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Convergence Platform of Cloud Computing and Internet of Things (IoT) for Smart Healthcare Application

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Abstract

Internet of Things (IoT) is a widely distributed network which requires small amount of power supply having limited storage and processing capacity. On the other hand, Cloud computing has virtually unlimited storage and processing capabilities and is a much more mature technology. Therefore, combination of Cloud computing and IoT can provide the best performance for users. Cloud computing nowadays provides lifesaving healthcare application by collecting data from bedside devices, viewing patient information and diagnose in real time. There may some concerns about security and other issues of the patient's data but utilization of IoT and Cloud technologies in healthcare industry would open a new era in the field of healthcare. To ensure basic healthcare needs of the people in the rural areas, we have proposed Cloud-IoT based smart healthcare system. In this system various types of sensors (Temperature, Heart bit, ECG, etc.) are equipped in the patient side to sense the patient's physiological data. For securing data RSA based authentication algorithm and mitigation of several security threats have been used. The sensed data will process and store in the Cloud server. Stored data can be used by the authorized and/or concerned medical practitioner upon approved by the user for patient caring.

Keywords

Cloud Computing, Embedded Hardware and Software, IoT, Smart Healthcare System

1. Introduction

With the development of smart mobile devices and cloud computing technologies, Internet of Things (IoT) has come up as a new computing paradigm for

building the next generation smart healthcare applications. IoT is based on self-configuring intelligent nodes (things) that are interconnected with each other in a global network infrastructure. It is disruptive technologies, enabling ubiquitous and pervasive computing scenarios. On the other hand, Cloud computing is service oriented, strong fault tolerant, business model, loose coupling, ease of use, high security, TCP/IP based and virtualization. Thus, a novel IT paradigm in which Cloud computing and IoT are two complementary technologies merged together is expected to disrupt both current and Future Internet [1]. This new paradigm can be named as Cloud-IoT platform. The data that has been sensed by the sensors is transmitted to actuator where an action is taken according to the sensed data. From the perspective of scientific research institution, use of mobile medical platforms can enhance patients' experiences; machine learning technique can be utilized instead of manual drug screening and to find suitable subjects using big data [2]. The combination of healthcare with the Internet and mobile technologies has led to increase the accessibility to healthcare providers, more efficient processing and higher quality of healthcare services [3] [4]. Many researchers think that limited access to patient-related information during decision-making and the ineffective communication among patient care team members are one of the main reason of medical errors in healthcare [5] [6]. We emphasizes on the issues on collection of patients vital data, delivery, and processing. Current manual note based solutions are so much time consuming. Moreover, it imposes a problem to real time data access that barrier the ability of clinical diagnosis and monitoring. We have presented a solution to automate this process from gathering the bedside data to information dissemination and remote access by the experts using Raspberry pi. Raspberry pi acts as the gateway for processing the patient's vital data sensed by the sensors. The information then becomes available in the cloud, from where expert systems can process it or distribute to the caregiver for analysis [7].

Healthcare is one of the basic human needs. But most of the people in our country living in the rural areas are continuously depriving from this basic right. This research work is based on the theme that patients can get treatment from the bedside within a moment from the doctors around the world. It will also make evolution for caregivers. The adoption of Cloud by the medical industry will help to reduce the capital expenses, allowing medical centers to upgrade existing IT system to manage their sensitive data. Cloud computing enables effective communication at the distance, thus making it easier for medical professionals to collaborate and provide care as a team. Many research work has been performed in the field of healthcare framework utilizing Cloud computing. Cloud computing is planned to produce a significantly more interfacing condition for social insurance suppliers, enable easy, quick and ubiquitous access to wellbeing [8] [9]. The fundamental obstructions to the selection of Cloud computing are seen in deficient security and security insurance [9]. Healthcare facilities in rural areas are very ancient and poor. At some point it gets hard for specialists or medical service providers to get to the patient at provincial zones. From the writ-

ing audit on Cloud-IoT based social insurance, we see that numerous scientists focused on planning and executing different Cloud-IoT based medicinal services administration outline work and taking care of different mechanical and structural issues [10]. To guarantee fundamental needs of the individuals in the rustic regions, we propose Cloud-IoT based framework for smart healthcare system. In this framework, there will be different sensors in the patient's side that will detect the patient's physiological information. The information at that point handled and stored in the Cloud.

Rest of the manuscript is organized as follows: Section 2 discusses about the Convergence of Internet of Things and Cloud Platform. Section 3 presents proposed IoT based smart healthcare system. Section 4 describes performance evaluation and finally, Section 5 concludes with mentioning future work.

2. Convergence of Cloud Computing and Internet of Things Platform

IoT is a network or combination of interconnected things. Where a thing can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object that can be assigned with an IP address and it must be able to transfer data over a network. This concept can be used to create a new types of applications involving the smart home and smart vehicle to provide services such as notifications, security, automation, energy saving, computation and entertainment [11]. IoT is based on a three-layer model which consists of the Perception layer, the Network layer and the Application layer [12]. Perception layer perceive the physical properties such as temperature, location, speed, etc. by various sensing devices and convert this information into digital signals which can be easily transmitted through digital communication networks and stored. The Network layer transfers the received data from the Perception layer to a data base, processing center or server. The main technologies used to realize this layer include cellular technologies 2G/3G/LTE, Wi-Fi, Bluetooth, or ZigBee etc. The Application layer provides the functionality of storing, processing, and analyzing the information received from the Network layer. These encourage end-client applications, for example, building automation, area based administrations, character verification, security and so on. Cloud computing, the future generation's computing model as a utility, has the ability to make Cloud-based software more attractive as a service. Cloud computing technology has several advantages such as flexibility, automation, low cost, fast service, and unlimited storage capacity. Cloud computing and IoT together can provide universal sensing services and handling of detected information past the individual things abilities, in this way animating advancements in both fields. Cloud platforms allow the sensing data to be stored and used intelligently for smart monitoring, controlling and actuation with the smart devices. Novel data fusion algorithms, machine learning methods, and artificial intelligence techniques can be implemented and run centralized or distributed on the cloud to achieve auto-

mated decision making. Cloud-IoT platforms can receive information from any devices having internet connection. Cloud-IoT can be used for controlling and monitoring the conditions of a device at any moment.

A health system, also sometimes referred to as healthcare system, is the organization of people, institutions, and resources that deliver healthcare services to meet the health needs of the populations. Healthcare is one of the basic human needs. Nations must design and develop health systems in accordance with their needs and resources, although common elements in virtually all health systems are primary healthcare and public health measures [13].

Traditional medicine with biotechnology as its core, has gradually begun to digitize and to informationize with the advancement of technology and scientific theory. This advancement has made the concept of smart healthcare to gradually come to the fore. Smart healthcare was born out of the concept of "Smart Planet" proposed by IBM in 2009. Smart Planet is an intelligent infrastructure that uses sensors to perceive information, transmit information through the internet of things (IoT) and processes the information using supercomputers and cloud computing [14]. Smart healthcare is not just a simple technological advancement, but also an all-round, multi-level change. It uses a new generation of information technologies, such as the Internet of Things (IoT), big data, cloud computing and artificial intelligence to transform the traditional medical system in an all-round way, making healthcare more efficient, more convenient, and more personalized [15]. This change is embodied in the following: medical model changes (from disease-centered to patient-centered care), information construction changes (from clinical information to regional medical information), changes in medical management (from general management to personalized management), and changes in the concept of prevention and treatment (from focusing on disease treatment to focusing on preventive healthcare) [16] [17]. These changes are making focusing on the individual needs of people during improving the efficiency of medical care, which greatly enhances the medical service experience and represents the future development direction of modern medicine. In this research, we implement wearable sensor devices, IoT and mobile internet to dynamically access patient's vital information, connect people, materials and institutions related to healthcare, and then actively manage and respond to medical ecosystem needs in an intelligent manner. Smart healthcare can raise interaction between all the involving parties in the healthcare field, ensure that patients get the services they need, help the parties make informed decisions, and facilitate the rational allocation of resources. At the patient's side, we have sensor nodes to monitor the patient's various physiological conditions. Sensor sensed the physiological data and sends it to the ThingSpeak cloud server through Raspberry Pi. The data can be then accessed by doctors, nurses, and hospitals from anywhere at any-time to diagnose and monitor health condition. The internet of things can possibly give doctors significant information that can improve persistent wellbeing; however there are few barriers in the adoption of IoT in healthcare services.

3. Proposed Cloud-IoT Based Application

We have developed a smart healthcare system using Raspberry Pi, where sensor nodes have been used for collecting the patient's physiological data. These sensed data will be collected by coordinator (Raspberry Pi) and the sensed data will be then sent to the Cloud server (ThingSpeak). User can monitor the data from anywhere at any time by login Cloud server. Figure 1 and Figure 2 show the functional block diagram of smart healthcare system & sensor node of the

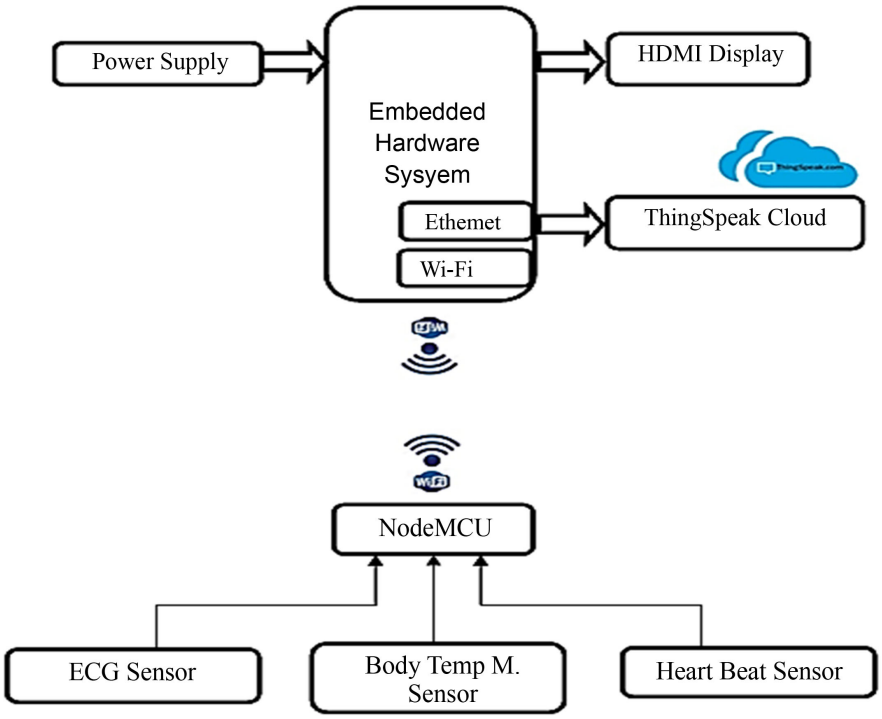


Figure 1. Functional block diagram of proposed system.

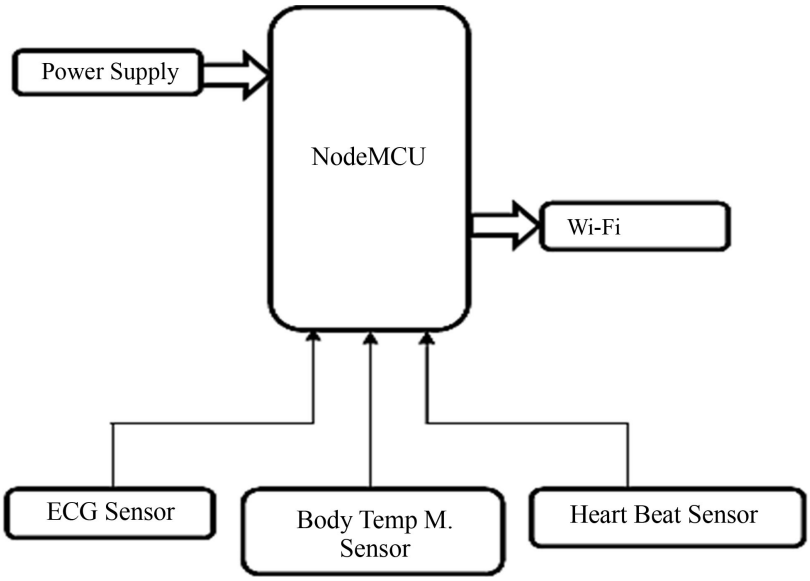


Figure 2. Sensor node.

system respectively. The main objective of this research is to develop an automated control and monitoring environment of patient's physiological data collection with IoT-Cloud using an embedded hardware and software platform. Numbers of sensor nodes, the location where they need to be used to collect data, requirement for real-time monitoring system facilities are the major factors defining the system architecture. Here we utilize some sensors to detect Electrocardiogram (ECG) data, heart beat data, body temperature (LM35).

Our proposal is based on automating the method of gathering patients vital physiological data via sensors connected to patient side and conveying this information to the medical centers cloud for the purpose of storage, processing, and dissemination using an embedded hardware platform. Here we use Raspberry Pi as an embedded hardware system. Figure 3 represents our proposed model for smart healthcare system. The system involves four main components: sensors, Raspberry Pi, server, and users. At the patient's side, we have sensor nodes that have the necessary system embedded to collect, encode, and transmit data over wireless communication channels. Raspberry Pi collects the sensed data from the sensor nodes. The sensed data can be used for further processing and provide it to different users like the cloud, doctors, nurses, and hospital to diagnose and monitor patient's health condition.

Through wireless communication, the sensed physiological data are transmitted to the Raspberry Pi and then via internet the sensed data is stored in the Cloud server. The Raspberry Pi acts as sensor gateways between the Cloud server and the rest of the components. All the communication is secure by applying proper authentication and data encryption mechanisms like block chain method. Many IoT services viz. storing, sharing, summarizing and searching for collected

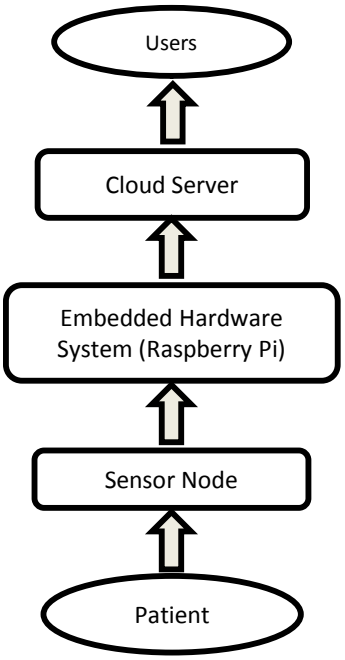


Figure 3. Proposed model for IoT cloud based healthcare system.

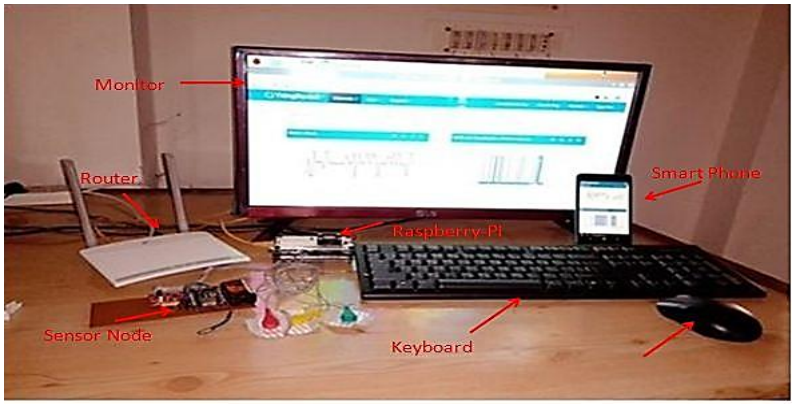
data as well as acquiring context-awareness to different users such as hospitals and other users of data or even patients are provided by the proposed integrated system. Following are the feature of the proposed model: 1) the long-term monitoring health status at any time and any place, 2) it can facilitate to build an intelligent cost effective and scalable data-driven pervasive healthcare service platform. In many models of Cloud-IoT healthcare system virtual machine is being used on the server, so we challenged their framework by using Raspberry Pi instead of the traditional virtual machine. Socket programming is used which creates a 2 way connection between two nodes in a network. The nodes are termed as client and server, the server performs the task requested by the client. In our case, Raspberry Pi receives data from the sensors and stores it to the cloud server. Selected care givers or medical practitioners can access the patient's vital data from anywhere of the world at any time. From the sensor nodes to Raspberry Pi, the data transfer is done using a 6LowPAN protocol. These protocols also help in creating a network of sensors via multi sensor board. Similarly from the Raspberry Pi to the local server 6LowPAN protocol is used, then from local server to remote server internet protocols (3G, LTE, Wi-Fi, etc.) used for data transmission and communication. 6LowPAN stands for IPv6 based low power wireless personal area networks, which is used for the smallest devices with limited processing ability to transmit information wirelessly using an Internet protocol.

Monitoring for the environment data can be done through ThingSpeak webserver. This channel provides cloud data storage for free to users that use this server. Firstly, we have to sign up at https://www.thingspeak.com/ and create a new channel. Fill in the channel name and enter the fields that will be used to receive data from coordinator (Raspberry Pi). For this research, three fields are used to collect ECG, Heart beat and Body temperature data. For sending the data to ThingSpeak, the write API Key needs to be inserted inside the programming section so that the data can be received by the server. For MATLAB simulation, the Read API Key will be used if users are interested for any simulation. The ThingSpeak channel enables users to access the data by accessing internet. It is a Cloud platform system that uses internet as a medium for data transfer. The data stored in the Cloud server can also be downloaded into devices for future usage and analysis. All the sensor values are stored and displayed in the form of graphs through ThingSpeak Cloud platform for monitoring the system. Data are available to export in different formats.

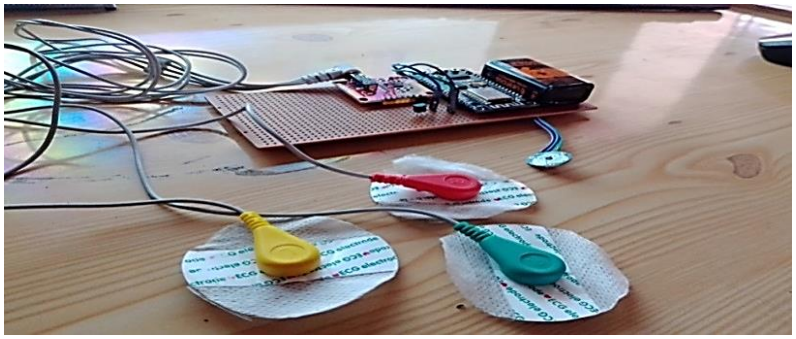
4. Evaluation of the Proposed Application

In this stage of the research we have discussed about the results for Cloud-IoT based smart healthcare System. The result obtained is regarding to the testing during the research development. For verifying the system we have made some discussions and analysis. **Figure 4** shows the test-bed scenario.

The circuit for the proposed system consists of a Raspberry Pi as coordinator,



(a)



(b)

Figure 4. Test-bed of proposed healthcare system (a) Whole environment, (b) Sensor node.

node MCU, ECG sensor, heart beat sensor and body temperature measuring sensor (LM35) as sensor node. For the monitoring assessment, data taken from the sensors is sent to ThingSpeak cloud server. **Figures 5-7** show the experimental data taken from this test-bed for evaluating the performance of this system using Cloud-IoT platform. These graphs show the ECG, heart beat and body temperature data respectively.

Here heart beat is measured in BPM. The normal heart beat rate for adults over the age of 10 years, including older adults, is between 60 and 100 beats per minute (bpm). However highly trained athletes may have a resting heart rate below 60 bpm, sometimes reaching 40 bpm. The resting heart rate can vary within this normal range. Body temperature is measured in the scale of degree Fahrenheit (˚F). Human body temperature with normal condition usually varies from 96˚F to 100˚F.

5. Conclusion and Future Work

In this research, we have utilized convergence of Cloud computing and IoT platform to implement a smart healthcare system using open source embedded hardware system. Wireless sensor network is utilized for implementation. The ascent of the IoT has possibly lifesaving application inside the healthcare industry by gathering information from bedside devices, seeing patient data and diagnosing

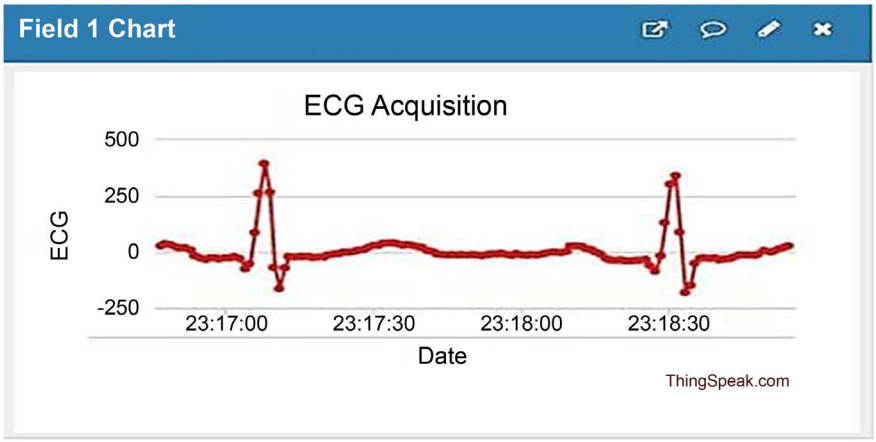


Figure 5. ECG data.

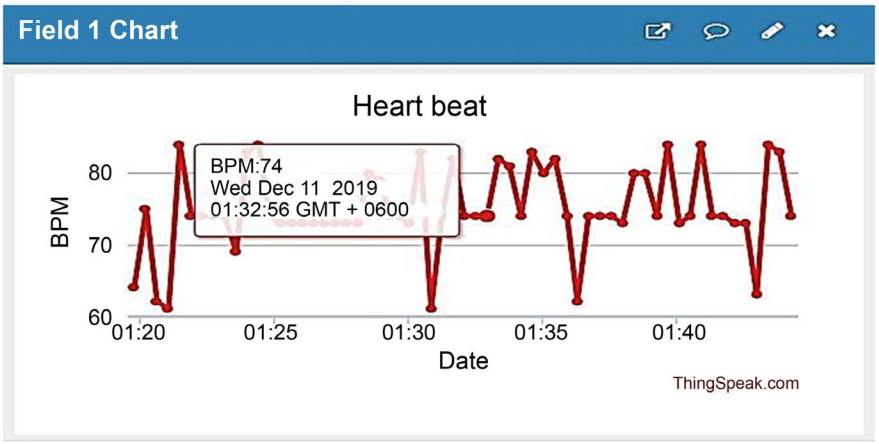


Figure 6. Heart beat data.

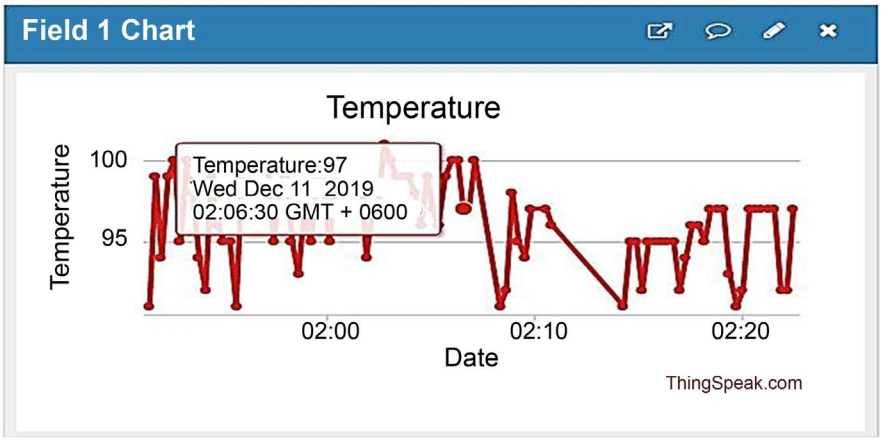


Figure 7. Body temperature data.

progressively. Patient physiological data is transferred to the cloud server. Care givers or user can monitor the data from the cloud server from anywhere at any time. In terms of patient experience, patients can access multiple functions, such as physical examination systems, online appointments, and doctor-patient inte-

ractions. These automated systems make patients' medical treatment processes more concise. Patients need a shorter time to get more adapted help. In total, coordination, refinement, and automation are the future headings of keen medical clinics. In future, we will try to implement various machine learning algorithms for better visualization and processing of patients physiological data. Furthermore, alert system or automatic prescribing system can be implemented by developing necessary algorithms.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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