IoT based Patient Telemonitoring System for Palliative Care

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***Abstract*— Palliative care is an approach that focuses on improving the quality of life of patients with life-limiting illnesses. It aims to relieve symptoms and provide comfort to patients and their families. A challenge of providing palliative care is the need for frequent monitoring of patients. Continuous monitoring is accessible to people in India mostly in a hospital setting to facilitate palliative care. In this effort, we explore an internet of things-based solution to facilitate remote monitoring of patients in an at-home setting. We utilize commercial off-the-shelf components to develop a proof-of-concept to explore the feasibility of a medical device for palliative care application. Our preliminary test results indicate that the developed proof-of-concept device is capable of enhancing the accessibility to patient information for the physician. Additionally, the built-in chat interface allows swift communication between the chat interface to facilitate swift communication to the patient care-givers. We hope such a medical device will enable effective asynchronous tele-monitoring of patients requiring palliative care at the convenience of their home, thus reducing the costs required for treatment.**

Keywords*— *internet of things, medical device, palliative care, commercial-off-the-shelf, proof-of-concept

I. INTRODUCTION

Palliative care is a specialized form of medical care that focuses on providing relief from the symptoms, pain, and stress associated with serious illnesses. Its primary goal is to improve the quality of life (QoL) for patients and their families facing a life-threatening or chronic condition. Palliative care is provided by a team of healthcare professionals, including doctors, nurses, social workers, and other specialists who work together to address the physical, emotional, and spiritual needs of patients. The World Health Organization (WHO) defines palliative care as an approach that improves the quality of life of patients and their families facing the problems associated with life-threatening illness, through the prevention and relief of suffering by means of early identification, assessment, and treatment of pain/other problems for the patient [1]. Effective communication and shared decision-making are essential components of the interdisciplinary challenges posed by palliative care patients [2].

Numerous studies have shown that palliative care improves symptom control, patient and family satisfaction, and overall QoL [3]. Palliative care reduces hospital admissions, healthcare costs, and the intensity of medical interventions, while increasing the likelihood of patients receiving appropriate end-of-life care [3]. Telehealth in palliative care has gained significant attention as a means to improve access, enhance care delivery, and support patients and their families in their homes or other non-traditional care settings.

A web-based video conferencing modality is used to provide healthcare services to remote location in [4] and the study provides useful results on the ease of use and adoption of technology for patient care. A recent integrative review on tele-palliative care post-corona period further adds that telehealth has contributed to improvements in qualitative aspects to the family members and care-givers of palliative care patients [5]. In [6], the use of video conferencing to connect with the patients showed significant improvements to the patient's involvement in their treatment. The authors quote the importance of continuous support to the care-givers for patients with critical illness such as heart failure [7]. In yet another recent study [8], the authors document importance of telehealth services in providing multidisciplinary care to palliative care patients. Medical device design and development requires several regulatory approvals and taking a low-cost and developing the device in an academic setting to transition into a clinical setting will be an effective method for device commercialization [9]. In this effort, we utilize commercial off-the-shelf (COTS) hardware and software platforms which, reduces the developmental costs and enable us to further the development through a robust product development life-cycle that will enable to generate significant evidence validating the usefulness of telehealth in palliative care.

Section II describes the design and development of a proof-of-concept (PoC) prototype. Section III explains the salient features of the user interfaces developed to interact with the prototype. Section IV concludes the paper and shares light on the limitations and future directions of the work.

II. PROOF OF CONCEPT PROTOTYPE

The design and development of the internet of things (IoT)-based palliative care home-based patient monitoring system for telerehabilitation of patients in this section.

A. Hardware architecture

The IoT hardware prototype consists of COTS components such as (i) Wi-Fi powered microcontroller (WμC), (ii) Electro-

[1]Students at Government College of Engineering, Salem underwent a Prototyping Semester (ProtoSEM) curriculum funded by the Department of Technical Education under the Ministry of Higher Education, Tamil Nadu
[2] Coimbatore Innovation and Business Incubator (Forge Innovation and Ventures) is a knowledge partner to the Department of Technical Education facilitating the implementation of ProtoSEM at GCE, Salem
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cardiogram (ECG) sensor, (iii) room temperature sensor, (iv) body temperature sensor, (v) pulse rate sensor, and an (vi) 16 x 2 liquid crystal display (LCD). The embedded system is powered by a battery/external power source for independent operation at the patient's home. The WµC connects to the Wi-Fi in patient's homes and communicates the data from various sensors to the cloud for visualization and analytics by the clinicians and physicians. Figure 1 presents a pictorial representation of all the components used in the hardware of the prototype developed.

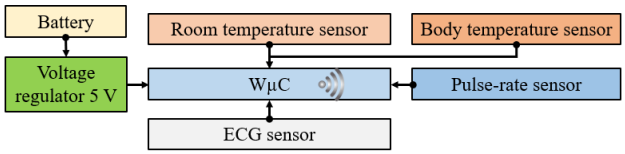


Figure 1: Schematic representation of the hardware architecture

B. Cloud Architecture

The hardware device connects to the Wi-Fi system in the patient's home and transfers a COTS cloud platform hosted in Firebase [10]. Firebase is a real-time database, which allows to store and sync data in real-time. Firebase service account provides a key-file that needs to be programmed into the WµC. The key file contains authentication credentials and is used to establish a secure connection between the hardware and Firebase. Next, the data collected in the WµC is pushed to Firebase in JSON format via the internet. Firebase additionally provides software development kits, event handling, and real-time synchronization capabilities so that other applications will be able to listen to the data collected by Firebase database in real-time. A smartphone application designed in MIT App Inventor further connects to Firebase database via HTTPs to retrieve the data sent from WµC for viewing by the patient caregiver/physician [11]. Another COTS ubidots [12] is used to retrieve the data and create plots for visualization at the hospital. The cloud architecture is schematically represented in Figure 2.

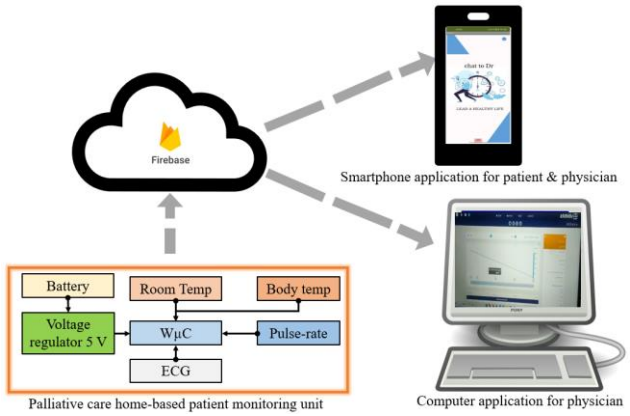


Figure 2: Schematic representation of the cloud architecture

III. SOFTWARE INTERFACES

Two software modalities are created to interact with IoT hardware for palliative care patient monitoring system: (i) smartphone application for caregiver and physicians and (ii) computer application to visualize the data.

A. Smartphone application

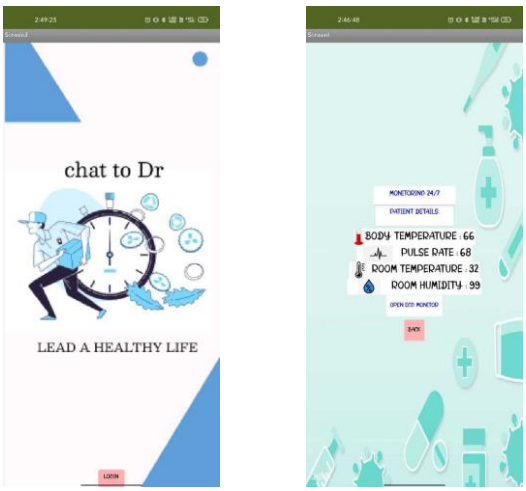
The smartphone application created in MIT App Inventor. MIT App Inventor is COTS web-based smartphone application platform that empowers us to develop smartphone application with minimal programming. MIT App Inventor has also created drag-n-drop plugins to connect with Firebase real-time databases to access the data sent from the WµC. The smartphone application has the following interfaces:

a) Login intergace: Allows a patient/physician to login to the smartphone application.

b) Patient monitoring interface: This interface presents the real-time data streamed from the WµC.

c) Physician communication interface: This interface allows the physician to chat with the care-giver of the patient.

All the above interfaces developed in MIT App Inventor are shown in Figure 3.



(a) (b)

(c)

Figure 3: Screenshots of the various smartphone interfaces developed to interact with the IoT patient monitoring device (a) Patient/physician login interface; (b) Patient monitoring interface; (c) Physician interaction interface

B. Computer application

built with ubidots to visualize the data in plots.

IV. Discussion and Conclusion

Acknowledgment

The authors acknowledge Viswanathan Srinivasan (Senior Engineer, Forge.Innovation) and Dr. Mahesh Veezhinathan (Principal, Forge. Academy) for their valuable inputs to this manuscript

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