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Adopting the internet of things technologies in environmental management in South Africa

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Abstract. This paper reports on potential applications of IoT technologies that could contribute to sustainable environmental management (EM in South Africa). These technologies have been categorised under environmental quality and protection, natural resource management, oceans and coasts management, climate change mitigation and adaptation, biodiversity, conservation and environmental awareness. A literature review was conducted to identify applications of the IoT at an international level that fall into the categories mentioned above. The research then analysed these applications and suggested applications that can be customised to the South African environment. The purpose of the paper, therefore, is to prove the potential of IoT as a possible contributor to sustainable EM in South Africa. This is in line with South Africa's Department of Environmental Affairs' mission of "creating a prosperous and equitable society that lives in harmony with the environment." The question that this research answers therefore is, "What IoT technologies should be adopted in South Africa to make an impact on sustainable environmental management?"

Keywords: environment, biodiversity, climate change, oceans, internet of things, natural resources.

1. Introduction

The mission of the South African Department of Environmental affairs is to create a prosperous and equitable society that lives in harmony with the environment. Environmental management (EM) through internet of things (IoT) technologies is a promising approach, but has seen little application in South Africa. EM, a term encompassing environmental planning, protection, monitoring, assessment, research, education, conservation and sustainable use of resources, is now acceptable as a major guiding factor for sustainable development. It leads to enhanced environmental protection, efficiency in natural resource management, diminished waste and emissions, mitigating climate change and conservation. The IoT, on the other hand, is what happens when everyday ordinary objects have Internet-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. IoT is likely to have a staggering impact on our daily lives and become an inherent part of areas such as electricity, transportation, industrial control, retail, utilities, management, healthcare, water resource management,.

Environmental degradation is occurring all over the world. It leads to the decline of natural resources and ecosystems. Land degradation, deforestation and desertification pose a growing threat to production and food security. Where water is in short supply and a lack of access to safe drinking water and sanitation, results in a threat of ill-health and life-threatening diseases. Widespread loss of biological diversity is undermining the productive capacity of terrestrial and aquatic ecosystems. This reduces access to essential environmental goods and services, including vital ecological processes such as water purification, nutrient cycling, control of pollution and soil erosion. Environmental degradation exacerbates the frequency and impact of droughts, floods, forest fires and other natural hazards.

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The paper is on identifying potential applications of the IoT in environmental management for the South African economy. It looks at available applications in the international market. Section 2 is an introduction to IoT. Section 3 is on the potential applications of IoT to environmental monitoring in South Africa. Section 4 is on the business benefits of IoT in environment monitoring and Section 5 is the conclusion.

2. The internet of things

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, (Internet of Things in 2020, 2008). Analysts describe two distinct modes of communication in the IoT: thing to person and thing-to-thing communication (Raunio, 2009). Thing-to-person and person-to-thing communications encompass a number of technologies and applications, wherein people interact with things and vice versa, including remote access to objects by humans, and objects that continuously report their status, whereabouts and sensor data. Thing-to thing communications encompasses technologies and applications wherein everyday objects and infrastructure interact with the human. Objects can monitor other objects, take corrective actions and notify or prompt humans as required.

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".

Semantically, the IoT means "A world-wide network of interconnected objects, uniquely addressable, based on standard communication protocols" (Internet of Things in 2020, 2008).

3. Applications of the internet of things in environment monitoring

These applications of IoT can be categorised into four broad categories. These are environmental quality and protection, oceans and coasts, climate change, biodiversity, conservation and environmental awareness.

3.1. Environmental quality and protection management

Environmental quality and protection covers issues of pollution, hazardous waste management, hazardous chemical management, waste disposal management and waste policy and information management.,

Toxic waste is a type of waste that can be hazardous to humans, other living creatures and plants. The various types of waste material that fall under this heading can pollute the environment and threaten life in a number of ways. They can be found not only on land but also in the air and water. Radioactive waste is one type of toxic waste. It is produced as a product of other processes, including, but not limited to those that involve the generation of power. Medical waste is another type of hazardous waste. This includes substances that cannot be disposed out with regular trash, such as blood, body tissues, medical instruments and medical chemicals. The agricultural industry can also be a source of toxic waste, such as when chemical fertilisers and pesticides contaminate not only the soil but groundwater (WiseGeek,2011).

The next paragraphs look at air, noise, waste and water pollution issues.

South Africa has two nuclear reactors at Koeberg that generate 5% of its electricity, given the deep uranium reserves that the country has. As a result there is the potential danger of nuclear radiation and lessons need to be drawn from the Japanese experience. In Japan a nuclear radiation monitoring system uses crowd-sourcing radiation data from Geiger counters to give a national real-time map of radiation data, accessible to everyone via Pachube. Pachube is a data brokerage platform for the IoT, managing millions of data points per day from thousands of individuals, organisations and companies across the world. The platform is designed to allow things to "plug-in" to other things in real-time so that, for example, buildings, weather stations, interactive environments, air quality monitors, networked energy monitors, virtual worlds and mobile sensor devices can all talk and respond to each other in real-time. An open-source customisable mobile application allows users to mash up their current location with radiation data and receive real-time estimates on radiation levels in their immediate vicinity (Crowd-sourced real-time radiation monitoring in Japan, 2011).

At the end of September 2009, there were 9.5 million registered vehicles in South Africa, all contributing to air pollution particularly in urban areas where the vehicle density is high. More cars on the roads means an increase in fuel emissions in the atmosphere. The fact that 80% of all freight in the country is transported by road is also an indication that the road network plays a major role. Lessons can be drawn from the European Union (EU) project RESCATAME. Pervasive air-quality sensors network for an environmentally friendly urban traffic management (RESCATAME) is an EU-funded project to monitor air quality and urban traffic through a Waspmote sensor board. With data collected from sensors across the city, providing full-time geographic coverage at low-cost, municipalities can efficiently achieve a way of better managing urban traffic in major European cities. The Waspmotes measure parameters such as temperature, relative humidity, carbon monoxide, nitrogen dioxide, noise and particles. If any of the 7 parameters goes above the threshold, the system analyses the information and reacts by sending an alarm to a central node. In order to know where the sensor is located each Waspmote integrates a GPS, that delivers accurate information. It is also possible to transmit data via GPRS, as a secondary radio module for better availability and redundancy in situations when it is critical to ensure the reception of the message, like possible fire alarms. The GPRS module is quad-band (it can operate in 4 different bands, meaning it supports any cellular provider), making it able to work all over the world (RESCATAME, 2011).

Pigeonblog provides an alternative way to participate in environmental air pollution data gathering. The project equips urban homing pigeons with GPS-enabled electronic pollution sensing devices capable of sending real-time location-based air pollution and image data to an online mapping/blogging environment (Pigeonblog, 2011).

The wearable Radio Frequency Identifier (RFID) sensor project by the National Institute of Environmental Health Sciences developed sensors that combine RFID tracking with an acute gas-sensing capability, which can detect the presence of potentially harmful chemical agents in the air. Detecting chemical agents in this way could provide more information about the relationship between a person's health and the environment in which a person lives (RFID-configured smell sensors, 2011).

Noise is not only a nuisance but can also be health-threatening resulting in hearing loss, deafness and heart attacks. An example can be drawn from the Dutch. Dutch Geluidsnet specialises in noise pollution monitoring using subsidiary deployments in the Netherlands. It proves the correlation between generated urban noise above accepted regulated standards with local air traffic operations. It has installed a number of unmanned noise meters which continuously transmit their measurements to a central database using Internet connections. These meters are compact, low-cost and low-maintenance and can be positioned in almost any location at ground or roof levels. They operate continuously and transmit their results over the internet to the database (Geluidsnet, 2011).

Cellular phone microphones can be used for sensing ambient noise levels (Masonneuve, 2010), and the accelerometers in PCs and smart phones for sensing seismic events (Cochrane, 2009).

An RFID-enabled garbage collection services can offer an easy and automatic means for weighing on-site storage bins during the curbside collection service. Waste collection trucks are fitted with a scale to weigh the waste bin and the household is identified through an RFID tag on the waste bin. An RFID antennae and reader on the refuse truck reads the tag on the waste container when it is placed on the truck's scale (Abdoli, 2009).

A weight-based pay-as-you-throw system for household waste collection has caused significant increase in household recycling rates in Germany. The RFID-enabled waste-weighing system provides the ability to measure the mass of the waste constituents and identify each waste component with RFID tags on it. RFID tags on each waste component are read simultaneously with the tag on the bin by a collection truck. Usage of this system makes possible the rebates for recycling products. As soon as a recyclable material is put on the bin it can be identified and data relayed through a central system to scrap dealers and other related parties such as internet-based sales services (Abdoli, 2009).

China has come up with a "Sensing China" strategy. In the environmental protection field and overall industrial pollution control system featuring real-time data perception, resource concentration and sharing, system integration as well as effective supervision and decision-making will be established to reduce waste, improve environment and prevent environmental accidents. The specific tasks include intelligent waste discharge and automatic monitoring devices, wireless monitoring for pollution treatment, water quality data monitoring, air monitoring system, and regional ecological monitoring.

SeWatch, a wastewater and sewerage wireless monitoring system provides a system-wide reporting solution for combined sewer overflow and sanitary sewer overflow discharge or overflow. Water level sensors for sewer system manholes relay information to an application running on a PC or server which alerts on computer screen or via SMS about manhole overflow and spill-overs (SeWatch, 2011).

Acid rain is the term for pollution when sulphur and nitrogen dioxides combine with atmospheric moisture to produce highly acidic rain, snow, hail and fog. The acid eats into the stone, brick and metal article and pollutes water resources. Coal in South Africa is rich in sulphur and the power stations in Mpumalanga province could be responsible for acid rain water over other areas of the country. Acid mine drainage (AMD) or acid rock drainage refers to the outflow of acid water from metal or coal mines. However, other areas where the earth has been disturbed e.g. construction sites, transportation corridors, etc may also contribute to acid rock drainage to the environment. Treatment of AMD usually costs more than control. Therefore application of appropriate control measures to the site at an early stage is the most effective way to minimise penetration of air and water through the soil cover. The other solution is draining the mines and converting the acid mine drainage into clean drinking water for use.

In London, IoT enables environment protection departments to understand changes in water quality of a basin and the water treatment process of water plants in a timely manner, promote energy conservation and develop a low-carbon economy. Through distributed wireless monitoring substations, electronic equipment monitors the operation of equipment in the plant. The signal is forwarded wirelessly to a wireless monitoring master station which then sends it to an industrial computer. After processing the data the industrial computer sends back commands which will control the start and stop of equipment in the water plant to achieve its overall automation control. The project is aimed at using the IoT to achieve wireless automatic online monitoring of river quality water in selected sites, establishing water risk source identification and forecasting to give early warning against pollution incidents.

Satellite light radiation can detect the level of pollution of water. It uses the wavelength of pollutants to identify the class of pollutant. An example would be a river source that is contaminated with e-coli bacteria. By sensing the speed of water, IoT models can predict when the polluted water will get to the supply dam. That means measures can then be taken to alert the homes in the vicinity of the supply dam on when they can expect an outbreak of e-coli and take preventive measures.

Rather than concentrating on sensors, Ushahidi is a technology that simplifies volunteering unstructured geo-referenced information through a variety of channels (email, SMS, web, etc). The so-called crowd sourcing allows citizens to record their observations of an event as it is happening. The earthquake in Haiti shared the crowd sourcing approach as an observation and communication platform for crisis. Each report received is linked to additional reports from the same area (Ushahidi, 2011).

South Africa's climate is characterised by severe fluctuations in rainfall. This affects crop production and the economy. The Agricultural Research Council's (ARC) GIS " Umlindi Information system" keeps a watchful eye on agricultural factors and publishes maps on a web site. Acting as a watchman, Umlindi system attempts to inform decision makers of current drought conditions, fire risks and vegetation growth. Using ArcView 3.2 Spatial Analyst, the GIS produces rainfall and crop growth maps. The fire map shows sites where active fires occurred in a 10 day period, and rainfall for a period of 10 days. Vegetation maps are GIS-processed satellite images that show vegetation activity.

3.2. Natural resources management

Natural resources are materials and components that are found within the environment. This includes biotic resources, abiotic resources, and renewable resources. Biotic resources as obtained from the biosphere include forests, animals, birds and fish and fossil fuels such as coal and petroleum. Abiotic resources are land, freshwater, air and heavy metals including gold, copper and iron. Renewable resources include sunlight, air, wind.

South Africa's rhinos are still facing a poaching onslaught, caused by the illegal rhino horn trade. For 2011 alone, the rhino death toll stood at 443. Therefore a system for monitoring rhino herds has to be put in place, to detect their movement and alert the authorities in case there are no detected animal movements for a prolonged period and hence dispatch rapid response. (Juang, 2002) proposed a system for monitoring wild Zebra herds in Kenya game reserve on which the South African rhino monitoring system can be based. The system measures the GPS location of each animal and communicates the information using peer-to-peer short range radios. In addition to the mobile zebra collar nodes, the base node is mobile within the network, receiving information from whichever nodes are nearby through long-distance radio during fixed communication windows.

Five endemic bird areas (EBAs) occur wholly or partly in South Africa, a number equalled in Africa only by Madagascar and which supports 25 restricted-range species. The EBAs by name are Cape Fynbos, South African Forests, Lesotho Highlands, Southern African grasslands, South East African Coast and Karoo Secondary Area. For conservation and support for tourism, an example can be drawn from the eBird application. The eBird application allows the scientist to capture through a mobile device, precise data on bird sighting. The data collected by eBird is both specialised and highly structured, with the main data load consisting of pre-defined species names, counts of individual birds for each of the recorded species, areas of interest and the time span in which sighting was performed (eBird, 2011).

IoT also allows real time detection of animals, for example, during outbreaks of contagious disease, for control, survey and prevention. Livestock would be fitted with RFID chips and RFID readers would be placed at various monitoring spots. It is common for the buffalo which carries foot and mouth disease to venture into the farming areas from the game reserves. It is also common for communally grazed or other animals to venture into game reserves. It may also be required to track animals to avoid such contacts which result in passing on diseases.

Overfishing in South Africa's oceans and dams, for example, can deplete critical food supplies and forever alter the ecosystem. How do we sense and measure fish numbers and where to fish? We do not know where fish are in real-time and where they are likely to be tomorrow currently. IoT can be adapted to measure fish species in real time and collect much needed data.

Overfishing has threatened highly-valued species such as salmon and cod. ThisFish is partnering with a number of conservation groups who have their eye on bad fishing behaviour. A new tagging system traces food back to the fisherman who caught it. ThisFish is a new internet tracking system that allows seafood lovers to trace their dinner back to the fisherman who caught it. When a fish is caught it is tagged and assigned a unique ThisFish code. The fisherman use this code to document their catch at ThisFish. Information detailing the type of fish, where it was caught and when is made available. The online fisherman profiles include vessels and crew information. Customers make informed decisions about the seafood's authenticity, quality and sustainability (ThisFish, 2011).

In Fishpal, at the click of a button, you can see what fish was caught last month, last week and yesterday. This information is fed by fishery owners and looks at species all over the world. It predicts water levels and fish runs more precisely. It shows what attributes affect particular river systems and how the fishery will respond (Fishpal, 2011).

In China, a special syringe is used to inject a microchip into a fish's body, storing information about the chip, that is species, spawning place, weight, features and breeding record. The chip is wirelessly connected to an information system to enable real-time monitoring (Tracing fish, 2011).

Forests cover less than 0.25% of South Africa's surface making this the smallest biome on the subcontinent. Partly because of their rarity, forests are an important tourist attraction in South Africa. The Electronic Design Group at the University of Zaragoza in Spain is developing a wireless sensor system for early forest fire detection (Forest fire detection, 2011), which could also be handy to South Africa, especially the Karoo regions where dry weather increases the risk of fires.

In tropical forests across South America, Africa and East Asia, over a million hardwood tress have had plastic barcodes hammered into them, to help sustainable forestry practices and exportation to other countries, as well as preventing illegal logging of the coveted hardwoods. The local forest managers use hand-held computer devices to scan the tag as soon as the tree is cut, uploading the information via satellite , Wi-Fi or any other internet connection to a secure database. The database tracks tree inventory, and provides reports. Trees can be tracked from the forest all the way through its supply chain to the consumer. Since conservation is a priority in South Africa, such a system can be adopted.

A sensor network to monitor redwood trees was developed by Tolle (Tolle, 2005). Installing nodes through the height of a 70 metre tree, the system measures temperature, relative humidity and solar radiation. The system logs data every 5 minutes and transmits it via GPRS modem to an external computer for processing.

Botanicalls is a plant monitoring system. It has sensor probes, and is placed deep in the soil to measure the amount of moisture present. Readings are sent to a microcontroller built into the unit that translates the data into information that can be sent over the internet through an embedded Ethernet connection. The information is sent to a Twitter account. Twitter sends the plant's information via a message to the user's cell phone (Botanicalls, 2011). During times of drought such a system can be of use in South Africa.

Water scarcity is now the single biggest threat to food production. For agricultural purposes and in an environment where with the advent of climate change results in unpredictable rainfall patterns, automated drip irrigation can be adopted in South Africa. An example can be borrowed from Israel's green deserts. In Israel, drip irrigation, is the crop watering technique that waters only the soil closest to a plant's roots. Linking data on temperature, radiation, humidity and soil water content collected by varied sensors, controls not only where water is released but how much is needed to meet a plant's need for transpiration. Farmers "fertigate" their crops or mix nutrients into the drip irrigation system to get fertiliser where it is most needed (Water: a global innovation outlook report, 2009).

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.

Water management can be about having first hand information on the water situation for quick decision making. An example would be the "virtual" river basin.. The 'virtual' river basin is a web site with real-time presentations of river basins. These river basin web sites, coupled with low-cost automatic control on all major structures, allows for nearly instantaneous decision-making. The ability to see what is happening throughout a river basin and react promptly to changing hydrologic and weather conditions improves the way rivers are operated. Sensors monitor the environment in the river basin and wirelessly feed the information into the website. Mathematical models make calculations of the resultant conditions and the results are visualised on the website. The components of the IoT system are: 1) a comprehensive real-time environmental monitoring system, 2) web displays that provide accurate real-time visualisations of conditions, 3) databases and 4) decision support systems (Berger, 2002).

Just as an example of IoT at play, the Beacon Institute's River and Estuary Observation Network (REON) is a system of sensors and observation platforms that feeds a constant stream of data to scientists and analysts. REON measures and monitors chemical, biological and physical data throughout the Hudson ecosystem using a combination of floating platforms, submerged buoys and semi-autonomous underwater robots. The goal is to be able to understand in real-time, how the river responds to everything, from storms to droughts to human interaction. With that information, a new level of eco-management would be possible. For example, industrial intake from the river could be better planned to coincide with optimal water conditions, like avoiding intake during the spawning season of critical endangered species. If man-made waste was polluting an area used for public drinking supply, appropriate action could be taken (Water: a global innovation outlook report, 2009).

3.3. Oceans and coastal management

Oceans and coastal management is about coastal conservation strategies, coastal pollution management, ocean conservation strategies and biodiversity management. The south African coastline stretches more than 2500 kilometres with the Atlantic Ocean in the West and the Indian Ocean in the East.

There is a strong link between water resources above and below ground. Infiltration is the process by which water gravitates downwards through the soil. Heavy irrigation, fertiliser and pesticide run off from farms pollutes rivers and groundwater. Extraction is removing groundwater in coastal areas, reducing water pressure underground, thus allowing saltwater to intrude and mix with freshwater reserves. Saltwater intrusion is when underground supplies of freshwater in coastal areas are invaded by seawater due to extraction of coastal aquifers. This makes it difficult to purify underground water for human consumption and agriculture. The IoT can be adopted to measure the levels of pollution of underground water in order to inform decisions on soil and chemical usage and extraction.

Carbon dioxide in the atmosphere is sequestered by the oceans raising water acidity levels. Carbon sequestration is the removal and storage of carbon dioxide from the atmosphere through natural or man-made means. Acidification is the lowering of pH levels in the ocean due to uptake of carbon dioxide from the atmosphere. This impacts on marine life. Blanketing the earth with sensors, constantly collecting data on everything from ocean temperature to air quality, the Global Ocean Observing System (GOOS) is part of a multi-country data collection effort involving satellite ocean topography, ships filled with sensors, water temperature buoys and thousands of free-floating sensors bobbing up and down in oceans around the world, collecting data on currents, temperature and salinity.

In South Africa, Marine GIS has been used to offer information about the earth's oceans, seas and watersheds. Near shore and deep water phenomena, such as current, salinity, temperature, biological and ecological mass and density all play an integrated role in offshore and coastal management. Some other areas of marine GIS development include oceanography, coastal zone management, navigation and charts, ocean industries and conservation. Management and remediation decisions about marine fisheries are more easily made using spatial analysis. Geographical representations of fish populations make planning and resource management more accurate (GIS for Africa, 2011).

In an IoT system in Galway Bay, Ireland, data collected from a variety of sources is used to inform host industries, weather data, water data, wave data, tidal data, current data, sea floor mapping and topography. In aquaculture, farmers cultivating shellfish need the information on salinity, temperature, water quality, especially harmful algae that may threaten crop. In commercial fishing, fishing boats are mostly interested in weather and water quality, to better locate catches and ensure safety. In restaurants, fishing boats can communicate with local restaurants to inform them of when they will dock and with what catch. Energy companies are interested in data on the potential energy in the waves. The water safety association can close beaches or alert lifeguards to dangerous water conditions, like jelly fish or rip tides. Controlling the industrial shipping ports of the bay requires real-time information on high tides and flow rates (Water: a global innovation outlook report, 2009)

3.4. Climate change adaptation and mitigation

Severe geophysical or climatic events including earthquakes, volcanic eruptions, landslides, droughts, floods, cyclones and fires that threaten people or property are termed natural hazards. Remote sensing – the art of acquiring information about the earth using remote instruments such as satellites – is inherently useful for disaster management. Satellites offer accurate, frequent and instantaneous data over large areas anywhere in the world. When a disaster strikes, remote sensing is often the only way to view what is happening on the ground. An early warning system consists of an awareness subsystem, forecasting subsystem, warning subsystem and an action subsystem. Awareness is on monitoring the climate conditions. Forecasting is the prediction of what will happen. The warning subsystem provides communication and the action subsystem is on the evacuation.

An early warning system is an orderly structure of either a technical or a biological network of mechanisms that can sense an incoming danger with a purpose of enabling the user to be warned and thereby act according to control or avoid it. A technical warning system refers to man-made sensing devices such as satellites, radar warning, earthquake warning, fire alarm systems and many other tools. Disaster management is a set of activities to reduce risk by reduction of vulnerability of elements at risk, ensuring adequate measures are implemented before disaster strikes and responding efficiently and effectively as possible to disasters when they occur. Vulnerabilities to disaster can be in the form of floods, fires, earthquakes, outbreak of disease, hunger, etc. The following section is on examples of applications that can be adopted by South Africa for disaster management. With climate changes resulting in severe flooding recently in the Mpumalanga and Limpopo provinces, flood alert is a priority for South Africa. The lessons for South Africa come from Italy, Honduras and Central America.

Italy's Piedmont Region Hydrometeorological alert and real-time flood forecasting system produces a daily report of observed and expected meteorological situations, paying attention to precipitation forecast. It issues warnings for flood risk due to prolonged heavy rainfall on floodplains endangering towns and infrastructure in the valleys and lowlands, and local hydrogeological flood risk due to short intense storms on small areas. Data is monitored in real time. Numerical modelling is adopted in forecasting floods.

In the Honduras Flood Alert System, with a sensor network events over large geographic regions of approximately 10,000 km^2 are monitored. A sensor network for flood prediction that withstands river flooding and severe storms causing floods, monitors and communicates over a 10,000 square kilometre basin , predicts floods autonomously and limits costs allowing feasible implementation of the system in a developing country. To predict flooding, a model that requires knowing how much rainfall falls and what the soil's time dependent response to the rainfall is required. A variety of variables contributing to the occurrence of the event are measured. Detection and prediction of river flooding occurs. To cover long range communication links of 25 km the system uses radios of 144MHz. For short range communications links with an 8km range, the system operates within the 900MHz band. The system consists of 4 different regimes of operation: sensing, computation, government and office interface and community interface. The state of the river, soil conditions and meteorological conditions are measured at nodes powered by solar panels. Due to the inability to populate entire areas with sensors and cost limitations, a network consists of nodes to communicate over long distances in the order of 25km (Basha, 2007).

In flash flood early warning systems, environmental data including rainfall and stream flow information is required. The rainfall information comes from in-situ precipitation gauges, radar measurements and satellite estimates. The Central America Flash Flood Guidance System covers 7 countries. Flash flood guidance, which is rainfall required to produce flash flooding is calculated every 6 hours for stream basins from 100km^2 to 300km^2. A physically-based hydrologic model is run every 6 hours to simulate soil moisture for the region and determine flash flood guidance. Graphical and text rainfall, soil moisture, flash flood guidance and flash flood threat products are created and posted to the internet for access, analysis and dissemination to disaster preparedness agencies. Digital spatial databases, real-time remotely sensed on-site precipitation and temperature databases are utilised (Flash flood early warning system reference guide, 2011).

IoT can also predict where a flood can occur. Geographic Information Systems (GIS) is used to analyse the topography of a catchment area and run models to compare the peak discharge against the minimum peak discharge. A difference between the two will spell flooding down river

Scientists from the Urban and Civil Engineering Department at Ibaraki University and the Fukuyama Consultants in Japan are working on wireless sensor integrated circuit (IC) tag to collect and visualise ground environmental information through microscopic vibration and tilt change of ground. This information will be helpful for prevention of disasters in earthquake-prone zones (Saitou, 2010).

The quake warning system in Japan provides seconds of notice. Each seismograph location in Japan is linked to a central computer that detects the weak but fast-moving primary waves that are generated by an earthquake and use them to triangulate the location of the quake and estimate its size. The amount of warning provided depends on the distance from the earthquake's epicentre. Those closest to the source and susceptible to the strongest shaking get little or no warning. The warnings begin to make a difference around 50 to 100 kilometres from the epicentre of strong quake where up to 30 second warning is provided. Warnings come by TV, radio, email and cell phone. High speed trains are brought to a halt and factory production lines stopped.

A Chilean earthquake early warning system has an earthquake detector on an Arduino board. The board is connected to a computer. Instead of the detector ringing, it has been customised to send out a tweet. The detector is also modified to send SMS through internet-to-text service providers.

In the US, the early warning is designed to sense the first pulses of energy after a fault breaks and estimate the magnitude based on limited information. This is possible because of the different speeds at which seismic waves travel. A sprawling web of underground sensors can detect the faster-moving and less-damaging primary or "P" waves before the secondary "S" waves that can cause a building to collapse. A warning is issued ahead of the arrival of the stronger waves. A map on computer the screen lights with red dots, signalling an earthquake has struck. A clock on the screen counts down the seconds until the shock waves arrive. Trains can be slowed and stopped. Air traffic controllers can halt take-offs and landings. Power plants can close valves.

3.5. Biodiversity and conservation and environmental awareness

Biodiversity is the variety of life: the different plants, animals and micro-organisms. It is the degree of variation of life forms within a given ecosystem, biome or entire planet. Biodiversity supports ecosystem services including air quality, climate, water purification, pollination and erosion. Crop diversity aids recovery when the dominant cultivar is attacked by disease or predator. Health risks associated with changes in biodiversity e.g. scarcity of fresh water, distribution of disease vectors as a result of climate change, and availability of food resources. Industries derive raw material from biological materials such as materials, fibres, dyes, rubber, etc.

There is a lack of awareness about woes facing South Africa's biodiversity and what is at stake. There is an unavailability of tools that foster community participation in conservation and get them interested. Also the issue is making biodiversity available. Irrespective, there are lessons to be learnt from other countries.

The project Brahma in India is a robust knowledge base for all kinds of information about diversity. The database pulls in various pieces of information such as binomial classification, habitat, geographical distribution, genomic data, folk medicinal and mythic folklore for every species. The database runs on two entities – species pages and query pages. Through technologies such as Twitter, Facebook, YouTube, etc, awareness is spread about the biodiversity.

The birding and internet site provides extensive information on bird species, photographs, range maps, articles on attracting and feeding birds, home study courses in bird biology and participation in international bird studies. It is a leap beyond the paper-based book for the following reasons:

- You are using a computer with sound capability by offering bird calls you can listen to
- Few sites provide video galleries where you can view birds in motion
- The site offers forums to share experience with other birders and even has experts

There is also cellular and Wi-Fi connection o your PC and any other device.

Biodiversity data surveying works by enabling human support by mobile devices to become one of the contributors for biodiversity occurrence data. Virtual reality-based applications come in two forms. Virtual-reality based applications allow users to navigate into a virtual world without performing any physical motion. Some applications allow users to explore computer generated spaces and interact with other users and things within these spaces without physical motions. Augmented reality applications superimpose the additional information onto the real world (for example seen through cell phone camera or through augmented reality glasses) (Havlik, 2011).

In the early 1990s, the South African government began formulating a long-term strategy aimed at eradicating invading alien plant life. Clearing millions of hectares of land will release four billion cubic metres of water per year, or more that 7% of the country's entire water supply which is currently consumed by alien plants. GIS tools have been developed to manage data efficiently. An alien catchment management system helps managers prioritise areas to be cleared, determine costs and estimate water use of the alien vegetation in a catchment area (GIS for Africa, 2011).

Hydro-electric dams disrupt river ecosystems. How much hydroelectricity can we generate/ should we generate before we disrupt the ecosystem? This is an answer we can obtain through IoT technologies.

4. Conclusion

The research has identified potential IoT applications in environmental monitoring that can be handy to the South African economy. It has shown the business benefits that can be derived by various sectors of EM in South Africa. These sectors are environmental quality and protection, natural resource management, oceans and coast management, climate change mitigation management, and biodiversity management. The study is meant to influence policy on the adoption of IoT in EM. This study can be used by developers of IoT technologies to build new technologies based on the identified. The contribution of this paper is also about showing the marriage between IoT and EM. Technology not only automates processes and reduces time to perform tasks, but it also improves performance and efficiency. Integrating IoT into EM is likely to have a more enhanced impact on EM. This research though documents what is already in the market and not the future technologies that can emanate from these.

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