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A Flexible Approach of Mobile Cloud Computing and Big Data Analytics for Networked Healthcare Applications

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***Abstract*— Now a day's Mobile devices were rapidly growing as indispensable part in our daily life, facilitating to do various useful tasks. Mobile cloud computing combines mobile with cloud computing to enlarge their capabilities, benefits and reduces their limitations, like battery life less memory and CPU power. Big data analyzing technologies facilitate extracting value from data consisting four Vs: volume, velocity, variety and veracity. This paper focuses networked healthcare as well as the task of mobile cloud computing and big data analytics in its enablement. The inspiration and development of applications over networked healthcare and systems were offered along with the adoption of healthcare cloud. A cloudlet based infrastructure of mobile cloud-computing to be utilized for healthcare. The methods, tools, and applications of big data analytics were focused. Experimental results are considered in the design of networked healthcare systems with big data as well as the technologies of mobile cloud-computing.**

***Keywords:-* Cloud Computing, Mobile Cloud Computing, Bid Data, Network, Healthcare Applications;**

I. INTRODUCTION

Recently, there have been many advances in information and communication technologies that have been transforming the world; the world is increasingly becoming a small neighbor-hood. Among these technologies are the cloud computing, the wireless communications (3G/4G/5G), and the competitive mobile devices industry. The mobile devices can provide variety of services to facilitate our living style [1]. They are integrated in our daily routine to help performing variety of tasks such as location determination, time management, image processing, booking hotels, selling and buying online, and staying connected with others. Also, there are mobile applications to help you measure and manage your health through applications for blood pressure, exercises, and weight loss [2].

The mobility feature of mobile devices (Figure 1) changed the way that people use different technologies all over the world. There is no need any more to stay at your of ce to do your job or daily activities. The users can move to many

Figure 1. Features of mobility

locations based on many parameters for easier life such as ef ciency, stable and fast internet connection and data privacy concerns to impose the need to protect the users' data from unauthorized disclosure especially over non-secure wireless channels [3]. All these features of mobile devices and integrating them in our life speed up the transition towards greener and smarter cities [4].

Figure 2. The concept of Cloud Computing

Another recent technology is cloud computing (see Figure 2) which allows access to the stored information from anywhere at any time, and can be used in different organizations or by individuals to enhance productivity and increase performance and reduce the cost and complexity [5]. Cloud computing is de ned by NIST as ``a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of con gurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [6].

Moreover, integrating the mobile devices with cloud com-puting to utilize the unlimited service provided by the cloud through the mobile device results in what is known as Mobile Cloud Computing [7]. The Cloud Computing relies on a set of network-connected resources shared to maximize their utilization resulting in reduced management and capital costs. Mobile Cloud Computing (MCC) is set to bene t many sec-tors including the cloud-healthcare systems. As an example, MCC healthcare system was built to capture and analyze real time biomedical signals (such as ECG and Blood pressure) from users in different locations. On the mobile device, a per-sonalized healthcare application is installed and health data are being synchronized into the healthcare cloud computing service for storage and analysis [8].

MCC expands the capabilities and bene ts of the mobile devices, and overcomes their limitations, so the users will not be worried about the memory size and required CPU power to run intensive tasks that consume considerable amount of energy [9] and require extra memory. For example, multi-media applications which are known to be among the most common applications in today's mobile devices involve shar-ing and creating images and video les. These applications require high computing capabilities, big space to be stored, and maybe more security protection [10] which are chal-lenges for mobile devices. Mobile cloud computing resolves these issues by storing the large multimedia le on the cloud, and it will be available to the mobile users when requested resulting in better performance. And since the energy drain
is an important issue in mobile devices and sometimes limits the optimum utilization of these devices, the researchers are motivated to nd optimization methods to reduce the con-sumed energy by mobile devices in the cloud and mobile computing environments [11].

Besides all the great bene ts of using the mobile cloud computing, there are still some limitations such as the delays encountered when the mobile devices access the cloud ser-vices from far distance which are mainly due to/from the mobile devices. It is believed that using the cloudlet concept between the enterprise cloud and the mobile device has a good impact in reducing connection latencies and power consumption [12].

On the other side, there are many challenges associated with storing data on cloud, and mainly is to protect the privacy of the users' data from unauthorized access and from malicious attacks. Also, availability of the owners' data at any time request is an issue. The integrity is also a concern in which the data should not be altered or modi ed by intrud-ers. Many cryptographic techniques can be used to provide solution to these information security concerns [13], [14].

It is well-known that healthcare applications require large amounts of computational and communication resources, and involve dynamic access to large amounts of data within and outside the heath organization leading to the need for networked healthcare [15]. Mobile cloud computing could provide the necessary computational resources at the right place and right time through cloudlet and fog computing based architectures. Moreover, big data and relevant tech-nologies could provide the data management and analytics solutions that are necessary to reduce healthcare costs and improve system and clinical inef ciencies. Big data refers to the emerging technologies that are designed to extract value from data having four Vs characteristics; volume, variety, velocity and veracity. Big data is set to affect the future network traf c and hence the network architectures [15]. See [16] for a survey on big data.

This paper discusses the concept of networked healthcare and its enablement through the mobile cloud computing and big data analytics technologies. The motivation and devel-opment of networked healthcare applications and systems is presented along with the adoption of cloud computing in healthcare. A cloudlet based mobile cloud computing infras-tructure to be used for healthcare big data applications is described. The techniques, tools, and applications of big data analytics are reviewed. Conclusions are drawn concerning the design of networked healthcare systems using big data and mobile cloud computing technologies.

The rest of the paper is organized as follows. Section II presents the literature review, and Section III discusses the healthcare applications and systems. Section IV presents the cloudlet based mobile cloud computing infrastructure for healthcare use. Section V presents big data analytics, fol-lowed by a review of data analytics tools in Section VI. Section VII concludes the paper and provides an outlook for networked healthcare.

II.RELATED WORK

There are many related work in the literature about cloud and mobile cloud computing and their useful applications in many life aspects including health and nancial transactions.

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Not neglecting the important issue of securing users sensitive data on the cloud, a secure framework for cloud computing based on data classi cation is proposed in [17]. This framework categorizes the data based on its con dentiality, and selects the suitable encryption mechanism to provide the appropriate protection for each data category.

The authors in [18] presented a prototype implementation of cloudlet architecture. They pointed out the advantages of such architecture in real-time applications. In the straight forward approach, the cloudlet is xed near a wireless access points. But in this prototype, a cloudlet can be chosen dynam-ically from the resources inside the network to manage the running applications on the component model.

In [19], a large scale Cloudlet MCC model was deployed for the purpose of reducing network delay and power dis-sipation especially for intensive jobs such as multimedia applications. Also, the large scale deployment covering large areas allows the mobile users to stay connected with the cloud services remotely while they are moving within this area with less broadband communication needs while satisfying high quality service requirements.

The impact of using cloudlet along with mobile cloud computing on some interactive applications (including video streaming) was analyzed in [20]. The authors compared the two models in terms of system throughput and data transfer delay. Their results indicated that in most cases, the use of the cloudlet-based model outperformed the cloud-based model. A framework to provide personalized emotion-aware services by mobile cloud computing is proposed in [21].

Energy conservation is a major concern in cloud computing systems with huge number of operating data centers that consume large amounts of power. Moreover, the prediction of how much this consumption will increase depends on the dynamic expansion of their infrastructures to meet the increasing demand for huge computation and massive com-munication. The authors in [22] proposed resources man-agement and optimization policies in the Cloud such as using virtualization, VM live migration, and server consoli-dation. They presented an energy ef cient network resources management approach, and proposed a practical multi-level Cloud Resource-Network Management (CRNM) algorithm, which is implemented in a virtual Cloud environment using Snooze framework as the Cloud energy ef ciency manager. The results showed saving of more than 70% of power con-sumption in Cloud data centers compared to other non-power aware algorithms.

III.NETWORKED HEALTHCARE: MOTIVATIONS AND STATE-OF-THE-ART

This section provides the motivation for networked health-care followed by a review of literature on the state of-the-art of networked healthcare architectural and performance studies including those implemented on cloud computing platforms.

Healthcare, like many other sectors, has grown rapidly with the massive growth in ICT. The increasing role and benefits of ICT in healthcare are becoming visible in the health informatics, bioengineering and Healthcare Information Systems (HIS). We can now imagine a near future where healthcare providers can port powerful analytics and decision support tools to mobile computing devices aiding clinicians at the point of care helping them with synthesis of data from multiple sources, and context-aware decision making [23]. Major drivers for ICT-based healthcare include demands for increased access to and quality of healthcare, rising healthcare costs, system inefficiencies, variations in quality of care, high prevalence of medical errors, greater public analysis of government spending, ageing population, and the fact that patients and the public want a greater say in decisions about their health and healthcare. The scientific developments that are yet to reach their required potential for providing personalized healthcare include genetic and molecular research, translation of knowledge into clinical practice, new processes and relationships in product development and knowledge management [24]. However, we believe that the major hurdles for the healthcare industry in realizing the full potential of ICT include the social reasons including privacy of health data and public trust [25].

The key management strategies that healthcare executives should focus on over the coming years include Collaboration, Open Systems, and Innovation [26]. The key health information technologies (HIT), according to them to be deployed over the next decade include Electronic Health Record (EHR), Personal Health Record (PHR), and Health Information Exchange (HIE) systems. They projected that by 2020, 80% of health care provider organizations will have implemented EHR systems in the US, and 80% of the general population will have started using PHR systems in the US. A vision of Medical Informatics in 2040 is presented in [27]. The authors believe that transformation of healthcare will be enabled through the implementation of technologies including genomic information systems & biorepositories integrated with EHR systems; nanotechnology, advanced user interface solutions, e.g. wearable systems, health apps, health information exchange (HIE) with other industries/sectors such as pharma and manufacturing, Home-based TeleHealth solutions interconnecting patients with health care providers, and medical robotic devices interfaced to health IT (HIT) systems.

The United States Department of Health and Human Ser-vices [24] envisions personalized health care and gives a perspective on how far and how quickly we have come in treatment strategies of dangerous diseases including cancer, diabetes and heart attacks. In 2014, Apple introduced the mobile health platform HealthKit [28], a cloud API made available for IOS 8 [29]. HealthKit bene ts by the Apple's partnership on this enterprise with Mayo Clinic and soft-ware company Epic Systems. The HealthKit API provides

the users with an interface for accessing and sharing their PHRs. The information collected through the Apple Health App could be integrated with, for example, the Epic's EHR systems allowing the use of Epic's software tools. The Apple Health app provides a convenient entry point to personalized health services. Apple has also provided information for developers and extended an invitation to discuss the possibilities for interaction of various devices with the sys-tem [30]. The ``S'' Health app from Samsung for Android platform is also being used by many people on their smart phones [31]. These are important milestones in the move towards personalized healthcare. We believe that the major innovations in personalized healthcare will begin when open Source community will start contributing in the healthcare applications space.

Having discussed the motivation for networked healthcare, we now review literature on the architectural and performance studies in healthcare.

There have been many studies on performance modeling and analyses of healthcare applications over communication networks [15], and distributed systems [32], including cloud computing systems [15], [33]. A quantitative modeling study to demonstrate the potential of computational grids for its use in healthcare organizations to deploy diverse medical applications was presented in [32]. The study considered multiple organizational and application scenarios for grid deployment in networked healthcare including four different classes of healthcare applications and 3 different types of healthcare organizations. The computational requirements of key health-care applications were identified and a Markov model of a networked healthcare system was built. For each scenario, steady state probability distributions of the respective Markov models were computed in order to analyze the system performance. Various performance measures of interest such as blocking probability and throughput could be computed from these state probability distributions. The paper provides an interesting insight into computational requirements of healthcare applications, as well as provides a platform to explore communication requirements of healthcare applications. These requirements are important because the traffics on future networks connecting healthcare systems are likely to be dominated by the analytics applications that require frequent, low-latency, communications. These individual communications though may not be heavy in terms of data, however will create significant traffi c due to the large number of individual communications. This is also very typical of high performance computing applications. A healthcare monitoring system based on wireless sensor networks is proposed in [34]. Specifically, the monitoring system monitors physiological parameters from multiple patient bodies through a coordinator node attached to the patient's body that collects the signals from the wireless sensors and sends them to the base station. Continuous monitoring of physiological parameters is an important application area of healthcare and has major implication on the design of network that con-nects sensors, analysis applications, physicians, healthcare

systems and providers. For example, as exemplied in this paper, monitoring of blood pressure and heart rate of a pregnant woman, and the heart rate/movement of the fetus, is a vital requirement for managing her health. The sensors attached to a patient's body form a wireless body sensor network (WBSN) and provide information related to heart rate, blood pressure and other health related parameters.

A framework for a unified middleware based on Session Initiation Protocol (SIP) to enable mobile healthcare applications over heterogeneous networks is proposed in [35]. Their motivation is the need for anytime anywhere delivery of healthcare services that will in turn require operation over heterogeneous networks. Their approach is to use the pro-posed uni- fied middleware to isolate applications from mobility management and other transport/discovery related tasks. A survey of wireless sensor networks (WSNs) for healthcare is provided in [36]. An overview of the design issues for healthcare monitoring systems using WSNs is provided along with a discussion of the benefits of these systems. Several applications and prototypes of WSN healthcare monitoring systems are reviewed from the literature, as well as challenges and open research problems for the design of these systems.

A study of end-to-end network performance within and between three hospitals in the Central-West region of Ontario with the aim to examine the healthcare applications requirements was presented in [37]. The OPNET modeler is used to study the network performance. Results of four applications used in this study; database, HTTP, FTP, email, were presented and discussed for throughput and queuing delays for servers and the main router. A comparative study on mobile computing to get a better solution for mobile healthcare applications was presented in [38]. A mobile cloud architecture relevant to healthcare applications that stores and manages personal healthcare data was proposed. A number of other works have discussed cloud computing adoption in healthcare and the expected advantages and limitations, see e.g. [39].

In the context of networked healthcare we should mention the Health Level Seven International standard. HL7 is a not-for-pro t organization that was formed in 1987. It is accredited by ANSI (American National Standards Institute) and it is ``dedicated to providing a comprehensive framework and related standards for the exchange, integration, sharing, and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services'' [40]. ``Level Seven'' refers to the seventh layer (the application layer) of the International Organization for Standardization (ISO) seven-layer communications model for Open Systems Interconnection (OSI).

Many studies have explored the networked systems and QoS in transferring data over different networks, which is very important in many applications especially in healthcare. Service modeling of multimedia over Wi-Fi networks was explored in [41]. End to end Service Modeling of multimedia (video, voice and text) over VoIP networks within metropolitan area network environments was explored in [42] with a focus on VoIP. The study also presented a novel analysis methodology combining simulations and Markov modeling. A scalable multimedia QoS architecture for ad hoc networks was proposed in [43]. Cross-Layer QoS and provisioning for multimedia applications (video, voice and text) over wireless Ad hoc Networks was reported in [44]. Classification of ad-hoc networks design, infrastructure, and QoS for multimedia communications over wireless networks was reported in [45].

An important trend to enable next generation networked healthcare systems would be the networking and integration of healthcare and other smart city systems, particularly for healthcare related operations, such as integration with transportation [46] [49] and logistics systems [50], [51]. For instance, in [50] electronic health records (EHRs) and other smart city information systems are used together for capacity sharing and to provide enhanced efficiencies. Networked healthcare systems will eventually be designed as sustainable enterprise systems which will be part of networked smart city information and operations systems [52], [53]. Modeling methods that leverage high performance computing and are able to deal with big data, such as [47] and [49], will be required in studying such complex networked healthcare systems.

IV.MOBILE CLOUD COMPUTING INFRASTRUCTURE FOR HEALTH CARE BIG DATA

There are many mobile cloud computing infrastructures for different usages including the healthcare applications. The traditional infrastructures involve set of cloud resources accessed remotely by the users of different types of devices via through the Internet as shown in Figure 3.

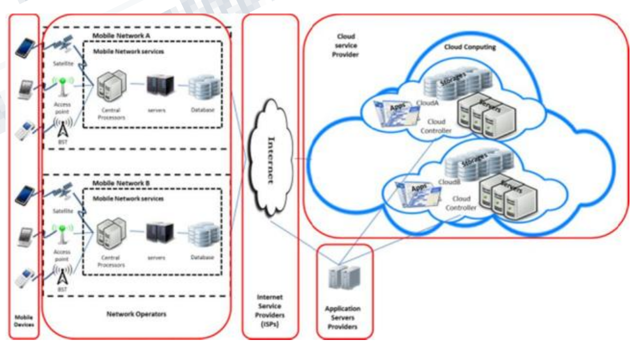

Figure 3. Traditional Infrastructure of Mobile Cloud Computing

The massive spread of mobile applications in all and every area of the peoples life resulted in huge amounts of data that need to be processed and analyzed efficiently in less time and power complexity which imposes the need for new competitive MCC models other than the traditional one.

Performance Enhancement Framework using the Cloudlet was proposed in [54]. The cloudlet (figure 4) can be

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considered as a closer cloud with many advantages and capabilities to avoid several limitations of distant cloud. And so, a limited resources cloudlet will not help, and might have bad impact on the performance. So, it is believed that the cloudlet scheme which is introduced as a middle stage between the cloud

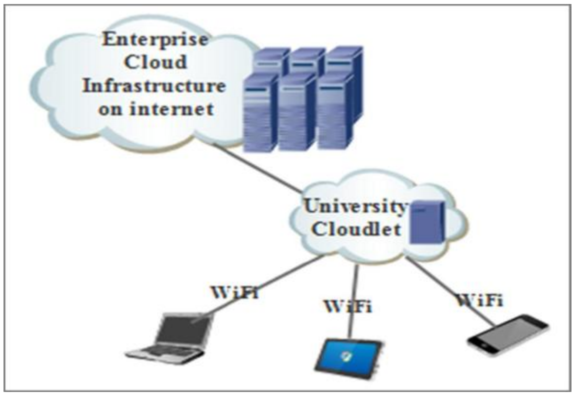

Figure 4. The Concept of Cloudlet

and the mobile device has a good chance to overcome the challenges associated with MCC such as latencies and power consumption [55].

But, in some cases, the mobile user has no choice other than connecting directly to the EC. This happens when the mobile device needs to update les stored in the Enterprise Cloud or request certain services that are not available in the Cloudlet.

Motivated by the cloudlet concept, the authors in [56] built a mobile cloud system to be used in different applications such as universities. Their system use different sensors to carry out many tasks. They proposed and implemented two main applications in traffic management and re detection and the data from sensors is processed in mobile cloud sys-tem. In the same context, the researcher in [57] introduced an efficient cloudlet MCC model in which the mobile users communicate directly to the cloudlet instead of the enterprise cloud. Their model can be applied in many environments including hospitals were big amounts of data need to be saved and processed.

The Big Data is a recent term associated with the huge amounts of stored /obtained data due to the revolutionary advances in different technologies including: cloud computing, spread of social media, and wireless communication technologies. It is de ned according to: the size of data (volume), types of data based on the producing source (variety), and the time frequency to generate the data (velocity); every, minute, day, month, or a decade [58]. Some of this big amount of data could be processed of fine, but some applications needs real time processing for this data such as health applications where the data analysis and extracting the right decisions makes a difference between patients life and death. Figure 5 shows Mobile cloud computing for healthcare big data applications. In this MCC model the cloudlets are placed nearby the hospital and cover an area that can be accessed by authorized people who can access the patients' information and follow their status remotely. Moreover, in this model, there is big amount of patients data being generated and need to be analyzed, and the next section discusses the data analytics.

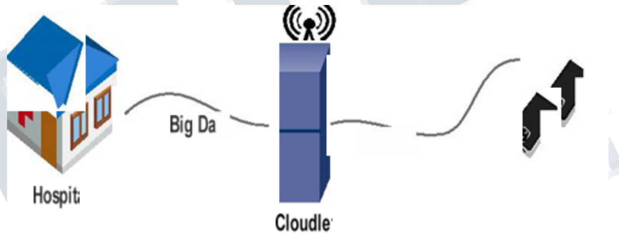

Figure 5 Big data Healthcare in MCC

V. DATA ANLAYTICS

The science of examining raw data with the purpose of drawing conclusion or inspecting, cleaning, modeling and transforming data with the purpose of highlighting useful information is called data analytics [59]. This method is being used in many industries to allow manager to take best business decisions and verify or disprove existing theories and models. This science is different from data mining by the purpose, scope and focus of analysis, in data mining, miners sort through huge data sets with the help of sophisticated software to identify hidden relationships and undiscovered patterns. While data analytics focuses on the conclusion reached on the basis of evidence and reasoning, the method of deriv-ing a result based solely on what is already known by the researcher. Recently Big Data and Big Data Analytics are being used to explain data sets and analytical methods in to the application which are very large, for example, TB to hexabytes and complex from sensor to social media data which require advanced and unique data management, storage, visualization and analysis technologies. See e.g. [60].

Data analytics science is divided into exploratory data analysis (EDA), conrmatory data analysis (CDA) and qualitative data analysis (QDA). In EDA new features in the data are discovered, in CDA existing hypotheses are proven true or false and QDA is being used in social sciences to draw conclusion from non-numerical data for example, photographs, videos or words. In IT sector data analytics has special meaning in the context of IT audits where an organization's information system, processes and operations are examined. Data analysis is also being used to get the information about data protection, operational efficiency and success in accomplishing an organization overall goals.

The term `analytics' has been used by business intelligence software vendors as a buzzword to explain different functions [59]. Data analytics is also used to explain, for example online analytical processing to customer relation management (CRM) analytics in call centers, bank and credit cards companies to analyze spending and withdrawal patterns for preventing identity theft or fraud, and ecommerce companies inspect web traffic to analyze which customers are more or less potential. Modern data analytics commonly use information dashboards which are supported by real time data streams.

It is argued [61] that spread sheets are the established data collection and data analysis tools in technical computing, business and academics. Excel is the example that offers attractive user interface and provide an easy to use data entry models and support interactivity for what-if analysis. The drawback of spread sheets and other common client applications e.g., Excel is that they do not support computation of large scale data analytics and exploration. Researchers in the area of social sciences to environmental sciences are facing a good of data and they often sit in spread sheets or other client application with the lack of easy methods to explore the data, or invoke scalable analytical models over the data or and related data sets. Developers developed a Cloud data analytics service which is based on Daytona. Daytona is an interactive MapReduce [61] runtime optimized for data analytics. In their model, Excel and other client application provide the data entry and other interaction interface to the user, and bridges the gap between the client and Cloud, user can use this service to discover and import data from the Cloud, invoke Cloud scale data analytics algorithms to extract information from big datasets, invoke data visualization and then store data back to the Cloud with the help of spreadsheet or any other client application to whom user is already familiar. This development is the ramp between any client application such as Excel and a new class of data analytics algorithms that are being implemented on Cloud. User only need to select an analytics algorithms from the Excel research ribbon with having concern for how to start up virtual machines in the Cloud or how to scale out the execution of selected algorithms in the Cloud.

VI. CONCLUSION

Mobile devices are increasingly becoming an indispensable part of people's daily life, facilitating to perform a variety of useful tasks such as scheduling meetings, ordering food, booking lights, buying cars online, real-time navigation, etc. Mobile cloud computing maximizes the utilization of mobile devices capabilities to run intensive-computing applications. These intensive jobs are executed in the mobile cloud computing infrastructure overcoming the mobile device limitations, saving energy, and providing better throughput.

In this paper, we discussed networked healthcare systems and the role that mobile cloud computing and big data analytics play in its enablement. The motivation and development of networked healthcare applications and systems was presented along with the adoption of cloud computing in healthcare. A Cloudlet based Mobile Cloud Computing infrastructure to be used for healthcare big data applications was described. The techniques, tools, and applications of big data analytics were reviewed. Healthcare applications require large amounts of computational and communication resources, and involve dynamic access to large amounts of data within and outside the heath organization. This was discussed to be the main motivation for networked healthcare system where big data such as patient records need to be analyzed in real time, and this can implemented efficiently via cloud and mobile cloud systems.

An important trend to enable next generation networked healthcare systems would be the networking and integration of healthcare and other smart city systems. Networked healthcare systems will eventually be designed as sustainable enterprise systems which will be part of networked smart city information and operations systems. Modeling methods that leverage high performance computing and big data technologies will be required in designing such complex networked healthcare systems. Further studies are needed on the integra-tion of mobile cloud computing and healthcare applications to design realistic networked healthcare systems that are able to provide personalized medicine, reduce healthcare costs and facilitate better clinical and operational processes.

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