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ORIGINAL RESEARCH ARTICLE

EXPLOITING IoT and LoRaWAN TECHNOLOGIES FOR EFFECTIVE LIVESTOCK MONITORING IN NIGERIA

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ABSTRACT

With global population predicted to rise continuously (from 7.2 billion to between 9~10 billion people by the year 2050), the world would need to produce almost twice the amount of food as it does today to sustain such human needs. This coupled with recent environmental/climatic changes and urbanization would continue to place enormous burden on the available land, water and energy resources required for both crop and animal farming which is even more critical for developing regions, such as Sub-Saharan Africa due to arid lands, poverty, extreme hunger and endemic diseases. Hence, there is an urgent need for more effective, intensification and industrialization of the region's agricultural sector to improve food supply. Internet-of-things (IoT) is a new and attractive family of technologies capable of modernizing Africa's agricultural sector in line with best practices to improve productivity and minimize cost with reduced energy consumption. This paper intends to kick-start discussions around IoT-based solutions in livestock farming in Nigeria, with a view to addressing issues of cattle rustling as well as improved livestock health-care and better herd management through real-time monitoring. The proposed solution leverages LoRaWAN (Long-range Wireless Access Network) technology, whereby very low-power sensors with extremely long-range are attached to the cattle, and communicate with a gateway for linking to the cloud/satellite network to the internet for data processing and analytics. Such a system is also ideal for rural/remote areas where there is limited or no cellular network and internet coverage, which is where most Nigerian farms/ranches may be located. The paper sheds some light on some real-life use cases, benefits and challenges of deploying such smart systems and provides some recommendations/action points for all relevant stake-holders towards a sustainable implementation in Nigerian agricultural sector

1.0 Introduction

Animal production has been a major source of wealth and employment for numerous people in Nigeria and Africa at large. With growing population figures across the continent, animal production is sure to play a key role in not just ensuring food sufficiency, but also help with accompanying manure for crop production as well as job creation (NRC, 2015). However, increasing land-use pressure and fast depleting agro-hydro-ecological potential due to climatic changes, urbanization and exploding population is seriously threatening the progress of livestock farming in Sub-Saharan Africa, as evidenced by recent herdsman-farmer clashes across Nigeria over land-use for example. To cope with these harsh realities, livestock farming must undergo a modernization process in the African continent, whereby production is maximized, cost minimized, and resources efficiently utilized. Technology, through Internet-of-things (IoT) can help catalyze this modernization in ways traditional and conservative methods can dare not (NRC, 2015); (Malvade et al., 2016); (Mohammed et al., 2017).

The Internet of Things (IoT), sometimes referred to as the Internet of Objects (Ezechina, 2017) or the Internet of Everything (Cisco Connect, 2015), is predicted to have a huge impact on our everyday lives as illustrated in Figure 1. Today, the internet plays a significant role in communication, government, science, education and humanity (Mohammed et al., 2017; Ezechina et al., 2015). It has become clear that the Internet of Things will revolutionize the way we live and relate with objects in our environment (Meraevents, 2018).

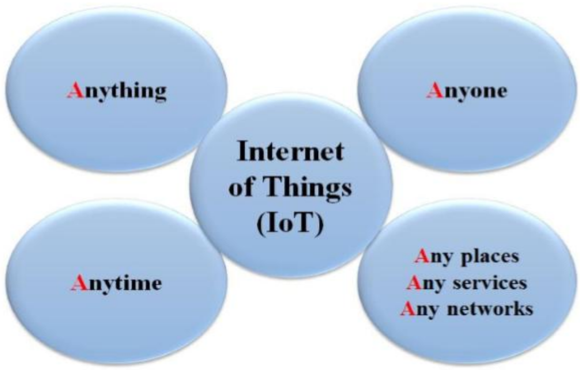

Figure 1: IoT impact on All (Mohammed et al., 2017)

IoT is an intelligent connectivity of physical devices driving massive gains in efficiency, business, growth and quality of life (Cisco Connect, 2015). With the use of IoT, objects are capable of communicating with themselves, making decisions and developing intelligent behaviour based on an aggregate of data supplied by other devices or other services (Ezechina et al., 2015); What the internet of things need, 2014). The IoT network consists of interconnected devices, which can transfer data efficiently without human interference. It involves different building blocks of sensors, network components and other external devices (Malvade et al., 2016). The concept of IoT has found application in various areas such as smart cities, smart farming, smart health, smart buildings, manufacturing, transportation, energy and utility, to mention but a few (Mohammed et al., 2017).

By 2020, it is estimated that about 50 billion things will be connected electronically by the internet (Cisco Connect, 2015; Gubbia et al., 2013). Figure 2 depicts the growth of things connected to the internet from 1988 to forecast 2020. IoT is set to provide the technology for smart actions for machines to be able to communicate with another with vast streams of information (Kejriwal et al., 2016).

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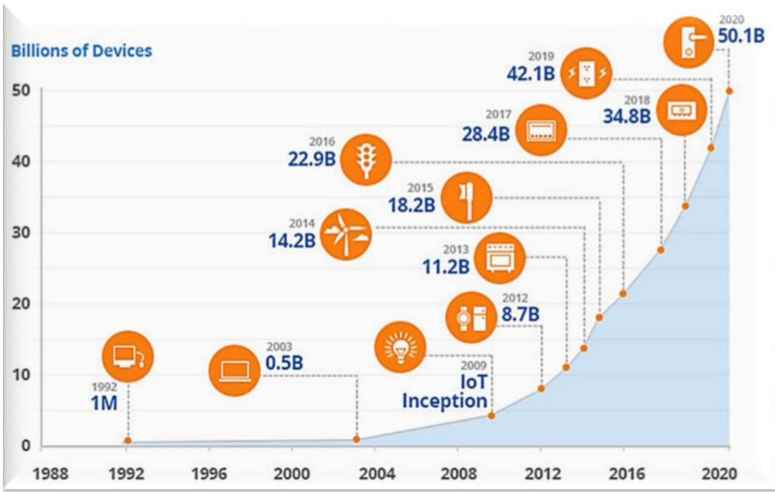

Figure 2: Likely growth in IoT (Mohammed et al., 2017)

1.1 Livestock farming in sub-Saharan Africa:

Livestock Farming constitutes a key component of the agricultural economy, especially in developing nations – food, manure, savings mechanism, contribution to GDP and so much more. It represents a critical socio-cultural aspect for millions of rural farmers for whom animal ownership directly relates to financial security, social standing as well as guaranteed food security in Africa.

However, Sub-Saharan Africa contributes among the lowest in Animal production globally as shown in Figure 3. Ensuring greater productivity in the livestock sector depends on sustainable development efforts that provide farmers and pastoralists with access to technology, training, and resources.

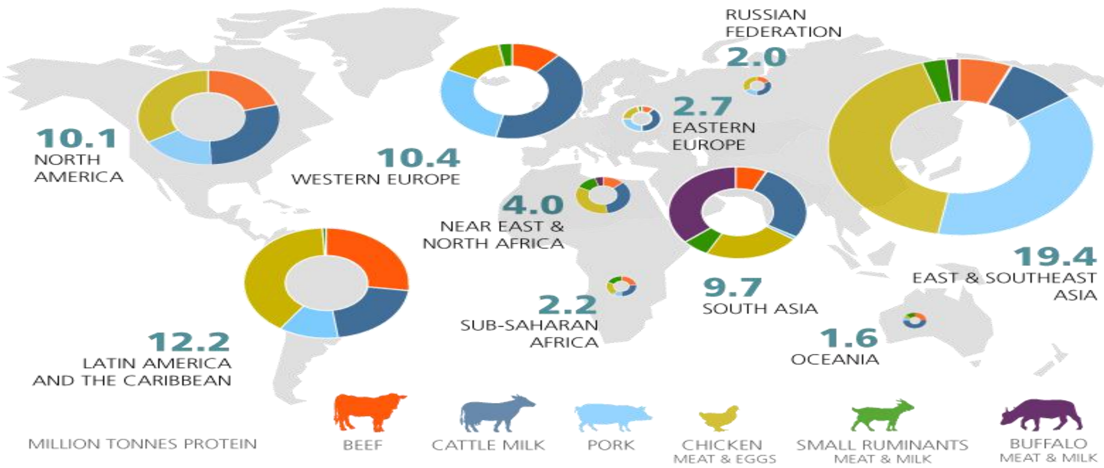

Figure 3: Global Livestock Productivity (FAO, 2018)

The aim of this paper is to present the application and benefits of IoT in agriculture, specifically livestock monitoring, and kick-start discussions around development of feasible models for implementation in Nigeria. Some lessons learned from other existing models are presented as well as recommendations going forward considering the unique Nigerian environment.

The rest of the paper is structured as follows: Section 2 highlights some related works on use of IoT for Livestock Farming, while section 3 presents the architectural model proposed in this paper. Section 4 discusses major benefits of such systems and also enumerates some challenges for practical implementation in Nigeria. In section 5, some key recommendations are provided and the paper is finally concluded in section 6.

2. Related Studies

2.1 Internet of Things in Livestock Monitoring

The world's population is estimated to be about 9.7 billion in 2050 (Mohammed et al., 2017; Elijah et al., 2016). This places a high demand on livestock farming. There is a need for the agricultural industry to rely on technology and innovation to bring about better yields with the most efficient use of limited resources (LinkLabs, 2016). As a result, the growth in technological advancements in farming has become more popular and significant in today's world (Xiaohui et al., 2014). Solutions have been proposed to meet such agricultural challenges of the future today. One of such solutions is the use of Internet of Things (IOT) in the farming of livestock (Elijah et al., 2016; Xiaohui , 2014).

The application of IoT in livestock monitoring is about empowering the livestock owners with the tools and devices that seamlessly integrate product and knowledge services to enhance efficiency, productivity in the global market, save time and cost with reduced human presence (Elijah et al., 2016; LinkLabs, 2016). The farmer can monitor the entire condition without their physical presence. The use of IoT in livestock farming is a field of precision agriculture that uses analytic measurements to optimize farming decisions.

With IoT sensors attached to cattle, farmers can easily locate livestock in the field, know their health state, determine when they are ready for reproduction and monitor milking frequency through the use of a smartphone or a computer. For instance, the identification of cow estrus which is critical to milk yields. Normally, a farmer needs to spend 20–30 min each time, four to five times a day in the stables to check if a cow is in heat, which is a sign of estrus. However, over 60% of estrus cases happen at night when the farmer is asleep (Anderson, 2016). Another example is the monitoring of cattle lameness that has a large impact on a cow's performance in terms of yield, fertility, and longevity (Van Metre, 2005).

In general, the IOT paradigm can help livestock farming or ranching to improve the productivity of water, energy, food, and other resources use, while maintaining the well-being of animals. It also helps farmers to make lists, prepare reports, sort cows by category, and track each animal's overall lifetime (Anderson, 2016; Van Metre, 2005).

2.2 Brief Insight on LoRA and LoRaWAN Technology

LoRa (short of Long Range) is a long-range, low-data rate, low power wireless technology platform developed by Semtech Corporation, which utilizes unlicensed radio spectrum in the industrial, scientific, and medical radio band (ISM band), and is fast becoming the de facto technology for Internet of Things (IoT) Networks. LoRa aims to eliminate repeaters, reduce device cost, increase battery lifetime on devices, improve network capacity, and support a large

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number of devices. LoRa range is extensive, capable of reaching 2-5 Km in urban areas and 15-20 Km in rural areas.

The LoRaWAN open specification is a low power, wide area networking (LPWAN) protocol based on LoRa Technology. It is designed to wirelessly connect battery-operated things to the Internet in regional, national or global networks. The specification defines the device-to-infrastructure of LoRa physical layer parameters and the LoRaWAN protocol, and provides seamless interoperability between devices worldwide.

2.3 Features of LoRa Technology

LoRaWAN strikes a balance between Cellular and WiFi networks which either require high bandwidth or high power, or limited range as shown in Figure 4 below. In essence, LoRa technology offers features, which enable flexibility of operation on ushering in new, unique use cases in smart cities, smart homes and buildings, smart agriculture, smart metering, and smart supply chain and logistics.

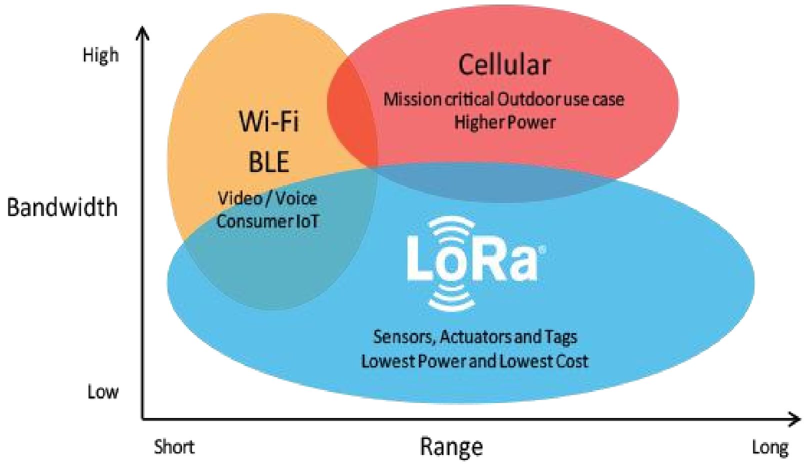

Figure 4: LoRaWAN as a Technology Gap-Filler (Semtech, 2017)

In December 2018, the LoRa Alliance announced that it had exceeded 100 LoRaWAN operators globally, significantly expanding coverage making it easier to deploy IoT solutions worldwide, as shown in Figure 5.

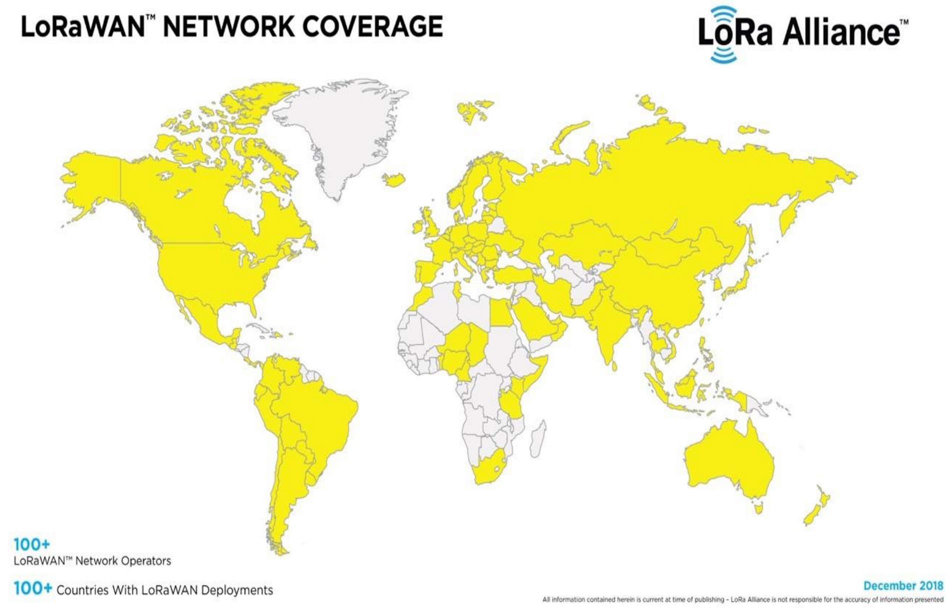

Figure 5: Worldwide LoRaWAN Coverage showing Coverage areas in Yellow (Source: LoRa Alliance, 2018)

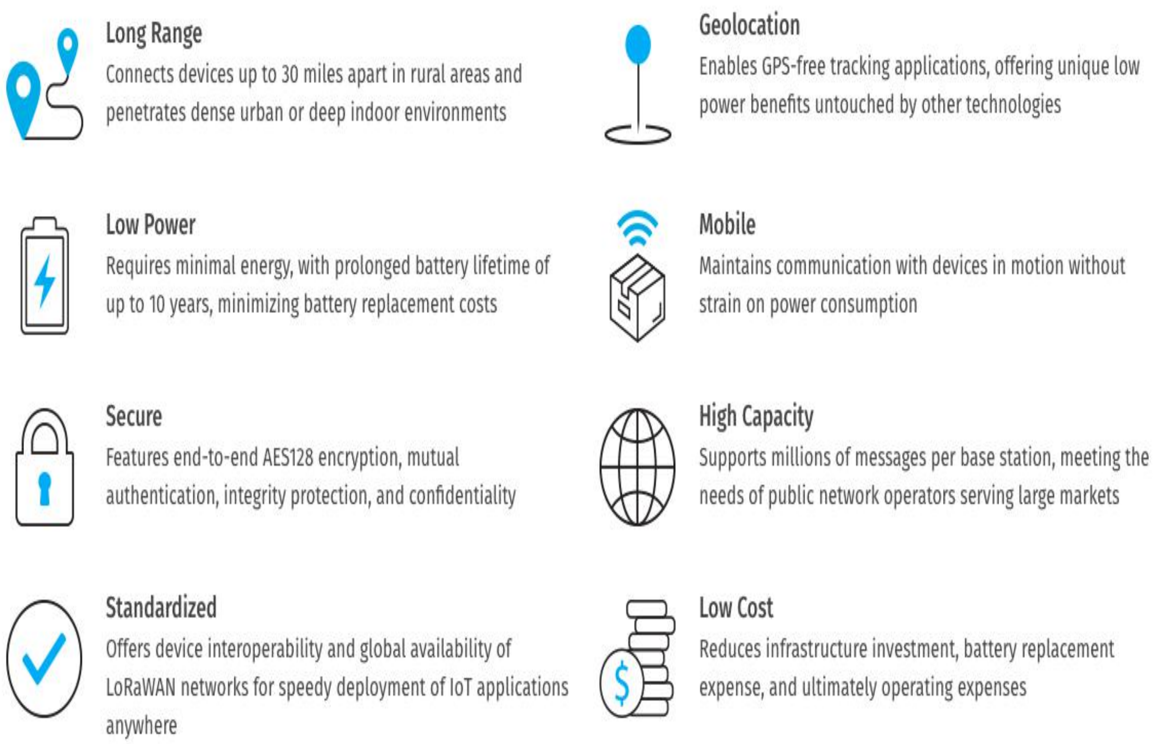

Figure 6: Key Features of LoRaWAN (Source: Semtech, 2017)

2.4 Proposed System Model

An IOT-based solution relying on the LoRa technology is proposed in this paper, whereby livestock (cattle in this case), are equipped with devices that contain built-in GPS nodes, temperature sensors and other important sensors, which communicate with one or more gateways installed around a ranch for reception and transmission of information (SEMTECH, 2017; Swedberg, 2018). Location updates, cattle body temperature readings etc. are sent from

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the attached devices to the gateways, and the data forwarded to cloud-based software for processing/data analytics (BRAEMAC, 2015; SEMTECH, 2017). Meaningful information is then transmitted to farmers/ranch managers on a PC or any mobile device on the location of cattle, body temperature status reports to predict reproductive patterns, and/or illnesses for prompt-action (SEMTECH, 2017, Swedberg, 2018). This is exactly what occurs the in scenario presented in Figure 7 below shows the typical set-up for such solution.

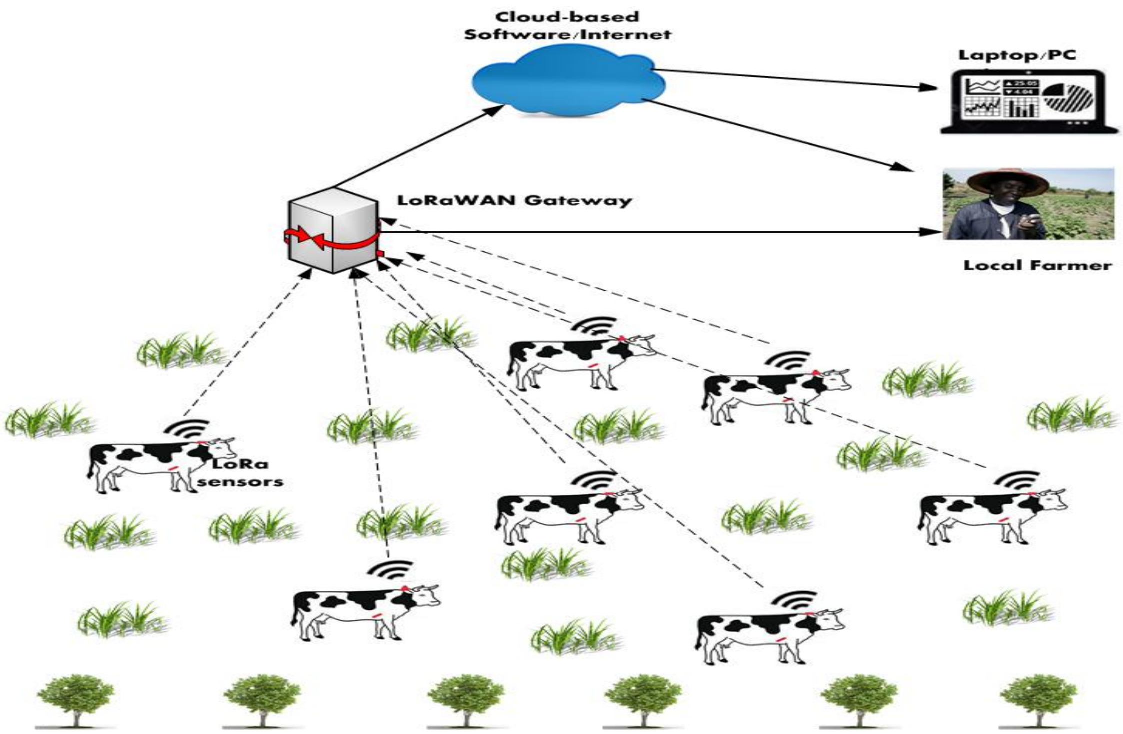

Figure 7: Proposed IoT-based cattle monitoring solution

As shown in Figure 7, the system relies on the LoRa technology, which is a specifically suited for IoT-enabled devices due to very lower power requirements and extremely long range. Sensors are relatively inexpensive with batteries able to last at least 2 years (SEMTECH, 2017). The proposed system could work independently as shown in Figure 7, or could be connected to a cellular or satellite network as shown in Figures 8 and 9 respectively.

The proposed solution allows farmers/ranch managers to easily monitor their cattle using an app on mobile device, or from a PC. It is also possible to detect anomalies in herd behaviour when some cows remain isolated/stationary for long, check for ideal fertility periods (studies show that cows could have as little as only 8 h a month when they are in fertility (Reese, 2018) using temperature readings, and mitigate cattle rustling with location updates. Farmers/managers could also set-up geo-fencing to receive alerts when cattle approach a prohibitive zone without actually installing physical fences over long fields. The device is expected to be indigenously designed and be highly ruggedized, solar-powered with water-proof casing (Swedberg, 2018).

In the case of Figure 8 where cellular network coverage is available, the data is relayed from the LoRaWAN gateway to a nearby base transceiver station (BTS) where now relies on cellular network to reach the end-users directly, or after further processing in the internet/cloud-based software.

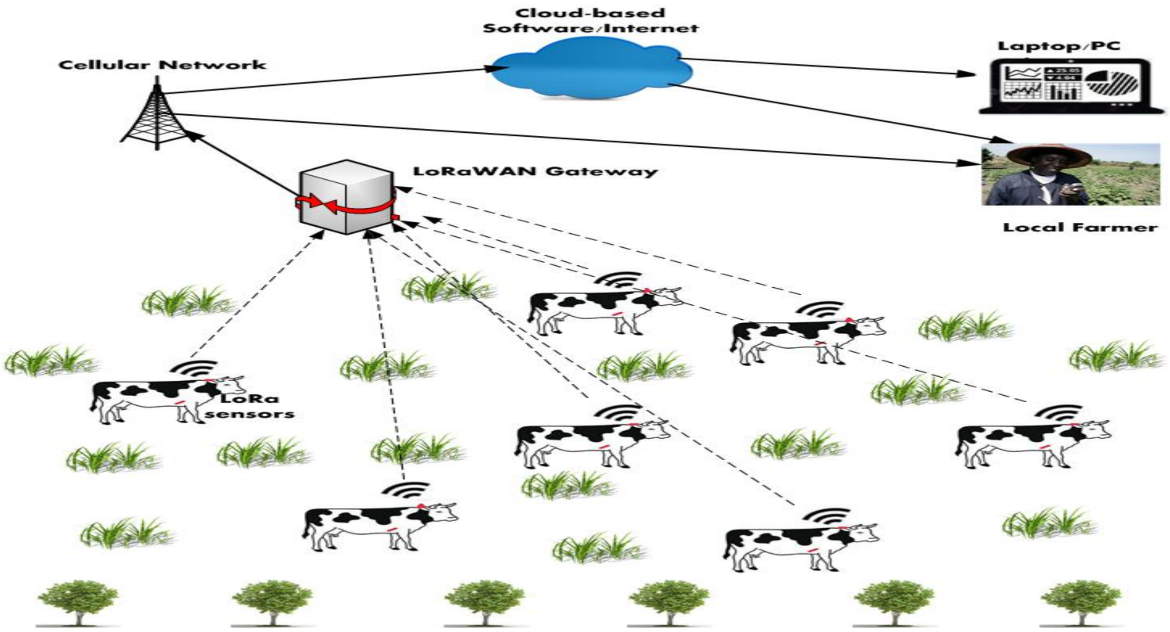

Figure 8: Proposed IoT-based cattle monitoring solution with cellular network

Lastly, another scenario is presented in Figure 9, where there is no cellular network and satellite link is used to improve coverage to the end-users, especially useful in remote areas, and where this is a critical need to connect vast farmlands (with livestock) to a central office for processing and subsequent dissemination of important information to rural farmers/groups of farmers across large geographical areas. This helps provide important information to curtail endemic livestock diseases promptly, provide key immunization/vaccination information, security information and so much more.

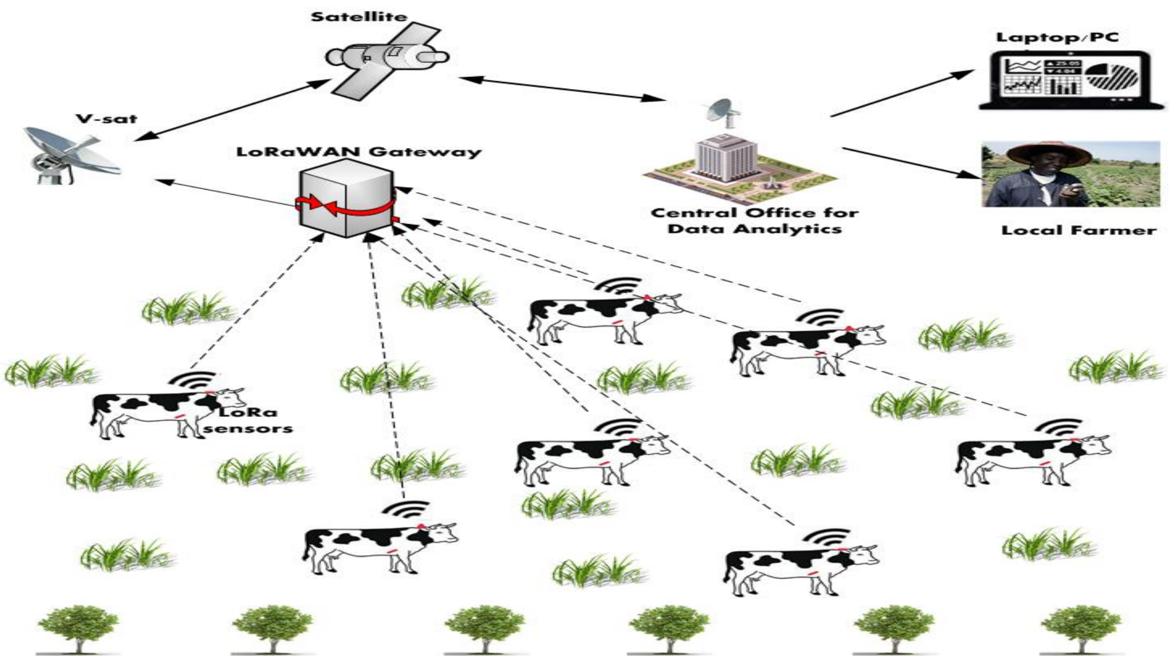

Figure 9: Proposed IoT-based cattle monitoring solution with satellite network

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3.0 Advantages and Potential Limitations of Proposed Solution

Sections 3.1 and 3.2 provide some likely benefits and potential obstacles to uptake of the proposed livestock monitoring system relying on IoT and LoRaWAN technologies.

3.1 Benefits of Proposed Solution

3.1.1 Improved Feeding

Feeding habits of the cattle can be monitored from their behavior such as grazing and sleeping. Knowing how often these happen will enable the farmers make adjustments towards the feeding requirements to prevent over feeding or wastage of food. Farmers can now use IoT to know when to purchase more feeds (Dawsey, 2017).

Maximize Milking

IoT devices can be useful to farmers that have cows that require milking several times a day. It can also track the milking speed of each cow, the amount and the quality of milk the cow produces, the steps taken by each cow, how much each cow eats in a given day. The data obtained can assist the farmer in knowing the cow that is able to produce more milk and make dietary changes where necessary (Cognizant Reports, 2014; Dawsey, 2017).

Monitoring Health

IoT solutions make it possible for farmers to monitor livestock health. Using IoT, blood pressure, heart rate, respiratory rate, digestion, temperature and other vitals can be monitored allowing the farmer to be alerted at the first sign of illness prompting quicker corrective measures to reduce losses. (Cognizant Reports, 2014; Dawsey, 2017).

Improved Livestock Tracking

The IoT platform makes tracking of cattle easier by providing advanced level of information to pin-point the location of a cattle spread over multiple acres. The farmer can locate ill cattle, or one that is in heat such that it can be separated and proper treatment can be carried out. In addition, livestock tracking can help in maximizing pastureland by establishing optimized grazing patterns (Bhayani, 2016; Dawsey, 2017).

Lower Operational Cost

With the use of sensors and connectivity, the farming business can benefit from better asset utilization. This reduces human error, the consumption of resources and minimizes cost (Cognizant Reports, 2014; C2M Plasma Business Intelligence, 2016).

Efficient Processes

IoT offers efficiency in the process such that the farmers or the ranch owners have real-time data and operational insight thereby accelerating the decision making process (Bhayani, 2016, C2M Plasma Business Intelligence, 2016).

Increased Production

IoT provides a platform for optimized livestock farming by offering accurate planning and monitoring which directly affects production rates (C2M Plasma Business Intelligence, 2016).

Improved Quality of Production

Analysis from data received such as the results from quality of treatment can teach the farmers to make adjustments to improve the quality of production (Cognizant Reports, 2014, C2M Plasma Business Intelligence, 2016).

Remote Monitoring

Commercial and local farmers can monitor a numerous field from different locations across the globe from the Internet. Real-time decisions can be made from anywhere in the world. (Bhayani, 2016, C2M Plasma Business Intelligence, 2016).

Potential Obstacles to the Proposed Solution

3.2.1 Power Supply

These mobile devices require a self –sufficient energy source to remain smart. The future is to look into low power processors and communication units for embedded systems that can function with significant low energy (Mohammed et al., 2017).

3.2.2 Cost

This is one barrier to the adoption of IoT especially in emerging markets. The cost of some of the sensors can be capital intensive to not just the small scale farmers but also the large ones as well (Agricultural Machine to Machine (Agri-M2M). 2015; Mohammed et al., 2017).

Limited Knowledge

Limited or no knowledge of IoT is a significant barrier to the growth of this technology. Developers and service providers need to understand the use of this technology, know when and how to apply this technology in various business and operational cases. The absence of this, will make the benefits of IoT unclear to the end-user thereby losing interest in what the service has to offer. To add, the end –user may lack the know-how on setting up, maintaining and using the application. For the developed world, this might not prove to be an issue, however, for the developing world this is a challenge because the users might not be familiar with the basic technology (Agricultural Machine to Machine (Agri-M2M). 2015).

Network Coverage

About 85% of the world's population is covered by mobile network. However, this coverage is heavily focused on the urban and sub-urban areas leaving the rural settlement, places where agricultural practices are dominant, underserved (Agricultural Machine to Machine (Agri-M2M). 2015; Mohammed et al., 2017).

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Reliability of Equipment

Due to operational environments such as continuous exposure to vapours from chemicals, heat, cold, dust as well as moisture, of some of these devices, the use of IoT in livestock farming imposes demands on existing technology. Owing to this, equipment with special requirements and resistance to these working environments will have to be used for better functionality (Agricultural Machine to Machine (Agri-M2M). 2015; Mohammed et al., 2017).

Security

There is a need to protect certain services from having access to the things on the IoT platform. A breach in security will result in compromising the confidentiality, authenticity, integrity and other requirements that are important on the platform. Also, there is a need for protection of the information from these smart devices from competitors (Mohammed et al., 2017; SEMTECH, 2017).

Software Complexity

A more extensive software infrastructure will be needed on the network and background servers in order to manage the smart objects and provide services for them (Mohammed et al., 2017).

Low Wages in Emerging Markets for Livestock Farmers

This poses to be a challenge because the value added per agricultural employee in developed worlds are much higher than that of developing worlds. In the developing world, labour is relatively cheap and where agriculture is the only source of employment available, it will be difficult to invest in IoT (Mohammed et al., 2017, SEMTECH, 2017).

Data Volume and Interpretation

Due to the amount of data collected on central networks, this will require many operating mechanisms and new technologies that will aid in storing, processing and managing information. The interpretation of this high volume of data poses to be a challenge when the data is not harmonized with other networks. The data generated will need to have a generalized conclusion that will be incorporated into the system to prevent contradicting solutions or scenarios in solving challenges on the IoT network (Agricultural Machine to Machine (Agri-M2M). 2015; Mohammed et al., 2017).

4.0 Conclusion

This paper has attempted to provide a starting point for practical implementation of IoT-based solutions for livestock monitoring in Nigeria with a view to improving productivity and efficiency to guarantee food security, address cattle rustling and enhance well-being of livestock. Bearing in mind the unique nature of rural areas in Nigeria whereby mobile coverage and associated internet connectivity may be unavailable or sparse at best, this paper proposes the use of the new LoRa technology which is becoming the candidate technology for IoT-enabled devices with low-power requirements and very long-range. Such LoRa-based sensors are attached to cattle and communicate to gateways in ranches/farms, sending location updates, body temperature readings, and other vital information such as pressure, humidity etc. depending on the different sensors included in the system. This enables farmers/ranch managers and other relevant stakeholders to pro-actively take measures to combat animal theft, spread of diseases and maximize cattle productivity by exploiting the best reproductive window via heating data derived over time.

5.0 Recommendations

It is important to educate the end-users regardless of them being individual farmers, co-operative societies, or agro-businesses as well as those on the value chain on the benefits and application of IoT. In addition, stakeholders might take up the role of setting up and maintaining the systems and provide analysis. Then, the farmer can make informed decisions based on the physical technology and the analysis of data handled by an application. This puts the farmer in the position of following some few simple instructions on the best course of action (Agricultural Machine to Machine (Agri-M2M). 2015).

The school curriculum, especially at primary and secondary school level, should be reviewed to include key modules on agro-technology and agro-economics to help re-orient the minds of young Nigerians towards commercial and efficient agricultural practices.

Pro-active Government policies should be created aimed at facilitating technology use in agricultural sector, ensuring that all stake holders across the eco-system are carried along right from inception to actual implementation.

Encouraging the use of cooperative societies and other social groups to facilitate collective agricultural practices and help subsidize costs of technology, raw materials and logistics for local farmers.

For practical implementation of such wireless-based systems in livestock farming, lower frequency spectrum (<1GHz) can be used rather than high frequency spectrum for rural areas. Lower frequencies offer extended coverage at a lower cost as fewer base stations are required (Mohammed et al., 2017).

Network providers and mobile software developers can also play a key role in creating and maintaining bespoke agro-apps and services which would lead to an increase in connectivity, market share, new value added services as well as improved revenue base (Mohammed et al., 2017).

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