Application of IoT in Zambia's FRA Grain Traceability Process

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Abstract—With advancement in technology, many sectors have seen growth and improvement in service delivery. Today, many areas such as health, transport and logistics, retailing among others have adopted the use of IoT. Agricultural sector has not been left out on the use of IoT. IoT is defined as a network of interconnected devices which can transfer data efficiently without human involvement. In agriculture, IoT can play a big role in increasing productivity and efficient storage management. Other applications include security, real-time object tracking and monitoring. In Zambia however, the agricultural sector through the Food Reserve Agency (FRA) while still underdeveloped, faces many challenges that range from spoilage, infestations, theft at site, spillage and storage among others. As the national food security agency, FRA has for many years been grappling with these challenges. In order to help curb theft problems, this study proposes the adoption of IoT and related technologies. The proposed IoT technologies will be a prototype model that will employ the use of GPS, RFID, PIR, Wireless radio communication module and the GSM technologies. The GPS will be used to monitor and track the location of the vehicle in transit using mobile and web applications. To curb theft of grain at stationary points, the system will use motion sensing through the use of PIR sensors, wireless radio communication module and the GSM/GPRS technologies. Lastly, RFID combined with GPRS and Arduino microcontroller will be responsible for grain bags tallying.

Keywords—FRA, GPS, IOT, RFID

1 Introduction

[1] Notes that the food sector is a challenging domain from a supply chain management perspective as it needs advanced control systems that can deal with perishable products, unpredictable supply variations and stringent food safety and sustainability requirements. With advancement in technology, many sectors have seen growth and improvement in service delivery. Today, many areas such as health, transport and logistics, retailing among others have adopted the use of internet of things (IoT). Agricultural sector has not been left out on this use of IoT. [2] Adds that different tools and

techniques are available for development of farming. According to the UN Food and Agriculture Organization [2], in order to feed the growing population of the Earth, the world will need to produce 70% more food in 2050 than it did in 2006 in [2]. To meet this demand, farmers and agricultural companies are turning to the Internet of Things for analytics and greater production capabilities. Internet of Things (IoT) can play a big role in increasing productivity, obtaining huge global market, idea about recent trends of crops. IoT is a network of interconnected devices which can transfer data efficiently with-out human involvement. Today many agricultural industries turned to adopt IoT technology for smart farming to enhance efficiency, productivity, global market and other features such as minimum human intervention, time and cost etc. The advancement in the technology ensures that the sensors are getting smaller, sophisticated and more economic [2].

In Zambia since its establishment Zambia's Food Reserve Agency (FRA) has been key in ensuring food security for the nation. Grain marketing is a key activity of the Food Reserve Agency [3]. The role of the agency though still remains in ensuring that the nation at large has enough food stored up for the future. The agency has also been key in ensuring that the commodity price for especially maize is regulated so as not to burden the citizens of Zambia with overwhelming costs [4] in [3]. Unfortunately, despite the government of Zambia through FRA ensuring national food security, almost every year huge quantities of food are lost due to many factors such as spoilage, infestations, theft and spillage during transporting [5]. A baseline study carried out by [3]further adds that FRA had challenges such as manual report generation, no connectivity to remote warehouses, inability to track stock on demand, theft, spoilage of stock due to lack of environmental monitoring. With the challenges FRA is currently facing there is therefore need to have a precise, and appropriate technique of tracking of the grain bags, provide remote monitoring on the grain that is stationary and ready for dispatch at the depot and provide electronic tallying of grain bags once moved from one depot to another within the FRA circulation. This shall be done in order to reduce theft of the grain and ensure management and monitoring of the grain that is being transported from one location to another in a credible and efficient manner. Food traceability is nowadays considered as essential and indispensable feature for food safety and protection of consumers [6]. It typically involves the monitoring and recording of the origin and various relevant characteristics of products while the goal is to ensure the quality of food during all the production chain [7].

To address the FRA challenges of grain theft the Internet of Things (IoT) and related technologies of Future Internet have been recognized as suitable approach for grain traceability solutions. This paper therefore seeks to highlight some of the IOT technologies that the proof of concept has proposed to adopt.

2 Internet Of Things (IoT)

The Internet of Things is a novel paradigm shift in IT arena. The phrase "Internet of Things" which is also shortly well known as IoT is coined from the two words i.e. the first word is "Internet" and the second word is "Things" [8] [9]. The Internet is the

global system of interconnected computer networks that use the Internet protocol suite (TCP/IP) to link billions of devices worldwide. Nowadays over 46% of the world population uses the Internet, this is according to [10] in [11]. Internet of Things is defined as "An open and comprehensive network of intelligent objects that have the capacity to auto–organize, share information, data and resources, reacting and acting in face situations and changes in the environment". Internet of Things is one of the latest advances in Information and Communication Technologies, providing global connectivity and management of sensors, devices, users and information [12][14].

2.1 IoT Applications

IoT technology has many applications and can be put to many uses, below is the table showing some possible areas where we can leverage the power of the Internet of Things (IoT) to solve day-to-day problems: among others.

Table 1. IoT Smart Applications And Its Services [15][16][19] [20] [21] [22], [23] [24], [25] [26]

Service Domain	Services
Smart City	City Management, Resource Management, Police Network, Fire Department Network, Transportation Management, Disaster Management.
Smart Agriculture	Area Monitoring, Condition Sensing, Fire Alarm, Trespassing, Food sustainability, Supply chains
Smart Energy & Fuel	Pipeline Monitoring, Tank Monitoring, Power Line Monitoring, Trespassing & Damage Management.
Smart Transportation	Road Condition Monitoring, Traffic Status Monitoring, Traffic Light Control, Navigation Support, Smart Car support, Traffic Information Support, Intelligent Transport System (ITS).

3 Related works

Despite the phenomena being relatively knew it seems to have taken the researchers by storm as quiet a number of papers do exist in literature, we reviewed a number of papers to define the scope and requirement of this work and to also see how IoT is being utilized and what gaps lie there in. According to [27] whose aim was to propose an effective and economical management platform to realize real-time tracking and tracing for prepackaged food supply chain based on Internet of Things (IoT) technologies, and finally ensure a benign and safe food consumption environment. To reduce the implementation cost while realizing fine-grained tracking and tracing, an integrated solution of using both the QR code and radio-frequency identification (RFID) tag was proposed. [28] In the proposed work, the authors used an IoT device which retrieves the location coordinates obtained from the GPS module connected to it and transfers them to Amazon Web Services for further processing and storage. This data is further processed

using Google Maps APIs for real-time display of the vehicle's location. The authors also developed a smartphone application, which can be used to switch ignition of the vehicle on and off and also scream the siren to alert the surroundings. [29] Designed and implemented a real time GPS tracker system using Arduino. When a user sends SMS on the number which is registered on the GPS-GSM shield attached to Arduino then user receives the location coordinates and data will get stored continuously on SD card at the same time. [30] To support sustainable transport systems in South Africa, the author proposed the adoption of internet of things (IoT) technologies. There exist a number of papers regards IoT technologies, however we reviewed a limited of them.

From literature we note that technological novelties are necessary to reduce transaction costs and facilitate the production and consistent supply of top quality, safe and traceable products to meet consumer demands. To implement traceable agricultural supply chains, technological innovations are needed for product identification, process and environmental characterization, information capture, analysis, storage and transmission, as well as overall system integration. Further, from reviewed literature we also note a number of gaps as far as IoT application is concerned as most papers have not applied IoT in grain traceability from source to destination as it is our main concern, despite most papers using IoT for various other services such as smart home, fleet management among others our paper will adopt some of the IoT devices used in the reviewed literature and apply them in our proof of concept.

4 FRA's current stock receipt business process transaction

In a stock receipt business process transaction, FRA buys stock from small scale farmers. FRA then delivers the stock to FRA warehouse depots for storage [5], at the warehouse shed, a depot checker tallies each bag coming from the transporter's truck into the warehouse on the tally sheet. Tallying is done to ensure that the number of bags offloaded from the truck matches the number of bags recorded in the transporters documentation. This whole process is manual as there is no current automated system [5] to support the traceability process, and we therefore propose an IoT business process.

5 Proposed IoT FRA Business Process

We propose an IoT business process that seeks to address some of the gaps reviewed in literature, in a paper presented by Cynthia and Jackson [5], Mulima and Jackson [3], both papers brought out the need for curbing theft of grain in FRA circulation. Therefore our proposed system seeks to address monitoring vehicles responsible for transferring of grain in the FRA circulation in order to curb grain theft using IoT devices. From literature it was also noted that IoT is the future as most of the authors that implemented IoT brought out success stories and as such we also would want to adopt the IoT smartness at FRA in order to improve on service delivery and the same time secure our staple food as food security is very cardinal especially in our developing country Zambia, further the novelty can also be adopted by other business processes in various supply chain activities. Our proposed IoT business process is divided into three, an efficient

control and real-time tracking system needed to improve the effectiveness of grain management by tracking the vehicle carrying grain from the source to the destination, management aspect shall combine Global Positioning System (GPS) with Global System for Mobile Communication (GSM) technologies and to transfer the information via General Packet Radio Service (GPRS) supported by GSM and Arduino UNO R3 microcontroller. The second module is an E-perimeter which shall be used to monitor unauthorized entry in the restricted zone were the grain shall be stocked so that our grain is further secured, this shall be made possible by the adoption of IoT devices called Wireless radio communication module, in our proof of concept prototype we propose to use APC220 and GSM/GPRS to alert management by sending an SMS once motion detection happens with the help of our motion sensors and we propose PIR (passive infrared) because these are mainly for intrusion detection by sensing motion, detects any trespassing that occurs in the range of the motion sensor. The third module shall be responsible for stock counting/tallying, once the grain bags are tagged and ready for dispatch, this module shall be used for tallying so as to compare the number of dispatched bags against the received from one depot to another within the FRA circulation, this shall be achieved by the use of an IoT device called Radio Frequency Identification (RFID) to uniquely identify each bag, additionally we shall use GSM,GPRS modules that are embedded in the SIM808 communication module.

Below are the proposed Algorithms for the three modules:

5.1 Tracking Module

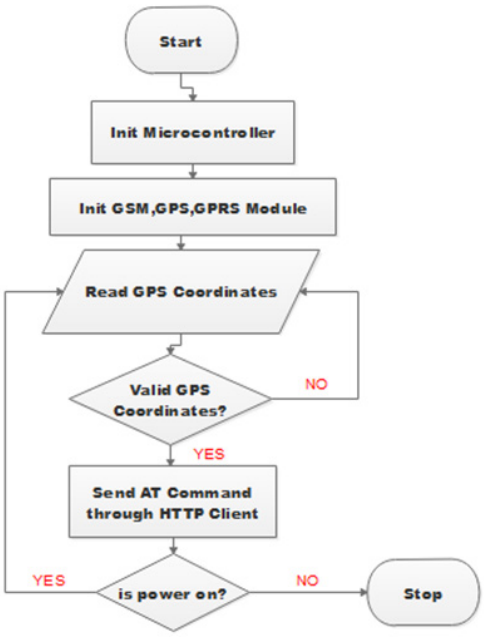

Fig. 1. Proposed Tracking Algorithm (Flow chart)

The flow chart depicts the proposed working of the tracking module. The application shall make use of the Arduino microcontroller that shall be fitted with a GPS, GSM and GPRS module. The microcontroller will communicate with the Sim808 module using AT commands, AT commands are merely instructions that are used to control a modem whose abbreviations stand for Attention. Then an HTTP client (GPRS) will be programmed through the microcontroller that shall utilize a parameterized URL to send GPS data and other related information to the remote server in the cloud using the underlying GPRS data network. Then the web application shall be used to display real-time GPS data as received in form of a binding on the satellite map using google maps.

5.2 RFID stock counting/Tallying module

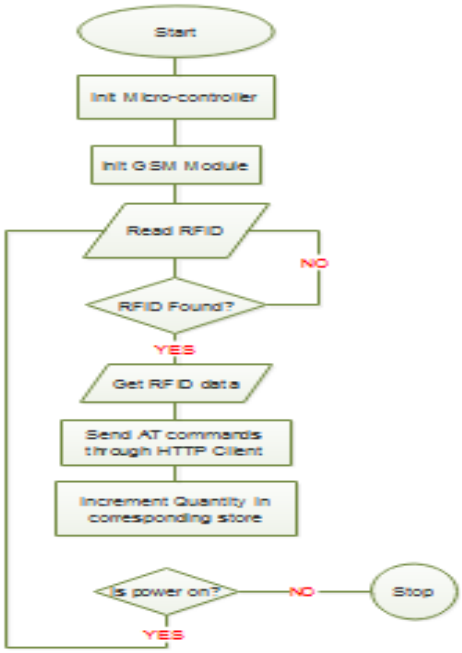

Fig. 2. Proposed Algorithm of the Grain Tallying using RFID

The flow chart above depicts the proposed working of the stock/grain counting module. The application shall make use of the Arduino microcontroller, GSM and GPRS module as well as radio frequency identification (RFID). This RFID module will read RFID tags containing a unique id fitted in the grain bags. At each reading point, we shall have an RFID reader that shall be embedded with a warehouse or depot id, this warehouse id shall be sent along with the tag id through a parameterized URL to the remote server. Then the server side application shall parse and store the received parameters in our remote database. Further, when an RFID tag is read, its id information shall be stored remotely by the application, the designated store id will then be used to increment quantities in the related store.

6 E-Perimeter Security Module

Our e-perimeter security system shall make use of a microcontroller Arduino, GSM/GPRS module, Wireless radio communication module to facilitate communication and lastly the Passive Infrared sensors for motion detection [32]. Below are two flow charts showing the working of the proposed PIR sensors and APC220 wireless radio communication module, which has the transmitter (TX), and receiver (RX) modules.

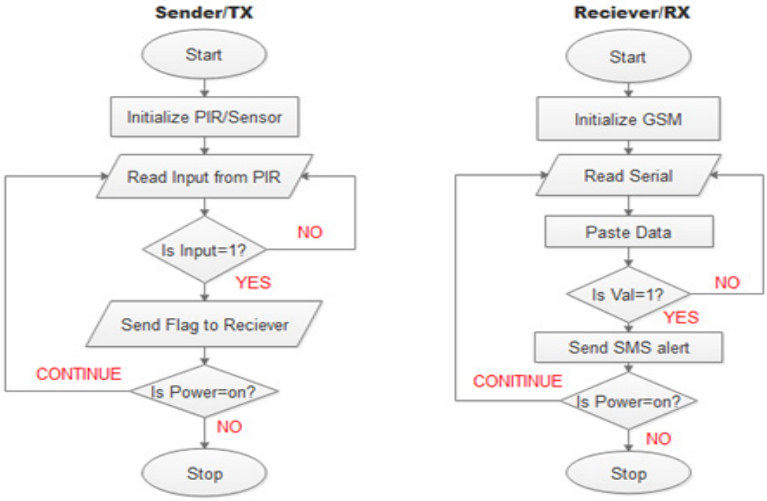

Fig. 3. Proposed Algorithm of the e-perimeter using the PIR and Wireless Radio Communication module APC220.

7 Conclusion And Future Works

In this paper we have proposed the adoption of IoT technologies for tracking vehicle carrying grain in transit that could be used by FRA to curb theft that occurs during grain transportation from one depot to another until the storage facilities within the FRA circulation. IoT adoption in our proof of concept implementation offers a novel approach that incorporates both security from theft of grain in transit within the circulation as well as monitoring the vehicle transferring the grain remotely. We also propose two additional IoT modules in our FRA circulation that shall as well use IoT devices, the named modules are the RFID grain counting and tagging modules and the e-perimeter security system. For the future works, we shall develop a software prototype to test the novelty and thereafter obtain pragmatic data regarding the performance of the system. As part of our future works and proof of concept we seek to develop the prototype for all the three modules and present the results from our implemented software. It is believed that once this technology is adopted, food security will be assured from every point of the FRA satellite Depot to the final storage point.

8 Acknowledgment

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