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Green Computing Trends: Potential Application of Location-based E-Waste Management in African Urban Setup using Green IOT

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ABSTRACT
Waste generation has become one of the worrying global negative trends, with generated figures from various studies showing its adverse impact on human survival. Many pandemics and diverse diseases have been attributed to improper waste disposal. Waste can generally be considered as hazardous or non-hazardous. Waste management in Africa has become a major challenge, and is mostly related to steady increase in population, especially in urban areas. Additional groups of wastes include industrial, municipal, e-waste and bio-medical waste. Increased sale and use of electrical and electronic devices and components with short life span has made e-waste to be a major global concern since it causes harm to human health and environment. Africa is a major recipient of e-waste as well as an upcoming e-waste generator. There is lack of adequate infrastructure and clear action plans by African countries in handling of e-waste. Green computing is an effort to efficiently use computing resources by significantly reducing any negative effect on environment through designing hardware and software that conserves energy in their use. It involves steps taken to manage e-waste using ICT technology such as use of IOT and design of smart bins that provides information related to collection of e-waste. Green IOT is aimed at designing green sensors, green microprocessors, green RFID and other devices that are energy efficient. This paper proposes use of location-based services in management of e-waste in a given African urban setup by applying almost similar strategy employed by marketing companies to communicate with their customers. An urban area is divided into geofenced regions, with citizens being targeted through awareness and alerts related to availability of smart bins at strategically located collection centers. Any person with e-waste will have necessary information about the nearest disposal point where there is a Smart bin. Such bins are located in electrical and electronic retail or repair shops, supermarkets or specific general retail shops. Green ultrasonic sensors will measure the level of e-waste in the smart bin and the information is made available to recycling/refurbishing company so that collection process can be undertaken when they are filled-up. A lock on the bin is triggered and a LED signal starts flashing to indicate it is full. A beep sound on the bin is produced whenever anyone presses the foot pedal to open the bin. The routes used by collection vehicles are based on a predetermined algorithm to minimize emissions.
Keywords — Green computing, Green IOT, Smart Bins, Geofencing, E-waste.

I. INTRODUCTION

Waste is any discarded substance, a raw material that is valuable but wrongly placed [1]. Continuous increase in quantity and complexity of urban waste has become a major concern among the members of the society presently and in the future [2]. According to UN estimates, global yearly collection of solid waste is 11.2 billion tonnes [3].

Waste management is causing Africa to experience increased crises. As much as the measure of waste generated in Africa is small when compared to nations which are developed, waste management in Africa is also causing human health and environmental problems [4]. The waste management problems in Africa is as a result of steady rise in population, mostly in urban areas. Urban growth in the last two decades has increased yearly at the rate of 3.55%, with this rate having potential of holding into 2050. African population in urban areas may grow up to 55.9% of entire population by 2050. Urban growth results in increased waste generation, resulting to low waste collection rate and open dumping. Infrastructural development of waste management in African cities is failing to keep up with the pace [5]. Rapid-urbanization leads to spread of informal settlements, which worsens the situation [6]. Other challenges include low technical knowledge, resource constraints, insufficient awareness, few collection vehicles, infrequent trips per vehicle and failed collection routes plans. Amount of collected waste will only increase by development of better strategies [7].

Waste can be categorized into either hazardous or non-hazardous. Further grouping of wastes include bio-medical waste, municipal waste, industrial waste and electronic waste. One of the waste streams that is growing very fast is E-waste. This is due to exponential growth in the use of computational resources and electronics in this information communication technology era [1]. E-waste is produced when electrical/electronic equipment being used fails to fit its original intended use and purpose, meaning that it has reached its disposal time or end of life [8] [9]. One major problem of disposal of e-waste is discarding it in the same manner like general household waste. There should be awareness on separate classification and disposal of e-waste [10].

E-waste treatment is more complicated than other materials that are discarded. This is because an electronic device has

many different components and hazardous materials that require special treatment since they affect the environment and human health [11]. There is emission of greenhouse gases during the process of removal and subsequent purifying of raw materials obtained from e-waste [12].General effect of e-waste on human health include birth defects, lung cancer, skin ulcers and death due to soil and water contamination [8].

Due to rapid growth in sales and short life spans of electronic products, e-waste stream are rapidly increasing [13]. In 2019, 53.6 million tons of e-waste generation was recorded in the entire world, meaning that each person generated 7 kilograms of e-waste. If there is lack of any action, this quantity is projected to be twofold by 2050. The amount of e-waste that is recycled properly is 17% [14].

Africa is a major recipient of e-waste which have been generated from high-income and advanced countries. It is one of the continents that is a major e-waste dumping ground from such countries [15]. There is struggle in Africa when dealing with e-waste management sustainably, whether they come from elsewhere or are generated locally [16]. The flow of e-waste to Africa and its impact need combined policy framework that will bring different actors locally, nationally, regionally and internationally [17]. There is lack of infrastructure and clear plans of action by governments in Africa on how to handle issues of managing e-waste [18]. Other challenges on e-waste management in Africa include financial limitations, lack of environmental legislation and lack of awareness. Research on e-waste management in Africa, impact, extent and scale is emerging but limited in context [19]. Therefore there is a desperate need of interventions related to e-waste in African countries. Some of the countries are addressing these issues by ratifying Bamako convention including development of some regional interventions. However there is lack of legislation, enforcement and national action [20]. Section 2 of this paper specifies the methodology used in the study. Section 3 contains literature review on green computing, IOT and use of smart bins in waste management, green IOT, and geofencing. Section 4 details the proposed e-waste management system.

II. METHOLOGY

This paper used methodology that is based solely on published literature including conference proceedings, books and journals. Databases that were searched for literature include Google Scholar, Springer, Wiley and Science Direct. Keywords that were searched include ‘Solid waste management’, ‘E-waste management’, ‘Green computing’, ‘Smart bins ’, ‘Green IOT’.

III. LITERATURE REVIEW

A. *Green Computing*

Green computing is use of computer resources in an efficient manner. It involves carrying out computing in an environmental responsible manner aimed at reducing power consumption. It is an effort to minimize the hazardous effect of computing resources on environment by using them properly [21]. It aims at considering eco-friendliness in manufacturing processes, using and disposing of all IT and other related artefacts. [22]. Green computing is a practice that is not only environmentally conscious, but also cost-effective and energy-efficient [23]. Green computing can also be referred as Green Information Technology or Green ICT. Its requirement includes promoting reusability of waste related to information technology and computing devices [24].

Green computing promotes design of information systems and their implementation in a way that supports business processes sustainably. Its adoption enables organization to realistically tackle environmental problems being experienced currently [25]. It can reduce global warming and climate change by potentially supporting reduction of CO2 emissions [26]. It strives to reduce resource consumption, minimise negative impact of technology on environment, and promote the use of technology responsibly and efficiently within the society and organizations [27]. Full integration of Green computing within organization marks the end of implementing information technology that is environmentally sustainable among users. The measure of success of this implementation process is based on management support, expected environmental impact, including involvement of all users [28].

Various green initiatives, policies and ideas have resulted in protection of environment by limiting carbon footprints and curbing wastage through reduction in energy and paper cost [22] [29].

B. *Use of IOT in E-Waste Management*

Various studies have proposed use of IOT in waste management. Majority of these studies aims at tackling general waste management problems without specifying its application in e-waste management. Very few of these studies consider use of Green IOT in this process. Whereas many of these proposed application of IOT does not target specific nations, developing nations lag behind in this intervention due to lack of infrastructure for appropriate e- waste management [18]. This is exacerbated by lack of policies related to Green ICT readiness [30].

However there is huge opportunity in Africa for ICT intervention, to help tackle problems, especially those related to IOT [31]. Mobile phone coverage in Africa is 93%, and therefore there is a potential in Africa to jump into open IOT arena directly [32]. IOT and ICT is increasingly being considered as a tool that is very necessary for development in Africa. Due to ICT and widespread use of smartphone, Africa is growing exponentially. Sensors, mobile phone apps, smart grids, big data and IOT will improve livelihoods in Africa and other parts of the world. [33]. There is a promising future in Africa for IOT due to continuous upgrade of energy capacity and initiatives related to renewable energy [34]. Collection of information by getting data from sensors, edge equipment, devices and networks connected to IOT platforms is aimed at improving efficiency in processes using optimization and automation and at the same time minimizing downtime and increasing productivity [31].

C. *Smart Bins*

Existing trends in waste management lacks sophisticated approach to attain waste management mechanism that is vibrant and effective [35].

Proper disposal of e-waste entails waste collection companies relying on society involvement in the process. There are various methods of collection which include collecting at supermarkets, municipal collection centers, electronic equipment stores, mobile collection and on-demand collection [36].

Use of garbage or dust bins in urban areas has been considered as one of the measures for managing disposal of waste. However, there are various challenges associated with this method. Garbage bins are traditionally emptied at fixed time schedule by garbage collectors. The main limitation is that garbage bins may fill up at varied times, with some bins filling up faster in a given area than in other areas. They overflow before the next collection schedule [35]. Other limitations include lack of proper monitoring of the bins when they are filled and lack of proper management of garbage collection, creating unhygienic atmosphere that affect people [37]. Garbage collection trucks have to visit every bin, leading to long journeys and huge loss of time. In modern world most devices use internet of things concept to be connected together as a result of increased internet growth. [38].

The key concern in collection of e-waste is the collection method and the location of collection centers. Key considerations in collection center evaluation include environmental and cost effectiveness. Lack of effective e-waste collection system makes most of electronic products to be stored at homes. Cost of collection should be minimized since it mostly contributes to overall cost of managing product end of life. Efficiency in collection system is determined by the collection method [13]. Increased ease of accessing collection network determines increase in collection of e-waste [39].

Use of IOT technology in smart solid waste management has replaced traditional waste management processes. This technology is cost-effective, efficient and friendly to the environment [40] [41] [38].

Smart Garbage collector architecture includes a sensor for input data collection. Attached Ultrasonic sensors detects whether dustbin is full or not. Full dustbin is detected by these sensors. A gas sensor detects toxic gases and IR sensor for automatic opening of the dustbin. RFID reader attached to the dustbin allows a person carrying RFID tag to open the dustbin to put the litter [42].

Arduino Uno controller is connected with pressure sensor which detects opening and closing of the bin. Temperature sensor for detect temperature and issue alert in case of fire. Ultrasonic sensor detects level of waste in the dustbin with LoRa being used for connectivity [35].

Information from Ultrasonic sensor used for detecting level of waste in the bin, is fed to a microcontroller (NodeMCU). Wifi-connectivity is used in updating acquired information into a firebase database and to a user simultaneously using android application. SMS alerts are also sent to authorities [38].

Smart bin fullness is detected with ultrasonic sensor, with load sensor used for weighing the garbage. GPS is used for locating the smart bin and a gas sensor for toxic gas detection. All sensors are connected to RISC microprocessor. Cost-effective Wi-Fi modems are used for communication purpose [43].

The measure of waste in the smart bin is done with ultrasonic sensors. Closeness of individuals is detected by IR sensors which triggers DC engine to open the bin cover. These sensors are controlled by Arduino UNO microcontroller with a GPS module for location identification and GSM for transmitting information [44].

Ultrasonic sensors and weight sensor for measuring the volume and weight of the waste consecutively and eventually correlate the gathered data. The data is then sent to a specific android device application through IOT [45]. IOT development can apply Green computing concept in order to solve environmental issues caused by technology using technology itself [46].

The reviewed literature illustrates application of smart bin, with diverse sensors, microcontrollers and connectivity being used in the process. However use of green IOT has not been factored by different researchers. Alerts are also concentrating on collectors of the e-waste but not generators of e-waste. Many of the smart bins lack a locking system that can prevent over-flow. There is also overuse of sensors that can as well increase energy use and e-waste. The proposed system uses energy-efficient sensors and microcontrollers. Citizens are alerted about availability of smart bins in their neighbourhood through location-based technology. The smart bin has locking system that protects against overflow.

D. *Green IOT*

IOT is connection of physical devices among themselves together with other services in a network that are deployed over the internet. These devices include sensors, communication transceivers, actuators, and a processing unit that is computationally constrained [47]. Due to increased use of IOT, there will be rapid creation of e-waste. Top priority should therefore be in building ecologically friendly IOT gadgets [48].

Green IOT is a methodology that is energy proficient and is designed to minimise greenhouse effect or reduce effect of greenhouse of IOT itself. It aims at decreasing energy waste through smart operation of devices. It involves green plan , green removal/reusing, green usage, green creation. It consists of communication technologies such as green WSN, Green cloud computing, green RFID, Green Data Centres and green Machine to Machine [49]. Efficient G-IOT devices can be developed and deployed through conditioning of their software as well as hardware. It is important to select the hardware parts that can allow for their energy efficient optimization and the communication interfaces [36].

E. *Geofencing*

Geofence is a geographical area around which a virtual border is defined. When an individual with a device such as a smartphone enters the area, stays in the area or exits the area,

the device collects geolocation data and triggers an invitation through geofence software that runs within an app [50]. The technology enables research or any other activity that is location-aware to be carried out. When an event is detected by the smartphone, a given action is triggered depending on the geofence application being used. It is used in applications such as market research for collection of feedback about an establishment in real-time [51]. It can assist in creating awareness of services existing in an area that is mostly underserved. Geofencing do not require tracking a location continuously, which can affect privacy, and lead to significant limitation of its applicability. A location is only identified when a device crosses the fence [52].

Due to rise in mobile devices popularity, many establishments have made geofencing a standard practice. Many people have turned out to be active users of mobile technology, at any time and in any place [53][54].

Some hospitality and retail businesses use the technology around their competition such that any potential customer who approaches a boundary receives a push notification that prompts the person to go to the other establishment [53]. Geofencing is also a valuable tool for researchers carrying out intervention research, enabling them to not only study but also implement the interventions in a given geographical areas [55].

There are various positioning technologies such as Global Positioning System (GPS), cellular data, radio frequency identification (RFID) or Wi-Fi that can derive the user location easily. These technologies form the basis for Location-Based Services (LBS) and have become standard features of mobile networks as well as Smartphones [54].

IV. PROPOSED LOCATION-BASED E-WASTE MANAGEMENT USING GREEN IOT

The proposed e-waste management system in an urban set-up involve identification of electronic and electrical equipment (EEE) retail or repair shops and supermarkets where electrical and electronic devices are sold or serviced. General retail shops are identified in areas where EEE retail/repair centers and supermarkets are not available.

The urban area is sub-divided into various sections based on population density. Selection of the outlets that are strategically located based on the proximity to targeted users in a given locality within the city is carried out.

Geo-location of selected outlets is undertaken. They are chosen as potential e-waste collection centers. Smart bins are put in these centers strategically.

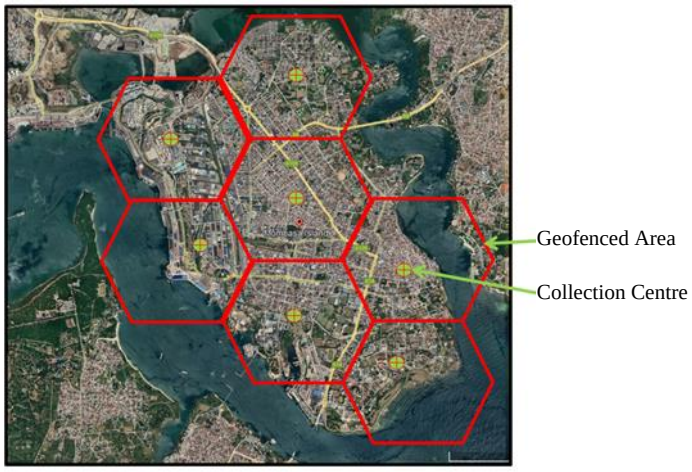
The next step is creating awareness and registration of customers in EEE retail or repair shops and supermarkets with one of the key strategies being to enrol every willing customer who buys or seeks the services in those outlets. The data gathered from all the customers in the different areas of the city is stored in a central database. Geofencing apps is installed or activated in their smartphones to allow e-waste management process to be realized.

These customers start receiving communication related to e-waste management disposal procedures and alerts. Scheduled awareness messages are sent to citizens around a given geofenced area with the information related to location of smart bins. Any movement to another part of the city will trigger an alert to inform about next available location.

The smart bin is composed of a green ultrasonic sensor attached on the inside part of the lid that will detect the level of e-waste. The sensor is connected to a microcontroller that handles processing activities. The e-waste bin will be opened using a foot pedal to reduce number of sensors. This will help in promoting green computing. The devices are powered by batteries stored with energy from a solar panel. The software being used is based on cloud-computing.

Once the smart bin is filled, an alert is sent to e-waste recycling/refurbishing company which will send vehicles to designated collection points using the shortest route algorithm to reduce emissions. It also triggers a locking system in the bin that prevents further disposal of e-waste in the bin so as to prevent any over-flow. A Red LED light on the lid starts flashing to indicate that the bin is full. A beep sound is triggered when anyone presses the foot pedal on the filled bin. Anticipated arrival of collection vehicles in a specific geofenced area triggers alerts to citizens. This enables those with large-sized EEE equipment to move them to their local collection centers for proper disposal by designated e-waste recycling/refurbishing company.

Fig. 1: The map showing proposed geofenced areas and designated collection centres using GPS and cellular data.



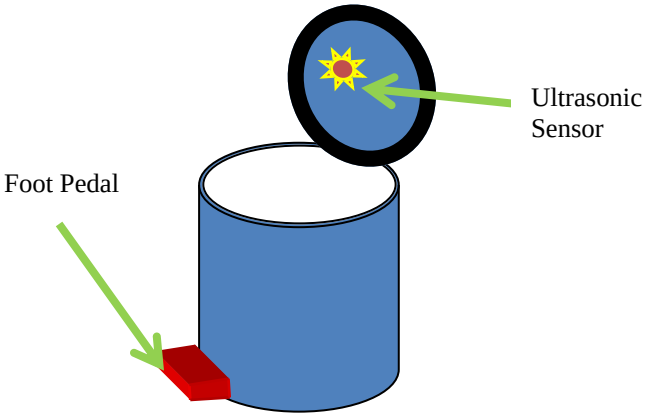


Fig. 2: Smart bin with ultrasonic sensor and a foot pedal.

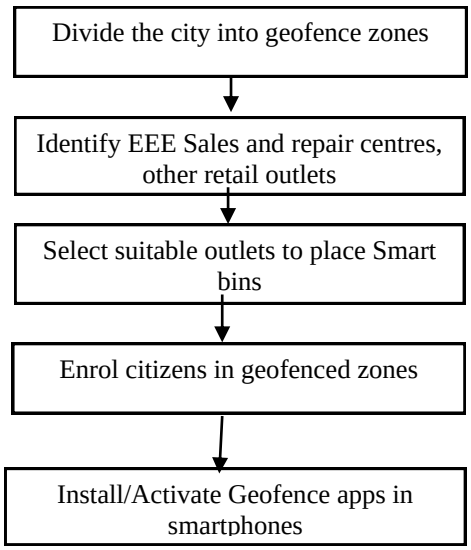


Fig. 3: Steps in registration process

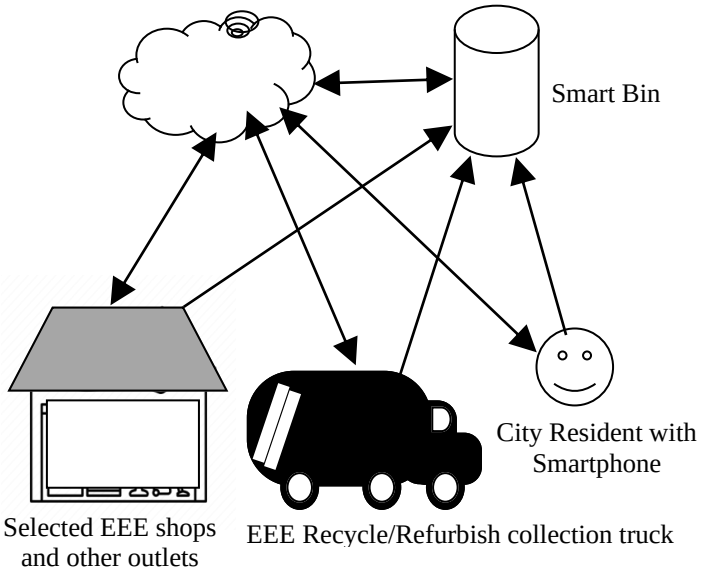


Fig. 4: Proposed Interconnections

V. CONCLUSION

E-waste management necessitates use of diverse methods for its disposal. Application of ICT in this process minimizes the challenges and dangers associated with e-waste. Choice of any method in e-waste management is determined by availability of necessary resources in a given area. One of the key resources in e-waste management is technology being used in a target area. The determination to reach out to customers leads to many organizations using geofencing as marketing tool by sending of customized and personalized alerts enabling potential consumers make informed decision. This technology is being proposed in order to reach consumers who have EEE and components that may need to be properly disposed. With strategically placed smart bins being readily available and within reach, deliberate creation of awareness can remind and encourage such users to be part of e-waste management advocates. By tapping to location-based technology and taking advantage of access to mobile phones and mobility of citizens, e-waste management can be considered as part of citizen lifestyle, such that with time, significant progress will have been made in minimizing negative effect of e-waste in African urban areas.

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