Telematics and Informatics 34 (2017) 311–322

Contents lists available at ScienceDirect

Telematics and Informatics

journal homepage: www.elsevier.com/locate/tele

On-Cloud Healthcare Clinic: An e-health consultancy approach for remote communities in a developing country

Shah J. Miah [a,*], Jahidul Hasan [b], John G. Gammack [c]

[a] Information Systems Group, College of Business, Victoria University, Footscray Park Campus, Melbourne, Australia
[b] IT Division, Ahsania Mission Cancer and General Hospital, Uttara Sector-10, Dhaka, Bangladesh
[c] College of Technological Innovation, Zayed University, Abu Dhabi 144534, United Arab Emirates

ARTICLE INFO

Article history:
Received 19 November 2015
Received in revised form 18 April 2016
Accepted 13 May 2016
Available online 18 May 2016

Keywords:
Healthcare model
Rural healthcare
e-health
Cloud computing
Developing countries
Patients

ABSTRACT

Advances in telecommunication and online service solutions help to bridge the digital divide between rural and urban healthcare services, enabling provision of suitable medical diagnosis and treatment consultations. Although applying e-health solutions has brought some positive impact full potential has not yet been realised, especially in regions where expertise is scarce. In this study we develop and evaluate an e-health consultancy system utilizing cloud computing (we so called "On-Cloud Healthcare Clinic") that enables doctors and healthcare workers to identify and treat non-communicable diseases in rural and remote communities in Bangladesh, a developing nation.

Adopting a design science research approach we developed the solution based around stakeholders' collaborative participation in prototyping and then evaluated the design using focus groups. The cloud-based solution supports doctors in evaluating and diagnosing patients' data and medical history through intermediary health care workers or community clinics. The design also knowledgeably allows informed decisions on a course of treatment with follow up for remote or underserved communities. Previously unavailable clinical work is thus practically achieved through utilization of the cloud based e-health system, and generalisation of this approach in healthcare management is discussed.

1. Introduction

Electronic health (e-health) services have the potential significantly to enhance patient diagnosis and to improve the accessibility and quality of treatment. The reality, however, has not yet matched the potential, with deployment in hospitals far short of maximum even in top performing countries, and remote monitoring of patients in European hospitals around just 9%, with a European average of under 42% across all deployment indicators (EU, 2013).

In developing countries, the healthcare situation is considerably worse, and is a pressing practical issue particularly in delivering healthcare services for rural and remote communities. Many developing countries such as Bangladesh have large rural populations, but lack proportionate medical expertise. Bangladesh has only one doctor for every 1700 patients, against a Millennium Development Goal of at least 2.5 physicians, nurses, and midwives per 1000 people needed to provide adequate coverage with primary care interventions (World Bank, 2015). The health sector in Bangladesh remains mostly unde-

* Corresponding author at: Victoria University, PO Box 14428, Melbourne, Victoria 8001, Australia.
E-mail address: shah.miah@vu.edu.au (S.J. Miah).

http://dx.doi.org/10.1016/j.tele.2016.05.008
0736-5853/

veloped not only due to limited government resources but also in the use of appropriate information and communication technologies (ICT) for rural and remote communities.

The growth of online ICT based innovative solutions (such as telemedicine, online health records and mobile based health applications) have for some time implied the capability, if used effectively, to bridge social and economic gaps that divide rural and urban communities and areas (Gurstein, 2005). These potentially improve access and allow provision of a wider range of health services to enhance the wellbeing and quality of life of underprivileged or underserved populations. In many countries specific ICTs have become essential components in successfully delivering operational healthcare services in rural areas (Barjis et al., 2013), through for example, Internet-enabled tools, mobile technologies and telemedicine (Marston et al., 2011; Hage et al., 2013; Hu and Bai, 2014). Very few effective and sustainable initiatives, however, have been introduced in Bangladesh to improve the quality of the healthcare service delivery for the people (e.g. Patients) in remote locations and communities. The availability of an adequate public health system in rural and remote areas is still scarce, severely impacting the quality of life for people when they become ill. In larger cities, some of the very few large private hospitals have attempted to develop e-health and telemedicine services, but are geared towards their registered patients and limited to specialised services. Various non-governmental organizations (NGOs) funded by international and private ventures have attempted small-scope initiatives such as rural health camps, mobile clinics, and organized visits by doctors from larger hospitals. However, for a densely populated country like Bangladesh, the impact and reach is very small, and scaling up such initiatives become prohibitively resource intensive.

So although e-health solutions through mobile communication networks promise impact, full potential has not been realised, especially across communities in remote locations where medical expertise is scarce (Sailunaz et al., 2016; Kaur and Chan, 2014; Hossain, 2015). Existing and legacy e-health solutions in developing nations have been error prone, inefficient and require extensive internal and external resources (Barjis et al., 2013; Hage et al., 2013). For the health care industry, both government and private, to maintain and improve diagnosis, clinical and business operations, a new focus on effective ICT platforms and solutions is required.

Over the history of evolving use of e-healthcare systems, emerging technologies have increasingly been pushed to shift the role of the healthcare professionals towards meeting more accurate, prompt and real-time treatment support not only for urban patients but also for those in remote communities. Paradoxically however, many recent mobile-based e-healthcare solutions have mainly focused on the engineered product and often, relevant users' participation in designing such types of solution and satisfaction with the outcome has not been fully considered. Specifically, attention to the end users' context and specific practice details need to be reflected into the solution design, consistent with good system development practice.

Moreover, with the more recent emergence of cloud computing, an affordable, configurable and scalable platform for enabling e-health solutions becomes possible, for example by linking medical information and practitioners who are geographically dispersed, enabling online communication about medical issues, diagnosis and treatment. Cloud computing is a ICT service model where computing services (both hardware and software) are delivered on-demand to customers over a network in a self-service fashion, independent of device and location (Marston et al., 2011). Cloud computing adopts a service oriented architecture (SOA) and supports the functionalities of an integrated e-Health system as a number of interoperable software services (Hu and Bai, 2014). Utilizing cloud computing for e-health introduces many opportunities for healthcare service delivery, and especially for developing nations. Cloud solutions using software-as-a-service (SaaS) are increasingly deployed in healthcare elsewhere with the main reasons given including cost savings, deployment speed, and overcoming lack of qualified staff on premises (HIMSS, 2014). This paper describes an *ensemble* artefact [1](Orlikowski and Iacono, 2001) approach to designing a new cloud-computing based e-health solution that ensures relevant end-users' active participation in, and satisfaction with, the application development.

General questions concern how effective access to healthcare services should be designed and managed. One basic requirement concerns the technology and literacy required to convey relevant patient data for knowledgeable initial diagnosis and consultation. Such consultation outcomes could result in medicine prescriptions, diagnostic tests, medical referrals and follow-up checks. Rather than requiring rare expert time for organised visits and one-on-one consultations, bringing the data to geographically dispersed doctors (healthcare professionals), and managing the consultation outcomes via more locally based paramedics suggests a more scalable and responsive general model for managing healthcare. This requires a pragmatic design cognizant of the realities of technology, expertise, resources, processes and end-user practice.

More specifically, the core question our research program focuses on is: "What e-health solutions could be designed to meet the diagnosis and treatment demands of rural and remote communities in Bangladesh?" Although the literature on healthcare ICT presents various studies addressing developing nations (e.g. Ruxwana et al., 2010; Hage et al., 2013; Lin et al., 2014), innovative developments in e-health application provision for rural healthcare have not, as yet, received much research attention. Our work therefore aims to develop and evaluate a general approach to e-health utilizing online services and cloud computing for effective patient consultation and health diagnosis. Whilst we detail the development and evaluation of one context-sensitive cloud based e-health solution for the case of rural communities in Bangladesh, we specify the design towards a wider applicability.

[1] For designing a solution artefact the ensemble view is an embedded system view that emphasises the dynamic interactions between target users and solution technology. This includes not only the use, but also the construction, implementation and deployment of the solution artefact (Orlikowski and Iacono, 2001:126).

As an illustrative case we develop an e-health solution for diabetic patients in rural and remote Bangladesh. According to the World Health Organization, almost one in ten adults in Bangladesh were found to have diabetes, which has become a major public health issue (Akter et al., 2014). Moreover, in relatively developed countries, such as the UAE, the figure is around one in five (IDF, 2015). Even among the most economically developed countries, such as the UK, diabetes is growing rapidly and is a major health threat (Diabetes UK, 2015). Urgent action is needed to counter the rise in diabetes through better detection, awareness, prevention and treatment.

Early identification, recording, diagnosis and treatment of diabetes through e-health solutions can lead to improved strategies for prevention and management. A diabetic patient needs regular medical attention, consultation and follow-up guidance in order to maintain health and improve their quality of life. Particularly in type 2 diabetes and similar lifestyle diseases, a virtual and web based medical consultancy can provide and communicate such services effectively in terms of storing individual data, test results, diagnosis and consultation details etc. Such data also, if replicated or centrally stored, allows aggregation and analytics to be applied, for convenient use by epidemiologists and policy makers. This suggests a promising direction in e-health research to design innovative and useful technologies that will be affordable, sustainable and effective in healthcare and medical services, both locally and nationally.

Our study extends longitudinal research presented in an earlier paper (Hasan, 2012) with specific focus on the ICT solution design and evaluation, proposing a cost effective and scalable e-health solution "On-Cloud Healthcare Clinic". Through this solution patient details can be entered by health care workers (and in principle by the patients themselves), with medical advice and diagnostic consultations provided by geographically remote or dispersed doctors. Our development adopted the action design research (ADR) methodology of Sein et al. (2011). This approach takes a socio-technical perspective of ensemble IT artefact design that integrates an emerging IT solution artefact with explicit consideration of use in a practical context (i.e. healthcare stakeholders' practical context). As Purao et al. (2013:76) note, "the building, intervention, and evaluation of the artefact help (shape) the emerging design theory and knowledge". This moves the artefact from being a mere IT tool bundle towards a dynamic role in the world, embedded in its space-time and community structures, with its emergence guided by its participants and organisational practices. This leads to a more natural uptake and fit of the technology within existing structures and practice (Miah and Gammack, 2014).

The paper is structured as follows. The next section describes the problem context in Bangladesh, followed by a review of relevant literature. The following section presents the methodological details followed by the conceptual e-health solution specification. The section after that provides the system evaluation details. The discussion and conclusion section provides overall discussion on the contribution of the study. The final section also presents limitations and further directions of the study.

2. Study background

The section describes the background details of the study undertaken in Bangladesh. We first discuss the practical problem context; then consider previous approaches to e-health solutions before outlining why cloud computing is a promising solution strategy for developing e-health solutions, particularly in the context of Bangladesh.

2.1. Problem context

The majority of the population in Bangladesh live in rural areas without access to modern healthcare facilities and specialized hospitals (Hasan, 2012; Akter et al., 2014). For the total population of approximately 160 million, there are approximately 96,000 registered doctors available. Although 70% of total population live in rural areas, 75% of total qualified physician are practicing in urban areas (Hasan, 2012). This implies an effective ratio of 1 doctor for every 47,000 patients in rural areas. Most of the rural hospitals and clinics are poorly equipped and understaffed. Rural and remote area patients have no other option but to travel and commute to regional towns, metropolitan and divisional cities to receive healthcare and medical services and consultation especially for chronic and major health issues. Commuting patients may have to face long queues and diagnostic tests that need to be done before they can even see a doctor. This increases the duration of their commute and wait. Most patients come without any previous health record information.

With the growing concern and epidemic of diabetes across the country, proper diagnosis and preventative measures are crucial healthcare strategies. Yet people in rural and remote areas may receive poor or inadequate treatment due to the lack of effective medical diagnostic facilities and expertise. They may not even get appropriate consultation and education on food, nutrition and lifestyle that could assist them to prevent and manage health complications. Proper diagnosis and expert consultations would make a huge positive difference towards tackling this chronic health condition.

The government has made healthcare a priority agenda in their budget and made efforts to achieve the millennium development goals. It has not, however, proved possible to deliver a satisfactory and effective level of health care, consultation, diagnosis and treatment. This is due to underlying issues including a large and widely spread population; lack of medical infrastructure and services in rural and regional areas; institutional legacies and bureaucracy, and limited health sector financing (Afsana et al., 2014). There is a recognised shortage of well-trained doctors and nurses in rural and regional areas: in particular, Bangladesh has few experts on diabetes care in most of its districts and subdistricts. Roads and highways are also underdeveloped in rural and remote areas; however, telecommunication infrastructure is quite advanced (3G mobility), with extensive and rapidly growing coverage. Developing e-health solutions utilizing this infrastructure with online services therefore suggests an effective pathway to provide health information and consultancy to remote and rural areas.

2.2. Previous e-health research implications

E-health application and implication research has gained popularity over the last few years. Based on Hage et al.'s (2013) systematic literature review on e-health service adoption in rural communities we can summarize the findings (in Table 1) for the following types of e-health services researched and their application contexts.

While the above mentioned e-health approach implications have their strengths and limitations, there has not been much consideration given to utilizing the adoption of cloud based solutions to tackle a lot of the e-health aims and healthcare objectives, especially for patient diagnosis and consultation purposes. A cloud infrastructure however can support applications developed in these areas in an affordable and scalable manner.

2.3. Healthcare cloud based solutions

As an emerging platform, more attention to the value of cloud-based solutions is becoming evident in many fields, including healthcare. Lin et al. (2014) suggested that cloud computing can empower healthcare practitioners (in rural areas of China) and service providers by offering scalability, online delivery of information, images, and collaborative services. A study by Sultan (2014) identified cloud-computing options that meet general expectations of health providers including more innovative and cost-effective practices. These studies highlight the growing requirements of cloud-based e-health, but none of them proposed a framework to implement such solutions. GE healthcare launched Centricity 360 cloud service in 2013 for streamlining clinical collaboration among unaffiliated caregivers and patients to help reduce duplicate testing, avoid unnecessary patient transfers and lower diagnostic imaging distribution costs (Monegai, 2013). Similarly de Assunção et al. (2010) conducted a cost-benefit analysis of cloud-based services and found effective performance and lower response times with lower usage cost when using cloud-based operations. As confirmed in the HIMSS (2014) survey, cost reduction is a major driver for government and private sector hospitals, with the most popular uses being for Hosting Clinical Applications and Data and for Health Information Exchange: both these areas directly addressing the problems in developing country contexts. Increased use of cloud services was strongly indicated in this survey, with *hosting archived data* and *operational applications* being the most likely areas of expansion. Although the survey was limited to 150 responses mostly from senior IT executives working for hospital-based organizations there is no reason to believe this does not reflect a wider emerging trend.

The outcomes and potentiality for utilizing cloud computing for providing health analysis, diagnosis and consultancy makes a strong argument for it to be adopted for rural and remote communities where a trained health worker or a nurse would be able to record and enable the entry of data, preferably using mobile computing devices. With the extensive and increasing usage of mobile communication, such a system infrastructure would be readily feasible to design and implement.

Recorded data may be shared through secure cloud computing interfaces with well-trained or specialist doctors scattered at various locations for analysis, feedback and recommendations. The mobile platform allows for direct doctor-patient discussion or appropriately mediated through health care workers for effective medical diagnosis, monitoring, consultations and follow-up. Patient records along with health care strategies and recommendations can easily be stored and followed up in the future to analyse the progress of the patient. Since cloud solutions can be designed as private, public or a hybrid, confidentiality of medical records can be maintained according to legislation or policy without changing the fundamental design. Aggregate or anonymised data can likewise be made available or shared non-locally by specifying the access rules involved. In the next section we describe our design approach, which takes into account the professional reality in which an IT artefact is used.

2.4. Cloud based solutions for developing countries

The distributed nature of cloud computing allows healthcare professionals to monitor, maintain patient's health records, collaborate with patients and other professionals, diagnose or analyse patient health conditions, and also improve patients' awareness on diseases or relevant care (Hossain and Muhammad, 2014; Sailunaz et al., 2016). Cloud services offer storage, processing and other services in relation to supporting healthcare through mobile applications. This support framework does not require physical storage devices to be installed on the client site, and often requires only minimal client interaction through simplified application interfaces.

Current studies in the e-health field suggest three dominant purposes of cloud-based approaches for delivering prompt and real-time healthcare support. These are for *health monitoring* (Hossain, 2015; Sailunaz et al., 2016; Song et al., 2015), for *health awareness* such as online social discussion groups for people with common health problems (West, 2013) and for *disease diagnosis* (Mamun et al., 2016; Parekh and Saleena, 2015). This implies that although most of the cloud-based solutions are proposed for the use of healthcare professionals, such approaches imply provisions for empowering patients for example, in terms of providing access to their personal health records (Song et al., 2015). The most popular type of cloud-based use is in health monitoring systems that promise to offer effective support both to healthcare professionals and patients who are living in rural or remote communities in developing nations.

Table 1
E-health service categories and their applications.

Type of e-health	Application context
Internet and social media	Social contact; economic development; access to information; empowerment; health; bridging the digital divide; education; reducing costs/time
Videoconferencing and tele-health	Health; bridging the digital divide; reducing costs/time; access to information; social contact
Telecommunications (mobile)	Access to information; education; bridging the digital divide; reducing costs/time; health; quality of life; social contact; economic development
Community networks	Access to information; education; bridging the digital divide; reducing costs/time; quality of life; social contact; economic development
Web portals	Access to information; bridging the digital divide; health
Computer labs	Education

Lai and Wang (2015) noted the Taiwanese government's significant efforts to switch attitudes of their populace to obtain their services from cloud based healthcare systems. Moving towards developing theories or methods for effective cloud-based healthcare delivery, this work recognises the importance of user acceptance, and suggests further motivation for researchers to understand people's intentions and attitudes in technology use. Mamun et al. (2016) developed a cloud-based approach for diagnosing neurological diseases such as Parkinson's Disease (PD) in developing countries. Through the system a patient with PD can be easily diagnosed by giving their voice samples through their phones regardless of their location. The system uses an artificial neural network classifier for diagnosis of PD patients' voice signal. Rural patients or those from the regions where health professionals are not physically available can communicate to the doctors provided Internet connectivity is there to access the cloud based solution through their mobile devices. Similarly, Parekh and Saleena (2015) proposed a cloud based e-health system for diagnosing various health conditions of patients living in a rural area of India. The key component of the system is the analyser, in that patient can login into their mobile application for entering symptoms and his location. The symptoms are all the health issues that are being suffered by the user for which s/he expects specific treatment. The analyser displays the nearest specialized doctors and hospitals within the location. Using data mining techniques the system produces outcomes by relating entered symptoms to diseases and by analysing historical data maintained by the system.

Hossain and Muhammad (2014) reported a cloud-based system in which collaborative media services are provided for efficient collaboration between caregivers and healthcare professionals. In the system, cloud based features mainly facilitate collaboration between the caregivers by considering a voice pathology assessment scenario, where doctors, caregivers and patient collaborate to assess voice pathology, using Extensible Messaging and Presence Protocol (XMPP) and the sensing ability of smartphones' microphones. From the patient side, Song et al. (2015) described a cloud based personal health record system that provides patients or guardians the ability to constantly monitor and control their personal health records. The proposed cloud based system allows constant monitoring capability by supporting dynamic creation of clinical document architecture (CDA) documents from a mobile device. The CDA data ensure the meaningful use of data from the clinicians.

Hossain (2015) proposed a "cloud-supported cyber–physical localization system" for patient monitoring using smartphones to acquire voice and electroencephalogram signals in a scalable, real-time, and efficient manner. The approach uses Gaussian mixture modelling for localization and is shown to outperform other similar methods in terms of error estimation.

Kaur and Chan (2014) designed a cloud based intelligent healthcare service to monitor user health data for diagnosis of chronic illness such as diabetes. In their design, body sensor components are utilized to record user data, and upload it to cloud storage. Analysis and classification are done in cloud-based storage repositories. Similarly Miah et al. (2013) used an Internet of Things approach to design a layered system for monitoring diabetes indicators, providing both individualised advice to patients, and general information for doctors and epidemiologists. With the advent of increasingly reliable medical monitoring wearables and implantables, and assuming security of data (Marrington et al., 2016), such solutions can realistically expect to become mainstream. Given the huge amounts of data that can be conveyed by continuous monitoring from sensors, the scalability of cloud solutions is especially relevant. Table 2 summarises the key features from ten major studies related to cloud-based healthcare solutions relevant particularly to patients and professionals in developing countries.

The development focus in many of these studies primarily concerned the artefact design or innovative software techniques, an engineering perspective which is called the *tool view* in the literature (Kling, 1980; Orlikowski and Iacono, 2001). Our work reported in this paper shares similar objectives of the above-mentioned studies in Table 2 but utilizing a sociotechnical approach of *ensemble* artefact design. In designing and evaluating an e-health solution for a target population in a developing country it is essential to consider the deployment realities. The cloud-based e-health solution is both for healthcare professionals and patients via healthcare workers when computer literacy is an issue for accessing the artefact. The doctor/patient ratio, the rapidly growing telecommunications infrastructure and the scarcity of resources mean a strong focus on the potential uses and other stakeholders is required throughout the technical design and development, and that relevant evaluation is conducted as part of good design science research.

Table 2
Major works in cloud-based e-healthcare relevant to developing nations.

Cloud-based e-health solutions	Purpose/solution classes	Technique used	Target beneficiary
Hossain and Muhammad (2014)	Monitoring system for efficient collaboration between caregivers and healthcare professionals	Extensible messaging and presence protocol	Healthcare professionals and care givers
Parekh and Saleena (2015)	Diagnostic system for analysing healthcare data using data mining	Clustering technique	Healthcare professionals, patients, and government
Song et al. (2015)	Health monitoring system to provide patients or guardians to monitor and control personal health record	Clinical document architecture for assessing current health against major diseases	Patients or guardians
Hossain (2015)	Elderly health monitoring/remote care for healthcare professionals	Speech and face recognition framework, support vector mechanism	Healthcare professionals
Rana and Bajpayee (2015)	Diagnostic system for analysing patient's EMR to help professionals in study and process improvement	Integrated and inter-operable solution technologies	Healthcare professionals
Muhammad (2015)	Proposed framework for speech-enabled remote healthcare	Interlaced derivative pattern for automatic speech recognition	Patients, healthcare professionals
Kaur and Chan (2014)	Intelligent system to monitor user health data for diagnosis of chronic illness such as diabetes	AI techniques for real time monitoring of patient data	Healthcare professionals
Hossain (2015)	System for patient monitoring by acquiring voice and electroencephalo-gram signals	Localization technologies such as GPS and signal processing	Patients, healthcare professionals
Mamun et al. (2016)	System for diagnosing neurological disease such as Parkinson's Disease	Support vector machine was used for classifying text or images	Patients, healthcare professionals
Ahmed et al. (2014)	System designed as a learning platform for monitoring rural patients through testing the EMRs	Morbidity was identified using triage stratification algorithm	Patients, healthcare professionals

3. Method of the study

Payton et al. (2011) suggested that healthcare IT must address issues of process, people, patients and interdisciplinary considerations in order to deliver effective and efficient care. To advance the design process of support for healthcare service, the ideas of socio-technical design science are considered useful. For example, in designing a HealthGrids system, Ure et al. (2009) utilized the socio-technical approach to focus the need for design and development strategies that are able to engage with local needs. Their study addressed both technical problems encountered in the development of a data infrastructure for sharing and re-using data across sites and also social scales for healthcare delivery and e-health research, aiming at better collaboration.

This study therefore adopts the socio-technical design science approach presented by Gregor and Jones (2007) that defined the eight structural components of IS design research. The components are (1) purpose and scope, (2) constructs, (3) principles of form and function, (4) artefact mutability, (5) testable propositions, (6) justificatory knowledge, (7) principles of implementation, and (8) an expository instantiation. These structural components also affirm and utilize the design science considerations for artefact design and implementation as discussed by McKay et al. (2008), Iivari (2007) and Carlsson (2006). This study followed IS design theory guidelines to design the functionalities of the e-health artefact, detailed in Table 3. Specifically, the work was informed methodologically by Sein et al.'s (2011) Action Design Research approach, which recognises the interwoven relationship between an artefact and its organisational context, and that the development involves ongoing relevance evaluation in the intervention context.

The evolutionary prototyping method (adapted from Barjis et al., 2013) was used to identify problems and outline solution strategies. The method consists of three steps. In the first step we elicit knowledge and understanding of the work processes in the healthcare service delivery. Doctors are asked about requirements and processes of their consultation strategies and medicine prescription. They are also asked about the type of data and information they need to analyse for effective diagnosis and consultation. We found that they prefer rule-based reasoning for decision-making. In step two, the initial design from step 1 is refined and separate processes of doctors and healthcare workers are developed to analyse patient records. One of the key functions in this step is registration of patient record as well as doctor and healthcare worker profile. In step three, the system is checked specially for the completion of the prescription and consultation process. After iterative development, the prototype system has evolved sufficiently to be initially evaluated and validated against its targeted practical context of use, and is ready to be engineered into a stable artefact linked to workflows and other systems in use. In the next section we describe this artefact design.

4. The On-Cloud Health Clinic artefact

The ensemble artefact perspective ensures that the IT tool is not a disembodied focus of an engineered product, but is developed within a context of practice, using the vocabulary and structures of the users so that it fits with workflows and

Table 3
Details of the e-health artefact design through the skeleton of design research outlined by Gregor and Jones (2007).

The specification of the design theory	Presented in this research
The *purpose and scope* of the artefact are addressed	Designing and utilizing cloud computing for e-health introduces many opportunities to healthcare service delivery especially for rural and remote areas in developing nations. Limitations are discussed
Principles of form and function incorporating *underlying constructs* are described	The general development method (evolutionary prototyping) is described in line with Design Science Research practice. For the artefact a specific rule-based technique (Woo et al., 2014) was used for developing a clinical decision support system (CDSS) that provides lifestyle support to chronic patients matched to doctors' use of rule-based inference in diagnosis. Table 4 shows further details
Artefact mutability is addressed	E-health services and implications for healthcare consultation and diagnosis in rural areas have been formulated around the context of utilization of cloud computing resources. The cloud-computing model and system design for e-health services can be replicated for similar contexts and application areas, which the illustrative case represents
Testable proposition of the design artefact is defined	Evaluation with users supports the argument that the design is workable in different conditions at remote locations (see discussion section)
Justificatory knowledge (kernel theory) is provided	The study details the e-health artefact with reference to underlying cloud computing theory and also socio-technical IS theory relevant to supporting professionals in their roles (see section below)
Principles of implementation are given	Testing and systematic evaluation including user acceptance are covered. Training and installation issues are considered, along with discussion of wider issues concerning adoption. Technical details are outlined
An *expository instantiation* is given	An illustration of working e-health artefact (system prototype) is provided with evaluation

processes already in effective use. The artefact itself, the *On-cloud health clinic* enables key interactions among patients, doctors and health care workers. Fig. 1 illustrates the core logical interactions between pairs of the main constructs in the designed ensemble system. The patient process initiates through registering with a healthcare worker (who could be an individual entity or part of a community clinic or hospital) and setting up an appointment with a subject matter expert doctor.

The 'community clinic' effectively is the intermediary tier through which patients are introduced and linked up with the doctors. Such community clinics could be local hospitals or health care centres or even mobile health care professionals. Access to the cloud based service is managed through local or assisted IT services. The structure allows for front end apps at patient level to be introduced as an extension to this, relieving the burden on intermediary assistance, and shifting the burden of data inputs to the patient, leaving a more monitoring and assessment role at intermediate level. In diseases such as diabetes, body sensors, wearable monitors and other specialised devices potentially provide key time-coded and accurate data as required in real time, and without necessitating physical travel.

Initial patient concerns and patient medical history are recorded and stored by the community clinics or mobile health care professionals. Access controls via login forms, and registration processes for new patients have been designed for web access using Navicat for MySQL, and implemented using PHP (server side): appointments are likewise managed through forms that are populated from the database of existing medical records, input or verified by healthcare workers (Fig. 2). Using open source software means the solution is not locked into proprietary data forms or devices and liable to commercial pricing vagaries.

Doctors likewise have to be registered with their expertise and availability details. Load balancing allocations can be naturally handled in the cloud, so the system is entirely scalable, and because it is in the cloud, appears seamless to the patients through to healthcare workers.

Initial patient information is formulated in terms of medical "rules" that begin to specify diagnosis and led to specific actions. This is mediated through the system, with the target users' roles defined as shown in Table 4.

The system's structure allows for keeping a detailed record of workflow, tests or medicines required, time spent and the like, making both individual and aggregate costing possible and informing future resourcing and provisioning decisions, whether or not private billings are appropriate. There is no overhead for such record keeping, as it is all mediated within the flow of the system activity.

Doctors can review the patient details and concerns, perform an initial diagnosis and pass on additional advice through the community clinic in case any further diagnostic tests are required. Doctors and patient will meet up online as required through an intermediary like a community clinic or health care professional and consultation will be provided. Medicine prescriptions or lifestyle adjustment guidance can be provided and followed up on over time, especially in the case of diabetes treatment. Similarly, like the doctors, health care workers details can be considered for coverage of areas as well as in terms of providing necessary support during and after doctor patient consultation process. Detailed reporting for the patients and doctors can be provided but any complete online-based healthcare system would need to be monitored for patient data security and privacy details. In setting up the complete system the intermediary community clinic or healthcare professional has a big role to play as training, data structures and secure network links would take time to setup and be operational. Due to the simple interface design however, the training in artefact use for healthcare workers, or for the doctors is not onerous, and BMI and cholesterol level assessment is likewise straightforward at the input end, which uses common medical formulation and vocabulary.

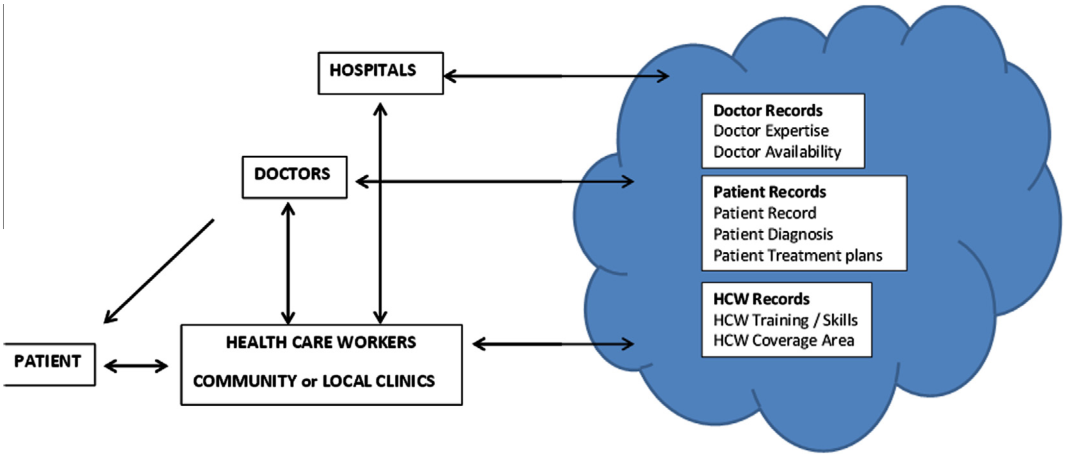

Fig. 1. Working components of the ensemble e-health artefact architecture.

Fig. 2. Patient data entry by healthcare workers.

The cloud-based system has the flexibility to include not only doctors, patients, health care workers, community clinics etc. but also in complex cases can integrate additional clinics, hospitals and other doctors. The cloud allows the flexibility for

Table 4
Roles of patients and doctors in creating rules for the cloud-based clinic.

Role involved	Rules creation	Rules (illustrative)	Types of management
Patient	Patients provide their existing records that lead to initial rules creation for providing feedback data both to doctors and patients	If patients have BMI = 23,Cholesterol = 236 and Blood pressure diastolic ⩾93, blood glucose readings = <> and other health conditions = <> then the patient is at high risk of diabetes	Doctors and patient will meet up online ASAP Lifestyle information and health screening schedule service will be managed by doctors and care givers are to provide timely support for better self-management to patients
Doctors	Rules are created to provide best possible guidelines to patients with diabetes on the basis of latest medical knowledge and clinical study results	If BMI is XX and total cholesterol or blood glucose readings is YY, then Patient_diabetes level = high, suggest medicine = XX, care plan = VV and support service = MM (XX, YY, VV and MM are variables that define field of entering or displaying number or string)	Doctors provide prescriptions and lifestyle adjustment guidance and followed up on over time. Specialist in particular areas is to be referred and option of time to time visits and if possible, patients can be hospitalised (for example)

joint collaboration, accountability and supervised medical consultation which naturally reduces the chances of incorrect treatment and consultations. The diabetic treatment and lifestyle changes do require various levels of involvements of local clinics, doctors, nutritionists, hospitals etc. These players can all be integrated into the cloud based system artefact solution as its architecture is scalable.

5. System testing and evaluation

A working system was designed, developed and extensively documented by the second author. Functional and structural testing was applied as part of this development. In order to evaluate the prototype system with users we utilized two approaches: focus group interviews and observations applying the descriptive method (Hevner et al., 2004). As a well-established evaluation method, focus group interviews are an appropriate approach for artefact refinement and evaluation within the design science research paradigm (Tremblay et al., 2010).

Our aim was to collect and analyse doctors and healthcare workers' suggestions (the participants were 2 consultants; 2 general practitioners and 3 healthcare workers) to validate a prototype of the system artefact and its utility for further refining it. Initially the facilitator presented an overview of system to the participants (doctors and health care workers), showing them every main concept and expected interactions of the proposed system. We requested doctors to go through the functions of the system. This allowed modification for some of the interaction processes (e.g. generating prescriptions).

To measure the perceived intention to use the new system, and the commitment towards using it in practice, a questionnaire was applied with the participating personnel to capture views on the system and potential issues for redesign. Indicative comments from the focus groups are shown in Table 5.

In addition to focus groups, we also utilized observations with the same group of people who were observed in a professional workshop for the purpose of this evaluation. This is another established technique in design science research that has been used when evaluating systems within a real problem space (Tremblay et al., 2010). The prototype system enabled care workers to enter specific patient data and disease descriptions so doctors could view specific required information and give feedback through the system. We also recorded three work sessions with care workers (professionals) during some patient visits on site.

Overall the evaluations showed that the attitude towards the system was very positive: one of the most obvious findings is a value of the role of an intermediary health professional as the bridge between the doctor and patient. Patient literacy in application use is a potential limitation but this can be expected to change generationally, and with health worker's assistance meantime. In terms of the on-cloud clinic design artefact, we found that the intermediary health professional could be an individual or part of a local community clinic, to fit with the familiar practice of a given region or locality. The comments and positive evaluations suggest a practical feasibility sufficient to take the system to the next stage of development and implementation.

6. Discussion and conclusion

While the current literature on e-health, healthcare models, and healthcare ICT presents a plethora of studies addressing different aspects of healthcare in developed countries, rural healthcare services provided through online systems has not received as much attention. This is especially relevant in countries with large rural populations, such as Bangladesh where millions of patients are suffering from medical conditions, which could be better managed through proper medical consultation and guidance. The concept of an on-cloud e-health clinic has real-world potential and points towards improving preventative and better managed health care services. This paper has outlined a promising design research direction for scientific attention as its potential implications can positively influence the lives of millions.

The present study has attempted to develop a practical e-health solution based on cloud computing technologies in order to improve health consultation and services to diabetic patients in rural and remote communities in Bangladesh. We believe that identifying the societal requirements that involve interplaying roles of healthcare workers, doctors/specialists and patients are important in the field of e-health research. Although we specified a prototype system solution for diabetic care needs, the idea can be generalised for designing e-health solutions for other health complications which require proper diagnosis, consultations and follow up, not just those involving self-monitoring and management.

Utilising action design research our study successfully developed and evaluated a solution to improve patient's healthcare demand and management for diabetes. The study extends the previous e-health theory proposed by Barjis et al. (2013), by employing a cloud computing architecture. While Barjis et al. (2013) focused on home based health care delivery model and the subsequent monitoring of a decision support system application using Unstructured supplementary service data (USSD) technology; our study differs from the approach in that a software as a service (SaaS) of cloud computing concept is proposed in which the healthcare service application runs on the cloud and usage is on 'on demand'. This eliminates the need to install and run the applications on the client computer (e.g. hospital or community computing resources). This proposed innovation would be ideal for a scenario of a developing nation where medical resources and expertise are scarce in rural and remote areas and communities, but due to ongoing telecommunication growth, a cloud based e-health service could be a realistic possibility to implement.

Table 5
Some comments that have been captured during the focus group sessions.

Participants	Comments Captured during the evaluation sessions
Consultants (Diabetes and endocrine)	*"Based on my experience using the system, I found that it is user friendly and easy to use to find patient records. . ..." specially for the patients [from remote areas] data" we can also analyse them to make our evaluation and decision"*
Patient 1	*I know I can't use the apps on my mobile but I can ask to my son or nephew to enter my detail for doctor's visit and get report send to doctors"*
General practitioner 1	*"This system offers knowledge sharing from various specialists as we look at their prescriptions given to individual patients, if we get access",. . .. . .. I think it will assist the health care workers to schedule patient better for us"*
Healthcare worker 1	*"Compared to the previous paper based activity, our work is much easier, we do not need to directly contact with doctors. . .. they can view the patients data every-time anytime"*
Patient 2	*"When I use the apps in my mobile phone, I found I may need assistance to entry my own details to get an instant appointment confirmation"*
Healthcare worker 2	*"I can get an instant appointment confirmation for the patients as well as provide them with any medical test required for doctors consultation"*

The proposed e-health approach can be generalised in order to provide similar health services in many other countries, developing or otherwise. The cloud computing for e-health services model is at a developmental stage and will require modifications of the processes and constant fine-tuning to cater to specific health conditions and interactions among the doctors, intermediary health care workers and the patients. Such models however illustrate the promise of a system that can completely bypass the traditional healthcare service delivery models which require traditional infrastructure and health workers. Developing countries cannot afford to waste time and nor do they have the resources to follow a traditional growth and health service delivery for their rural and remote communities. Such an innovative solution as illustrated in this study and extensive utilization of ICT and the cloud computing service provides a great opportunity to go forward and start delivering accessible e-health service models.

There are several core benefits that the resulting system can provide. Convenience of appointment, decreased commuting costs and time, reduced patient waiting period, improved access to medical specialists and health information along with guided plans and follow-up makes the complete process an improved quality of life for millions of rural patients suffering from medical conditions which can be better managed. The community clinic or intermediary healthcare workers can also get improved access to medical specialists, increased education and experiences, decreased professional isolation and potential for collaborative research and treatment plans. Such systems are also quite beneficial for the doctors as it helps reduce their need to travel and with the availability of patient information or medical history they can diagnose medical conditions better and if needed seek collaborative assistance from other professional doctors, hospitals and healthcare specialists. Reciprocally this ensures that the care at rural patient level is informed by the latest thinking available. Moreover, as such system solution can help developing countries to accelerate the delivery of health services through ICT. It also helps reduces load for local government clinics and hospitals and consequently reduces health care cost of its citizens.

Although the benefits are obvious, setting up such a health care system is an immensely complicated task that requires careful planning, investment and focused implementation strategies. Such solutions are not possible to be developed immediately and neither can the rewards be obvious to all the people and processes involved. With the Digital Bangladesh Initiative towards Vision 2021 (Government of Bangladesh, 2009) however, there is a positive political will and improving resource infrastructure, and pragmatics would dictate how a pilot or phased implementation for example could be designed.

Apart from the complexities of utilizing cloud based online systems, there is a shortage of healthcare workers who are technically competent to handle the process itself. There needs to be a massive training and awareness campaign to sell the potential benefits to all the stakeholders and users of the systems and that is an enormous task by itself. It is a huge learning curve for time poor doctors and healthcare professionals in the health industry. According to Gurstein (2005), the mere presence of and access to ICTs in rural areas is unlikely to be effective without relevant ICT-related skills, promotion of relevant content/information for ICT applications, and a policy framework in which interventions can function. Since cloud based system solution requires extensive ICT support and usage it is a crucial foundation for the whole healthcare service delivery outcomes. Unreliable or lack of ICT infrastructure will make the entire systems solution ineffective.

Pro-poor policies for underserved populations are embodied in the Access to Information concept of digital Bangladesh by 2021 (Government of Bangladesh, 2009), and parallel developments on technical infrastructure and human resource sides are in train towards this vision. A cloud platform is appropriate since it can be physically architected to the resources available and required, and its logical specification does not depend on particular technical commitments or legacy choices.

There are other issues however with cloud solutions which require proper consideration in the context of e-health solution development. Kotz et al. (2015) described the importance of security issues for mobile and cloud based healthcare solutions, in particular alerting designers to recognise pre-existing vulnerabilities and potential threats to health records. In this respect, apart from security (Kaur and Chan, 2014; Kuyoro et al., 2011; Sailunaz et al., 2016; Rana and Bajpayee, 2015), studies identify other common issues such as: privacy (Rana and Bajpayee, 2015; Sailunaz et al., 2016) and IP issues that could lead to medical identity theft, a rising danger with online health data (Shin, 2015).

Ownership, reliability of backup, access authorisation and protection against termination or deletion if third-party providers change terms of service present other known risks with cloud dependent services. Nonetheless many providers prefer cloud solutions, and take specific measures against known risks. For instance, Sailunaz et al. (2016) proposed an encryption decryption scheme for addressing the security issues for data transmission in their cloud-based healthcare solution, although these are relatively expensive and time-consuming for implementation. To address the security challenges in our system, we adapted relatively effective security mechanisms suggested by Kaur and Chan (2014). Specifically providing role based access control at multiple levels was the key to ensuring the protection of critical medical data of patients. The two types of user roles defined in our On-Cloud Health Clinic that is (1) Creator; (2) Trusted Users. The healthcare workers or individual patients whose medical data resides in the On-Cloud Health Clinic was designated as the creator of data, who can modify, add, delete the content sensitive details in the record. The creator may wish to share the personalised medical data with the other or any healthcare professionals for consultation or other purposes. The system named such user or user groups as trusted users, who are always under creator who can change their roles or viewing power or access level on the records.

In relation to privacy issues, Narayanan and Shmatikov (2010) noted that joining two de-identified datasets can lead to re-identification, and recommend supplementing anonymisation with other safeguards including informed consent and contracts. We used personal identity information such as anonymous ID and passwords initially to ensure general privacy which is important due to high multiplicity of personal data during the testing phases. Appropriate national laws for de-identification apply to digitised records generally, and technical assurance of compliance would be a standard requirement in healthcare systems design.

Another major problem was to address the computer illiteracy issues. This is of course a national and perhaps generational issue, but one with specific implications for systems design. During the focus group sessions we observed the main barriers to widespread computer use by patients (especially aged over 50 years of old) in rural communities; namely a low level of computer or mobile use and English literacy which is not uncommon. In this case representatives of patient stakeholders suggested that help in app use was available in their immediate communities, and beyond this we deliberately provisioned the initial system for healthcare workers and caregivers to help patients to enter their records into the system.

The study does have some limitations. Some of the respondents were reluctant to part with certain information on the pretext of the sensitivity of the information. Some of our analysis and interpretation is therefore based on secondary data. But also some doctors and health care professionals did not exhibit enthusiasm for the idea of a cloud-based solution as it potentially involves changes in their working preferences and practices. Thus an element of bias might have crept in from the side of such people interviewed. While resistance to innovation is common in information systems, top-driven levers combined with an effective change management process usually prevails, especially if the system design has been tailored to work for representative stakeholders to minimise resistance due to technical issues. Although we believe the approach generalises to other fields of healthcare, our case investigation would require supplementary corroboration for other domains of medicine, not all of which may be amenable to rule formulations. A more extensive evaluation would also be desirable, and would go beyond the system value and usability towards a wider integration with medical practice and security and privacy considerations. The action design research approach is suited to exactly this sort of learning and development approach to integration in practice, and is the subject of our continuing work.

Acknowledgement

This study is based on the second author's work initiated by BIRDEM Hospital, Dhaka Bangladesh and funded by the Health Ministry of Bangladesh. The other authors have collaborated mainly on research conceptualisation, technical content and publication.

References

Afsana, K., Grant, J., Evans, J., 2014. Crisis of health workforce in Bangladesh: a non-government organization's experience in deploying community health workers in primary health care. Perspect. Public Health 134 (5), 253–254.
Ahmed, A., Hargrave, A.R., Nohara, Y., Kai, E., Ripon, Z.H., Nakashima, N., 2014. Targeting morbidity in unreached communities using portable health clinic system. IEICE Trans. Commun. 97 (1), 540–545.
Akter, S., Rahman, M.M., Abe, S.K., Sultana, P., 2014. Prevalence of diabetes and prediabetes and their risk factors among Bangladeshi adults: a nationwide survey. Bull. World Health Organiz. 92 (3), 204–213.
Barjis, J., Kolfschoten, G., Maritz, J., 2013. A sustainable and affordable support system for rural healthcare delivery. Decis. Support Syst. 56, 223–233.
Carlsson, B., 2006. Internationalization of innovation systems: a survey of the literature. Res. Policy 35 (1), 56–67.
de Assunção, M.D., di Costanzo, A., Buyya, R., 2010. A cost-benefit analysis of using cloud computing to extend the capacity of clusters. Cluster Comput. 13 (3), 335–347.
Diabetes UK, 2015. Diabetes: facts and stats December 2015 report https://www.diabetes.org.uk/Documents/Position_statements/Diabetes_UK_Facts_and_Stats_Dec_2015.pdf, accessed on 21 March, 2016.
EU-European Union, 2013. European Hospital Survey: Benchmarking Deployment of e-Health Services (2012–2013) http://ftp.jrc.es/EURdoc/JRC85854.pdf, accessed on 28 March, 2016.
Government of Bangladesh, 2009. Digital Bangladesh Concept Note Access to Information (a2i) Programme, Prime Minister's Office, Dhaka, Bangladesh http://www.a2i.pmo.gov.bd/digital-bangladesh, accessed on 30 March, 2016.
Gregor, S., Jones, D., 2007. The anatomy of a design theory. J. Assoc. Inf. Syst. 8 (5), 312–335.
Gurstein, M., 2005. Why community technology matters: community informatics and the effective use of ICTs. Community Informatics Research Network (CIRN) conference. In: International Conference of the Community Informatics Research Network: CIRN2005 on Cape Town, August, pp. 24–26.
Hage, E., Roo, J.P., van Offenbeek, M., Boonstra, A., 2013. Implementation factors and their effect on e-health service adoption in rural communities: a systematic literature review. BMC Health Serv. Res. 13 (19), 1–16.

Hasan, J., 2012. Effective telemedicine project in Bangladesh: Special focus on diabetes health care delivery in a tertiary care in Bangladesh. Telematics Inform. 29, 211–218.
Hevner, A., March, S., Park, J., Ram, S., 2004. Design science in information systems research. MIS Q. 28 (1), 75–105.
HIMSS, 2014. 2014 Health Information and Management Systems Society Analytics cloud survey http://www.himssanalytics.org/research/AssetDetail.aspx?pubid=82160&tid=127, accessed on 2 April, 2016.
Hossain, M.S., 2015. Cloud-supported cyber-physical localization framework for patients monitoring. IEEE Syst. J. 99, 1–10.
Hossain, M.S., Muhammad, G., 2014. Cloud-based collaborative media service framework for healthcare. Int. J. Distrib. Sens. Netw. 10, 1–11.
Hu, Y., Bai, G., 2014. A systematic literature review of cloud computing in e-health. Health Inf. Int. J. 3 (4), 11–20.
IDF, 2015. International Diabetes Federation Global Atlas 7th edition http://www.diabetesatlas.org/, accessed on 4 April, 2016.
Iivari, J., 2007. A paradigmatic analysis of information systems as a design science. Scand. J. Inf. Syst. 19 (2), 39–64.
Kaur, P.D., Chan, I., 2014. Cloud based intelligent system for delivering health care as a service. Comput. Methods Programs Biomed. 113 (1), 346–359.
Kling, R., 1980. Social analyses of computing: theoretical perspectives in recent empirical research. ACM Comput. Surv. 12 (1), 61–110.
Kotz, D., Fu, K., Gunter, C., Rubin, A., 2015. Security for mobile and cloud frontiers in healthcare. Commun. ACM 58 (8), 21–23.
Kuyoro, S.O., Ibikunle, F., Awodele, O., 2011. Cloud computing security issues and challenges. Int. J. Comput. Netw. 3 (5), 247–255.
Lai, J.Y., Wang, J., 2015. Switching attitudes of Taiwanese middle-aged and elderly patients toward cloud healthcare services: an exploratory study. Technol. Forecast. Soc. Chang. 92, 155–167.
Lin, C.W., Abdul, S.S., Clinciu, D.L., Scholl, J., Jin, X., Lu, H., Chen, S., Usman, I., Heineck, M., Li, Y., 2014. Empowering village doctors and enhancing rural healthcare using cloud computing in a rural area of mainland China. Comput. Methods Programs Biomed. 113 (2), 585–592.
Mamun, K.A.A., Alhussein, M., Sailunaz, K., Islam, M.S., 2016. Cloud based framework for Parkinson's disease diagnosis and monitoring system for remote healthcare applications. Future Gener. Comput. Syst., in press
Marston, S., Li, Z., Bandyopadhyay, S., Zhang, J., Ghalsasi, A., 2011. Cloud computing—The business perspective. Decis. Support Syst. 51 (1), 176–189.
Marrington, A.D., Kerr, D., Gammack, J.G., 2016. Managing Security Issues and the Hidden Dangers of Wearable Technologies. IGI Global, Hershey PA (in press).
McKay, J.C., Marshall, P.H., Heath, G., 2008. An exploration of the concept of design in information systems. In: 2008 ISF Conference. Australian National University, Canberra, Australia.
Miah, S.J., Gammack, J.G., 2014. Ensemble artifact design for context sensitive decision support. Australas. J. Inf. Syst. 18 (2), 5–20.
Miah, S.J., Gammack, J.G., Hasan, M.J., 2013. An e-health infrastructure design to support management of lifestyle disease. Adv. Sci. Technol. Lett. 40, 1–4.
Monegai, B., 2013. GE Healthcare launches cloud service. Healthcare IT News http://www.healthcareitnews.com/news/ge-healthcare-launches-cloud-service, accessed on 23 February, 2016.
Muhammad, G., 2015. Automatic speech recognition using interlaced derivative pattern for cloud based healthcare system. Cluster Comput. 18 (2), 795-80.
Narayanan, A., Shmatikov, V., 2010. Myths and fallacies of personally identifiable information. Commun. ACM 53 (6), 24–26.
Orlikowski, W.J., Iacono, C.S., 2001. Desperately seeking the "IT" in IT research – a call to theorizing the IT artifact. Inf. Syst. Res. 12 (2), 121–134.
Parekh, M., Saleena, B., 2015. Designing a cloud based framework for healthcare system and applying clustering techniques for region wise diagnosis. Proc. Comput. Sci. 50, 537–542.
Payton, F.C., Pare, G., LeRouge, C., Reddy, M., 2011. Health care IT: process, people, patients and interdisciplinary considerations. J. Assoc. Inf. Syst. 12 (2), 1–13.
Purao, S.O., Henfridsson, M., Rossi, Sein, M., 2013. Ensemble artifacts: from viewing to designing in action design research. Syst. Signs Actions 7 (1), 73–81.
Rana, J., Bajpayee, A., 2015. HealthCare monitoring and alerting system using cloud computing. Int. J. Recent Innov. Trends Comput. Commun. 3 (2), 102–105.
Ruxwana, N.L., Herselman, M.E., Conradie, D.P., 2010. ICT applications as e-health solutions in rural healthcare in the Eastern Cape Province of South Africa Health. Inf. Manage. J. 39 (1), 17–30.
Sailunaz, K., Alhussein, M., Shahiduzzaman, M., Anowar, F., Mamun, K.A.A., 2016. CMED: Cloud based medical system framework for rural health monitoring in developing countries. Comput. Electr. Eng. 10, 1–13.
Sein, M., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R., 2011. Action design research. MIS Q. 35 (1), 37–56.
Shin, L., 2015. Why Medical Identity Theft Is Rising And How To Protect Yourself. Forbes Magazine http://www.forbes.com/sites/laurashin/2015/05/29/why-medical-identity-theft-is-rising-and-how-to-protect-yourself/#2b5dc0e7e200, accessed on 12 April, 2016.
Sultan, N., 2014. Making use of cloud computing for healthcare provision: Opportunities and challenges. Int. J. Inf. Manage. 34 (2), 177–184.
Song, Y.T., Hong, S., Pak, J., 2015. Empowering patients using cloud based personal health record system. In: 16th IEEE/ACIS International Conference on Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (SNPD), 1-3 June 2015, Takamatsu, pp. 1–6.
Tremblay, M.C., Hevner, A., Berndt, D.J., 2010. Focus groups for artifact refinement and evaluation in design research. Commun. Assoc. Inf. Syst. 26, 599–618.
Ure, J., Hartswood, M., Wardlaw, J., Procter, R., Anderson, S., et al, 2009. The DEVELOPMENT OF DATA INFRASTRUCTURES FOR EHEALTH: A SOCIO-TECHNICAL PERSPECTIVE. Journal of Association for Information Systems. 10, 415–429.
West, D.M., 2013. Improving health care through mobile medical devices and sensors. Brookings Inst. Policy Rep., 1–13
World Bank, 2015. Health Nutrition and Population Statistics report http://databank.worldbank.org/data/reports.aspx?source=health-nutrition-and-population-statistics, accessed on 10 April, 2016.
Woo, Ji.-In., Yang, J.Gi., Lee, Y.H., Kang, U.G., 2014. Healthcare decision support system for administration of chronic diseases. Healthcare Inf. Res. 20 (3), 173–182.