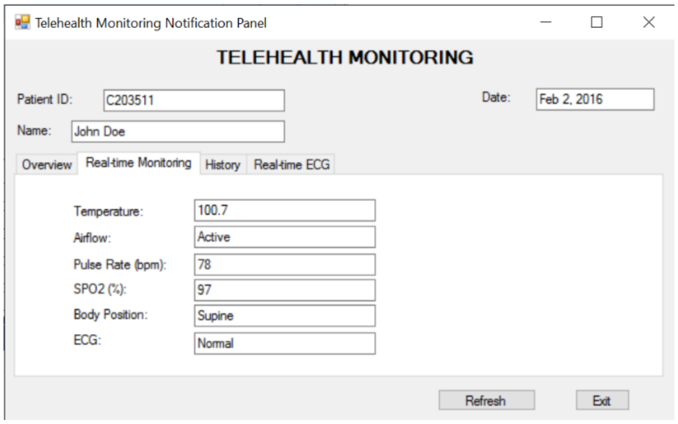

Figure 7. Notification Panel of the Computer Application

VI. CONCLUSIONS

The Tele-Health monitoring platform using STM32 microcontroller discussed in this paper makes healthcare accessible and affordable to a majority of people. It also facilitates the patients, caretakers and the doctors to maintain and integrate the health records. Availability of various peripherals make this platform reliable and easy to interact. The biometric data collected in this system will of great value for Data mining and Data fusion. This platform has a great potential when designed as a wearable device that can contain a number of biomedical sensors to determine the body condition of the user. As a wearable vest, this can be used by mountaineers, miners, fire fighters, old people etc. and this will allow the supervisors and care-takers to get alerts whenever there is any emergency situation. Also, this platform is expected to integrate with the fitness apps so that the users and doctors can have more information about their subject's every day physical routine.

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