The Internet of Things in bridging the gap in municipal service delivery in South Africa

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Abstract: There continues to be high expectations of the government from the citizens of South Africa to improve the delivery of services , and hence the need to come up with comprehensive measures to alleviate the problem**.** This paper proposes the adoption of Internet of Things (IoT) technologies in enhancing service delivery in the South African municipalities. The paper is an attempt to influence policy on the potential of IoT to lessen the impact of some of the service delivery hurdles through examples of IoT applications that can make a difference to the South African economy. The paper identifies not only the sectors of the economy that fall under municipal service delivery but also a number IoT of applications that can be of value.

Keywords: Internet of things, municipal service delivery, e-services.

1. Introduction

In South Africa, there continues to be high expectations of government in respect of improved delivery of services and close consultations with the citizens. In this regard there is a need for the government to recognise that the implementation of e-services affords them the opportunity to enhance service delivery to the citizens. The concept of e-service (short for electronic service), represents the utilisation of information and communications technologies (ICTs) in different areas. Chief among the benefits of e-service delivery are efficiency gains. With the advent of the Internet of Things (IoT) technologies the efficiency of service delivery is expected to increase as compared to the traditional modes of delivery (Raunio, 2009).

In the South African constitution, municipalities are mandated with provision of most of the public services to satisfy the basic needs of the citizens. These municipal services range from water supply, sewage collection and disposal, refuse removal, electricity supply, municipal health services, municipal roads, storm water drainage maintenance, street lighting, public education, municipal parks maintenance, recreational areas and right down to disaster recovery management (Municipal service delivery, 2011). These services have a direct/ and or indirect impact on the quality of lives of the people. If, for example, refuse is

not collected regularly, the situation contributes to an environmental health hazard. This may likely cause diseases such as cholera outbreaks and diarrhoea.

The objective of this paper is to showcase how a marriage between the IoT and service delivery can help in improving the quality of service delivery to the citizens hence, sustainable government. This paper is organised as follows: The next section is the problem statement. We explore service delivery and IoT concepts in section three. In the fourth section we explore applications of the IoT that can be adopted in service delivery. The fifth section is on the business benefits of IoT in service delivery, while the last section is a summary of the paper.

2. Problem statement

Most South African citizens are faced daily with problems of lack of access to basic services. Over the past recent years, service delivery protests have become a norm and the reasons for this vary from dissatisfaction with the delivery of basic municipal services such as running water, electricity and toilets, especially in areas of informal settlements, to lack of provision of houses. (Institute for Security Studies, 2009). The need arises therefore to strategise on the way forward to curb this problem. This paper proposes the introduction of e-services into service delivery, and in particular a subset of ICTs that is referred to as the IoT. IoT is about the integration of various traditional ICTs in the production of applications for various domains. ICTs automate processes and lead to improved efficiency and effectiveness. The question that this paper answers is:

" What role can IoT technology play in improving service delivery in South Africa".

The approach that is used in this paper is the identification of the various IoT applications that can be adopted in the various municipal service delivery domains.

3. The Internet of Things and e-services

(Rowley, 2006) defines e-services as "deeds, efforts or performances whose delivery is mediated by information and technology". The three main components of e-services are the service provider, the service receiver and channels of service delivery (i.e. the technology).

(Lu, 2001) on the other hand identifies a number of benefits of e-services as:

- Broadening market reach
- Alternative communication channels to customers
- Increasing services to customers
- Accessing a greater customer base
- Gaining competitive advantage

(Jiang, 2000) came up with a service quality model called SERVQUAL, that is one of the widely used tools for measuring quality of service. The components of the model are:

- Reliability
- Responsiveness
- Assurance
- Tangibles

- Empathy

The Internet of Things (IoT) is what happens when everyday ordinary objects have inter-connected microchips inside them. These microchips help not only keep track of other objects, but many of these devices sense their surrounding and report it to other machines as well as to the humans. Also called M2M, standing for Machine to Machine, Machine to Man, Man to Machine or Machine to Mobile, the IoT intelligently connects humans, devices and systems (Raunio, 2005), (Internet of Things in 2020, 2008).

From real time monitoring of water quality in the ocean through sensors connected to a buoy that sends information via the 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. 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.

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".

4. Applications of the Internet of Things

For each of the service delivery areas of water supply, sewage collection, refuse removal, energy supply, traffic control, tourism, disaster recovery and management, public health services, public safety, road maintenance and public facilities a number of potential IoT applications are identified.

4.1 Water supply

An IoT-based system can enable water suppliers to quickly and efficiently locate leaks in a water network by listening for the noise made by water leaking from pipes. These sensors are powered by batteries and their location identified through GPS. When a leak is detected an alarm transmitting a radio signal is set on. The information is transmitted to an office computer. The data can be displayed on a map, as a satellite image or terrain as a live on-screening tracking. Such a system removes the need for site visits, increases response time and risk to surrounding buildings.

Water meters will communicate directly with providers helping the latter predict the consumption of each household more accurately while at the same time allowing the consumers to intelligently manage the resources they use.

Real-time and continuous monitoring and remote monitoring of water quality is a necessity for environmental protection and the health of the citizens. The quality of the water body in key sections of the main basin is monitored through remote wireless monitoring of the point source and early warnings given and a forecast for major pollution incidents given. Using telemetry and remote control of water plant equipment effectively improves water use efficiency, reduces ecological and health risks caused by deterioration of water quality and leapfrogs development of water plant control technology. Environmental protection departments are better placed in understanding the changes in the water quality of the basement and water treatment process of water plants in a timely manner. Consequently, industrial energy conservation and a low-carbon economy can be promoted.

The system adopts wireless technology and sets distributed wireless monitoring substations in areas with intensive signal acquisition points of the water plant and electric control equipment to monitor the operation of the equipment in the water plant. The signal of on-site monitoring equipment is collected by a multi-data acquisition collecting system after it passes through the signal conditioning circuit and is then sent wirelessly to a wireless monitoring station which in turn sends the signal through wirelessly to an industrial control computer by which the relevant water treatment process monitoring and control is completed. After information processing according to the signal it receives, and based on the current status of the process, the industrial control computer sends control command which is then sent by the wireless master station to the substation. By doing so, the wireless controlled sub-station will control the start and stop of the equipment in the water plant to achieve its overall automatic control. Therefore the system is about wireless automatic monitoring of water quality at different sites, establishing water risk source identification and management systems to forecast and give early warnings against pollution incidents.

4.2 Sewage collection and disposal

Where sanitary wastewater and storm water share the same pipes, when it rains, the systems overflow. Sensors are installed at the sewer system's overflow location. These sensors function to alert the citizens to the state of the sewer systems. A bulb in the home of a citizen receives a signal from a radio transmitter, and the colour of the bulb changes to signal a problem. This smart drainage system senses the water supply and drainage pipelines and facilities. The drainage condition can be monitored around the clock, while systematic analysis of the overflowing and water-logging process is conducted. Monitoring personnel utilise the analyses to remodel the drainage pipelines and avoid possible flooding. In addition, through real-time monitoring, the system can identify the domestic and industrial waste water and discharge them at different times and phases to avoid secondary pollution.

It takes along time for municipalities to respond to burst sewage pipes. Crowd sourcing can be used in such situations. With bills for utilities comes a telephone number showing the relevant department to contact for reporting. The number has a special code for the particular service. The SMS uses free bandwidth of the service provider and can be subsidised for the user or paid for by the municipality. The hot points are reflected on a map in the reporting centre.

4.3 Refuse removal

Smart bins 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 is 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.

4.4 Electricity and gas supply

In the ubiquitous computing world, connections between devices and combinations of gathered data will create a large amount of new interaction possibilities. In the home environment, this network of devices is called the smart home where a lot of objects can produce, send and process data. The road towards a society without energy waste can be made easier thanks to the availability and management of large information on energy consumption in the home. IoT has a major role to play.

Real-time visibility and control of the home appliances from anywhere in the world at anytime is possible where the IoT-based system exists in the "cloud" and part in the home, creating a secure Home Area Network that connects the user to their home, energy and devices. Other devices such as home energy management, heating/cooling control, and smart meters can be deployed on this network. The network itself can be accessed via mobile platforms and personal computers. A web-controlled phone can connect with the home automation controller and the lights turned on or off remotely.

Electrical appliances each have a similar computational capability. They can sense the amount of electricity they consume, how frequently they are used, for how long they are used and at which intensity. This information is sent to a central device that makes smart combinations of the incoming data streams. Alternatively, an energy service platform resides in the cloud and offers real-time and historical analytics about the energy consumption of devices posted to smart phones. This solution incorporates behavioural science knowledge to facilitate energy awareness and decisions for residents. There are multiple ways to show the electricity consumption in the house and these can be: per location, (i.e. comparison between the kitchen and the living room), continuous feed of information on electricity events, e.g., when a particular appliance switched on and off, and/or energy consumed per device. This supports people in decreasing the energy consumption.

A data logger is an interior circuit to the system which is not interfaced to the user. It keeps a history of application usage, e.g. what applications were logged on at any point in time, and what power was consumed. This assists in the event of a dispute with the user by providing a history. The data logger is used precisely for logging data with a geolocation and time stamp for each new data point. History graphs can also be viewed. Technology allows one to interact with, control and monitor any device remotely via the Internet. Module live feeds can be accessed and incorporated into desktop, web and social applications.

Smart meters differ from conventional meters in their ability to continuously measure and record electricity or water consumption in households. In addition, they are connected via a

communications system for supplier metering purposes. On the other hand, real-time energy display devices provide consumption data to consumers and not the supplier. Mobile payment options can then be provided for the consumer to make their payments.

The home thermostat learns from the heating and cooling preferences of the home owner to create a custom heating and cooling schedule. It programs itself on the temperature and learns the homeowner's schedule throughout the week, which means it can turn down heating and cooling when one is not there to save energy. The thermostat can be adjusted remotely via WiFi.

4.5 Traffic and parking control

To avoid physical toll booths on the highways where each vehicle will stop and pay, which can also worsen congestion problems, e-tolling is used. RFID is the technology used to automate toll-taking on the roads. RFID is a technology that uses radio waves to transfer data from an electronic tag, called an RFID tag, attached to an object through a reader for the purpose of identifying and tracking the object. Drivers are given a plastic card with an RFID chip inside allowing them to drive through tool gates without stopping. The plastic card hooks up to the user's account and keeps a set balance. It is almost a prepaid debit card that refills itself based on usage and a low-balance level.

Crowd sourcing can be adopted for monitoring traffic jams. Motorists send information via twitter on areas where there are traffic jams. This information is captured by a central server, and gives a visual picture of the state of affairs via Google maps. Alternatively drivers who have intelligent computer applications on the cell phones which connect to this system and advises on the best route to work. It also gives live traffic updates. Crowd sourcing can also be used to report potholes on the roads. Google maps gives a visual picture of the state of affairs.

A large percentage of congestion in urban areas is linked to the search for parking spaces. Low-cost sensors can be mounted in parking spaces to feed from existing meters and tying them into a wireless mesh network to draw a real-time picture of spaces available, the cars needing ticketing and how much to charge for parking. The signs would guide motorists to open spaces in guided parking. Parking departments get a view from a Google map of where to send attendants to write tickets for expired meter locations. Looking at the map planners can make decisions about a city's parking infrastructure based on empirical evidence. Based on data, a city can lower and raise parking rates to alleviate congestion or raise revenue; a strategy known as dynamic pricing.

Driving patterns of cars can be tracked by equipping them with position sensors and wireless connection. The information is shared between multiple nodes on a network when those nodes are on the move, drifting in and out of close contact with one another. Equipping cars with positioning and network technology has advantages over traditional traffic-tracking methods. Planners can see traffic tie ups before they even happen. Having knowledge of actual traffic patterns helps urban planners improve their transport infrastructure, from retiming traffic lights to restructuring bus routes

4.6 Tourism

The Urban Memory for tourism is the architectural and urban heritage. To access this urban memory a technology that has memory and sensing abilities has to be in place. In object recognition, by taking a picture of an object using a mobile phone with integrated cameras, users can interact with objects. This picture is converted by the camera to a matrix code. This matrix code interrogates a central databases which has the urban memory of multiple recognition features of the architecture such as local visual features, geometry and GPS location of the architecture. The full details are returned to the user's phone as the matrix from the database . The matrix code from the database can be decoded using open source software sitting on the phone

Mobile IPv6 combined with GPS would have beneficial effects on the tourism industry, rendering real-time situational awareness information to the tourist, highlighting services available within the travellers current locality.

4.7 Disaster recovery management

Dealing with and avoiding risks, preparing for a disaster before it occurs, disaster response as well as supporting and rebuilding society is the duty of disaster management bodies. Every municipality must have a disaster management plan. This plan must set up the structure and mechanism for dealing with disasters and must anticipate future disasters. The role of disaster management is to coordinate the response to disasters and emergencies, ensuring that resources are applied effectively. The activities include coordination of disaster response agencies, the compilation and exercising of contingency plans and disaster management education and training. Potential disaster include storms, flooding, fires, transport accidents, earthquakes, hazardous material spills. The department usually deals with traffic policing, fire brigades, ambulances, and law enforcement agencies

An IoT application to search 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 the 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 will ignore some information from the nodes, which have a higher traffic jam that average.

The early warning network is a multichannel emergency early warning system that provides the ability to instantly and simultaneously broadcast alerts and notifications to individuals, groups, or persons over multiple communication mediums. The system is geographically aware; when people register to receive alerts and notifications their location is fixed via latitude and longitude. This means that those people needing the information get it. Messages can be sent to physical locations (name, street, postal code, town or map location) or any grouping type. Notifications are sent to desktop alerts, mobile phones, landline (text to voice), email and websites

In a fire assistance system, the heat and smoke sensors detect a fire and they communicate the details to a server. The intelligent server functions as a safety monitoring device. It also

controls the topological exit route assistance by communicating with the exits to display the exit route via wireless sensor networks. The server automatically sends messages to the relevant parties. At the same time it communicates with the fire brigade. Fire station alerting systems are used to alert personnel who are based at a fixed facility. Personnel alerting systems are used to alert personnel who are away from their stations.. The fire truck dispatched is GPS guided towards the site. Fire-ground systems support communication at the scene. Most networks are designed so that dedicated channels or talk groups are available for fire-ground and tactical communications.

A location-based transport monitoring system 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

4.8 Public health services

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.

In healthcare, sensors and data links offer possibilities for monitoring a patient's behaviour and symptoms in real-time and at relatively low cost, allowing physicians to better diagnose disease and prescribe tailored treatment regimens. To protect the safety of the elderly but also around monitoring of the health of the elderly are wrist type blood pressure monitors, hand-held GPS locators which monitor their physical condition anytime anywhere but also track their activities. The smart toilet will monitor the elderly's urine and faeces and send data to their personal health records or alert authority in case of any deviation from the norm. Intelligent presence/motion sensors deployed throughout the home learn the occupant's behaviour and notify the care giver when the daily pattern is broken.

Traditional telemedicine has relied on a problematic network connection schemes: dial-up phone, USB cable into PC and then to the Internet. Wirelessly connected health monitoring devices send their readings to the Internet without connecting a cable. This practice results in the development of positive health The medicine cabinet is an intelligent cabinet with a umber of functions; is a tool for the elderly and impaired to manage their self care with the need for extra support for medical intake. The system keeps track of medication, and sends notifications when the user or the mobile health care service needs to refill medicines.

To reduce time spent queuing and queues at clinic, a mobile health platform for appointment services can be put in place. Customers can pay with mobile handsets when they make an appointment. They can then print out their appointments at self-service terminals in the hospital before they attend the appointment

4.9 Public safety

By scanning on the bar code of a driver's licence, motor car licence or liquor licence, its validity can be automatically verified. Information is transmitted wirelessly to a central

database, for verification and response obtained on the same device. This will cut down on accidents due to unlicensed motorists, unauthorised liquor outlets which are normally the hub of crime and car jacking.

IoT-based testing of public transport comes in handy in the reduction of car accidents. Instruments to measure tyre pressure and strength of brakes automatically.

The establishment of a mesh of street lights, will ensure that when one of the lights is off the mesh connects wirelessly to the control centre to alert staff on the problem, rather than rely on power line transmission. Alternatively the working light takes over the functionality of the one that is off.

4.10 Municipal roads maintenance and storm water drainage

Smart roads, are roads that are capable of communicating with the motorist. Sensors are placed in hotspots such as high bends to transmit signals to the drivers before they reach such points. These sensors may be placed on street lights and signal transmissions are relayed from each sensor to the next until they get to the receiver. These smart relays are in a mesh therefore.

Smart roads can also be designed to speak to the blind. The camera can be used as a sensing device to collect data, on the state of a collapsed bridge, for example. This data collected is converted to voice through human language technology conversion mechanisms.

Rains can occur unexpectedly and render roads impassable. Therefore sensors that can detect changes in temperature, humidity and cloud changes can be placed on bridges and transmit information on risks of flooding.

4.11 Public facilities and recreation

For bridging the South African cultural heritage with technology, museums can form e-museum networks where South African museums share their collections and enable tourists to search for data across all participating collections from any access point in the network. This can be done from paid kiosks in the municipalities or from web-sites they can subscribe to in order to generate income for the municipalities. The digital content should be 3D images to enable virtual tours of the museums and online exhibitions.

Self service is the practice of serving one-self when purchasing. A machine resides on each table in a restaurant and allows guests to display menu items and also make payments via credit cards. Credit card thefts predominantly occur in restaurants, hence paying at one's able reduces the risk. The menus are programmed according to the time of day, meaning that items only served at breakfast will not appear during lunch. Once payment has been made patrons can then collect their orders. This avoids long waiting queues.

Maps showing various tourist sites, recreational facilities can be made available via mobile phones and can be interrogated for directions to these various facilities and what the facilities offer. The e-municipality/recreation service is used to browse a catalogue of currently available programs and payment made online to reserve exciting activities.

The safety of tourists is of vital importance. A tourist / foreign national e-registration online submission form should be in place to be submitted to a database of tourists by hotels and resorts. This is meant to keep track of the tourist's movements within the municipality for safety. Tourists can also register online for accommodation in tourist venues after an internet search.

4.12 Public education

Public information can be disseminated via public portals. Educational or awareness information can then be accessed in a protected environment such as via kiosks or in public facilities such as libraries or health clinics via video, and even from home via cell phone.

Public billboards on electricity poles can also be another technology that is adopted. Public billboards mounted on trees will be the future. When trees use carbon dioxide for synthesis they give out oxygen. Oxygen supports combustion and hence can be harvested for electricity generation. This is called the green economy. Electronic sensors can also be implanted on trees to relay information.

A "baraza" is a Swahili word for an organised meeting/council with a question and answer service to educate members of the community. Instead of physical meetings of citizens, municipalities can set up "virtual barazas" for public education and communication. The communication can be via cell phone, microphone communication from the municipalities or the Internet.

5. Business benefits of IoT in municipal service delivery

There exists a number of service delivery sectors in which the adoption of IoT will significantly reduce the cost of investment in business. A few examples are listed below. In the agricultural sector farmers wishing to purchase seeds, fertilisers, pesticides and weed suppressors can utilise the IoT opportunities at minimal costs. To study weather and climatic conditions within the region over predicted periods of time, farmers can liaise with meteorological services for data, in order to reduce risks and costs and consequently, increase investment

In the health sector, with IoT, doctors can access remote patients, or patients can remotely access first world treatment administration without having to physically travel to a hospital or clinic at an additional cost. Consequently, patients only pay for treatment fees, while doctors still make their money back since no unnecessary travelling is required.

In the education sector, the IoT can benefit learners in a number of ways including as access to quality education through technology, remote fee payment and remote lesson delivery. Access to many students leads to increased returns to the education service providers.

Small, medium and micro enterprises (SMMEs), such a craft centres, micro-financiers, village kiosks, art centres etc., also stand to benefit from IoT. To the customers there is increased availability of goods and services through the various technologies such as cell

phones, televisions, personal computers, etc. To the sellers, the IoT leads to enhanced access to markets, increased profits and an increase in efficiency of delivery.

To the citizens there is an increased prospect of employment opportunities.

6. Conclusion

This paper shows the potential applications of the IoT in service delivery. 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

7. References

CASAGRAS, RFID and the inclusive model for the Internet of Things report, EU Project Number 216803, pp 16-23, 2011

Human Sciences Resource Council democracy and Governance, 2005, National Study of Service Delivery in District Management Areas (dmas): Study Undertaken for the South African Local Government Association and the Department of Provincial and Local Government, http://www.hsrc.ac.za/research/output/outputDocuments/2982_Makgoba_Nationalstudyofservicedelivery.pdf

Institute for Security Studies, 2009: The Reasons Behind Service Delivery Protests in South Africa, http://www.polity.org.za/article/the-reasons-behind-service-delivery-protests-in-south-africa-2009-08-05

Internet of Things in 2020: Roadmap for the future, Infso D.4 networked enterprises & RFID Infso G.2 Micro and Nanosystems in co-operation with the Working Group RFID of the ETP EPoSS, Version 1.1, 27 May, 2008

Jiang, J.J., Klein, G., Gampton, S.M., 2000, A note on SERVQUAl reliability and validity in information system service quality measurement. Decision Sciences, Atlanta, Vol. 31, Issue 3, pp. 725

Lu, J., 2001, Measuring cost/benefits of e-business applications and customer satisfaction, Proceedings of 2nd International Web Conference, Perth, Australia, 29-30 November, pp. 139-147

Municipal service delivery, Available on http://www.etu.org.za/toolbox/docs/localgov/munservice.html

Raunio, B., The Internet of Things, A report from the November 5, 2009 seminar, .SE:s Internet guide, Nr. 16, - English edition, Version 1.0, Sweden, http://www.internetdagarna.se/program-2009/5-november, 2009

Rowley, J., 2006, An analysis of the e-service literature: towards a research agenda, Internet research, Vol. 16, No. 3