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Editor

Fog Computing for Healthcare 4.0 Environments

Technical, Societal, and Future Implications

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Preface

Over the last few decades, we have witnessed various trends in industry standards and applications. For example, Industry 1.0 focused on mechanical engineering and automation, whereas Industry 2.0 focused on electrical energy. The third generation is Industry 3.0, which had telecommunication and information communication technology (ICT) as its core components. However, with the evolution of the Internet of Things (IoT) and cloud computing (CC), the current form of industries, i.e., Industry 4.0, is based on intelligent devices deployment and their usage. Advances in industries allow interaction with billions of objects across the world. According to an industrial survey conducted by Grand View Research, it was confirmed that the revenue obtained from the automobile industry segment was more than 25% in 2016. Also, it was observed that the healthcare sector garnered good revenue, which is more than 15% in 2016. To fulfill the requirements of Industry 4.0, the acceptance of IoT devices is growing at a rapid pace. To make the environment eco- and user-friendly, the healthcare industry needs to be prioritized with respect to service availability (as compared to other industries as mentioned above). Similar to other industries (mechanical, electrical, or civil), the healthcare industry has also developed from 1.0 to 4.0 generation. The healthcare industry is still in its nascent stage as it marked its beginning only in 1970. The efforts were preliminary, and resources were limited; therefore, this stage was termed as Healthcare 1.0. The subsequent gain in the momentum of the information technology (IT) field and in then medical technologies, the development of advanced medical imaging and tracking systems were introduced in the era of Healthcare 2.0. The advent of new and effective treatment methods has started with the intervention of computational methods and data processing systems. In this context, during the period 2006–2015, Healthcare 3.0 became popular due to the use of electronic health records (EHR), an alternative version of patients' data chart. This generation has adopted the EHR to help doctors to get the relevant information on time.

The revolution in Indian healthcare industries with the adoption of artificial intelligence (AI) techniques and the usage of robust communication interface in healthcare systems enable the doctors to analyze the medical data more efficiently to get meaningful insights from it. Such a value-based system enables the healthcare industry to improve the quality of service (QoS) provided with well-informed decisions. Healthcare 4.0 is being considered in the USA, where 90% of the healthcare system has been planned to shift towards a value-based system. In India, it is expected to run the healthcare industry with an estimated budget of 6000 million US$ by 2020. Numbers of healthcare IoT devices are producing a large amount of data at regular intervals; therefore, storage and security of such vast/enormous data are major issues in this environment. Physical data storage in a hospital may not be possible in every situation, so CC, an emerging technology, can handle this situation easily. With high storage capabilities and flexible processing services, CC has considerably expanded the application scenario of wearable medical sensor (WMS)-based systems. Across the globe, investigators and institutions have engaged in developing prototypes to employ WMS-based technologies and services offered by the cloud. Regardless of the multifaceted advantages, the cloud fails to address various issues for the delay sensitive applications:

- In real time, the hindrance in data transfer and processing over the cloud and relay of the outcome back to the user are unacceptable.
- In some cases, just a little delay or lack of application availability due to any reason (power failure, loss of Internet connectivity, cloud failure, etc.) may become life-threatening.

This book is organized into five parts. The first part focuses on the background and preliminaries of fog computing in Healthcare 4.0, which includes six chapters. The second part discusses the enabling technologies for Healthcare 4.0, which has four chapters. The third part illustrates the security and privacy issues with five chapters. The fourth part highlights the resource block for Healthcare 4.0, which has four chapters. Finally, the last part focuses on the next generation health fog analytics for Healthcare 4.0 and has four chapters.

Part I: Background and Preliminaries

The chapter "Adoption of Fog Computing in Healthcare 4.0" presents an introduction to fog computing in the healthcare domain. The major aim of this chapter is to provide a systematic view of the fog computing technology used in Healthcare 4.0. This chapter also gives a comparative study of the different versions of healthcare with current version 4.0. Furthermore, the authors discuss the different researchers' views about the healthcare industry in detail. This chapter also discusses the importance of fog computing in healthcare with some case studies for better understanding in solving health-related issues.

The chapter "Background and Research Challenges for FC for Healthcare 4.0" highlights the background and research challenges of fog computing in Healthcare 4.0, intending to guide the researchers and stakeholders for the overall improvement in the functioning of the healthcare domain. At the end of the chapter, the authors summarize findings to describe the advantages and limitations of existing mechanisms and provide insights into possible research directions.

The chapter "Fog Computing Architectures and Frameworks for Healthcare 4.0" discusses the existing architectures and frameworks available for the healthcare industry. The chapter presents the classification of architectures and frameworks developed for healthcare applications with respect to fog computing. Then, the authors have performed a comparative study of architectures and frameworks based on the issues addressed in them. Along with that, each study was classified on the basis of performance criteria such as low latency, minimum response time, time sensitivity, mobility, scalability, reliability, location awareness, energy efficiency, and power consumption. In the end, the study has been concluded with the future research direction.

The chapter "Importance of Fog Computing in Healthcare 4.0" discusses the relevance of fog computing in the area with its issues and challenges. This chapter focuses on the basics of fog computing, its advantages to the healthcare sector, and details about the features that can be used with it. Then, the security issues of fog computing are also highlighted. Further, a case study is given that provides evidence about the prolific integration of fog computing and IoT.

The chapter "A Comprehensive Overview of Fog Data Processing and Analytics for Healthcare 4.0" highlights the background of fog computing in the healthcare domain with its issues and challenges. This chapter is divided into five major sections, namely architecture of fog data processing and analytics, applications of fog-based data processing and data analysis, data processing algorithms in fog computing and data compression mechanisms, and data analysis mechanisms in fog computing towards Healthcare 4.0. The fog data architecture discusses various layers, namely sensing layer, fog gateway layer, fog-based data processing and data analysis layer, cloud layer, and service layer. Here, the process of sensing of healthcare data, maintenance of data, and various methods to analyze healthcare data are discussed.

The chapter "Data Processing and Analytics in FC for Healthcare 4.0" provides insights about the future of fog computing in healthcare. In the first section of the chapter, the emerging technologies in Healthcare 4.0 and their impact on the healthcare systems are discussed. In the second section, the three-layered fog architecture is discussed. Then, the need for data processing and analysis, along with various stages of data processing, is highlighted. Then, the chapter discusses issues and challenges in fog computing. Finally, the chapter also discusses different use cases involving fog computing.

Part II: Enabling Technologies for Healthcare 4.0

The chapter "Enabling Technologies for Fog Computing in Healthcare 4.0: Challenges and Future Implications" presents an overview of the challenges of Healthcare 4.0. The challenges are regarding the data (data collection and analysis), security and privacy, and e-healthcare services and also present a novel taxonomy of fog computing that can be a better solution to Healthcare 4.0. In the end, the chapter focuses on the future implications of fog computing in Healthcare 4.0.

In the chapter "Healthcare 4.0: A Voyage of Fog Computing With IoT, Cloud Computing, Big Data, and Machine Learning," the role of IoT, fog computing, and cloud computing has been described along with applications of machine learning and big data that runs on these paradigms. Issues related to cloud computing and motivation behind bringing the fog computing paradigm have also been explained in detail. Several architectures of fog computing are also discussed in this chapter, along with their application and comparison. The application of big data and machine learning modeling has also been explained in the latter part of the chapter. Lastly, case studies related to fog computing, big data, and machine learning in healthcare have been discussed.

The chapter "Fog-IoT Environment in Smart Healthcare: A Case Study for Student Stress Monitoring" provides a case study for student stress monitoring. This chapter proposes a temporal dynamic Bayesian network (TDBN) model to depict the event of stress as conventional or sporadic by readings through physiological means congregated from medicinal devices at the fog layer. It is constructed from four parameters: leaf node confirmations, outstanding tasks at hand, context, and understudy well-being quality. The experimental results aimed at both fog and cloud layers on stress-related datasets that illustrate the usefulness and accuracy of the TDBN model in the proposed system. The final experiments attain an accuracy value of 95.5% and a specificity of 97.3%, compared to the state-of-the-art approaches. At last, Healthcare 4.0 software-based multi-layer fog tools demonstrate their applicability for potential observation and regulation of eHealth.

The chapter "IoT Based Cloud Based Rx Healthcare Expert System" highlights the most up-to-date IoT or fog and cloud-based SMART system proposed and covered in previous literature. The authors propose a comprehensive IoT cloud-based healthcare system capable of monitoring, diagnosis, automatic medication dispensing, interaction between patients and system, interaction of the system with doctors, and interaction of the system with emergency personnel. They also demonstrate a process model of the proposed system. Finally, the chapter discusses the challenges and impact of IoT fog and cloud-based healthcare system.

Part III: Fog-Assisted Security and Privacy for Healthcare 4.0

The chapter "A Secure Fog Computing Architecture for Continuous Health Monitoring" discusses the evolution in IoT, the concept of cloud computing, and related issues. Thereafter, the chapter presents the concept of fog computing along with associated constraints and challenges. Furthermore, it describes the proposed secure fog computing architecture, which is integrating the security aspect in the fog layer. In the proposed architecture, a two-step approach is discussed to maintain the privacy and integrity of health data. The proposed architecture caters to the demand for a secure automated HMS that advocates its widespread deployment in real life.

The chapter "Security and Privacy Issues in Fog Computing for Healthcare 4.0" presents an extensive and organized overview of the security and privacy issues which state the need for security in fog-based medical devices. Different possible attacks and threats are covered with the scenario of the implanted medical device. Security challenges for different segments of fog computing like device, network, and data have been discussed with an in-depth analysis of security challenges, privacy, and trust issues with regard to Healthcare 4.0.

The chapter "Fog-Assisted Data Security and Privacy in Healthcare" explores the field of fog-assisted data security and privacy issues, that is, how patient data can be retrieved for monitoring while reducing the latency and securing the private data of the patient. A pairing-based cryptography technique such as an elliptic curve Diffie–Hellman key agreement protocol and a decoy technique are presented to access and store data more securely along with the help of some cryptographic algorithms. The chapter also includes some of the security issues that may arise in the healthcare sector. Then, the chapter discusses existing resolutions and emergent threats.

The chapter "Data Security and Privacy Functions in Fog Computing for Healthcare 4.0" details the fundamental issues related to the big data health monitoring system by leveraging the fog computing principle at smart gateways, offering advanced network edge techniques and services. Then, a system model for data protection at fog node is proposed. In particular, the chapter presents a case study on electrocardiogram (ECG) as it plays an important role in the diagnosis of many heart diseases. The experimental results show that fog computing helps to reduce encrypt and decrypt time compared to other traditional algorithms, and the information will be transmitted more safely using the proposed approach with less computational overhead.

The chapter "Fog Computing Application for Biometric-Based Secure Access to Healthcare Data" explores the complete design process of a multi-mode biometric-based security layer to provide secure authentication to access healthcare data at the edge devices deployed in hospitals and patients' smart homes. This chapter discusses the prototype design for authentication of end users of healthcare data and carries out a face recognition experiment for authentication. In the end, a case study is presented and the challenges faced in fog computing implementations in Healthcare 4.0 are discussed.

Part IV: Resource Block and Healthcare 4.0 Applications

The chapter "Efficient Resource Discovery and Sharing Framework for Fog Computing in Healthcare 4.0" describes the challenge and issue of fog computing related to the fog node discovery and utilization of available resources. Then, the chapter describes the proposed frameworks using publish/subscribe and P2P overlays to overcome the problems of resource discovery, sharing, and self-organization.

The proposed networking infrastructure can provide efficient resource sharing, discovery, and self-organization of nodes.

The chapter "Healthcare Using Different Biofeedback for Tension-Type Headache: IoT and Fog-Based Applications in South Asian Context" presents experiments for the treatment of stress. The focus of this study is to compare the impression of electromyography (EMG) biofeedback (BF), and galvanic skin resistance (GSR) and EEG integrated biofeedback on stress due to headache and quality-of-life. EMG biofeedback (BF) and GSR are considered an effective therapy for headaches. In this chapter, the experimental group showed a significant reduction in the level of stress using EMG and GSR biofeedback therapy. Hence, it is concluded that continuous positive thinking has the capacity to reduce stress among students and increase their working performance.

The chapter "Electronic Healthcare System: Mental Disorder Assessment and Intervention with Self-Treatment System Using Rule-based Techniques" facilitates a new version of a quick and practical electronic self-assessment and coping guide called electronic Mental Assessment and Self-Treatment System (e-MAST) for all patients. This system offers patients with three different sets of questionnaires measuring current stress, anxiety, and depressive symptoms generated using rule-based techniques. Besides, the weighted sum method is used to calculate the sum of answers from the patients. It also explores possible life stress domains and self-treatment techniques while awaiting professional help. This system helps to increase the scientific community's awareness of mental health and creates an opportunity to embrace a healthy generation of people. Also, this system can be used at all times, anywhere, and can be of benefit to all towards smart hospital ideas.

The chapter "Breast Cancer Detection Based on Antenna Data Collection and Analysis" presents a simulation of a wearable hexagonal T-shaped microstrip antenna for sensing of breast tumor in an initial development juncture. In this chapter, different distinctiveness of the aerial such as return loss, gain, smith chart, group delay, radiation pattern, and VSWR has been analyzed and observed that the antenna is best suited for breast tumor detection application. From the simulation results, one more application is observed at 1.75 GHz. The proposed work is virtuously dedicated for breast tumor detection, but it can find its application in GPS unit for radar and IoT.

Part V: Next Generation Health Fog Analytics for Healthcare 4.0

The chapter "Yajna and Mantra Science on Healthcare Domain: A Futuristic Scientific Approach with Indian Scenario" presents a deep insight into the impact of yajna and mantra in people's lives. The authors have performed a case study on the impact of Yajna and Mantra science on the healthcare domain considering the Indian scenario. In their case study, the authors took data from different sets of people and analyzed it using big data tools. Also, the authors have used the fog data analytics to find out the impact of Yajna and Mantra science on human health. The proposed study was performed on some patients (men = 4) and (women = 7) with an age range of 44–70 years. The results obtained after undertaking yagyopathy treatment indicated considerable improvement in the healthy lives of individuals.

The chapter "The Interoperability of Fog and IoT in Healthcare Domain: Architecture, Application, and Challenges" discusses the IoT and fog computing, their architecture, their application domains, and their integration and importance in healthcare. A literature survey involving all the works that include fog and IoT is discussed. Case studies involving fog and IoT in healthcare systems are also presented to provide light on how fog and IoT eliminate pressures on healthcare systems that require real-time processing.

The chapter "Application of Fog Computing, Internet of Things, and Blockchain Technology in Healthcare Industry" highlights the amalgamation of fog computing, blockchain, and the Internet of Things (IoT) in healthcare. Fog computing extends the capability of cloud computing that works between the cloud and end user devices called IoT devices to perform operations such as computation, storage, and communication over the Internet. It provides better data storage facilities with real-time access, lower latency, higher response, better fault tolerance, and secure and concealed environment. In IoT, conglomerate devices are interconnected and fragment IoT systems into five layers, such as fog, access, data interface, application, and security layers. To provide better security of the data in the healthcare environment, it discusses blockchain technology and consensus mechanism. This research focuses on the use of technologies for existing patients and normal users and improves the services of the healthcare industry.

The chapter "Social, Ethical, and Regulatory Issues of Fog Computing in Healthcare 4.0 Applications: Discussions and Resolutions" discusses the ethical, legal, and social issues arising with the growth of healthcare data and personal records. Apart from the location of the cloud servers and gateways based on the industry 4.0 architecture, this chapter also provides an integrated model for the adoption of gateways, fog nodes, and IoT devices in their respective areas, with a view of reducing the total installation cost, given maximum request capacity, latency time, devices in use, and reportage area.

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