

Biochip Design and Health Informatics Using IoT and SDN

Edited by Suman Lata Tripathi · Akanksha Gupta
Abhinav Gupta · Anurag Sewak · Vivek Srivastava

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Preface

Biochip technology, Internet of Things (IoT), and Software-Defined Networks (SDN) have the potential to revolutionize healthcare by making medical systems smarter, more personalized, and efficient. Biochips can detect and monitor health conditions, while IoT allows for the continuous transmission of this data in real-time, enabling healthcare providers to make faster and more informed decisions. SDN, on the other hand, helps manage and optimize the networks needed to handle this data, ensuring smooth and secure communication across devices and systems. However, despite their potential, the healthcare industry faces significant challenges in adopting these technologies. The first major issue is data security as healthcare data is highly sensitive, and the large volumes of information generated by biochips need to be transmitted and stored securely to prevent breaches. The amount of data collected through biochips and IoT devices can be overwhelming, making data management and storage as a critical challenge. Additionally, managing the large flow of data in healthcare effectively requires scalable SDN networks, but integrating these solutions into existing systems poses significant challenges. Hence, there is a need for a guide that explains how to design biochips, use IoT for real-time health data, and apply SDN to manage networks in healthcare.

This book, titled *Biochip Design and Health Informatics Using IoT and SDN*, provides a deep dive into the amalgamation of the biochip technology, IoT, and SDN for healthcare informatics involving advanced drug discovery and development. In the rapidly evolving landscape of precision medicine, biochips play a crucial role in high-throughput screening, biosensing, and real-time data acquisition for pharmaceutical research. The use of IoT and SDN technologies helps in accelerating drug screening, pharmacokinetic modeling, and personalized medicine applications. These technologies enable real-time monitoring and remote management of patients, making healthcare more accessible and efficient. The design of biochips is based on lab-on-a-chip technology that depends on VLSI for real-time analysis and diagnostics. VLSI technology plays a crucial role in the miniaturization and enhancement of medical devices, enabling the development of low-power, high-performance chips that can be integrated into wearable and implantable devices for continuous health monitoring.

To support seamless communication between the medical devices of health infrastructure and wearable sensory units, IoT as a connectivity framework facilitates the creation of a smart healthcare network that ensures secure and real-time data transmission. Deployment of IoT and allied technologies helps in efficient and remote monitoring of patients in real-time. The network traffic between IoT-connected devices carries sensitive real-time patient data that requires efficient and secure handling. SDN offers a flexible and scalable solution for managing network traffic, optimizing communication pathways, and ensuring efficient data transmission within biochip-based ecosystems. Integration of VLSI-based biochip technology, IoT, and SDN

addresses critical challenges such as data security, network architecture design, privacy concerns, and resource optimization in drug discovery workflows.

This book showcases a comprehensive study and exploration of emerging interdisciplinary technologies that are capable of revolutionizing modern healthcare system. The early chapters start with the fundamental device-level integration and innovation that emphasize the role of advanced scalable MOS transistors and VLSI in miniaturization and performance enhancement of medical devices. Chapter 1 introduces the reader to the critical need for energy-efficient biosensor design, leveraging tunnel field-effect transistors (TFETs) for ultra-low-power operation. The chapter presents a comparative analysis of multiple TFET architectures designed for biosensing and also suggests possibilities to deploy TFET-based biosensors in medical diagnostics and health management systems. Chapter 2 discusses the integration of biochips and lab-on-a-chip systems to offer insights into the convergence of VLSI with biomedical diagnostics. It emphasizes the role of MEMS and nanotechnology for improved sensor sensitivity, the convergence of VLSI with microfluidics for real-time data acquisition, and usage of AI for intelligent medical diagnostics. The next chapter explores advanced device structures designed to improve the efficiency and sensitivity of medical devices. Chapter 3 particularly discusses the design, fabrication, and uses of negative capacitance junctionless nanowires (NCJLNW) biosensors that are highly sensitive and are suitable for wearable health monitoring systems and point-of-care diagnostics. This is followed by a discussion of real-world applications of these devices in Chapter 4, where an extensive study of wearable and implantable systems for real-time health monitoring is presented. Additionally, Moving forward from device-level to high-level bioinformatics applications, the book explores the role of biochips in accelerating pharmaceutical research. Chapters 5 and 6 emphasize the amalgamation of biochips with microfluidics that are capable of biosensing applications and support rapid compound screening and biomolecular analysis. These chapters demonstrate the impact of biochips in diminishing drug development time and cost along with improved accuracy and predictive reliability. The advancements in multiplexed biochips and real-time monitoring guarantee refined precision medicine and streamlined pharmaceutical workflows.

The next segment of the book addresses the role of IoT and SDN in the healthcare setup for real-time patient monitoring, medical diagnostics, and smart drug delivery. Chapter 7 focuses on the fundamental concepts of IoT, its architecture, and protocols that serve as a conceptual framework for the design, development, and usage of IoT-enabled medical devices. It also throws light on advancements in architecture and protocols of IoT devices related to AI and security. Chapter 8 provides an introduction to basic concepts of SDN including its principles, components, and advantages over traditional networking. The chapter explores the architectural framework of SDN with emphasis on control and data plane separation, centralized network management, and programmability. The fundamentals of IoT and SDN lay down the foundation for understanding practical implications of these technologies in the healthcare scenario, where IoT sensors, edge computing, and SDN-based centralized control facilitate real-time monitoring of patients along with early diagnosis and post-hospitalization care. Chapter 9 explores how IoT is revolutionizing healthcare by enabling continuous and real-time patient monitoring beyond traditional clinical settings with the use of Internet of Medical Things (IoMT). The chapter discusses the integration of medical devices with the sensing and communication infrastructure of IoT for continuous real-time patient monitoring, personalized treatment, and improved clinical decision-making. Further, Chapter 10 discusses the design schemes, implementation methodologies, and several critical challenges to establish IoT-enabled healthcare systems. The chapter presents the current state-of-the-art of IoT-based systems with emphasis on the architecture, technologies, applications, problems, opportunities, open-source platforms, and operating systems. The next two chapters

focus on the role of SDN in providing more agile, secure, and efficient healthcare services. Chapter 11 describes the basic principles and operational advantages of SDN in the healthcare setup. It also highlights the problems of the traditional healthcare network infrastructures and their scalable solutions using the features of centralized control, programmability, and flexibility provided by decoupling of data and control planes in SDN-based networks. Additionally, Chapter 12 throws light on the advanced applications of SDN in healthcare and drug delivery systems, especially blockchain-secured pharmaceutical supply chains, AI-driven network management, and real-time data analytics. The chapter also investigates the possibility of integrating SDN with multi-access edge computing (MEC) to enable improved real-time monitoring of patients by the use of IoT-enabled medical devices. Further, Chapter 13 proposes a lightweight cryptographic block cipher to be implemented in the hardware of IoT devices, specifically tailored for resource-constrained bioinformatics systems. The chapter introduces an S-box that uses simple logic gates to offer a hardware architecture for a lightweight Midori cipher that can be used to enhance the security and privacy of patient data.

In the final two chapters of the book, recent and emerging trends in healthcare technology have been discussed, and some case studies showcasing real-life applications of the technologies have also been included. Finally Chapter 14 provides a forward-looking perspective on how emerging technologies like cloud computing, blockchain, big data, and AI improve the healthcare system by addressing important aspects like scalability, interoperability, data integrity, security, transparency, system efficiency, and smarter decision-making. The chapter highlights how advanced data analytics, decentralized systems, and scalable cloud platforms can be integrated to build predictive, resilient, and patient-centric modern healthcare systems.

Altogether, this book makes an effort to converge diverse but interdisciplinary domains, like semiconductor technology, IoT devices and embedded systems, artificial intelligence, programmable communication, and bioinformatics into a unified narrative for building an efficient, secure, and flexible patient-centric smart healthcare system. The book aims to equip readers with both the theoretical foundations of the technologies and their innovative research implications in different directions in the healthcare setup. Through a combination of foundational topics, application-driven chapters, and research perspectives, the book contributes in shaping the future of today's patient-centric healthcare systems with digital health monitoring and diagnostics, precision medicine, and intelligent therapeutic systems.

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IoT-Enabled Healthcare Systems: Design, Implementation, and Challenges

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Abstract

In the past couple of decades, there have been significant changes in the healthcare industry, mostly with the genesis of an emerging technology called Internet of Things (IoT). IoT provides a platform that allows people and objects to connect with one another in a seamless manner, thereby enhancing and simplifying our respective lives. This vision takes us from computer-based centralized schemes to a more dispersed environment that offers a large array of applications, including smart wearables, smart homes, smart mobility, and smart cities. The development of intelligent systems that have a high capacity for communication and data collection is made feasible by successive technological advancements. This opens up a number of potential applications for a wide variety of IoT applications, particularly healthcare systems. Although there are many benefits associated with the IoT, there are still a number of unresolved difficulties that constitute the most significant hurdles, including accessibility, portability, interoperability, information security, and privacy. The present state-of-the-art IoT architecture for electronic health records and healthcare systems is taken into consideration in this chapter. Particular attention is paid to the technologies, applications, problems, opportunities, open-source platforms, and operating systems. In addition, this chapter provides a synthesis of the existing body of knowledge and identifies common threads and gaps that open up potentially major future research avenues.

Keywords *Healthcare; IoMT; HIoT; wireless sensor network; smart devices*

10.1 Introduction

In the past couple of decades, the healthcare business has demonstrated a remarkable rate of expansion with tremendous growth, and it has been a significant source of both revenue and jobs [1]. The Internet of Things (IoT) connects devices, networks, and apps to ease data transmission, hence enabling a range of multiple and different services in many domains [2]. Essentially, it paves a way for associated communication channel, amalgamation of several network technologies, and communication solutions through linked devices [3]. Notably, IoT technology has facilitated numerous services and applications [4]. Applications of information

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