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Wireless Sensor Network (WSN): Applications in Oil & Gas and Agriculture Industries in Nigeria

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Abstract: This paper x-rays the various possible deployments of smart micro wireless sensors in industrial applications especially in Nigeria. This paper focuses more on wireless sensor applications in oil & gas industry and agriculture in Nigeria. In Oil & Gas industry, International Oil and Gas Companies (IOCs) have already massively deployed this technology since 2005 to monitor vast oil and gas installations in Nigeria Niger Delta region. In agriculture, these devices can be used in Nigeria to monitor greenhouse temperature conditions for crop growth, in field monitoring to measure temperature, relative humidity and soil moisture to prevent fungi infections and in livestock to detect the pH-value of the rumen of dairy cows as well as monitor movement of cows. Also they can be applied to monitor the micro-climate in the woods. This paper finally identified the several benefits of applying these micro devices as well the key challenges facing their deployment of these devices in the industries in Nigeria. The paper finally suggested some solutions to some of the identified challenges.

Keywords: ICT, WSN, IWSN, wireless sensor, cattle colony, rumen, greenhouse, transducer, oil well, pipeline, sensing, terrestrial, underwater, control, base station, multi-hop, adhoc, IOCs, Nigeria, Niger Delta,

I. INTRODUCTION

Wireless sensor networks are IEEE 802.15.4 enabled devices capable of robust and reliable multi-hop communications [1],[2]. Wireless sensors can be deployed in unattended environments and can enable collection of data from there to distant base stations and then to control room [3],[4]. Wireless sensors are smart devices capable of communicating with themselves and their immediate environments. Several wireless sensor devices or nodes can come together to form what is referred to as Wireless Sensor Network (WSN).

Recent advances in wireless sensing technology encourages the further optimization and improvement of the product development and service provision processes. Industrial Wireless Sensor Networks (IWSN) is an emerging class of WSN that faces specific constraints linked to the particularities of the industrial production.

In Nigeria, for example, wireless sensor network (WSN) technologies are not new in industrial applications; oil and gas industries had seen its tremendous deployment and applications in oil-rich region of Niger Delta as far back as January 2005 [5]. Wireless sensor network was adopted then by several major International Oil Companies (IOCs) such as Shell Petroleum and Development Company (SPDC) , Mobil and Texaco to aid them to monitor their vast oil wells, pipelines and to optimise their productions. According to [6], the applications of wireless sensor networks (WSNs) and other wireless technologies in oil and gas industries include process monitoring, asset management, plant management, productivity enhancements, Health, Safety and environmental (HSE) monitoring and applications for meeting regulatory requirements.

Prospects or Benefits of Wireless Sensor Network:

The IOCs in Nigeria chose wireless sensor then because of its inherent prospects and advantages such as : -

- It is small enough so that they attracted less attention,
- It has low power and it is battery operated, without expensive solar panels required by the conventional satellite communication,
- It allows bi-directional wireless communication that can provide timely well flow of data and allow downhole valve control that opens and closes wells remotely.

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- It has long-range wireless communication capabilities, greater than 4-5 miles in a dense jungle,
- It enhances well integrity and health, safety, and environment performance through availability of continuous real-time well parameter monitoring, ability to avert disasters, and reduced repairs, walkovers, and drilling of new wells.
- It has low-cost, almost at a price that would make it disposable and maintenance free unlike the conventional technologies wired and wireless technologies,
- Above all, it is easy to deploy and install and does not require daily maintenance [5].

Shell employed a model of wireless sensors known as vMBusX-SP micro wireless sensor. The model of wireless sensor Shell deployed in its oil wells and pipelines is depicted in Fig.1.

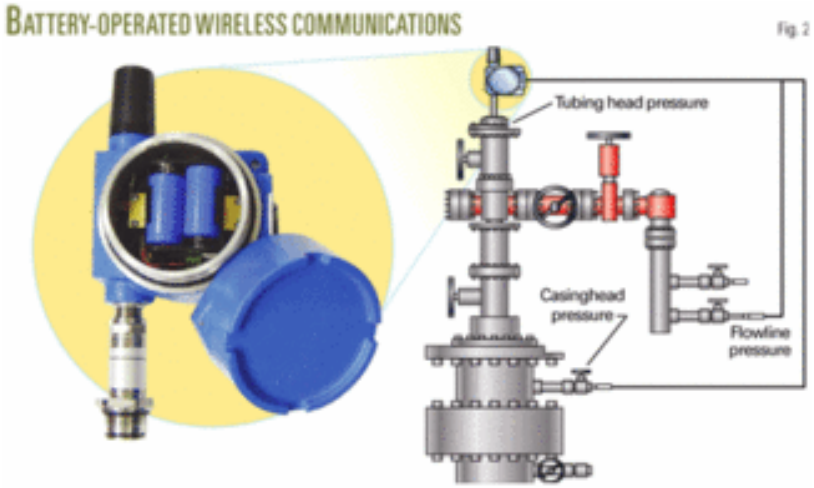

Fig. 1. A model of vMBusX-SP battery-powered Smart Wireless Sensor installed by SPDC in her over 1000 oil wells and other oil facilities in the fields of Niger Delta [5]

Fig.2. The vMBusX-SP unit is barely noticeable on this well in the Niger Delta, thus providing a feature that helps prevent theft and sabotage [5]

Wireless Sensor Network cannot be deployed only in Oil and Gas industry. They can be applied massively in Agriculture (another sector the Nigerian Federal government is focusing on to diversify the economy). It can be deployed as well in a wide range or diverse industries such as homeland security, smart city, industrial automation and healthcare. Using an array of smart sensor gauges, wireless sensor networks (WSNs) find key applications in numerously varied military projects, effort tracking, effort management systems, habitat and water quality monitoring, agricultural studies, radiation detection, homeland security, as well as preventive maintenance of machinery. The key benefit of wireless sensor systems lies in their ability to poll the data read by sensors wirelessly, thus allowing storage and analysis at a local facility [7].

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II. Wireless Sensor Network (WSN) Applications in the Industry

According to [8], the three major applications of wireless sensors in the industry include:-

1. *Environmental Sensing*
2. *Condition monitoring, and*
3. *Process automation.*

1. Environmental sensing.

This group generally represents the widest field of WSN application nowadays. Industrial WSN (IWSN) applications for environmental sensing cover the problems of air, water (together with waste water) pollution, but cover the production material pollution monitoring as well. Furthermore, in hazardous environments, there are numerous needs for fire, flood or landslide sensing. Finally, the security issues arise in markets with competing product and service providers, where IWSN are used for point of interest, area and barrier monitoring.

2. Condition monitoring.

This group generally covers the problems of structural condition monitoring, providing both the structure health information (the condition of the buildings, constructions, bridges, supply routes, etc.) and machine condition monitoring including possible automatic maintenance. Therefore, this group of IWSN applications is vital for the production in all the branches of industry.

3. Process automation.

The last group of applications provides the users with the information regarding the resources for the production and service provision (including the materials, current stock and supply chain status, as well as the manpower included in the industrial process). Finally, one of the most important issues from the user perspective is the production performance monitoring, evaluation and improvement that are achieved through IWSNs.

Fig. 3 depicts the major groupings in the applications of WSN in the industry.

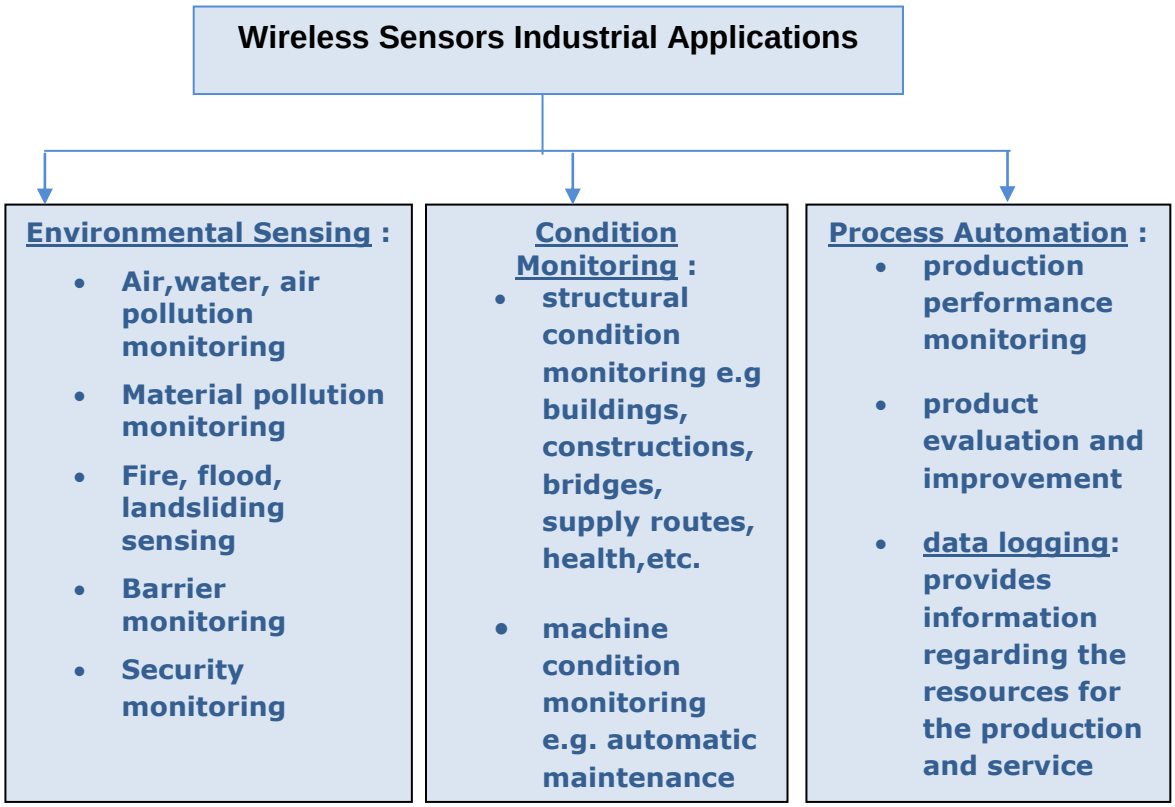

Fig.3. The industrial wireless sensor applications major groupings

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III. PROSPECTS OF APPLYING WSN IN AGRICULTURE

Apart from oil and gas industry, which is the main stay of Nigerian economy, agriculture is another industry that can revitalize Nigerian economy. The Federal government recognizes this fact and has invested so much in this regard. Wireless sensors can be applied massively in this industry to turn around the fortunes of this industry and the nation's economy.

In Greenhouses:

Accurate measurement of temperature with high spatial resolution, horizontal as well as vertical, is recommended in order to achieve reliable and consistent results as shown in Fig. 4.

Fig.4. Temperature measurement in the greenhouse

In the field:

Precision agriculture is one of the most promising application domains where wireless sensor networks may deliver a feasible or even optimal solution. Sensor nodes can be used to monitor micro-climates in a potato, millet or cassava field. Sensor nodes can be deployed in farm field to measure air temperature, relative humidity and soil moisture as shown in Fig. 5. This monitoring will help indicate when the field or specific parts of it are at risk of developing fungal diseases.

Fig.5. Sensor nodes on a potato, millet or cassava field

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In the livestock:

A wireless measuring system, consisting of sensors and transmission units, helps to keep livestock healthier with a minimum use of resources. The system determines the pH level and the temperature inside the cow's rumen. The data are wirelessly transmitted to an external receiver node via an encapsulated measuring probe referred to as bolus in Fig.6. The Federal government proposed Cattle colony or ranching can benefit a lot if this technology is applied there. The objective of this application is the development of a wireless rumen monitoring system for early detection of sub-acute rumen acidosis by quasi-continuous measurement, transmission and indication of the pH-value of the rumen of dairy cows.

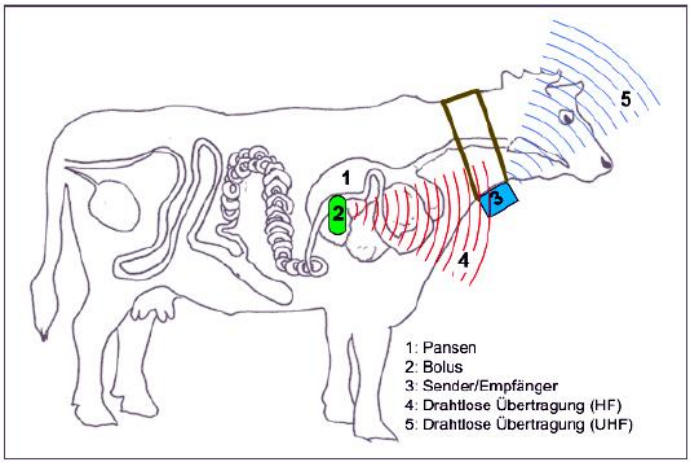

Fig.6. Rumen monitoring in cows using wireless sensors [9]

IV. WIRELESS SENSOR TYPES

Wireless sensors can monitor targets in either three (3) modes:

- ***Underwater wireless sensors***
- ***Underground wireless sensors***
- ***Terrestrial or Above the Ground wireless sensors***

Underwater wireless sensors consist of several sensor nodes and vehicles that are deployed underwater. Underwater sensor nodes are more expensive and fewer in number than terrestrial wireless sensors. Autonomous underwater vehicles are used for exploration or gathering data from sensor nodes. Typical underwater wireless communications are established through transmission of acoustic waves.

Underground wireless sensors consists of number of sensor nodes buried underground or in a cave or mine that are used to monitor underground conditions. Some additional sink nodes are located above ground to relay information from the sensor nodes to the base station. An underground WSN is usually more expensive than a terrestrial WSN in terms of equipment, deployment, and maintenance.

Terrestrial wireless sensors typically consist of hundreds to thousands of inexpensive wireless sensor nodes deployed in a given area, either in a pre-planned or in an ad-hoc manner. In ad-hoc deployment, sensor nodes can be dropped from a plane and randomly placed into the target area.

A. Wireless Sensor according to the transducer types

Also, wireless sensor exists in various types of transducers or sensors and can monitor/measure different physical variables that cut across several industrial applications. They can monitor/measure the following variables or parameters:-

- ***Flow,***
- ***Level,***
- ***Pressure,***
- ***Temperature,***
- ***Gas,***

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- ***Biosensor,***
- ***Humidity,***
- ***Light Intensity,***
- ***acceleration,***
- ***vibration,***
- ***velocity,***
- ***Position,***
- ***Proximity,***
- ***Photoelectric sensors,***
- ***etc.***

V. KEY CHALLENGES OF WSN INDUSTRIAL APPLICATIONS IN NIGERIA

Industrial Wireless Sensors (IWSNs) face several challenges such as the reliability and robustness in harsh environments, as well as the ability to properly execute and achieve the goal in parallel with all the other industrial processes. Furthermore, IWSN solutions should be versatile, simple to use and install, long lifetime and low-cost devices – indeed, the combination of these requirements are very hard to meet.

- ***Interferences in industrial environment***
- ***Multivendor equipment interoperability***
- ***High cost of procurement/installation***
- ***Limited hardware Architecture***
- ***Problem of remote and unattended installation***
- ***Lack of adequate open bandwidth***
- ***Constantly evolving standards***

Interferences in industrial environment:

Reliable and real-time communications are required for industrial automation applications. The harsh industrial environment, however, may decrease the network performance due to some reasons as follow:-

1. Multipath propagation: the signal strength may be severely affected by the reflections from the walls.
2. Interferences from other devices using ISM bands.
3. Noise generated from the equipments or heavy machinery.
4. Wide operating temperatures, strong vibrations, and airborne contaminants.

Multivendor equipment interoperability:

Interoperability is a major challenge for market participants. This is further worsened by the embedding of proprietary communication protocols and support software. Wireless communication technology is successful only if the equipment of different vendors can communicate. This multivendor interoperability environment is expected to be a long-term challenge—from a design standpoint—for both sensor and test vendors. In the future, we expect widespread use of different functions packaged together in a single control box and large-scale development of interoperable devices for industrial systems. Also, equipment must have plug-and-play options for ease of use as well as to improve market acceptance.

In terms of the development of industrial-safety-rated devices, vendors' ability to make a wireless sensor system fail-safe depends heavily on the type of application in which the wireless sensor is used. As such, understanding the application helps vendors to provide appropriate fail-safe measures that can be embedded into wireless systems.

Licensed bandwidths are a subject of disagreement in the market. Market leaders and large companies feel that the use of unlicensed bands interferes with the licensed ones and therefore should be completely eliminated. Tier-two and tier-three market participants feel that even though there are benefits to wireless sensor networks operating in licensed frequency bands, certain challenges remain to be solved. Presently most wireless sensor network devices operate in unlicensed bands such as 915 MHz and 2.4 GHz, and reliable communication can be affected by interference from other devices operating in the same frequency band. However, the majority of the market participants feel that the use of unlicensed bands is likely to bring in larger benefits accompanied by unrestricted growth as well as to provide equal opportunity to market participants operating on the same platform. There are various initiatives taken up by companies to promote open bandwidths.

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High cost of procurement/installation:

Wireless sensors of various types and makes are not that cheap. It costs about $100-$500 per unit to purchase these smart devices from abroad to Nigeria. Due to the high cost of exchange rate of Naira to US Dollars, this means it will cost a minimum of N37,000 to N180,000 to purchase a unit of wireless sensor, apart from shipping and import duty costs. To deploy a wireless sensor network over a vast area may require up to about 20-50 units. This will certainly increase the cost of ownership. The cost will go down if Nigeria begins to manufacture these devices locally or if the exchange rate of Naira to US dollar goes down appreciably or the device makers are encouraged to set up their factories in Nigeria since there is a huge market here.

Limited hardware Architecture:

Wireless sensors are miniature in size, have very small battery that can last barely one year, have limited processor bandwidth and process capability, and have very small memory for storage and processing. But these constraints will disappear with time as the development of fabrication techniques improves.

Similarly, there is no ideal wireless sensor or transmitter that could be used for all conceivable applications. In fact, each application determines what attributes the wireless transmitters should have.

Wireless sensors, transmitters, and networks are used for diverse applications with varying requirements and characteristics Designers and the research community are developing a hardware design platform capable of supporting multiple applications. It is imperative for market participants to have a set of hardware platforms with different capabilities that cover the design space and cater to most market opportunities. A modular approach under which individual components of a sensor node can be easily exchanged is a solution for multiple applications.

Unattended Installation and Deployment:

In Nigeria, especially in remote oil wells and pipelines, wireless sensors are installed remotely, without human attendance. This makes them to be prone to attacks and destruction by criminal-minded elements who may want to compromise the assets they are supposed to monitor. Typical example is in oil and gas installations.

Lack of adequate open bandwidth:

Wireless sensor network lack communication bandwidth for robust communication. This makes reasonable communication amongst different nodes of WSN difficult.

Constantly evolving standards:

This is a very big challenge for researchers because different vendors continuously introduce different standards at a high rate that may not be open or interoperable with products from other vendors making it difficult to integrate wireless sensor nodes from different vendors together in a research project.

VI. SUGGESTED SOLUTIONS

The researchers suggested the following recommendations to enhance and maximize the use of wireless sensors in Nigerian industrial concerns both in oil and gas sector and agriculture industries.

1. Wireless sensors should be installed with other smart devices such as Close Circuit Television (CCTV) cameras to ensure a holistic tracking and monitoring of critical assets and industrial installations especially in remote or unattended locations.

2. Wireless sensor's battery life is limited, hence cannot last forever. Energy scavenging methods or optimisations can be used to save limited battery energy of the device in order to increase its productive life. Solar source of energy can also be combined to increase the life span of wireless sensor's energy.

3. The cost of wireless sensors can be brought down in Nigeria if the exchange rate of Naira to US Dollar is reduced by Central Bank of Nigeria (CBN) or some vendors/manufacturers of these devices are lured to Nigeria from their home countries such as China, Europe etc. to come and open production factories here in Nigeria so that these devices can be manufactured locally. There is a wide market for these devices in Nigeria.

4. With improvement in research in the near future, there is possibility of convergence of standards by different vendors in wireless sensor production. This will help researchers improve on their efforts to make wireless sensor applications easier and applicable to other industrial sectors. Nigeria government can fund these researches in Nigerian research and educational institutions by making sure that *TETFund* is judiciously applied by researchers.

5. With improvement in research, wireless sensor's hardware architecture can be improved in terms of memory capacity, processor's capability and bandwidth; battery power of wireless sensor can be improved to last for more than 5 years and solar energy can be incorporated in it to improve its life span and productive life.

VII. SUMMARY AND CONCLUSION

Wireless Sensor Networks (WSNs) consist of small nodes with limited sensing, computational, and wireless communications capabilities. Despite these challenges, it can still be very useful when applied with some modifications in key industries such as oil and gas and agriculture. The Federal government of Nigeria can monitor the movement of cows if the proposed cattle colony sells through. The monitoring will ensure that any strayed cow will be identified before it causes destruction on people's farm. Supervisory Control And Data Acquisition (SCADA) has been adopted successfully in Nigeria oil and gas industry, hopefully it will be repeated in Agricultural sector and other industries. Researches are on going to resolve several issues arising from difficulty in applying WSN in industry. Such issues such as energy supply and miniaturization will be resolved successfully.

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Photograph <Optional>

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Photograph <Optional>

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