An IoT-Based Healthcare Platform for Patients in ICU Beds During the COVID-19 Outbreak

ITAMIR DE MORAIS BARROCA FILHO[ID]1, **GIBEON AQUINO**2, **RAMON MALAQUIAS**[ID]1, **GUSTAVO GIRÃO**1, **AND SÁVIO RENNAN MENÊZES MELO**[ID]2

1Digital Metropolis Institute, Federal University of Rio Grande do Norte, Natal 59078970, Brazil
2Department of Informatics and Applied Mathematics, Federal University of Rio Grande do Norte, Natal 59078970, Brazil

Corresponding author: Itamir de Morais Barroca Filho (itamir.filho@imd.ufrn.br)

ABSTRACT There is a global concern with the escalating number of patients at hospitals caused mainly by population aging, chronic diseases, and recently by the COVID-19 outbreak. To smooth this challenge, IoT emerges as an encouraging paradigm because it provides the scalability required for this purpose, supporting continuous and reliable health monitoring on a global scale. Based on this context, an IoT-based healthcare platform to provide remote monitoring for patients in a critical situation was proposed in the authors' previous works. Therefore, this paper aims to extend the platform by integrating wearable and unobtrusive sensors to monitor patients with coronavirus disease. Furthermore, we report a real deployment of our approach in an intensive care unit for COVID-19 patients in Brazil.

INDEX TERMS Healthcare, Internet of Things, COVID-19, remote monitoring, platform.

I. INTRODUCTION

There is a growing trend in the medical field to minimize the need for hospitalization, moving several health care procedures from hospitals (hospital-centric) to patient's homes (home-centric) [1], [2]. This strategy has been praised mainly due to its potential for improving patient's wellness and treatment effectiveness for a wide range of health conditions [3]–[5]. It can also reduce the costs of the public health system worldwide and its efficiency, which in the last decade has been challenged by the population aging and the rise of chronic diseases [6], [7]. Furthermore, the current COVID-19 outbreak has exposed the importance of rapidly scaling the health system and keeping at home patients who are high-risk but not severe enough to stay hospitalized [8].

Internet of Things (IoT) provides the scalability required for this purpose, supporting continuous and reliable health monitoring on a global scale. This paradigm is increasingly becoming a vital technology in healthcare [9]. Furthermore, the recent progress in low-power consumption, miniaturization, and biosensors has revolutionized the process of monitoring and diagnosing health conditions, bringing

comfort, personalization, and effectiveness through unobtrusive healthcare devices [10], [11].

This paper extends the authors' previous works [12], [13] by instantiating the Reference Architecture for IoT-based Healthcare Applications (RAH) for healthcare applications for the context of the COVID-19 outbreak. We show how wearable and unobtrusive sensors can be integrated into the proposed platform and used to collect and process patient data to promote rapid clinical interventions while preventing contagion between clinical staff and infected patients. Finally, we report the results from a real experience, which used our approach to develop and deploy a system used by the intensive care unit (ICU) for COVID-19 patients in Brazil.

Therefore, this paper aims to extend the platform proposed in [12], initially designed for patients' de-hospitalization, by including wearable and unobtrusive sensors to monitor patients with coronavirus disease. We developed software components guided by the Reference Architecture for IoT-based Healthcare Applications [14] for interoperability with existing multiparametric monitors in a real intensive care unit (ICU) for COVID-19 patients in Brazil. By describing the engineering process and the application deployment steps performed in this experience, we provided relevant guidelines to practitioners and researchers concerned with IoT-based