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Telemedicine Based on Mobile Devices and Mobile Cloud Computing

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ABSTRACT

Mobile devices such as smartphones and tablets support kinds of mobile computing and services. They can access to the cloud or offload the computation-intensive part to the cloud computing resources. Mobile cloud computing (MCC) integrates the cloud computing into the mobile environment, which extends mobile devices' battery lifetime, improves their data storage capacity and processing power, and improves their reliability and information security. In this paper, the applications of smartphones in telemedicine and MCC-based telemedicine were presented. Issues on the information security of smartphones and tablets, challenges of smartphones in telemedicine and challenges of MCC-based telemedicine were also introduced.

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1. INTRODUCTION

Telemedicine typically involves physicians using interactive real-time video and/or store-and-forward consultations through an IP bandwidth or telephone line to diagnose and treat patients. Interactive videos permit medical specialists to assess and diagnose patients who are in another location using television monitors and specially adapted equipment that provide a real-time or recorded image. Store-and-forward techniques include physicians sending pictures, x-rays, and other patient information directly to a remote specialist. After reviewing that information, the specialist then sends the diagnosis back to the local doctor, who then treats the patient and provides the follow-up care. Some hospital facilities also use a telemedicine system to support emergency care at remote facilities staffed with Physician Assistants (PAs) or Nurse Practitioners (NPs). Such systems often electronically link emergency physicians oversee rural clinics as well, where providers are often unavailable and the clinics are also staffed with mid-level providers like PAs and NPs. Assessments by medical practice specialists or a supporting physician for a mid-level provider are done using high-quality videoconferencing cameras with a deep-zoom lens, capable of capturing even the minutest detail with extreme clarity for exams. Assessment information is gathered from these remote devices and an additional on-site examination is performed by the provider at bedside [1].

Telemedicine also represents an alternative plan for controlling chronic diseases. Patients with poorly regulated Type 2 Diabetes could benefit from hospital or community-provided telemedicine. A telemedicine conference with a nurse, along with clinical data entry and review, web-based educational materials, and monitored videoconference chat can improve diabetes control among this group [2] [3]. The use of telemedicine in the pre-hospital environment is still in its infancy. The design and architecture of a multifunctional telemedicine system for real-time tele-consultation in pre-hospital emergency medical services (EMS) was presented [4].

Deploying high-performance bandwidth networks economically in rural areas is fundamentally difficult for three main reasons. First, any type of widespread Internet access is virtually impossible as bandwidth coverage is so limited; widespread area connectivity is probably doubtful except via satellite, which is very expensive. Second, the typical rural landscape features a low population density. This creates a problem for deploying new network infrastructure among only a small pool of users; it is costly. Third, users in rural regions have low purchasing power. An information and communication technologies (ICT) project in rural India used long-distance Wi-Fi networking to enable high-quality videoconferencing between eye hospitals and remote village clinics. Wi-Fi reduces both deployment and operational costs in many ways. However, Wi-Fi is generally designed to work in high-density, short-range zones. Standard Wi-Fi makes little sense in point-to-point long-distance settings in rural areas with sparsely distributed populations. The two main reasons for poor performance are protocol- and channel-induced losses [5].

Wireless networks offer devices different levels of mobility support: room-level (personal area networks), cell-level (fixed wireless), campus level (wireless LANs), country-level (3G/4G networks), and planet-level (satellites). In some cases—such as for implanted radio frequency identification (RFID) sensors—the networks offer “human-level” support, and NASA is even working on interplanetary-level mobility. The goal for 4G wireless networks was to let users move from one type of wireless network to another. The demand for more sophisticated applications, such as content-rich mobile commerce, and high-end health care applications, such as mobile telemedicine and wellness monitoring, will affect the future of 4G and 5G networks [6].

A mobile health (m-health) system for real-time wireless communication of medical video based on open-source software was presented to deliver a low-cost telemedicine platform which will allow for reliable remote diagnosis m-health applications such as emergency incidents, mass population screening, and medical education purposes [7]. One method of reducing the computational burden of mobile devices is to set up an agent between the mobile devices and cloud computing resources to provide mobile devices access to the cloud. Another approach to reducing the burden of mobile devices is to offload the computationally-heavy executions to the cloud computing resources. For example, CloneCloud is a system that allows a smartphone device to partially offload its application to the phone’s clone (an application-level virtual machine) in the cloud. Results showed that the CloneCloud approach saved execution time and energy consumption on the mobile devices [8].

This paper deals with the features of smartphones and tablets, their information security, smartphone applications and challenges in telemedicine, and MCC-based telemedicine and its challenges.

2. MOBILE DEVICES

2.1. Tablets and Smartphones

There has also been a rise in development and sales of mobile devices like smartphones, tablets, etc. supporting different kinds of mobile computing and networking technologies [9]. Tablets are larger than a smart phone, but interact with the user in much the same way, using a touchscreen as a primary input device. Tablets offer a choice of applications (apps) similar to smartphones, which are becoming increasingly popular. Apps are downloadable programs designed to run on either the iPhone, Android (Google), or Windows operating system (OS) [10].

Tablets have become popular among consumers because they are easy to carry around and because their intuitive, touch-based user interface (UI) makes them easy to operate. Tablets also have more appeal as cloud services have become more popular and tablets make it easier to use this service as doorways to numerous applications, increasing their appeal. Tablet applications are beginning to expand from the traditional applications centered on service and personal computer (PC) applications such as Word and basic gaming applications to more complicated and intriguing games, fully developed, complete packages of Word, Office Suite, Quicken, etc., and more attractive applications to assist with lifestyle including health apps. The latest apps include Doctor On Demand by Dr. Phil and his team, which are promoted as a group of physicians dedicated to being available at a moment’s notice from any location service is available with the mere download of an app and the push of a button. The fee is usually around forty dollars or so and most insurance is looking in to paying for such services [11].

Apps have virtually expanded over the last few years to accommodate just about any need. Apps are typically interchangeable between the tablet and smartphone, usually with only minor changes. Five major smartphones are iPhone, Android, Blackberry, Nokia/Symbian and Windows Mobile. In one study, the majority of apps relating to the generic condition of pain were available on the iPhone, which is unsurprising given its dominance in the smartphone market [12].

Various smartphones have different computing power and storage capabilities; some, such as the iPhone 5c and the Android Motorola products are well ahead of other smartphones on power and distribution, as well as having a set of improved advanced features (camera, gorilla glass touch-screen) and advanced application programming interfaces (APIs) for running third party data-based applications [31]. Customers are generally most concerned with portability, storage space and battery life as the main characteristics of a smartphone [13].

Many smartphones are equipped with various sensor devices, positioning systems such as GPS, accelerometer and thermometers. They create significant opportunities for a range of new applications such as location-based services (LBS). Smartphones were used to detect car accidents and provide situational awareness to emergency responders. The problems of preventing false positives were considered in utilizing mobile context information and polling onboard sensors to detect large accelerations. The architecture of a smartphone-based accident detection system prototype was presented and its ability to resist false positives as well as its capabilities for accident reconstruction was empirically analyzed [14] [15].

The mobile devices are facing some challenges in their resources (battery life, storage, and bandwidth) and communications (mobility and security) [16]. Typical smartphones are equipped with multiple types of sensors including Bluetooth, accelerometer, audio, camera and GPS. The growth of sensors in smartphones drives applications such as location awareness and augmented reality. However, due to the increase in these growing feature-sets and sensing capabilities, smartphones continue to suffer from battery life limitation. GPS is the core enabler of location-based services, but aggressive use of GPS could severely increase the power consumption services. An energy efficient framework for location-based service (LBS) was proposed to reduce power dissipation. The framework detected phones' mobility state by using less-power-intensive sensors and eliminated unnecessary invocation of location sensing. This is because continuous location sensing may not be needed when the smartphone is in static state such as being put on a table in an office. Smartphone are generally less powerful than other mobile computing devices. Therefore, it is necessary to offload the computation-intensive part by careful partitioning of application functions across the cloud computing. For realizing this, web service is the best fit technology for a framework that does not depend on a certain smart-phone operating system (OS) platform. A novel approach was proposed to realize the mobile cloud convergence in transparent and platform-independent way [17].

A new method on how to backup and restore data between the mobile device and the cloud was proposed in a recent study. In this method, a compression technique was used when performing data backup from the smartphone to the cloud and when restoring data from the cloud to the smartphone. Data backup was fulfilled from Android platform to the online server on the cloud. Data could be restored back to the smartphone when needed [10].

2.2. Information Security of Mobile Devices

Smartphones are also used for privacy sensitive tasks such as on-line-banking, which makes them an attractive platform for attackers. A number of different kinds of threats that affect smartphones are described as follows [18]:

Denial of Service (DoS) Attacks: DoS attacks against the smartphone itself can flood the device, intentionally drain the battery, or consume other limited resources (such as memory, central processing unit (CPU) cycles, and port numbers, etc.). Flooding is possible by sending a large number of corrupted packets of data.

Malware: Mobile malware (i.e., malicious software) is the software that can harm a mobile device without the owner's informed consent. Malware includes viruses, worms, spyware, Trojan horses, and so on.

Social Engineering Attacks: Social engineering in a security context refers to trickery or deception for information gathering by manipulating people into performing actions or divulging sensitive information.

Theft: Valuable data that a smartphone may carry make it attractive to thieves. Losing a smartphone can pose significant threats to the owner of the smartphone as well as the owner's employer if the smartphone is used for corporate or government use.

Smartphones can become infected through a wide range of infection routes. There are the following infection channels [18]:

Bluetooth: Infection through Bluetooth™ depends on physical proximity of the attacker to the infected device. It requires the smartphone's Bluetooth connection to be switched on, sufficient signal strength, and that the phone is in its discoverable mode.

SMS/MMS: Malicious software can spread to mobile devices by attaching a copy of itself to a short message service (SMS)/multimedia messaging service (MMS) that is sent from the infected mobile device.

*Internet Connectivity***:** Most smartphones can be connected to the Internet. Smartphones run similar risks as fixed devices and become infected through viruses contained in downloaded files, and cross site scripting, etc.

Portable Memory: Usage of secure digital memory cards is commonplace in smartphones. Cardtrap is a Trojan that affects Symbian smartphones (Symbian was the operating system of Nokia smartphones). The Trojan also attempts to disable applications in the smartphone itself.

Connection to other devices: Smartphones are often connected to fixed devices. This kind of connection facilitates the transfer of the malware from the fixed device to the smartphone or the reverse.

The following security functions are commonly used to protect smartphone data and applications [18]:

Encryption: Encryption is the process of transforming plain text data to a cipher text data using an algorithm and a key. Many different encryption algorithms can be used to protect the data.

Digital Signatures: Digital signatures verify the authenticity of the sender of the message involved in a communication. Validating this signature gives a reason for the receiver to believe that the message was sent by the claimed sender.

Anti-virus: Anti-virus software for a smartphone can be used to detect, prevent, and remove malware from the phone. It can be used to remove malware such as viruses, worms, Trojan horses, spyware, etc.

Authentication: Authentication ensures that only the authorized user is able to access the functions of the device. Passwords do not offer robust authentication as most users choose weak passwords due to the keyboard constraints of smartphones. More advanced authentication methods such as two factor authentication, behaviour based authentication, voice recognition, and key stroke could be used.

Security as a Service (SaaS) for smartphones is also a way in which improved security could be offered as a service in the cloud for the users of smartphones [18].

To secure a tablet, the tablet screen should be locked with some types of hard-to-guess PIN, passcode, swiping motions, or biometric authentication such as a fingerprint. Attentions should be paid when the tablet is configured for the first time. The most important configuration choices should be the user’s privacy and cloud options. Privacy is about protecting personal information. One of a tablet’s biggest privacy issues is its ability to know and track the user’s location. It was recommended that the user go into the privacy features and disable location tracking for everything, then enable it on an app-by-app basis. The other important option is Cloud storage. Most tablets have built-in options for automatically storing just about anything in the Cloud, including documents, pictures and videos. The sensitivity of a user’s data should be considered and it is decided whether it is appropriate to store it in the Cloud [19].

3. CLOUD COMPUTING AND MOBILE CLOUD COMPUTING

Cloud computing (CC) has been widely recognized as the next generation’s computing infrastructure. CC offers some advantages by allowing users to use infrastructure (servers, networks, and storages), platforms (middleware services and operating systems), and software (application programs) provided by cloud providers (Google, Amazon, and Salesforce) at a low cost [20]. CC combines virtualization (one computer hosting several “virtual” servers), automated provisioning (servers have software installed automatically), and Internet connectivity technologies to provide the service [10].

Virtual Smartphone over IP, which provides cloud computing environment specifically tailored for smartphone users. It allows users to create virtual smartphone images in the cloud and to remotely run their mobile applications in these images. The motivation is to allow a smartphone user to more easily tap into the power of the cloud and to free the smartphone from the limit of processing power, memory, and battery life of the physical smartphone. Using the system, smartphone users can choose to install their mobile applications either locally or in the cloud. Users control their virtual smartphone images through a dedicated client application installed on their smartphones. This client application receives the screen output of a virtual smartphone image and presents the screen locally in the same way as conventional thin-client technology. The client program transmits various events from the physical device to the virtual smartphone and receives graphical screen updates from the virtual smartphone [14].

A pair of scientists at Intel Research Berkeley have developed CloneCloud, which creates an identical clone of an individual’s smartphone that resides in a cloud-computing environment. CloneCloud uses a smartphone’s Internet connection to communicate with the phone’s online copy, which contains its data and applications in the cloud. CloneCloud would make smartphones significantly faster and more powerful, enabling them to perform processor heavy tasks in the cloud. CloneCloud would also provide improved smartphone security, with virus scans of a device’s entire file system being conducted in the cloud.

Moreover, CloneCloud would improve a smartphone's battery life by having cloud-based computers handle the most processor-intensive tasks. The CloneCloud approach could also help create a computing environment that would make it easier to share data between mobile devices and home-based computers [21].

As processors are getting faster, screens are getting sharper and devices are equipped with more sensors, a smartphone's ability to consume energy far outstrips the battery's ability to provide it. Thus, battery life of mobile devices is a key limiting factor in the design of mobile applications. Computation offloading techniques migrate the large computations and complex processing from resource limited devices to resourceful devices, thus avoiding mobile devices to take a large execution time. Storage is also a major concern for mobile devices. Mobile cloud computing (MCC) was developed to enable mobile users to store and access large amounts of data on the cloud [22].

Mobile cloud computing (MCC) refers to an infrastructure where both the data storage and the data processing happen outside of the mobile device [10]. MCC integrates the cloud computing into the mobile environment (mobile devices such as smartphones, tablets) and overcomes mobile device obstacles related to the performance (battery life, storage, and bandwidth), environment (heterogeneity, scalability, and availability), and security (reliability and privacy). The detailed advantages that MCC offers are as follows [20]:

- Extending battery lifetime: Computation offloading technique migrate the large computations and complex processing from resource-limited devices (i.e., mobile devices) to resourceful machines (i.e., servers in clouds). This avoids taking a long application execution time on mobile devices which results in large amount of power consumption.
- Improving data storage capacity and processing power: MCC is developed to enable mobile users to store/access the large data on the cloud through wireless networks.
- Improving reliability: Storing data or running applications on clouds is an effective way to improve the reliability. This reduces the chance of data and application lost on the mobile devices. Also, the cloud can provide mobile users with security services such as virus scanning, malicious code detection, and authentication.

Unlike conventional mobile computing technologies, the resources in mobile cloud computing are virtualized and assigned in a group of numerous distributed computers rather than local computers or servers. The mobile devices can be laptops, PDAs, smartphones, tablets, and so on, which connect with a base station or a hotspot by a radio link such as 3G, Wi-Fi or GPRS [22]. As shown in Figure 1 [23], the mobile devices are connected to a network through 3G, WIFI or GPRS. Mobile users can send requests to the cloud through web browser and the resources are allocated to the established connection. After the web application is started, the monitoring and calculating functions of the system will be implemented to guarantee that the *quality of service* (QoS) is maintained until the connection is completed [9]. Tablets access the cloud in the same manner as smartphones [10].

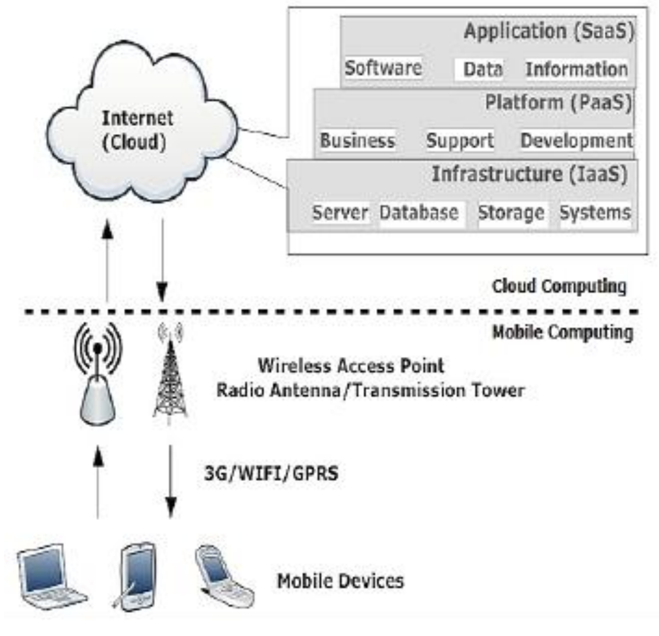

Figure 1. Mobile cloud computing architecture

A system, named GEMCloud (Green Energy Mobile Cloud) was developed. This system used mobile devices (e.g., smartphones and tablets) to provide distributed computing services to support computationally-complex and parallelizable applications. It was shown that a cloud computing system with enough mobile devices working cooperatively was able to save 55- 98% of the energy consumption of conventional server-based clouds while providing comparable computing speed [8].

Cloud computing can both improve and degrade the smartphone's user experience and introduces new problems related to connectivity, application distribution, and data ownership. Integrating smartphones with cloud resources is challenging and comes with threats for the user in terms of loss of control of applications and data as portions move into the cloud. In particular, the user becomes dependent on the cloud service providers in many cases and applications become unusable when the smartphone is offline. By using the cloud, applications are transformed into distributed applications running partly on the smartphone and partly in a remote cloud. As a consequence the different components need to connect to each other and to communicate with each other. However, connectivity is not always available and communication costs energy, time and money. A method was proposed to prevent such problems by bundling client and service code together in the smartphone application. For using the data services of the cloud, users should have the ability to select which data will be stored on the cloud, and how this data should be secured, in order to protect their own privacy. Programming models dealing with data exchange with a cloud service should always offer both the means to get data on and off the cloud in combination with local replication, so that the user is free to move from one cloud computing provider to another, without being locked into a service. Furthermore, local replication may be required in order for applications to work properly when the smartphone is not connected to the network. Users might even run cloud services on their own home server in order to maintain the privacy of their data, or reduce the cost associated with the service as provided by the cloud vendor [24].

4. MOBILE DEVICES IN TELEMEDICINE

4.1. Overview

Mobile telemedicine systems include satellite telemedicine systems, cellular telemedicine systems, and short-range telemedicine systems, whose applicability depends on the transmission distance. Satellite telemedicine systems function satisfactorily in remote areas, as well as in oceanic and mountainous areas, forests, and deserts. Further, they can be installed in aircraft. However, ground cellular mobile communication systems are not suitable for use in the above-mentioned environments. Ground cellular telemedicine systems can be used to transmit clinical data such as blood pressure and pulse/stroke data, electrocardiogram (EKG) signals and digital clinical images via global system for mobile communication (GSM), general packet radio service (GPRS), third-generation (3G) mobile telephony, and Wimax. Short-range wireless transmission systems include ultra- wideband networks (UWB), Bluetooth networks, and wireless local area networks (WLANs) [25].

In terms of medical and health care usage, smartphone applications offer instant access to multimedia information, including medical references, calculators, medication databases, and relevant news updates [12]. A healthcare provider could speak using a smartphone while reviewing a patient visually on an iPad. In addition, all of the data collected by the smartphone could be transmitted to the computers of medical staff via GPRS to secure websites, thus, allowing easy telemonitoring and teleconsultation [26].

Smartphones have contributed to the feasibility and availability of telemedicine in oral and maxillofacial surgery. Smartphones are able to read and display 3D computer reconstructions of head skeleton, giving instantly the necessary information to distant teleconsultants in oral and maxillofacial surgery. It is very useful in emergency conditions requiring immediate interdisciplinary consultation. Maxillofacial surgeons are thus able to monitor the condition of their patients even after very complex interventions, such as osteotomies, removal of ameloblastic fibromas, and so on. Teleconsultants access the server via computers or smartphones, and based on the available information give opinions, including diagnosis and treatment recommendation [27].

A real-time remote monitoring system can provide valuable information for diagnosis and therapy. Real-time data from wearable sensor devices are sent to smartphones over a short range wireless connection then forwarded to the remote monitoring platform via Wi-Fi, 2G or 3G. At the monitoring platform the medical data can be displayed or stored in a database. A multi-physiological parameter real-time monitoring system was presented and it implemented functions such as multi-physiological parameter data collection, testing, storage, network transmission, and real-time online custody [28].

The rapid rise of tablet and smartphone use by healthcare providers coupled with the mobility and multi-person meeting capabilities is set to radically change today’ s telemedicine. The new applications and ability to reach a much wider audience are ready will improve patient outcomes [29].

4.2. Smartphone-based Medical Services

4.2. 1 Measurement and monitoring

Current generation smartphone video camera technology enables photoplethysmographic (PPG) acquisition and heart rate (HR) measurement. Many cellular phones now possess high-speed data transmission capabilities (e.g., 3G, 4G) and have embedded microprocessors (Bluetooth, ANT) with the capability to wirelessly connect to external devices. As a result, cellphones offer several advantages over desktop or laptop computers in telemonitoring-related applications such as higher population penetration, increased privacy, as well as lower cost to purchase, easier ability to transport, and overall increased personal convenience of use. Cell phones are widely used in telemonitoring (blood pressure, glucose and pulse oximetry monitors, weight scales, physical activity; accelerometer counts, heart rate, respiration rate, and pulse pressure). Once cell phones have received the pertinent information, it is micro-processed, encrypted, and the data packets are transferred to some form of localized or web-based server for secondary processing. The Android HR acquisition software embedded in a Motorola Droid smartphone provides valid measurements of HR while at rest and when engaging in mildly stressful motion-free perceptual motor/cognitive activities. The software application and smartphone video camera may be capable of detecting HRs while engaged in walking, possibly jogging, as long as consistent fingertip connection is made with the LED and photodetector lens [30].

There exist sensor systems worn on the body or around the body forming a body area network (BAN), for which a smartphone is a central processing unit. These BANs can measure user’s psychophysiology and environmental conditions; integrating, for example, heart rate, respiratory rate, and body temperature, as well as ambient temperature sensors. These BANs and associated mobile applications can be used as a tool for gathering quality data for medical research, or regular health care practice [31].

Smartphone-based telemedicine was used by physicians to communicate insulin measurements to diabetic patients and their caregivers [32]. A system, comprising of a smartphone coupled to an Internet website to provide individualized insulin dose adjustment and telemedical support, has been shown to significantly improve HbA1c levels in patients with poorly controlled Type 1 Diabetes [26].

Smartphone-based telemedicine was used by remote dental surgeons to visualize X-ray reports, by resident surgeons to monitor point-of-care information and to share knowledge with a local mentor [32].

Smartphones can be connected wirelessly to physiologic monitors worn on a patient’s body or embedded into a patients garment. Some of the small monitors such as blood glucose, blood pressure, temperature, and EKG are available. The wearable/portable embedded physiological and cognitive monitoring system could enable a medical team to closely monitor patients without bringing them into a hospital or a specialty care center. This real/near-time monitoring could enable a health care team to address patient problems before they require major intervention in a specialty care center. This monitoring could be ideal for managing chronic conditions such as diabetes, hypertension, and cardiovascular disease and could reduce hospitalization and, in some cases, reduce mortality rates [33]. One of the most widely used EKG recording formats is the 12-lead ECG. Smartphones capture the information from the 12-lead ECG device and store it on a removable solid state memory card [34].

Remote monitoring and mobile devices enable patients with serious problems to record their own health measures and send them electronically to physicians or specialists. Real-time management is especially important in the case of chronic diseases. Access to medical care in rural areas is a challenge in every country around the world. Rural doctors could have mobile devices which can access electronic health records and health treatment data bases. This allows physicians to see patient health information and learn how to treat common problems. If necessary, clinicians are also able to remotely consult with specialists in urban systems [35].

4.2. 2 Evaluation/Assessment/Diagnosis

Smartphone applications adapted to telestroke appear to be promising. Gonzalez et al5 and Smith et al reported that a standard real-time cellular video-phone was a feasible, reliable, and timely tool that carried potential for remotely assessing the National Institute of Health Stroke Scale score for patients presenting with acute stroke to a remote hospital.6 When coupled together, real-time video-phone neurological examinations and smartphone teleradiology assessments may offer a vascular neurologist (VN) a single mobile health tool with which to expeditiously conduct full telestroke and teleradiology assessments necessary for a complete virtual stroke consultation in a remote environment. [36].

Medical images from a smartphone were used to evaluate stroke patients in remote locations through telemedicine. The quality of the medical images using a particular smartphone application was compared with the same types of images typically viewed via desktop computers. The neurologists worked with emergency physicians and radiologists to compare brain scan images from patients with a stroke. The scans were reviewed by radiologists and a separate adjudication panel of stroke neurologists to determine the level of agreement between the traditional interpretation routes and new images and scans on smartphones interpreted by telestroke doctors. It was showed that there was a high level of agreement (92-100%) among all the reviewers over the most important radiological features [37]. Smartphone-based telemedicine was used by neurosurgeons to make decisions about immediate actions after a stroke [32].

Employing smartphones can improve the diagnostic process. Yamada *et al* developed a smartphone application that used a build-in accelerometer to objectively assess abnormal gait in patients with rheumatoid arthritis (RA). Quinley *et al.* evaluated the use of smartphone photo-based inspection of the cervix for cervical cancer screening. Mitchell *et al.* evaluated that the accuracy of diagnosis made with a smartphone based teleradiology system for acute stroke were comparable to the ones conducted with a workstation. Oresko *et al.* developed a wearable smartphone-based platform for real-time cardiovascular disease detection via electrocardiogram processing, where the smartphone was capable of performing real-time EKG acquisition and display, feature extraction, and beat classification [31].

4.2. 3 Interventions/Treatments/Rehabilitation

Smartphone with its applications can support an ongoing chronic treatment or enable new acute treatment procedures. Quinn *et al.* developed a smartphone based diabetes intervention study including personalized treatment via a communication between patients and practitioners. Kristjansdottir *et al.* designed an online situational feedback via a smartphone, to support self-management of chronic widespread pain. Focosi enumerated smartphone utilities for infectious diseases specialists in case of emergency, which allowed them to identify chemical and biological hazards on the basis of reported symptoms and signs [31].

Worringham *et al.*developed and proved feasibility of a smartphone, Electrocardiography (EKG) and global positioning system (GPS) based system to remotely monitor exercise behaviours in cardiac rehabilitation (CR). The system provided a feasible and very flexible alternative form of supervised cardiac rehabilitation for those who were unable to access hospital-based programs. Piotrowicz *et al.*evaluated home cardiac rehabilitation, where the patient is telemonitored with an EKG device, transmitting its data via mobile phone to a monitoring center [31].

4.2. 4 Workflow and collaboration

A telemedicine application was proposed whereby a smartphone not only regulated the proposed *in vivo* temperature scheduling technique, but also established collaboration between local clinicians and remote experts of different treatment modalities. Figure 2 [32] shows the internal workflow of the smartphone application. In this telemedicine application, at first the local clinician inputs cancer type and position in the local cancer treatment control unit (CTCU), and a hypervisor ascertains experts on hyperthermia, radiotherapy, and chemotherapy. It then communicates with the remote CTCU to connect to remote experts through a smartphone. Remote experts recommend drug measurement, radiation measurement, and heating temperature to the smartphone kept near the patient. After treatment, notification is sent to the remote expert from the local CTCU through the smartphone. Moreover, the smartphone updates the electronic health record (EHR)/patient health record (PHR), prior to and after treatment. Local clinicians can apply the treatment method recommended by remote experts, assuming that the hospital had the correct medical equipment. The smartphone enables the notification of local or remote clinicians and experts or nurses regarding the treatment method, regardless of whether the patient was at the point of care or outside the hospital. The smartphone receives the treatment procedure from the CTCU. The CTCU manager inside the smartphone first installs the treatment information. Then, the EHR/PHR manager updates the EHR/PHR database with the new information and manages the local database so, in the case of network unavailability, it can store information. A synchronization module is present to synchronize the local database to a remote EHR/PHR. The clustering manager assigns subscriber/publisher/broker roles to the *in vivo* sensors (*In vivo* sensors are an emerging technology in healthcare). The publish-subscribe manager continuously coordinates publish-subscribe methods to control *in vivo* sensors. In a communication failure, the smartphone’s fault-tolerance manager publisher or the subscription manager handles the failure. The notification manager’s local module updates the EHR/PHR manager with the post-treatment information. The remote module provides the same information to a remote CTCU or an expert’s smartphone [32].

A patient’s bedside smartphone, updated with the suggested treatment method, can communicate with *in vivo* sensors to control temperature for cancer treatment. The smartphone plays a vital role by notifying local or remote clinicians or healthcare devices of the treatment outcome. This smartphone-based telemedicine application can be used in the monitoring of cancer patients or treatment of other chronic diseases [32].

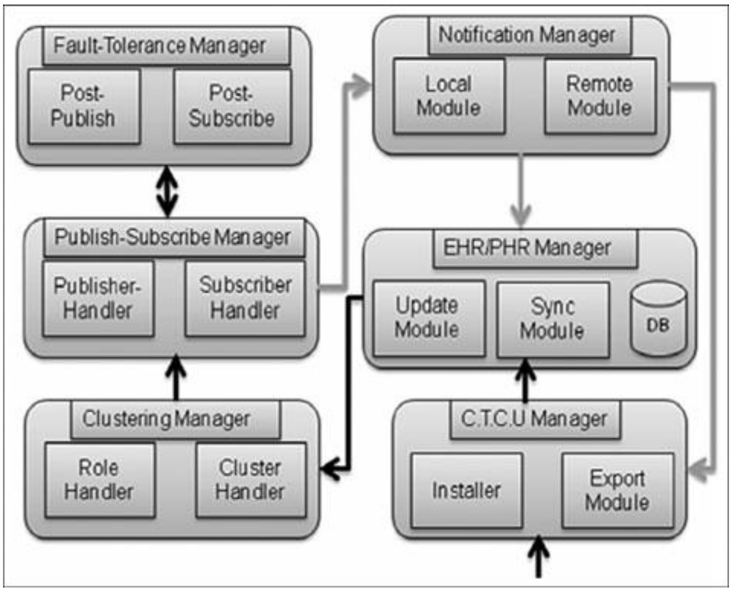

Figure 2. Internal workflow of smartphone application

4.3. Limitations and challenges

Smartphone-based personal health informatics services exist, but still have a long way to go to become an everyday, personalized healthcare-provisioning tool in the medical field and in a clinical practice. Main challenges involve lack of user acceptance striving from variable credibility and reliability of applications and solutions as they a) lack evidence-based approach; b) have low levels of medical professional involvement in their design and content; c) are provided in an unreliable way, influencing negatively its usability; and, in some cases, d) being industry-driven, hence exposing bias in information provided, for example towards particular types of treatment or intervention procedures [31].

5. MOBILE CLOUD COMPUTING IN TELEMEDICINE

Cloud computing (CC) can augment smartphone capabilities by providing vast pool of computation power and unlimited storage space. Smartphone computation power has risen enormously due to cloud computing. Cloud enabled smartphones consumes less battery. CC in smartphones eradicates the computation power, storage and battery constraints that limited smartphones from running PC like capabilities. It makes smartphones scalable in terms of storage and processing capability. Shared resources, storage, hardware and software are the peculiar characteristics of cloud computing, which makes the smartphone motto work anywhere anytime [13].

Mobile healthcare (m-healthcare) enables patients to be monitored at any time, any place through wireless technology. Mobile computing devices create more free space, less clutter and lower costs, while delivering more services more efficiently [9].

Applying mobile cloud computing (MCC) in medical applications could minimize the limitations of traditional medical treatment (e.g., small physical storage, security and privacy, and medical errors [20]. m-healthcare provides mobile users with convenient helps to access resources (e.g., patient health records) easily and quickly. In addition, m-healthcare offers hospitals and healthcare organizations a variety of on-demand services on clouds. MCC presents the following mobile healthcare applications in the pervasive environment [20]:

- Comprehensive health monitoring services enable patients to be monitored at anytime and anywhere through broadband wireless communications.
- Intelligent emergency management system can manage and coordinate the fleet of emergency vehicles effectively and in time when receiving calls from accidents or incidents.
- Health-aware mobile devices detect pulse-rate, blood pressure, and level of alcohol to alert healthcare emergency system.
- Pervasive access to healthcare information allows patients or healthcare providers to access the current and past medical information.

MCC is still in an early stage of development. Mobile users may face delay in communication with the cloud because of congestion due to bandwidth limitation, network disconnection and signal attenuation. Further studies should try to incorporate technologies like 4G to overcome this issue [9].

6. CONCLUSION

Mobile devices like smartphones and tablets have been used in telemedicine. Smartphone applications can improve patient outcomes through quality services in measurement and monitoring, evaluation/assessment/diagnosis, interventions/treatments/ rehabilitation, and workflow and collaboration.

Mobile Cloud Computing (MCC) integrates cloud computing into the mobile environment and overcomes mobile devices' obstacles in performance, environment, and security. MCC- based telemedicine could minimize the limitations of traditional medical treatment such as medical errors, small physical storage, and security and privacy problems.

There are different kinds of threats that affect smartphones. Smartphones can become infected through a wide range of infection routes. Smartphone data and applications can be protected through a number of security measures. Privacy and security of tablets is also a big issue. Improved information security could be offered in the cloud for the users of both smartphones and tablets.

There are limitations and challenges for MCC-based telemedicine and smartphones in telemedicine. These issues could be overcome with further research, incorporating advanced technologies like 4G, and more and more people's acceptance and applications of these new technologies.

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