Introduction to Large-Scale Distributed Computing in Smart Healthcare

Assad Abbas, Samee U. Khan and Albert Y. Zomaya

1 Background Information

Conventional healthcare services have seamlessly been integrated with the pervasive computing paradigm and consequently cost-effective and dependable smart healthcare services and systems have emerged [1]. Currently, the smart healthcare systems employ Body Area Networks (BANs) and wearable devices for pervasive health monitoring and Ambient-Assisted Living (AAL). The BANs utilize smart phones and numerous handheld devices to ensure pervasive access to the healthcare information and services [2]. However, due to the intrinsic limitations in terms of the CPU speed, storage, and memory, the mobile and several smart computing devices appear scanty to handle huge volumes of unceasingly generated sensor data [3]. The collected data is used for multiple purposes, such as tele monitoring, activity recognition tasks, and therapies. In addition, the aforementioned data is highly complex and multi-dimensional and consequently is difficult to handle using the conventional computing procedures. Therefore, integrating the BANs with large-scale and distributed computing paradigms, such as the cloud, cluster, and grid computing is inevitable to handle the processing and storage needs arising due to continuously originating data from the BANs [1, 4].

Moreover, the contemporary research efforts mostly focus on health information delivery methods to ensure the information exchange across various devices at a

A. Abbas (✉)
COMSATS Institute of Information Technology, Islamabad, Pakistan
e-mail: assadabbas@comsats.edu.pk

S.U. Khan
North Dakota State University, Fargo, USA
e-mail: samee.khan@ndsu.edu

A.Y. Zomaya
The University of Sydney, Sydney, Australia
e-mail: albert.zomya@sydney.edu.au

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small scale. Consequently, the efforts have been very limited in connecting several BANs remotely through the servers. Therefore, the need to develop large scale solutions, such as Internet of Things (IoT), Cloud Computing, and Fog Computing to connect heterogeneous devices to transmit and process large amounts of data without requiring rigorous explicit human-to-human and human-to-machine interactions increases manifold [5]. Moreover, integrating the High Performance Computing (HPC) paradigms with the BANs and smart healthcare services brings several key benefits including scalability, storage, and processing to handle online and offline streams of data [6].

2 New Research Methods to Integrate the Smart Healthcare and Large-Scale and Distributed Computing Paradigm

In the recent past, plentiful research has been carried out pertaining to human activity recognition for rehabilitation, fall detection, mobile health, pervasive computing, and home health monitoring. However, very few researchers have only considered utilizing large-scale distributed computing methodologies in conjunction with smart healthcare systems. Considering the high growth of healthcare data flowing into the systems, this is the appropriate time to devise methodologies that are capable enough to proficiently deal with the data from its origination to processing and from processing to storage. Currently, there is no specific book that comprehensively reports the efforts made to integrate pervasive healthcare and BANs with the large-scale distributed computing approaches. Therefore, this book provides advanced perspectives and visions for the cutting edge research in smart healthcare with emphasis on large-scale and distributed computing systems in smart healthcare, QoS and resource allocation issues of BANs, healthcare IoT, Fog Computing, data quality and big data analytics for healthcare, machine learning methods, and models for multidimensional data.

This book explores the intersection of e-health services and distributed computing paradigm to improve the overall delivery of healthcare services. The book explains several recently emerged topics, such as IoT, Fog Computing, and big data in context of their large-scale implementation in healthcare domain.

The topics in the book have been mainly divided into five parts. Part I includes chapters on High Performance Computing and Large-Scale Healthcare Architectures. Part II of the book contains chapters on Data Quality and Large-Scale Machine Learning Models for Smart Healthcare whereas chapter on the IoT, Fog Computing, and mobile and connected health are included in Part III of the book. Part IV contains chapters that establish the connection between wearable devices and distributed computing for activity recognition and patient monitoring. Part V contains chapters on resource allocation, Quality of Service (QoS), and context-awareness in smart healthcare. A brief description of each of the chapters is given below.

Part I: **High Performance Computing and Large-Scale Healthcare Architectures**

Part I of the book comprises of four chapters mainly focusing on high performance computing and big data architectures for smart healthcare. Chapter 2 discusses the challenges in designing algorithms and systems for healthcare systems followed by a survey on various relevant solutions. The chapter also discusses next-generation healthcare applications, services, and systems related to big healthcare data analytics. Chapter 3 proposes a task-level adaptive MapReduce Framework to process streaming data in healthcare. This framework extends the generic MapReduce architecture by designing each Map and Reduce task as a scalable daemon process. The proposed architecture is claimed to be capable of scaling up and scaling down the resources as per real-time demands.

Chapter 4 presents a brief introduction of optical brain imaging techniques and highlights challenges specific to such techniques. Moreover, this chapter also introduces a massively parallel GPU based Monte Carlo simulation framework. Furthermore, the chapter explores a number of optimization techniques to improve computational efficiency and discusses the current and potential applications of this technique in biomedical imaging. Chapter 5 gives a concise review of Building Automation and Control Systems (BACS) addressing healthcare issues in the home environments. The strong aspect of the chapter is that it emphasizes on the effects of the BACS on well-being and health. The BACS can be considered as a large-scale network of distributed, interacting, and autonomous components where the size (scale) of the network is depending on the number of components, such as heating, ventilating, air-conditioning and refrigeration (HVAC&R), lighting, and window blinds/shades control. As a result, a BACS can contribute to the optimization of the physical environment toward individual users' needs, health, and well-being.

Part II: **Data Quality and Large-Scale Machine Learning Models for Smart Healthcare**

Part II comprises of four chapters on the importance of data quality and large-scale machine learning models for smart healthcare. Chapter 6 presents a detailed discussion on the data quality issues in Electronic Health Records (EHRs) and highlights the challenges pertinent to data that are crucial for the interoperability and standards across healthcare organizations. In particular, the discussion focuses on the large-scale Database Management Systems (DBMSs) and the importance of data quality for intelligent interfaces, structured data entry, and mobile computing. Chapter 7 covers all aspects of large-scale knowledge mining for medical and diseases investigation. A genome-wide association study is used in the chapter to determine the interactions and relationships for Alzheimer disease (AD). The chapter is a useful resource for details on mining the large-scale medical datasets for accurate diagnosis using big data methods.

Chapter 8 gives an overview of machine learning methods for analysis of heterogeneous and high dimensional healthcare data and also describes the effects of dimension reduction on the computational efficiency. The chapter reviews two case studies to evaluate the patients' health related concerns through data-driven models. Chapter 9 discusses the major issues related to large-scale and distributed architectures involving mobile sensing data for healthcare research, data curation, data provenance, and the data quality.

Part III: **Internet-of-Things**, **Fog Computing, and m-Health**

Part III of the book contains chapters on Internet-of-Things (IoT), Fog Computing, and mobile and connected health. Chapter 10 analyzes the ideas and impacts of the based healthcare systems on the design of new e-health solutions and also highlights various challenges, for example privacy and confidentiality to estimate the successful adoption of the IoT based e-health system. To ensure the widespread acceptance of the e-health systems, the chapter establishes six objectives and suggests that the development of future healthcare systems should primarily be based on the IoT, big data, and cloud computing. Chapter 11 defines and explores Fog Computing (FC) in the context of medical IoT. The chapter presents discussion on the FC as a service-oriented intermediate layer in IoT, providing an interface between the sensors and cloud servers for orchestrating connectivity, data transfer, and providing a queryable local database. The experimental results demonstrate that the FC can minimize the obstacles of existing cloud-driven medical IoT solutions and can significantly enhance the overall performance of the system in terms of computing intelligence, transmission, storage, configurability, and security.

Chapter 12 presents an innovative medical image cloud solution that enables accessible mobile healthcare and supports the hierarchical medical care services in China. A real scenario of regional medical imaging centers is also presented to compare its operational feasibility in comparison with traditional Picture Archiving and Communication Systems (PACS) services. Chapter 13 describes issues of the innovative large-scale technological developments for the community healthcare and well-being in context of developing nations with particular emphasis on receivers' perspective. The chapter presents discussion on utilizing large-scale technologies and their effective provision in community support and also highlights the benefits of Software-as-a-Service (SaaS) and mobile health infrastructure.

Part IV: **Wearable Computing for Smart Healthcare**

Part IV of the book comprises of six chapters that present variety of information on wearable devices and distributed computing for activity recognition and patient monitoring. Chapter 14 proposes a wearable system for recognition of American Sign Language (ASL). The proposed system design is an example of fusing different sensor modalities and addressing computation cost challenge of wearable computer based Sign Language Recognition (SLR) due to the high-dimensional data. The study is claimed to be the first American Sign Language recognition system fusing Inertial Measurement Unit (IMU) sensor and surface Electromyography (sEMG) signals which are complementary to each other. Chapter 15 introduces a novel ECG anomaly detection technique to be implemented in the cloud. The proposed technique which works by comparing the beat segments against a normal beat, succeeds in fulfilling all the necessary prerequisites for large-scale monitoring. The complexities of such systems are also highlighted and real-time signal processing methods and heuristics are applied in the chapter to estimate the boundary limits of individual beats from the streaming ECG data.

Chapter 16 presents a motion recognition method to the upper-limb prosthetic and robotic devices with emphasis on myoelectric pattern recognition techniques. The potential of distributed computing in healthcare with particular focus on the design and development of robust upper-limb rehabilitation devices has been discussed in the chapter. Chapter 17 proposes a novel data segmentation technique that harnesses the power of change point detection algorithm to detect and quantify any abrupt changes in sensor data streams of smart earrings. The presented framework is evaluated on two wearable sensor-based daily activity benchmark datasets to attest the scalability and adaptation of the presented techniques for other activity and large-scale participatory sensing health applications.

Chapter 18 outlines several challenges that developers, patients, and providers face in recent times. Several commercial platforms for health monitoring are reviewed and their impacts are discussed. The chapter also includes recently developed Berkeley Telemonitoring Framework and Android-based open source solution for development of health-monitoring applications. Chapter 19 describes the exploitation of physiological sensors and related signal processing methods to enhance monitoring care in patients with mental disorders. The authors in this chapter describe a pervasive and wearable system comprising of a comfortable t-shirt with integrated electrodes to monitor bipolar patients to support the diagnosis in clinical settings.

Part V: **Resource Allocation, Quality of Service** (**QoS**), **and Context-awareness in Smart Healthcare**

Part V of the book contains chapters on resource allocation in large-scale smart healthcare systems, QoS, and context-awareness. Chapter 20 reviews recent progress on multiple energy sources for BANs and the corresponding energy harvesting techniques. In particular, discussion on multi-node communications with energy harvesting for large-scale BANs where complicated network structures are employed is presented. Apart from conventional energy sources, for example photovoltaic, thermoelectric, and electromagnetic energy harvesting that can be applied in BAN, the chapter also describes the energy sources, such as kinetic and biochemical energy harvesting that are exclusively adopted on human body for BAN. Chapter 21 proposes an Analytic Hierarchy Process (AHP) based algorithm to manage m-QoS based on Telemedicine service selection, evaluation, and assessment on the priority and urgency basis by randomly selecting three decision parameters namely throughput, delay and jitter, to provide cost-effective and quality life to emergency patients at remote location in the hospital.

Chapter 22 presents an ontology based system to collect the contextual data, before, during, and after a digestive surgery. The proposed system is used in a clinical setting as a part of the E-care medical monitoring platform and is applied to the rehabilitation process after a digestive surgery to collect the data. The collected data are subsequently statistically analyzed to make decisions regarding the patients' health status. Chapter 23 presents a methodology to design a multi-agent telemonitoring platform. The preliminary results show that this platform is able to assist health professionals in providing an automated processing of data sent from the sensors and automatically generating alerts in order to detect and report risk situations.

3 Perspective on Future Research Directions

Despite the effectiveness of large-scale computing techniques in healthcare delivery methods and services, there are certain areas that need further investigation. The first possible direction for future research is to investigate the potentials of deploying the IoT based solutions for epidemic control and predict possible disease breakouts. The aforementioned solutions can definitely be beneficial for community healthcare in general and for developing economies in particular because despite all of the economic and financial issues still large number of people possess smartphones. Devising techniques that emphasize on epidemic data collection through smartphones can help government agencies in efficiently identifying the affected areas. Off course at individual and consumer level, implementation of such methods is challenging due to high involved costs but is certainly possible at government level.

The second potential area to be emphasize on is the curation of healthcare datasets. Veracity of healthcare data not only ensures the accuracy of the monitoring procedures but can also lead to energy efficiency if effective dimension reduction techniques are applied on the healthcare data. In fact, the inception of BANs and the IoT in healthcare have resulted in excessive data volumes and thereby increased number of features. Therefore, to truly benefit from the parallelism offered by big data tools and techniques, the machine learning methods capable of optimizing the datasets while preserving the accuracy are needed.

Another direction worth exploring in context of smart healthcare services is the privacy and security of healthcare data. Although the health data privacy and security in general attained significant attention of the researchers in past, measures are needed to ensure the privacy of the healthcare applications and methodologies typically designed for smartphones and several other handheld devices.

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