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Mobile Cloud Computing Model and Big Data Analysis for Healthcare Applications

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ABSTRACT Mobile devices are increasingly becoming an indispensable part of people's daily life, facilitating to perform a variety of useful tasks. Mobile cloud computing integrates mobile and cloud computing to expand their capabilities and benefits and overcomes their limitations, such as limited memory, CPU power, and battery life. Big data analytics technologies enable extracting value from data having four Vs: volume, variety, velocity, and veracity. This paper discusses networked healthcare and the role of mobile cloud computing and big data analytics in its enablement. The motivation and development of networked healthcare applications and systems is 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 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. An outlook on networked healthcare is given.

INDEX TERMS Healthcare systems, big data analytics, mobile cloud computing, cloudlet infrastructure, health 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 neighborhood. 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].

FIGURE 1. Mobility features.

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 office to do your job or daily activities. The users can move to many locations based on many parameters for easier life such as efficiency, 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].

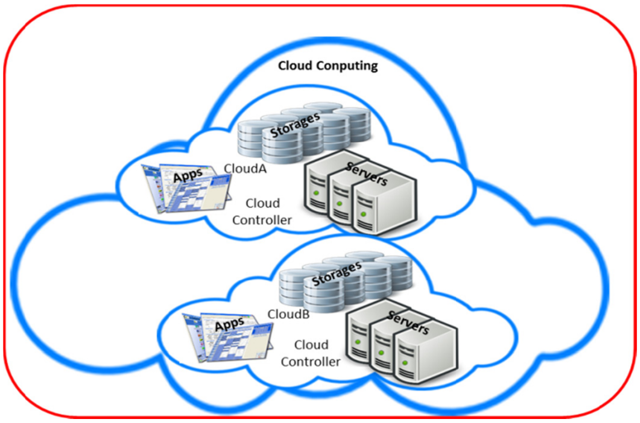

FIGURE 2. **Cloud computing concept.**

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 defined by NIST as ''a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable 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 computing 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 benefit many sectors 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 personalized 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 benefits 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, multimedia applications which are known to be among the most common applications in today's mobile devices involve sharing and creating images and video files. These applications require high computing capabilities, big space to be stored, and maybe more security protection [10] which are challenges for mobile devices. Mobile cloud computing resolves these issues by storing the large multimedia file 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 find optimization methods to reduce the consumed energy by mobile devices in the cloud and mobile computing environments [11].

Besides all the great benefits of using the mobile cloud computing, there are still some limitations such as the delays encountered when the mobile devices access the cloud services 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 modified by intruders. 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 technologies could provide the data management and analytics solutions that are necessary to reduce healthcare costs and improve system and clinical inefficiencies. 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 traffic 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 development of networked healthcare applications and systems is 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 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, followed 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 financial transactions. Not neglecting the important issue of securing users sensitive data on the cloud, a secure framework for cloud computing based on data classification is proposed in [17]. This framework categorizes the data based on its confidentiality, 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 fixed near a wireless access points. But in this prototype, a cloudlet can be chosen dynamically 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 dissipation 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 communication. The authors in [22] proposed resources management and optimization policies in the Cloud such as using virtualization, VM live migration, and server consolidation. They presented an energy efficient 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 efficiency manager. The results showed saving of more than 70% of power consumption 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 healthcare 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 & bio-repositories 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 Services [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 benefits by the Apple's partnership on this enterprise with Mayo Clinic and software 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 system [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 healthcare 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 traffic 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 connects sensors, analysis applications, physicians, healthcare systems and providers. For example, as exemplified 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 proposed unified 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-profit 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.

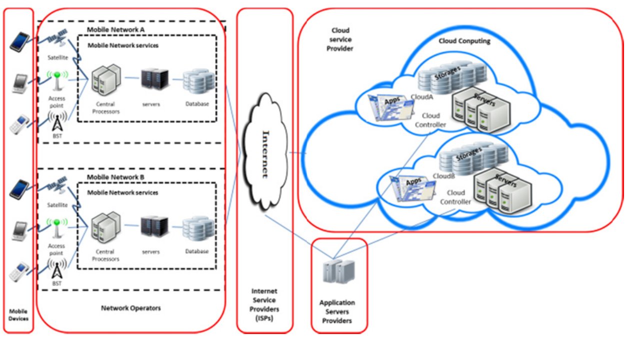

FIGURE 3. Mobile cloud computing traditional infrastructure.

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 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

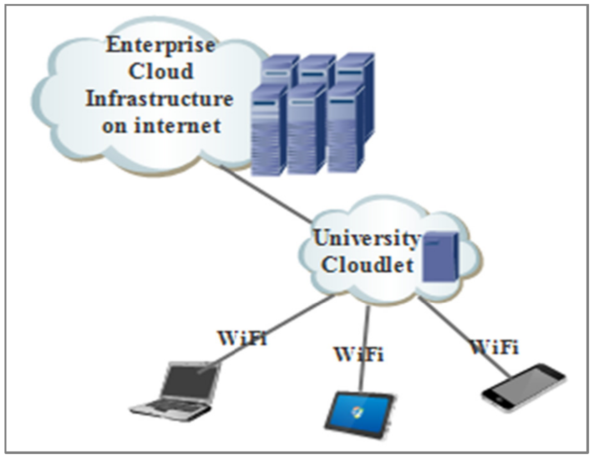

FIGURE 4. The cloudlet concept.

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 files 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 fire detection and the data from sensors is processed in mobile cloud system. 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 defined 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 offline, 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.

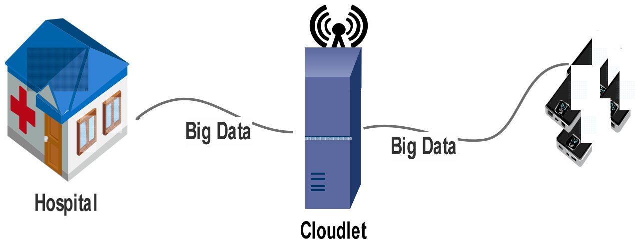

FIGURE 5. Healthcare big data in MCC.

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 deriving 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 exabytes 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), confirmatory 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 flood 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 find 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. TOOLS FOR DATA ANALYSIS

There are different tools available for data visualization and analysis [62], for example, (i) DataWrangler is web based service from Stanford University's Visualization Group and is designed for cleaning and rearranging data. (ii) Google Refine is explained as spreadsheet on steroids for taking a first look at numerical and text data, it can import and export data in different formats which includes tab and comma separate text files and XML, Excel and JSON files. (iii) The R Project for statistical computing is a general statistical analysis platform which runs on command line. It also graphs, charts and plot results. This is open source project which significantly extend functionality. It runs on Linuz, Mac OS X, Windows XP or later and Unix. (iv) Google Fusion Tables, is one of the simplest way to turn data into chart or map. File could be uploaded in several different formats and then choose how to display it, for example in form of table, map, line chart heatmap, bar graph, pie chart, timeline, scatter plot, motion or storyline. It also provide option to enable others to make comments on the data itself. Google Fusion Tables could run on any web browser. (v) Impure, is like Yahoo Pipes for data visualization and it is designed for creating various types of highly polished graphical representations of data by using a drag and drop workspace. This tool provide highly visual interface for creating visualization, and it run on any web browser.

Another tool, (vi) Tableau Public, can turn data into any number of visualization, for example from simple to complex.

User can drag and drop files onto the work area and get help from the software for suggesting visualization type and then customize everything, for example, labels and tool tips to size, legend display and interactive filters. This tool runs on Windows 7, Vista, XP, Server 2008, 2003. (vii) Many Eyes, is a pioneer in web-based data visualization, IBM's Many Eyes project combines graphical analysis with community and encourage user to upload share and discuss information. This tool is easy to use and have well documentation which gives suggestion on when to use what kind of visual data representation. More than a dozen output options are available for example, graphics and word clouds, treemap, charts, plots and network diagrams. A free account is required to upload and post data. This tool can run on Java and any modern Web browser which can display Flash. (viii) VIDI, the web site of VIDI's bills this as a tool for Drupal content management system. No Drupal is required when graphics created by the site, visualization wizard can be used on any HTML page. This tool is easy in use just like Many Eyes which have more mapping options. VIDI can run on any web browser. (ix) Zoho Reports, this tool can take data from number of file formats or directly from a database and then turn it into tables, charts and pivot tables and other formats which are familiar to spread sheet users. User can schedule data imports from source on the web. This tool can run on any web browser. (x) Choosel, this tool is currently under development and is a open source web based framework which is designed for charts, graphs, clouds, maps and timelines. Choosel can run on Safari, Chrome, and Firefox.

A tool called Exhibit (xi) is developed for users to easily create web pages with advanced text search and filtering functionalities. Users who are comfortable with coding, Exhibit offer them number of views for example, charts, maps, timeplots, and calendars. (xii) Google Chart Tools, is a full fledge self-contained application for uploading and sorting data, and also generating maps and charts. It runs on any web browser. (xiii) JavaScript InfoVis Toolkit, this is not among the best known JavaScript visualization libraries but White House agrees that it was used to create the Obama administration's interactive budget graphic. This tool runs on JavaScript-enabled web browsers. (xiv) Protovis, is a graphical toolkit for turning data into visualization. The best thing about this toolkit is that it is well documented with number of examples and sample code, and also this toolkit is designed to balance simplicity with control over the display. It runs on JavaScript-enabled web browsers. (xv) Quantum GIS (QGIS), this tool is designed for creating maps that offer sophisticated, detailed data base analysis of geographic regions. ArcView is an application which cost money but the open source QGIS is an alternative for ArcView. QGIS runs on Linux, Mac OS X, Unix, Windows. (xvi) OpenHeatMap is user friendly website that generate colour coded maps. Colour will change depending on the underlying information for example, population or average income change. It runs on web browsers enabled for flash or HTML 5 Canvas. (xvii) OpenLayers, is JavaScript library for displaying map information. It works with OpenStreetMap. This is not developed yet but the project page says that it is still undergoing rapid development.

OpenStreetMap (xviii) is somewhat like Wikipedia of mapping world. It runs on any web browser. (xix) TimeFlow, is desktop software is being used for analysing data points which involve a time component. This software allows to the use to store and filter information and give get statistical summaries of the data. It runs on desktop systems running Java 1.6, Windows and Mac OS X. (xx) IBM Word-Cloud Generator, different tools mentioned in previous sections are able to create word clouds, for example, Many Eyes and the Google Visualization API, but if the user is looking for easy desktop software dedicated to the task then IBM's free Word Cloud is the an option. It runs on Mac OS X, Windows and Linux running Java. (xxi) Gephi, is photo shop for data and this open source beta project is designed for visualizing statistical information, for example relationship within the networks of 50,000 devices, it is used for network analysis. It runs on Windows, Linux, Mac OS X running Java 1.6. (xxii) NodeXL is Excel plugin and displays network graph from a given list of connection. It help to analyse and see the patterns and relationships in the data. It runs on Excel 2007 and 2010 Windows.

Talend Open Studio for Big Data [63] is an open source vendor for data analytics it provide all you need to easily design and implement big data transfer and big data analytics by using Hadoop technologies [64]. With this feature rich open source solution user can quickly get to work with big data and Hadoop. Talend is one of the largest companies with an open source business model. It was founded in 2005 and it's the first commercial open source vendor of data integration software. Hadoop is also an open source software framework which supports data intensive distributed applications. Map/reduce a computational paradigm is implemented by Hadoop, where application is divided into various pieces of work and each of which may be executed or- re executed on any node in the cluster. Hadoop is written in Java, it is a top level Apache project being built and used by a global community of contributors. It operates on a cross-platform, its type is distributed file system, and developer of this software is Apache Software Foundation. It consists of Hadoop Common (package) that offers access to the file systems supported by Hadoop, this package contains necessary JAR files and scripts required to start Hadoop. This package also provide documentation, source code and different projects.

Another open source tool for data analytics is called Weka [65] which is a collection of machine learning algorithms for data mining. These algorithms cloud be called from a java code or directly applied to a dataset. Weka provide tools for data pre-processing, regression, classification, clustering, visualization and association rules. Weka has two primary versions, (i) the stable version and (ii) development version. The stable version is the latest edition of data mining book that only receives bug fixes. The development version that receives new features and exhibit package management system which makes it easy for the Weka developers to add new methods to Weka. For the latest download of Weka every night a snapshot of the subversion repository is taken and compiled and put together in zip files for download, Weka 3.6 is the latest stable version available. Another tool called Rapid Analytics [66] is open source and is one of most widely used data mining and predictive analysis solutions worldwide, it is built around RapidMiner which is a powerful engine for data analytics. It rely on industry standard application servers. User can remotely schedule execution of analytical processes. It also offer web based access to results, reports and processes that built on industry standard application and web services. It combines the advantages of RapidMiner with collaborative working environment and dedicated computing power. During the process the user is assisted with (i) meta data propagation, it means no more trial and error but real time inspection. (ii) on the fly error detection, (iii) quick fixes, (iv) profiler, means that RapidMiner can continuously monitor the storage and runtime behaviour of analysis process in the background. (v) community extension, (vi) recommender, (vii) intelligent discovery assistant, (viii) MLWizard, this assistant concentrate on the generation of optimal classification processes for a given dataset. RapidMiner provides various chart and visualization options.

VII. 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 flights, 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 integration 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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