Potential applications of the internet of things technologies for South Africa's health services

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Abstract *There are strong commitments from the South African (S.A.) government to promote improved health services and the quality of life of its citizens. Through the National Health Insurance system all citizens of South Africa will be provided with essential healthcare. The challenges that face the health sector in South Africa currently are a shortage of health professionals, inefficient health record management, poor communication between the various health entities, and poor disease control and surveillance, to name but a few. This paper reports on potential applications of internet of things (IoT) technologies that could contribute to an efficient health sector, by impacting on the challenges identified. The said technologies were identified through a document review of the international landscape. These technologies have been categorised under ambient-assisted living for the aged, chronic medication management, telemedicine, disease surveillance, oral health, baby care, sport and fitness, emergency services, community and home-based care, mental health, nutrition, occupational health, environmental health, heart disease, and diabetes management. The purpose of this paper is to prove the potential of IoT as a possible contributor to sustainable health service for South Africa.*

Keywords: internet of things, ehealth

1. INTRODUCTION

The National Health Insurance (NHI) is a financing system that will make sure that all citizens of South Africa are provided with essential healthcare, regardless of their employment status and ability to make a direct monetary contribution to the NHI fund. The NHI will offer all South Africans legal access to a defined package of comprehensive health services. The package will offer care at all levels, from primary health care, to specialised health care and highly-specialised tertiary and quaternary levels of care. The benefits provided will cover preventive, promotive, curative and rehabilitative health services. The emphasis will be on prevention of disease and promotion of health as opposed to a focus on curing of disease and performance of procedures when people have developed complications (National Department of Health website, 2012).

eHealth is the application of ICT in healthcare resources and the health industry to improve the access, efficiency, effectiveness and quality of clinical and business processes utilised by healthcare organisations, practitioners, patients and consumers in an effort to improve the healthcare of patients. Efficient health records management, real-time access to and communication of health-related information, improved interaction between healthcare providers and patients, education and training of healthcare workers, ICT-aided diagnosis, health knowledge sharing among professional health staff, health awareness and education, improving patient safety and research support are some of the benefits that ICTs impart to the health sector. The World Health Organisation defines eHealth as 'the use of information and communication technologies (ICTs) for health to, for example, treat patients, pursue research, educate students, track diseases and monitor public health". This definition covers a vast domain including electronic health records to enable the sharing of patient data between points of care, routine health management information, vital registration, consumer health informatics, health knowledge management, mHealth, that is, the use of mobile devices such as cell-phones to share information, telemedicine, virtual healthcare and health research (eHealth strategy, 2012).

The main purposes for which health programmes use information technology are (Lewis, 2011):

- Overcoming the distance between the physician and patient by replacing a traditional office visit through telemedicine (e.g. videoconferencing with patients in rural areas, helplines, instant messaging with a health practitioner for medical advice)
- Facilitating communication between health workers and patients outside regular office visits
- Improving diagnosis and treatment through real-time assistance with clinical decision-making and diagnosis
- Improving data management
- Expediting financial transactions by making it easy for patients to pay for their care and the physician to receive the payment
- To prevent fraud and abuse by verifying medical product, verifying patient identity, tracking human resources and verifying financial transactions

This paper is a contribution towards South Africa's NHI strategy. The paper proposes the adoption of a subset of ICTs that is referred to as the internet of things (IoT) technologies to improve the performance of South Africa's health sector. It reports on a limited number of examples of IoT applications in an effort to prove the potential of IoT technologies as an enabler to an improved health service sector. Section 2 is on the status of ehealth in South Africa. Section 3 is on the problem statement, while section 4 introduces the IoT concept. Section 5 identifies the various IoT applications and section 6 is on the discussions. Section 7 is the conclusion.

2. THE STATUS OF EHEALTH IN SOUTH AFRICA

South Africa, like most African countries has limited health information systems infrastructure. Some health information system components are implemented on an ad-hoc, piecemeal basis and are designed to solve specific problems. Little attention is paid to how these components can be integrated into a national health information system (Moodley, 2008). In a survey of ehealth readiness of hospitals in the North West province of South Africa, (Coleman, 2008) concluded that urban hospitals in South Africa have more ICT equipment than rural hospitals. Internet connection is more reliable in terms of connectivity and speed in urban hospitals. In rural hospitals however, the connectivity and speed of Internet services are affected by poor telephone lines and interruption of electricity power supply. The average ratio of computers to doctors in rural hospitals is 1:3 while it is 1:2 in urban hospitals. However, doctors do not use computers for their clinical duties but for searching for information and sending emails. Computers are used by staff for capturing patients' demographic information and revenue collection. There is no patient ehealth record system, econsulation, eprescription, ereferral and etraining in both urban and rural hospitals in the North West province. The ICT systems are not integrated to work together within and across hospitals to allow healthcare professionals to gain benefits of ehealth solutions and applications. This means that the ehealth maturity curve is at zero level. This is a picture that is repeated all over South Africa.

Historically, health information systems in South Africa have been characterized by fragmentation and a lack of coordination, prevalence of manual systems and a lack of automation, and where automation has existed, a lack of interoperability between different systems. There are efforts towards the establishment of a National Normative Standards Framework for ehealth, thereby ensuring interoperability of health information systems. The standards fall into categories of identifier standards, electronic health records standards, health smart cards standards, messaging standards, structure and content standards, terminology and classification standards and security and access control standards.

Service delivery such as the quality of healthcare in rural South Africa is fraught with deep-rooted challenges, many of which entail access problems emanating from remoteness and spatial dispersion of rural communities. ICTs can strengthen the decentralised healthcare system to address issues of power management and functions of healthcare and to address healthcare backlogs. For example, HBC ICT system (Chakwizira, 2010) is used by the HBC organization and clinics to monitor home-based patients in the area of Leroro, Enhlanzeni District in Mpumalanga. USSD technology enables mobile phones in the hands of caregivers to send data from a predefined menu system by dialing a dedicated number that is linked to the menu system and selecting options within the menu. The data on the USSD is then routed via WASP (wireless access protocol) and stored on a remote database that is accessible to doctors on the web via an internet connection. Although the USSD system is not two-way (i.e. it cannot respond directly to the sender), it can identify the information and credentials of the sender through the logged data, which normally contains the sender's mobile number, time and date of the sent data.

According to (Mars, 2008) only a third of South Africa's provincial hospitals have some form of functional electronic medical record (EMR) system and the several systems that are in place are not interoperable. The commercial EMR market in South Africa is dominated by Meditech, Medicom and Clinicom. In the Free State Province, for example, Meditech has an integrated patient management system implemented across the province. The application links to the national health laboratory services information management system. The Inkosi Albert Luthuli Central Hospital in Durban is a paper-less hospital, meaning everything is digital. The National Department of Health (NDOH)'s Electronic Health Record system eHR.za is meant to create an electronic health record system in South Africa. The Patient Administration and Billing (PAAB) system developed by the NDOH has also been implemented in a few sites although it does not offer the same functionality as the commercial applications. PADS is another web-based patient registration and billing system, developed in-house in the Free State province.

Public health informatics and telemedicine in South Africa are coordinated by the National Department of Health (NDOH). The departments of health in each of the 9 provinces are responsible for individual health information systems and telemedicine in their province. The NDOH coordinates ehealth through the Directorate of ICT and the National Health Information System of South Africa. The NDOH has implemented several public health information systems and the National Electronic TB register. More recently the NDOH formulated an ehealth strategy for South Africa (eHealth strategy for South Africa, 2012).

3. METHODOLOGY AND PROBLEM STATEMENT

The health sector in South Africa is struggling to meet the demands of a growing population for quality service delivery. The need therefore arises to come up with the way forward to enhance health delivery. This paper proposes the adoption of ICTs into health delivery and in particular a subset of ICTs that is referred to as IoT. The question that this paper answers is: "What role can IoT play in improving the delivery of health services in South Africa". The approach that is used in this paper is the identification of various IoT applications that can be adopted in the various domains of health services by drawing from the international landscape.

The objectives of the paper are:

- To show the advantages that the adoption of IoT can bring to South Africa's health sector
- To showcase the potential role that IoT applications can contribute to health service delivery in South Africa
- To influence South Africa's policy on the adoption of IoT in health services delivery

Various domains of the South African health services sector were identified from the provincial health departments and national health department websites. These domains were categorised under ambient-assisted living for the aged, chronic medication management, telemedicine, disease surveillance, oral health, baby care, sport and fitness, emergency services, community and home-based care, mental health, nutrition, occupational health, environmental health, heart disease, HIV/AIDS management, diabetes management and health education. For each of these domains a document review and internet search were conducted to reveal the various IoT applications, as reflected in the sections below.

4. THE INTERNET OF THINGS CONCEPT

The basic concept of the internet of things is the pervasive presence around a variety of things or objects such as radio frequency identifiers (RFID), tags, sensors, actuators, mobile phones, etc. – which are able to interact with each other and cooperate with their neighbours to reach common goals (Atzori, 2010). CASAGRAS defines the IoT as (Casagras, 2011): "A global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor and connection capability as the basis for development of independent federated services and applications. These will be characterised by a high degree of autonomous data capture, event transfer, network connectivity and interoperability".

The following are examples on the applications of IoT in real life. The IoT has many applications in the health sector. These may include wearable staff support systems to locate both doctor and patient in a hospital at any point in time. It may also include IoT-based knowledge systems to detect adverse reaction to drugs in patients. The combination of sensors, Wi-Fi, and other technologies come handy in the monitoring of vital functions of the body such as temperature, blood pressure, heart rate, cholesterol levels and to stimulate the heart muscle in case of a heart attack, etc. Implantable wireless identifiers can be adopted to store health records of people with chronic illnesses. IoT applications have an enormous impact on independent living and support for aging population by detecting daily living and support using wearable and ambient sensors and monitoring chronic disease. Microscopic laser pulses reshape the human cornea to restore perfect vision. Magnetic resonance imagery and computerised axial tomography show intimate details of living tissue, even the human brain. Robotic systems with tiny cameras and instruments perform delicate microsurgeries. Sound waves create three-dimensional images of unborn babies. Artificial hearts made of titanium and plastic sustain the lives of humans after their natural hearts have failed.

In other areas, the emergence of applications of sensor networks has room for adoption by law enforcement, military, border patrol, customs, etc. Vibration sensors distributed along national borders form an effective virtual fence. From real time monitoring of water quality in the ocean through sensors connected to a buoy that sends information via the general packet radio services (GPRS) network, to the monitoring of goods being shipped around the world, and smart power grids that create conditions for more rational production planning and consumption can all be achieved via microchips implanted in objects that communicate with each other. Retailers tag individual objects using radio frequency identifiers (RFID) to solve many problems all at once: accurate inventorying, loss control and the ability to support un-attended walk-through point-of-sale terminals. Innovation in logistics allows improving efficiency of processes. The warehouse becomes completely automated with items being checked in and out and orders automatically passed to suppliers. Items in transit make intelligent decisions on routing based on information received via readers or positioning systems. Utility meters rely on machine-to-machine communications, eliminating the need for a human meter reader and allow fully-automated billing. Weather forecasting infrastructure collaborates with in-ground sensors and irrigation-control software. The irrigation system engages, based on intelligent decisions involving the level of moisture in the soil and the likelihood of precipitation. Roadside sensors detect the flow of cars that have RFID-based toll collection tags and provide traffic reports. A variety of things can report their location to owners including keys, wallets, eyeglasses, jewellery and tools. Some applications related to the IoT aren't new: toll collection tags, security access key cards, devices to track stolen cars and various types of identity tags for retail goods and livestock. Other monitoring and tracking systems have more business uses such as solving or averting problems like sending a cell-phone alert to drivers that traffic is backed up at a particular exit ramp, and increasing efficiencies such as enabling a utility to remotely switch off an electric meter in a just-vacated apartment.

The technologies that support the IoT are what we are traditionally familiar with. These technologies include wireless sensor networks, robotics, vision recognition, smart tags, microcontrollers, mobile devices, near-field communications (NFC), radio frequency identifiers (RFID), bar codes, social networks, EPCglobal networks, Wi-Fi, cloud computing, CoAP, 6LowPAN, geographic information systems (GIS), GPRS, actuators and satellite technologies, to name but a few.

5. TECHNOLOGY DESCRIPTION

For each of ambient-assisted living for the aged, chronic medication management, telemedicine, disease surveillance, oral health, baby care, sport and fitness, emergency services, community and home-based care, mental health, nutrition, occupational health, environmental health, heart disease and diabetes management, potential applications of the internet of things are identified.

5.1 Ambient-assisted living

The population of elderly people is increasing as people live longer. As such, cost-effective solutions to address the needs of the elderly need to be put in place – to construct safe environments and help them maintain independent living. Ambient-assisted living extends the time older people can live in their home environment by increasing their autonomy and assisting them carry out activities of daily living through the provision of remote services including care services. Most efforts are based on developing pervasive devices to construct a safe environment.

CAALYX-MV (Sama, 2012) is a platform that supports ambient-assisted living. It interfaces different communication and health message exchange standards. It enables the addition of devices from different manufacturers. It also uses open standard protocols. The Home System includes all devices at a patient's home including medical sensors. The mobile system contains a mobile phone and a garment comprising wearable body sensors. Temperature, heart rate, smart textile devices that monitor respiratory rate, bed sensors, smoke detectors and flood sensors all make up part of the wearable body sensor system. Data from different sensors is aggregated and triggers alerts if it is outside the norm. The Home System communicates using CWMP protocol defined in the Broadband Forum's TR-069, which is the de-facto remote management protocol used by telecom operators. The physicians contact can contact patients through videoconferencing.

CONFIDENCE (Lustrek, 2009) is a ubiquitous care system to support independent living. CONFIDENCE system will unobtrusively monitor the user in order to detect health problems such as falls and diseases. It reconstructs the user's posture and movement, recognises abnormal situations and raises an alarm if a critical situation such as a fall is detected. CONFIDENCE system consists of a small base station, a small portable device and several tags. The base station determines the 3D location of each tag in the home using radio technology. Tags are attached to the user in the form of bracelets, necklaces or sewn into the clothes. Accelerometers and gyroscopes combined with threshold algorithms raise an alarm if a certain acceleration or velocity threshold is reached.

5.2 Chronic medication management

Compliance to chronic medication describes the degree to which a patient follows medical advice. A lack of patient's compliance with regards to their medication can have devastating, or even fatal consequences. Non-compliance also drives up healthcare costs when the same non-compliant individuals have to be admitted to hospitals. The medication should be authentic and also taken at the right times.

Counterfeiting of medicine is quite rampant. There is a need therefore to guarantee the quality of medicines' manufacturing processes as well as its distribution processes. Insufficient information transmission capability among the supply chain parties results in counterfeit goods entering the market. To enhance the information transmission capability, auto-identification technologies serve as a promising tool in visualising information between enterprises in the supply chain. RFID is adopted to track better and trace the product movement. Integrating RFID and EPC technologies enables automatic information acquisition and effective information sharing in the supply chain. The mobile EPC-RFID based self-evaluation system (MESS) (Kwok, 2010) visualises the RFID data transaction associated with EPCglobal network. EPC is a collection of interrelated standards for hardware, software and data interfaces. All EPC are shared and transmitted under the umbrella of EPCglobal network. Therefore when applied to supply chain, RFID can be deployed to track mobile equipment and movable assets and even combat counterfeit problems encountered in product transmission. Visualising the supply chain information, parties within the chain can share and access the product movement information for improving their responsiveness, planning, decision-making and quality of products.

CorrectoSpecto is a system that combines optical markers, software subsystems, web cameras and a medicine cabinet to remotely monitor and control a patient's access to prescribed medication. A facial recognition subsystem controls access to the contents of the medicine cabinet. A numeric keypad and one-time password subsystem serves as an alternative access control mechanism. An optical-marker recognition-and-tracking subsystem provides information on the medicine containers manipulated by the user (Smith, 2012).

Philips Medication Dispensing Service makes it easy to know what medication to take at what time. The patient's medication is put into individual cups and loaded into a dispenser. The medication schedule is provided to Philips Lifeline and it will program the dispenser. The patient presses the button when they hear the reminder and it dispenses the loaded medication at the programmed time. The dispenser is connected to the patient's mobile, so that should they miss a dose the dispenser can contact them or another family member.

Glowcaps are special prescription bottles to improve compliance to medicine regimen. Inside the Glowcap is a wireless chip that enables four services. Collectively, the services help people stick to their prescription regimens. Glowcaps flash and play a ring-tone so that the patient does not forget. They even call the patient's home phone. Glowcaps order refills from the pharmacy. They send weekly email updates to a friend or family member that the patient selects. Each month the Glowcaps send the patient and their doctor a printed report on compliance.

The use of SMS text messaging improves the drug compliance of TB patients undergoing treatment in homes in Capetown, South Africa (Husler, 2005)

5.3 Telemedicine

Telemedicine is defined by WHO (WHO, 2004) as '…the practice of medical care using interactive audio-visual and data communications including medical care delivery, diagnosis, consultation and treatment, as well education and the transfer of medical data". Telemedicine is broadly defined as the use of audio-visual media by medical professionals and patients for the purpose of medical consultation, examination and procedures. A shortage of healthcare workers and a reliable transport infrastructure, means access to healthcare facilities is impeded for some. Telemedicine has the potential to increase access to care for remote populations.

For mobile tele-dermatology, which is screening the skin as an important strategy for a range of illnesses (e.g. leprosy, HIV), in Botswana, lesions are photographed via cell phone and transmitted to a tele-dermatology website where a number of dermatologists evaluate the cases. For tele-radiology, Botswana uses existing mobile infrastructure and email services. Radiography images and a form with clinically-relevant information are emailed from phones using GPRS to an email account shared by radiologists. Radiographers send the radiologists an SMS informing them of the report request and its agency (Littman-Quinn, 2011). For mobile cervical cancer screening in Botswana, nurses send clinical information and photographs in Visual Inspection to more experienced gynaecologists.

Voice-based community-centric mobile services for social development (VOICES) (Boyer, 2011), is an mHealth project funded by the EU. It uses speech technology and mobile phones to improve social development in African countries such as Mali and Senegal in agriculture and health. It provides voice-based interfaces for the illiterate people. In Senegal, the objectives of the project are to investigate how mobile and speech technologies strengthen epidemiological surveillance by strengthening the transmission of epidemiological data between peripheral laboratories and the National Network of Laboratories (RNL), and the capacity of laboratory technicians to detect epidemic diseases. Technicians use the mobile phones to capture and transmit epidemiological data to the RNL through the VOICES platform. The voice interface is based on IVR (interactive Voice System). Head doctors of health centres receive information via SMS. Laboratory technicians' knowledge is developed through vocal quizzes aimed at training them in different topics concerning biomedical analysis and procedures created via the VOICES platform and issued through the Emerginov platform

In Croatia, the Ericsson Mobile Health (Sablic, 2010) is an easy to use system for ECG, spyrometic, oxygen saturation, pulse rate, blood pressure and weight measurements. It enables patients to take the required measurements anytime, anywhere and anyplace, with no need to visit the clinic. Information on results is transmitted via mobile networks. Through a backend application such data are immediately available to authorised medical experts. This remote monitoring is about patients with chronic illness and long-term patients, patients in homecare as well as patients discharged from hospital. The mHealth ecosystem involves many stakeholders like healthcare service providers, health insurance companies, state and local administrations, telecom operators, healthcare players and elderly care/nursing homes

5.4 Disease surveillance

In tracking disease outbreaks, Google Flu Trends follows online behaviour and provides a powerful tool for watching influenza outbreaks. Twitter can track cholera outbreaks quicker than professional disease investigators. HealthMap uses news reports, blogs and online discussions to watch for mentions of disease. HealthMap automatically trolls new sites, eye witness reports, government data, wildlife disease cases to identify new patterns in outbreaks, presenting the results on a clickable map. This is referred to as 'participatory epidemiology". HealthMap has a related mobile application called Outbreaks Near Me, which gives users news about public health around their location and allows them to report information as well.

The Health Mapper Tool (WHO, 2006) is a computerised public health information system for disease surveillance system involving the use of GIS and satellite technology. This PDA-based system combined with GPS has been used by low-level health workers in Zambia and Uganda to collect data on health service availability and for HIV/AIDS prevention data in schools and workplaces within the community.

RFID is a technology that enables automatic identification and data transfer using radio frequencies. In Finland, with the help of RFID technology, real-time monitoring of operational medical activity in a brigade-sized population was achieved (Kesseli, 2010). Each conscript had a personal identifier, which was used to monitor the patient's movement along the medical supply chain; starting from their original unit. Each conscript was identified and data embedded directly into the patient information system. Information on the numbers of casualties and information on operational planning was processed. The technology enabled registering of symptoms and events, allowing symptomatic monitoring of patients in real time. Epidemics could be detected even before the first patient arrives at the medical facility.

5.5 Oral health management

Studies have suggested a relationship between periodontal disease and systemic health issues, including cardiovascular disease, respiratory illness, and diabetes and pregnancy complications. Therefore preventive dental care is the best defence. Dental problems should be treated before they become expensive.

In Botswana mobile oral telemedicine provides remote access to oral medicine consultants. Dentists send digital referrals from cell phones over GPRS and these are stored on a secure website for the attention of oral and maxillofacial surgeons. The surgeons respond through smartphones (Littman-Quinn, et. al, 2011).

5.6 Baby care

A healthy child results in a healthy adult. It is important therefore that efforts must be made towards a healthy younger generation. Immunisation strengthens the child's immune system to help fight germs that may cause diseases like polio, measles, hepatitis, diphtheria, tuberculosis and meningitis. Vials can be tracked through RFID tags. Keeping track of temperature in transit, vibration and counterfeit immunisation medication is of vital importance. For easy access to medical advice, a jumpsuit can have sensors embedded into it to check the baby's temperature, heart rate and sound in the stomach.

e-IMCI in rural Tanzania is a tool for diagnosing and treating childhood illness. The personal digital assistant makes its own decisions and will advise what medication is necessary and at what dosage, when treating a child. The software guides the health workers step-by-step through the full IMCI assessment, classification and treatment plan. The system uses mobile technology to store information about each child, including immunisation records and growth history and will prompt the health worker to offer preventative care.

5.7 Sport and fitness

Regular exercise is an important part of a healthy lifestyle. People who lead an active life are less likely to get ill. Exercise reduces the risk of heart disease and stroke, reduces the risk of certain cancers, prevents diabetes, prevents mental illness and manages weight. The Endomondo Sports Tracker is an Android application for runners, cyclists, joggers, roller skaters and people who walk from time to time. It helps keep track of their time, distance, speed and altitude and keeps a history of their workouts. It also integrates Google Maps.

CardioTrainer is a free application for Android smartphones that lets one track and record all of their fitness activities. GPS-tracking enables one to track their work activity and see their route on a map. The pedometer counts the number of steps taken. The user receives real-time voice feedback about distance, time, pace and calories burned. It compares the user to the other CardioTrainer users around the world and displays the statistics.

5.8 Emergency services

The time between a call for medical assistance and the arrival of emergency service is a life and death situation. An IoT application can be adapted to search for optimal routes for the ambulance, taking into account the effects of traffic in the ambulance running time. With the help of RFID tags in the ambulance and wireless sensor nodes on the roads, the dispatch control centre in the hospital can collect the real-time traffic conditions where wireless sensor nodes are located. The report messages are sent to a control centre. Based on information from the sensor nodes, the control centre forecasts the optimal path to provide the fastest route for the ambulance. In this decision process, the control centre can ignore some information from the nodes, which have a higher traffic jam that average (Wang, 2011).

A location-based transport monitoring system based on M2M and called e-call (e-call, 2012), enables vehicles involved in an accident to automatically alert emergency services to an incident rather than waiting to be discovered, even if passengers are injured. The system in the car establishes a direct link between the occupants and the emergency services so that their condition can be assessed remotely and quickly. In less pressing issues, roadside assistance can be informed immediately of a breakdown with details of the problem so that they can arrive with the right tools.

5.9 Community and health-based care

Community-based care provides quality health services at home and in communities to help restore and maintain people's health standards and way of living by providing services at home. It offers services to people with physical impairment and medication adherence support and counselling to people with chronic diseases. The advantage is that it reduces the burden on informal caregivers, who are family members and friends of those in long-term care. It also serves as a bridge between the hospital and the home, thereby cutting down on costs associated with hospitalisation.

The use of the smart meter infrastructure in the UK as a means to provide home-based patient monitoring (Clarke, 2010) is taking off. The smart meter transmits frequent meter readings to the utility supplier over a digital backhaul network. Such a network is ubiquitous in all homes. This infrastructure suits well in telehealth applications. This, coupled with the power industry choice to use Zigbee as the home wireless network, provides ready-made infrastructure in which telehealth can operate seamlessly. Telehealth-enabled smart meter over the Zigbee network forwards data to the healthcare provider.

The lack of information and resources is a primary cause of problems or delays in providing optimal patient care and contributes to inefficient workflow. The tablet PC supports pen navigation and the capability to write directly on screen and convert to printed text, offers today's mobile care health workers the ability to revolutionise the way they work by making it easy to capture, access and use information wherever the job takes them. Collection of patient data, patient record retrieval, meetings, house calls, wireless interaction among staff and physicians can all be enabled via table PC. Information from several sources can be accessed via wireless connection and also easily accessed during diagnosis and treatment. It facilitates transition to electronic patient records, reduces medical errors and increases productivity. The tablet PC offers one-stop solution for recording information including keyboard, pen and voice input. This mobile PC allows work from anywhere. You can create, edit, organise handwritten notes and drawings that you would normally record on paper into a searchable format. Many third party healthcare applications can be integrated. Healthcare organisations can capture information the first time reducing the time and cost associated with inputting patient data. A tablet PC is a laptop or slate-formed mobile computer that is fitted with a touch-screen or screen that can be controlled with a digital pencil stylus, or via finger touch. End-users can directly key in data on a tablet PC.

A new solution for mobile phone-based data acquisition based on near-field communication (NFC) acts as an intuitive interface between patients and the technical infrastructure of a home monitoring system (Morak, 2008). The NFC-enabled phone has a Java application and a web platform to receive, store and process health parameters. The medical measurement devices have an NFC capability. The software application is able to be launched automatically after bringing the mobile phone close to the NFC-enabled device. Since NFC is compatible to RFID the application behaves analogue after touching an RFID tag or contactless smart card

5.10 Mental health

Mental health treatment needs are often overlooked and frequently misdiagnosed. The internet of things can mitigate in certain circumstances.

Generalised Anxiety Disorder (GAD) is a psychiatric disease characterised by long-lasting anxiety that is not focused on a specific object or situation. Physical (relaxation and controlled breathing), behavioural (visualisation and controlled exposure) and cognitive strategies (challenging negative thoughts) represent a key part of GAD treatment. The EU-funded

INTREPID research project (Pallavicini, 2010) is working on improving the treatment of GAD through the use of biofeedback in an enhanced virtual reality (VR) system used to provide both relaxation and controlled exposure. The patients are made aware of their reactions through the modification of some features of the VR environment in real time. Using mental exercises the patients learn to control their physiological parameters, and while using the feedback provided by the virtual environment, they become able to gauge their success. The experience is strengthened by the use of a mobile phone that allows patients to perform the virtual experience even in outpatient settings, enhancing the patient's ability to deal with their symptoms in real life.

5.11 Nutrition

To ensure a balanced meal a plate can be modified to calculate the nutritional value of food.

New ICT-based approaches for supporting allergy and diet management are set up in the Mobile Expert and Networking Systems for Systematical Analysis of Nutrition-based allergies (MENSSANA) project (Arens-Volland, 2009). A mobile personal allergy assistant (PAA) for keeping diary entries by scanning the EAN barcode of food packages has been developed. By linking the device with a central Electronic Patient Record for Allergies (EPRA), it is possible to give warnings before consumption, if necessary. The treating allergist has access to the electronic food and symptoms diary of the patient to draw conclusions and thus support the diagnostic findings

5.12 Occupational health

The amount of light in the room and ergonomics, posture, overweight, the angle one is looking at monitor and height of desk to the sitting position can all pose threats to occupational health

(Lund, 2012) describes a tool for physical rehabilitation of diverse patients (e.g. disabled children, cardiac and stroke patients) to be used in community-based rehabilitation by community rehabilitation workers, to motivate users and to be robust to power failure in remote areas. It is made up of modular interactive tiles for rehabilitation through playful interactions with technological building blocks. This is drawn by scarce availability of electricity, technology professionals and heath personnel, and skills to maintain equipment in remote areas. The tile can run for 30 hours before recharge, an important long battery life for utilisation in rural areas. Modular tiles are used for feet or hand interaction. The different parameters such as the amount of tiles, arrangement of tiles, the games and the amount of time are parameters which the physiotherapist can fine tune to suit individual patients.

The homecare scenario of SAPHIRE (Nee, 2008) offers a platform for tele-rehabilitation of cardiac patients by providing a modified ergometer bike and a series of wireless sensors (3-lead ECG, SpO2 and blood pressure) to facilitate a safe and supervised training that emulates and continues the exercise experienced in a rehabilitation clinic. The patient communicates with the SAPHIRE system by using the touch screen of a panel PC that has been mounted on the ergometer. The PC also controls the ergometer bike, gathers and analyses sensor data received via Bluetooth, and serves as a gateway between the patient's home and the rehabilitation clinic.

5.13 Environmental health

In Korea, research has been done on smart bins that are equipped with solar panels and batteries. Waste is compressed to a fraction of its original size which allows the bin to hold a lot more that its usual capacity. As it utilises space more efficiently, a smart bin needs to be emptied less often, which reduces the pollution created by garbage trucks which come to collect it. Each bin can be equipped with a 3G transmitter which provides sanitation workers with real-time alert when it is full through a smart phone application that displays its location (Tebay, 2011).

Medical waste disposal bags should be tagged so that they can be located via GPS positioning. If the sensors detected that the tag is located in the wrong place, such as a non-approved dump site, then environmentalists can be alerted by the system and dispatched. The bags can then be removed for proper disposal.

There is mounting evidence that some environmental and climatic factors trigger infectious disease outbreak: for example, increased water temperature favours multiplication of microbial agents, extreme rainfall causes excessive runoff, washing of fecal origin into potable water can cause contamination of water systems. To prevent and predict disease outbreak. Early Warning Systems (EWS) can assist revealing any alarming data or trend change in climatic or environmental factors influencing the presence of pathogens. Currently, satellite-based EWS predict infectious disease – earth observing and meteorological satellites facilitates the construction of databases of clinical and epidemiological data, for accurate predictability (Benito, 2006)

5.14 Heart disease

HeartRate is a simple Android tool to monitor your heart rate. Users put a finger on the camera phone and a few seconds later the monitor will show the heart rate. It has a first aid guide demo and a BKS medical encyclopaedia.

Home monitoring (HM) for pacemaker has been designed for implantable Cardioverter Defibrillator (ICD) and heart failure (CRT) patients. It combines the patient's pacemaker with a cell-phone like device which works on GPS-enabled network and transmits important data of the patient's cardiovascular progress and even the status of the implanted pacemaker's battery, to their doctors, from the source to anywhere in the world ((ICD, 2012), (Collet, 2012)).

A mobile solution makes use of a wearable wireless ECG miniature sensor in combination with a mobile phone. It collects, stores and forwards ECG data to a cardiologist for analysis through a wireless connection such as GPRS, GSM, CDMA or 3G (Galbiati, 2007). Feedback from the healthcare provider is sent directly to the mobile phone of the patient. The mobile phone also keeps a record of registered events, which will be available for future reference.

5.15 Diabetes management

Diabetes is a disease where blood glucose levels are above normal. Environmental factors, physical inactivity and genetic factors are the causes

A personal device has been developed to assist and consider factors in the insulin therapy dosage calculation. The solution is IoT to support a patient's profile management architecture based on personal RFID cards and provide global connectivity between the developed patient's personal device based on 6LowPAN, nurses/physicians desktop application to manage personal health cards, glycemic index information system and patient's web portal (Jara, 2010).

A wireless identifiable device implanted for diabetes monitoring steadily measures blood sugar levels and informs when it is about to reach a critical status via a smart phone equipped with a built-in IoT –communicator that allows it to communicate with any wireless network interphone. The smart phone sets an immediate alarm and audio. The phone can also send an alert to the doctor and the GPS location of the patient in case of emergency. The nearest energy centre is alerted and it dispatches an ambulance (Bui, 2011).

6. DISCUSSIONS

There is room for South Africa to take advantage of the IoT technologies to develop its health services sector. The technologies that support the IoT are what we are generally familiar with, only that in this case they are being integrated to generate more data, ensure there is efficient and intelligent processing of this data and result in a greater impact when such data is analysed. These technologies include wireless sensor networks, robotics, vision recognition, smart tags, microcontrollers, mobile devices, near-field communications, RFIDs, bar codes, social networks, EPCglobal networks, cloud computing, CoAP, 6LowPAN to name but a few. The question therefore is why these technologies should be rebranded the IoT, when they have been in existence in the market for a long time.

IoT is already here, as can be deduced from the health applications that have been identified in this paper. Therefore the role of researchers is to enhance this concept of "an IoT approach" to application development, for the socio-economic benefit to the South African society. The way to go is for South Africa and Africa in general, to join the IoT research bandwagon at its early stages if they are to obtain any benefits.

There is still room in the area of internet of things for further research into low-cost appropriate technologies specifically customised and providing specific functionalities to health operations for the South African environment. These components should be integrated into a national health information system. The national health information system should therefore encompass health record system, ediagnosis, econsultation, eprescrition, ereferral, etraining and telemedicine. The re-skilling of staff to be not only health professionals but people able to use the IoT applications to the benefit of health constitutes an important aspect of this research. This national health information system should cut across all health institutions, making it possible to access patient details from anywhere in the country. The buzz word here is interoperability between both software and hardware components of the health system, generation of data and intelligent decision-making – which is what the internet of things is about. Interoperability can only be made possible in this case through access to broadband and uninterrupted electricity supply to the health institutions. Therefore research on models of broadband access and electricity supply should be put in place. The issues of broadband access and electricity though, not only affect the health sector but other sectors of the economy as well. To create an enabling environment for health, appropriate policies should be in place at both national and provincial levels.

7. CONCLUSION

This paper research has identified potential applications of the IoT in the health sectors that can make a difference to the South African economy. It has shown the benefits that can be derived from IoT by various health sectors of South Africa's economy. These sectors include ambient-assisted living for the aged, chronic medication management, telemedicine, disease surveillance, oral health, baby care, sport and fitness, emergency services, community and home-based care, mental health, nutrition, occupational health, environmental health, heart disease and diabetes management. The study is meant to influence policy on the adoption of IoT in health. The study can also be used by developers of new IoT technologies to build S.A. specific technologies based on the identified. Technology not only automates processes and reduces time to perform tasks, but it also increases performance and efficiency. Integrating various technologies in the IoT for various application domains of service delivery is likely to have a more enhanced impact on the quality of service delivery

8. REFERENCES

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