e-Cattle: OPPORTUNITIES IN THE APPLICATION OF WIRELESS SENSOR NETWORKS (WSN) TO CATTLE HEALTH/BEHAVIORAL MONITORING AND TRACKING FOR FARMERS IN NIGERIA.

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ABSTRACT
This paper presents various opportunities in the application of Wireless Sensor Networks (WSN) to Cattle Health/Behavioral Monitoring and Tracking for Farmers in Nigeria. The untimely losses in many cattle farm had been most of the time as a result of lack of timely and adequate discovery of diseases in the farm. The problem of limited technological solutions in monitoring the well-being of cattle has led to various diseases that reduce the yield in production of cattle farming. Early detection of diseases will help in making further provision for preventive measures and also reduce the overall cost of treatment in cattle farming. The use of WSN is therefore inevitable in other to address the problem usually face by cattle farmers in Nigeria. Various mode of WSN application are discussed and different technological approaches are identified with the aim of suggesting an adoptable solution for effective monitoring and tracking system for cattle farming in Nigeria. In conclusion, the paper discusses proven beneficial effect of adopting and implementing WSN solutions to monitor and track cattle status in Nigeria.

Keywords: e-Cattle, WSN, Cow, Agriculture, Nigeria.

I. INTRODUCTION

Cattle (colloquially cow) monitoring is essential in order to objectively measure the wellbeing, maintenance and improvement levels of herds and their productivity. The common traditional method for cow monitoring is visual observation. This is primarily achieved by the farmers who watch their cows for several hours a day in order to learn about their wellbeing and detect heat and abnormalities. However, the value of visual observation is limited since it is dependent on skill and experience, it is also not fully accurate, and does not allow thorough analysis. It is very difficult if not impossible to maintain visual observation for 24 hours a day; this means that a significant share of heats and infrequent symptoms may be missed by visual observation (SCR, 2013).

Cattle's monitoring can be categorized into three, these are:

i. Organized herds (as in dairy farms) monitoring;
ii. Unorganized herds (as in villages/communities with one or more cattle to one/several farmer(s)) monitoring, and;
iii. Nomadic herds monitoring.

Major problems prevailing in the field both at organized dairy farms as well as unorganized sector are identification of animals, health monitoring, heat detection, comfort level of animals, automation of milking process, segregation of animals based on health and production, shelter management etc. which causes great losses in terms of livestock, milk production and money to dairy farmers (Subrat,2013). Precision Agriculture (also called among other names Precision Farming) which involves the use of technology is gaining momentum in the developing countries which hitherto had relied mainly on the traditional method in Animal husbandry and in most areas of Agricultural value chain. Technology is already part of modern farming and is playing an increasing role as more advanced systems and tools become available. In recent years, one of the biggest areas of development has been in electronic cow monitoring (SCR, 2013).

In recent times, e-Cattle (electronic-Cattle) monitoring uses Wireless Sensor Network (WSN) which is also being deployed in various applications that include industrial, environmental, medical, agricultural and societal monitoring (Ankit et al., 2013). Application of WSN to cattle monitoring can be used to gather qualitative and quantitative data on vital parameters of cattle from any category of herd monitoring, this will in turn help in decision making on disease prediction and prevention and also on overall cattle management. The behavior of cattle includes its movement, position and feed/water intake. Cattle's health status can be determined by observing its body temperature, respiratory rate, heat period and rumination. Tracking and monitoring these parameters can be achieved with the aid of wireless body sensor network. An example of nationwide peer to peer architecture for cattle monitoring system with wireless sensor networks is shown in Figure 1. It indicates the mobile users, farm building, mobile ad-hoc networks, sensor nodes and data couriers using the internet for real-time data aggregation and processing from the cattle.

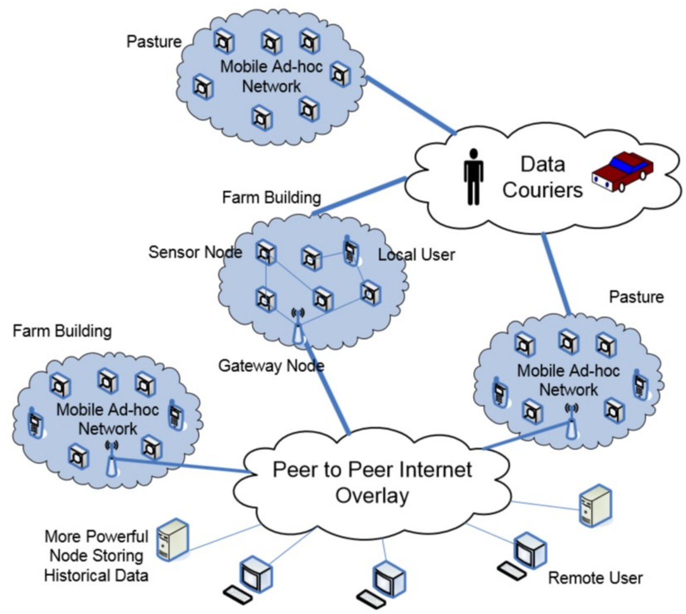

Figure 1: Nationwide Peer to Peer Cattle Monitoring with WSN Architecture
(Source: Randekovic and Wietrzyk, 2006)

2. WIRELESS SENSOR NETWORK

Wireless Sensor Networks (WSNs) have offered new opportunities for remote data collection in the recent time (Baratchi, 2013). WSN is made up of many nodes that has collaborative capability and make use of multi-hop communication to aggregate and transmit data to a base station for onward data processing. Different technologies can be combined in a WSN to achieve sensing purposes and to collect data wirelessly from the animals in remote locations. According to Bolaji (2012), sensors can be applied to the body in three major ways, these are: swallowable, wearable and implantable sensor modes.

(a) Swallowable sensors

This is a swallowable sensor in the form of capsule containing a tiny camera that snaps picture as it glides through the intestine of the animal can be used to collect internal physiological data of cattle. It examines the gastrointestinal tract by visualizing inside of small intestine to detect diseases, or causes of bleeding and anemia. A swallowable sensor can also be used to monitor the blood sugar level in the body of the animal.

(b) Wearable sensors

Wearable sensor can be in the form of wireless sensor unit mounted on the collar of the animal, pedometer and Geographical Positioning System (GPS) unit can be worn on the cattle to examine its location and distance from specific location and also accelerometer attached to the cattle's body can be used to measure its movement and speed per time.

(c) Implantable sensors

Implantable sensors could solve many problems in the monitoring of chronically ill animal. It can be in the form of ear tag attached to the cattle's ear to measure the change in temperature of the cow or in the form of a pulse rate sensor that monitors the blood flow in the animal to detect special cases of unusual change in its physiological parameters.

3. RELATED WORKS

According to Ahsan and Ahmed (2012) application of WSN to agriculture for the purpose of improved overall productivity can be achieved through what is known as Precision Farming (PF), Greenhouse and Animal Monitoring. Ankit and Harshal (2012) proposed a system that uses WSN architecture to monitor the environmental scenario and health of animals located in the rural area of the state of Gujarat. The monitoring was focused on ensuring healthy environment for the well-being of the animals. WSN is also applicable for use in weather prediction. According to Chaudhary et al., (2011), farmers have historically experienced huge financial losses because of wrong weather predictions and incorrect irrigation timings. Based on FAO (2011) report, climate change is expected to further aggravate the existing challenges that agriculture faces. The evolution in wireless sensor technologies and miniaturized sensor devices makes it possible to use WSN for automatic environment monitoring and controlling the parameters in a confined environment called a Greenhouse. Greenhouses have been in use for decades, but it is not until recently that there has been an increase in its use due mainly to availability of diverse range of sensors and actuators with rich and diverse sensors to monitor/control several environmental parameters in the Greenhouse (Pawlawski et al., 2011).

Climatic differences have resulted in the development of a greenhouse system based on simple structures and low-cost climatic control systems having some intrinsic shortcomings which are poor humidity and ventilation control along with reduced light transmission through the plastic coverage.

One of the first major applications of WSN for animal monitoring was tracking system developed for monitoring zebras by Zhang et al., (2008) as part of the ZebraNet project. The operation of ZebraNet is such that it relies on the zebra's GPS position data which was taken at interval of few minutes. The taken data was subsequently hopped in a peer-to- peer fashion to other zebras that are in range on the network. Researchers could download the historical position data of multiple zebra from any of the zebras on the network, the available data is subject to the amount of storage capacity of each device on the zebra. Researchers have since proposed advanced systems for ad-hoc routing of data through large networks of mobile cattle nodes (Radenkovic and Wietrzyk, 2006).

Butler et al. (2004) and Lee et al. (2008) have used similar stimuli but achieved different goals using different algorithms. Butler et al. (2004) developed a "moving virtual fence" algorithm for herding cows. This involved the use of smart collar consisting of a sound amplifier, a Personal Digital Assistant (PDA), a Geographical Positioning System (GPS) and a radio unit on each animal in the herd. The animal's location on the field was determined by using the GPS unit, the actual location is also confirmed with a measurement of vicinity of the cow relative to the fence boundary. An auditory stimulus warns and directs the animals away from the fence when they approached its perimeter.

Lee et al. (2008) also examined the possibility and potential of controlling bulls during mating using mild electric shocks delivered through radio controlled collars. Cows were assigned to the bulls; the non- assigned bull received a mild electric shock on approaching either the unassigned cow or another bull. Non-assigned bulls were sometimes observed avoiding the cow despite a change in its location. This suggests that the bull associated the electric shock with the cow and not with the location in which they received the electric shock.

4. e-Cattle HEALTH MONITORING

Electronic-Cattle health monitoring with WSN is very important to achieve greater yield in agricultural product chain system. The reports of Burney et al. (2010) and Bruinsma (2009) estimated that by 2050, the current world population will grow from 6.7 billion to 9 billion, with major part of the increase to occur in sub-Saharan Africa and South Asia. The increase in the population brings about considerable changes in the consumption level and composition associated with growing household incomes, it was also estimated that a 70 percent increase in total agricultural production will be required to feed the world in 2050.

In order to meet up with the impeding challenge, the considerable provision must be made for agricultural product consumables. The cattle farming is expected to be increasing significantly on yearly basis but in the year 2010, cattle industry in the United State of America alone suffered a significant loss of 3,773,000 cattle to non-predators which largely comprised of different diseases such as digestive, respiratory and metabolic diseases (USDA, 2011). Good tracking and monitoring of cattle is essential to succeed in maintaining a growing yield in today's business climate, which includes larger herds to manage and an increasing shortage of skilled cattle farmers and herdsmen. The use of technology, especially WSN to track and monitor cattle status is therefore inevitable to improving cattle's wellbeing and producing higher quality of beef and milk.

The use of WSN in tracking and monitoring cattle's behavior / health status in real-time is yet to be widely implemented in African countries despite the numerous presence of cattle farming. The development of a system that is suitable for cattle farming in Africa can be achieved by leveraging on the available tracking and monitoring sensor devices that is in use in the developed countries but not perfectly suitable in the developing countries' environment due to various challenges like erratic power supply and bandwidth constraint. An improved management system for cattle farming can be achieved by providing an opportunity for farm managers and directors to remotely observe and monitor the prevailing condition of their herds on the internet instead of depending on traditional visual observations by the herdsmen (commonly known as 'Fulanis') who are usually hired to manage the herd.

According to Ankit et al. (2013), Cattle diseases can be categorized as contagious and non-contagious based on their modes of spreading and causative agents. The contagious diseases caused by Bacteria are Anthrax, Black Quarter, Haemorrhagic, Septicaemia, Mastitis and Tuberculosis while the diseases caused by Virus are Cow pox, Rinderpest, Foot and Mouth disease etc. The non-contagious diseases are Milk fever, Tympanities, Diarrhoea, Metritis, Mammits and Constipations. The symptoms of cattle diseases can be identified early by consistent monitoring of the cattle's temperature, respiration rate, pulse rate, breathing rate and rumination. All the cattle's health parameters can be measured wireless using WSN.

5. TECHNOLOGICAL APPROACHES

The classification of technological approaches used in monitoring animal is based on two major animal movement modeling approaches according to Baratchi et al., (2013). The approaches are known as Lagrangian and Eulerian. The Lagrangian approach is individual-based and entails tracking a specific animal, while the Eulerian approach is place-based and deals with the probability of presence of an animal or a group of animals in a place and the change of this occurrence over time.

5.1 Lagrangian technological modeling approach

The Lagrangian based technologies are in form of a tag or device which is attached to the animal, such tags can be attached to the ear of cattle or leg. Generally, when choosing Lagrangian based technology for cattle monitoring the following requirements need to be kept in mind:

(i) the overall weight of the device should be less than 3–5% of the animal’s total body weight (for terrestrial mammals, it should not be more than 10% (Hanunna et al., 2005)).

(ii) the lifetime of the device should be relatively long so that it is not needed to trap the cattle again before the necessary amount of data is collected.

Compared to the Eulerian approach, the choice of the hardware and retrieval of data from the tagged animal are the issues that are greatly concerned in Lagrangian approaches. When the approach is used on wild animals, there must be a provision for a mechanism that will allow for the retrieval of the data from the tag through single/multi hop networks automatically because the chance of recapturing the animal is small. The technologies available for cattle monitoring in this approach are active and passive Radio Frequency Identification (RFID) tags sensing units, Indoor and Outdoor GPS sensors, Inertial sensors and Radio Transmitters.

5.2 Eulerian technological modeling approach

The environmental disturbances produced by the animals are the target measure of Eulerian approach technologies. According to Arora et al., (2004), the technologies which are used to detect these disturbances can be classified as passive and active. (Active detection technologies such as radar and sonar detect a target’s presence by how it modifies an artificial sensing modality. Passive detection technologies simply record natural sensing modalities (visual, thermal, chemical, seismic, and acoustic) already present in the environment. In other words, active technologies both generate and receive sensing modality while passive technologies only receive a modality (Baratchi et al., 2013).

Three factors are of concern from the technical point of view when designing a system for Eulerian modeling. These factors are: (i) choice of modality, (ii) technology and (iii) data analysis techniques to extract the spatio-temporal properties of cattle. The technologies available for cattle monitoring in this approach are Camera units, Infrared technologies, E-nose and Geophone.

Comparison of the technologies used in monitoring cattle can be based on the following:

(i) The type of information the technologies can provide.
(ii) The performance metrics of individual technology.
(iii) The type/specie of animal being monitored.

6. BENEFITS OF WSN APPLICATION TO CATTLE MONITORING

Technology has made modern farming easier; it plays an increasing role in making more advance tools and systems available to cattle farming (SCR, 2013). There are numerous benefits of monitoring and tracking cattle with wireless sensor networks, some of them are indicated thus:

(i) **Farming Environment**: WSN makes it easier to monitor the wide open field where cattle’s farming usually takes place. End-to-end monitoring coverage which is difficult to achieve in a large sized farm can be made easier through the use of WSN. Continuous monitoring of the environment where cattle are kept which is achievable with the use of WSN will ensure hygienic environment for healthy habitation of the cattle. Weather and other climatic conditions that may affect the well-being of the cow can also be easily monitored with WSN to prevent future problems in the farm.

(ii) **Cattle Movement**: The use of WSN makes animal movement tracking easy. The use of wireless transmission of data makes it easy for a farmer to know the exact location of the cattle in case of emergency or cattle wandering loss. WSN can be used to achieve effective time-to-time communication of animal movement to remote servers and tracking systems. Nomadic herds can be tracked with WSN and cattle behavior and activity can be monitored over a long range of distance.

(iii) **Cattle Health**: WSN provides a smart technology for cattle’s health monitoring. The physiological, nutritional, behavioral and reproductive aspects of cattle farming can be monitored, diagnosed and transmitted to data centers for onward processes in order to forestall the outbreak of diseases on the cattle farm. Various cattle diseases can be identified and prevented early based on the parameters measured with the WSN. Early detection of diseases in cattle usually reduces the overall cost of treatment and also leads to increase in effective treatment.

(iv) **Reproduction Management**: The use of WSN in cattle farming can improve heat detection in cattle. The activities of cattle is known to reduce during heat, this leads to corresponding drop in rumination which can provide actionable validation of those cattle that are undergoing their heat period. Activities and behavioral pattern of the cattle can be monitored with WSN for heat detection.

(v) **Lactation Monitoring**: WSN makes lactation curve management in cattle farming easy by providing a means by which dairy farmers can maximize milk production in cow. It makes the reduction of milk loss possible by early detection of metabolic issues affecting milk production.

(vi) **Rumination Monitoring**: Rumination is an important indicator of cow welfare and health status. Before the clinical signs in cattle become apparent, a drop in rumination serves as a clear indicator that a cattle is having health issues. WSN can be used to monitor cattle's deviation from and return to normal rumination. Monitoring cattle's rumination with WSN provides timely sensitive information that can be used for cattle treatment.

(vii) **Nutrition Management:** Monitoring cattle with WSN gives insight into feed ration and nutrition issues, it provides information that are useful for improvement in nutrition strategy by monitoring and analyzing the cattle's reaction to changes in ration formulations and feeding protocols. It also helps in determining the level of effectiveness in case of feeding or rations change.

(viii) **Data Aggregation**: Application of WSN to cattle farming in Nigeria will help in aggregation of useful cattle data in terms of breeds, reproduction rate, seasonal reactions, dairy capability, migration effects, disease prediction and management and so on. Available data in cattle farming will make future progress projections and product yield predictions in Nigeria's cattle farming industry possible and this will in turn make life easier for the cattle farmers, veterinary doctors, animal scientist, cattle surgeon and general populace that consumes cattle products like milk and beef.

7. CONCLUSION AND RECOMMENDATION

This paper presented various opportunities in the application of Wireless Sensor Networks (WSN) to Cattle Health/Behavioral Monitoring and Tracking for Farmers in Nigeria. To achieve this different related works were appraised, technological modeling approaches were reviewed. At the end of the review and having taken into consideration the peculiarities of cattle farming in Nigeria with limited technological resources, the benefits of adopting the technology in Nigeria cattle farming were discussed. This work has thus made it possible to suggest working solution to the problem of cattle's health care provision and management from remote places in Nigeria.

Furthermore, the work if properly optimized is a viable option for mobile healthcare provision for cattle farm or diseased cows that require frequent monitoring to reduce the incidence sudden loss and avoidable health disaster in cattle farming which will also directly affect the consumers of cattle products like milk and beef. Future research work on this could be done around the issue of sensor power consumption, physiological information routing protocol, security, and interoperability with different body area sensor networks.

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