Wireless Sensor Networks based Pipeline Vandalisation and Oil Spillage Monitoring and Detection: Main Benefits for Nigeria Oil and Gas Sectors

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***Abstract*—**Wireless sensor network has been applied in many areas of human endeavour since its development, especially in environment monitoring. The technology can be used to monitor pressure and temperature of pipeline carrying petroleum product, detection of oil spillage and pipeline vandalisation. Wireless sensor network has also been developed and deployed by many developed countries for other numerous applications, but it is yet to be utilized in Nigeria despite the country facing daily pipeline vandalisation and oil spillage. To ensure that the country benefits from the advantages of using wireless sensor network, there is need to enlighten organisations in oil and gas sector about the technology. This research paper specifically explore the wireless sensor network technology, types, applications, challenges and the features that makes the technology, a viable alternative in pipeline vandalisation and detection of oil spillage in Nigeria.

***Keywords*—**Ad hoc Networks; Application of Wireless Sensor Networks; Pipeline Monitoring; Wireless Sensor Networks; Wireless Sensor Network Model and Oil Spillage.

***Abbreviations*—**Analogue to Digital Converter (ADC); General Packet Radio Service (GPRS); Global Positioning System (GPS); Media Access Control (MAC); Microelectronic Mechanical Systems (MEMs); Quality of Service (QOS); Radio Frequency Identification (RFID).

I. INTRODUCTION

PETROLEUM and its products is the mainstay of many countries' economy especially Nigeria. Since the commencement of commercial oil production in 1958 by Dutch Oil, Nigeria has witnessed a phenomenon growth in her economy [Egberongbe et al., 1]. The production and growth of oil and natural gas sector are constrained by Sabotage and incessant vandalisation of pipeline carrying petroleum products. According to Society for One Nigeria, the country has lost more than seven billion dollars ($7.0bln) in revenue due to pipeline vandalisation and crude oil theft [Society for One Nigeria, 2]. While Okpo & Eze [3] noted that, the use of fossil fuel such as petroleum has negatively impacted on the biosphere as it releases pollutants and greenhouse gases into the air and damage the ecosystem through events such as oil spillage. Specifically, pipeline vandalisation has led to oil spillage into the environment. The resultant effects are the loss of arable land, destruction of soil organisms and plant nutrients, and decreasing fish stock which is the main livelihood of people at the Niger Delta of Nigeria. Nigeria is considered to have the worst oil spillage and environmental pollution resulting from such activities in the world [Benedict, 4].

To protest the adverse effects of oil spillage to their environment and community, Indigene of the oil producing areas and other criminally minded individuals often attack oil infrastructures, kidnap oil workers, engage in oil bunkering, causing more damage and forcing companies to shutdown oil productions with its consequent revenue loss [Egberongbe et al., 1]. To ensure effective monitoring, detection and report of oil spillage into the environment, petroleum industries in developed countries and recently developing countries are now using latest network technologies to monitor pipeline to ensure environmental safety and economic growth [Imad Jawhar et al., 5]. One of these technologies is the wireless sensor networks, which monitor and report uninterrupted updates and status of what is happening within and outside the pipeline installation areas. Research in computing and communication technologies has led to the development of wireless sensor networks that offer distributed sensing, which can be used for numerous applications. Some of these

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applications apart from pipeline and environmental monitoring are medical, military, and civil engineering and for commercial purposes [Puccinelli & Haenggi, 6]

There are a lot of research efforts in both developed and developing countries in the use of Wireless sensor Networks in pipeline and environmental monitoring and detection of oil spillage. These researches include development and deployment of Wireless sensor network [Ivan Stoianov et al., 7; Ning Xu et al., 8], framework for oil and gas pipeline monitoring [Imad Jawhar, 5], Deployment, security and risk assessment [Iwendi & Allen, 9], Quality of Service provision and routing protocols [Bhaskar Bhuyan et al., 10], Ambient Data collection and QOS implementation in Wireless sensor Networks [Shukla et al., 11] and Energy aware routing and Quality of Service [Akkaya & Younis, 12]. These researches have been conducted for different applications in organisations outside Nigeria Shore. With the increasing security threat to oil and gas installations and, the human and material resources in monitoring these infrastructures, there is need for Nigeria government, agencies and companies in oil and gas sectors to think towards applying wireless sensor networks to counter the above mentioned menaces. This paper set to specifically explore the wireless sensor network technologies, applications and the driveable benefits of using this technology to combat pipeline vandalisation and secure oil installations in Nigeria petroleum industry.

II. Overview of Wireless Sensor Networks

As stated earlier, researches in microelectronics mechanical system (MEM) technology, computer science and communication has given rise to the development of cheap and low powered sensor nodes that can communicate wirelessly in short distance. These devices are made up of sensing capabilities, communicating components and data processing; leverage the idea of sensor network based on collaborative effort of different nodes [Akyildiz et al., 13]. Wireless sensor networks are the collection of self-powered sensor nodes that coordinates to perform some specific tasks. The sensor nodes gather information or detect special events and send the data to base station to be processed. The technology is made up of three main elements. There are target sensing, processing the gathered data from the field of applications and communicating the processed results to the user [Puccinelli & Haenggi, 6].

2.1. Wireless Sensor Network Model

Typical wireless sensor networks has several components [Egea Lopez et al., 14], some of these components are:

- Nodes: These are physical devices used in monitoring a set of physical variables which communicates through a radio channel. There is also physical node tier that is connected to the environment. The sensor nodes are physically scattered or deployed in the environment in two or three dimensions for effective information gathering. The topological component of the node controls the node coordinate and can be from few nodes to several nodes. Other parts of the sensor nodes are sensing units made up of sensors and analog to digital converter (ADC). Analog to digital converter converts the analog signal produced by the sensors to digital signal and vice versa which is fed into the processing unit. Processing unit is the part that manages the storage of data, and procedure that enable sensor nodes to collaborate with other nodes in wireless sensor networks to carry out the assigned task.–Transceiver unit connect the nodes to the wireless sensor network, while the power unit is the sources of power to the nodes. It is supported by a power scavenging unit such as solar cells [Akyildiz et al., 13]. Other parts that are worthy of mention are location finding system and mobilizer. Location finding system helps to find the best routing techniques and location paths to transmit information and mobilizer is needed to move sensor nodes when it is required to carry out the assigned task.
- Environment: Environment is the wireless sensor network model that generate and sends the events that are sensed by the model, and trigger sensor action. The event to be sensed can be physical magnitude such as pipeline carrying petroleum products, sound, temperatures or building and home appliances.
- Radio channel: Propagate the radio signals among the nodes in the networks.
- Sink nodes: Sink nodes are special nodes that receive data from the networks and process the data which is communicated to the user. They may query the sensor nodes for events of interest.
- Agents: The wireless sensor network agents generate events of interest and transmit them to the nodes. Egea-lopez et al., [14] stated that sensor agent may cause variation in a physical magnitude which can be propagated through the environment and simulates the nodes. The agent is useful in the implementation of independent behaviour of the nodes.

2.2. Node Model

Wireless sensor nodes are divided into four abstract tier models [Egea Lopez et al., 14]. They include:

- Protocol tier: Comprises all the network communication protocol layers such as MAC layer, routing layer and application layer.
- Physical tier: This represents the hardware components such as the set of physical sensor, energy module and mobility module and their effects on the performance of nodes. The composition of the physical tier depends on the applications. Physical hardware describes how the monitoring hardware behaves, the energy module simulate the power consumption of the nodes while the mobility module control the physical positions of the nodes.

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- Media-tier: Media tier is the link connecting the individual nodes to the physical environment. The link maybe a radio channel or physical channels such as micro wave, radio wave or infra-red and cables respectively. Typical structure of wireless sensor network is shown in figure 1 below.

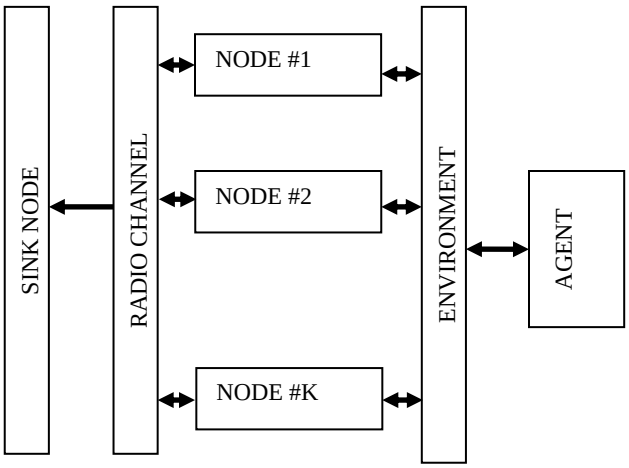

Figure 1: Typical Structure of Wireless Sensor Networks [Egea Lopez et al., 14]

2.3. Types of Wireless Sensor Network

According to Jennifer Yick et al., [15], there are different types of wireless sensor networks available depending on the environment where they are deployed. They included terrestrial, underwater, underground, multi-media and mobile wireless sensor networks. This section of the research paper will explain extensively these types of wireless sensor networks and their application in environmental monitoring and target tracking.

i. Terrestrial wireless sensor networks: These consist of thousand of cheap wireless sensor nodes deployed in a geographical area in ad hoc or pre-planned manner. Ad hoc deployment allow sensor nodes to be dropped randomly on the location of interest while pre-planned deployment, nodes are placed in grid, optimal, 2-dimesional and 3-dimesional models. The major challenges of terrestrial wireless sensor network are how to ensure reliable communication between the individual nodes and the base stations, longer battery life and conserve energy of the sensor nodes. With advance in research, industries have developed energy conservation mechanism such as multi-hop optimal routing, short transmission range, and in-network data aggregation, eliminating data redundancy, minimizing delays and using low duty-cycle operations. Terrestrial wireless sensor networks are equipped with solar cell as secondary source of power.

ii. Underground wireless sensor networks:–Underground Wireless Sensor Networks consist of number of sensor nodes deployed in underground system such caves or mines to monitor underground conditions.–Sink nodes are placed above the ground to relay information gathered by the underground sensor nodes to the base station. The challenges facing underground deployment in wireless sensor networks are the expensive nature of the procuring the equipments and maintaining them when compared to terrestrial deployment. Reliable communication through rocks, soil, water and other mineral contents. These natural elements contribute significantly to signal degradation, and high levels of attenuation, therefore it require careful planning and energy and cost consideration.

iii. Underwater wireless sensor networks: These are sensor nodes deployed underwater for exploration and gathering of sensor data through transmission of acoustic waves. It is more expensive, hence fewer nodes are deployed underwater. Challenges of underwater wireless sensor networks are limited

iv. bandwidth, long propagation delay, signal fading, self-configuration of sensor node, and their adaptability of ocean environment and how to replace or recharge battery life of underwater wireless sensor networks.– High energy consumption in underwater wireless sensor networks can be enhanced by developing efficient water communication techniques.

v. Mobile wireless sensor networks: Consist of sensor nodes that have the capacity to move on their own and interact with the physical environment. They can sense, compute, communicate, reposition and organise themselves in the network. Mobile wireless sensor networks starts with initial deployment at a point and spread out to gather information, these information gathered are communicated to

vi. Other mobile nodes in the network. Dynamic routing algorithm is used to

vii. Distribute data to the nodes mobile sensor networks. Challenges facing wide deployment of mobile sensor networks are how to ensure efficient deployment of the nodes, localisation, self-organisation, navigation and control, coverage of sensing location, energy maintenance and processing of the gathered data [Egea Lopez et al., 14]. Application of mobile sensor networks can be found in environmental monitoring, target tracking, search and real time monitoring of hazardous environment.

viii. Multi-media wireless sensor networks: multi-media sensor networks were developed to enable real time monitoring and tracking of events in the form for video, audio and pictures. They are collection of low cost sensor nodes equipped with cameras and microphones which interconnect each other using wireless media for data retrieval, processing, correlation and compression. The nodes are deployed in pre-planned manner into the environment to guarantee proper coverage. Multi-media wireless sensor networks are faced with a lot of challenges. They include high bandwidth usage, high energy consumption due to type of sensor data, and quality of service provisioning caused by variable delay and variable channel capacity. These constraint listed

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above can be minimised within the network through the development of transmission techniques that support high bandwidth and low energy consumption. To enhance the quality of service provisioning in the network, and ensure reliable content delivery, in-network processing, filtering and compression need to be adopted. Also, cross layer interaction among the layer can improve the processing and delivery process.

Table 1 below lists the different types of wireless sensor network, applications and the challenges hampering their deployment and acceptance.

Table 1: Types of Wireless Sensor Networks and their Applications [Egea Lopez et al., 14]

Types	Definition	Challenges	Applications
Terrestrial WSNs	Made up of hundreds to thousands of sensor nodes deployed on lands	The main challenges of terrestrial wireless senor networks are improved performance, cross communications, energy consumptions, how to find optimal route for the nodes, how to maintain network connectivity and reduce redundancy.	Can be applied in Environmental sensing and monitoring, Industrial monitoring for high level pollutions and surface exploration.
Underground WSNs	A network consists of wireless sensor nodes deployed in caves or mines or underground	Challenges of underground WSN are high cost of deployment, equipment and maintenance, prevention of threats such as animals, non-replaceable battery power, topology changes and signal loss.	Underground wireless sensor networks can be applied in Agricultural and landscape management, underground structure monitoring, mineral and military border monitoring.
Underwater WSNs	A network consists of wireless sensor and vehicles deployed into the ocean environment	Water sensor are expensive to implement, hardware failure such as corrosion, limited bandwidth, delay and high latency rate.	Water pollution monitoring such government water projects, undersea surveillance and exploration, disaster management, seismic monitoring and underwater robotics.
Multi-media	Multimedia sensor can store, process and retrieve multimedia files such as videos, audio and image files.	The major problems of multi-media wireless sensor networks are how to enhance in-network processing and filtering, compression of multimedia contents, energy consumption, problems of deployments, flexible architecture to support different areas of applications, and quality of service provisioning.	Can be used for target tracking and monitoring.
Mobile WSNs	A network consists of mobile sensor nodes that have the ability to move	How to navigate and control mobile nodes, automatic self-organisations, how to minimize energy consumptions, maintain consistent network connectivity and adequate sensing coverage.	Can be applied in Environmental, Habitat and underwater monitoring, military surveillance, target tracking, and search and rescue during emergency.

2.4. Applications of Wireless Sensor Networks

As stated in the table above, there are diverse areas of applications of wireless sensor network. Some of these applications can be categorised into military, medical and health, environmental monitoring, bio complexity mapping, flood detection, home application and commercial application [Puccinelli & Haenggi, 6; Akyildiz et al., 13; Egea Lopez et al., 14; Jennifer Yick et al., 15]. These applications are discussed below:

2.4.1. Military Application

Measure and detect the time of arrival of muzzle blast and shock waves from a shot. The sensors route their measurement to a base station to compute the shooter's location.

- Urban warfare where sensing devices are deployed to detect an enemy movement.
- To respond to anti-tanks mine and redistribute the mines in order to heal breaches created by the mine and slow progress of enemy troops. Example is the self healing and self organising wireless sensor networks developed by Defence Advance Research Project Agency using peer to peer communication [Puccinelli & Haenggi, 6].
- Battle field surveillance where critical terrain, approach routes and paths are closely monitored for activities of opposing forces. This wireless sensor network techniques can be deployed by Nigeria military to track down terrorists in inaccessible areas in the north-east part of the country.
- Assessing the damages caused by aftermath of battle encounter between opposing troops and relay the information gathered to the base station.
- Detection of Nuclear, Biological and Chemical attacks, the deployed sensor nodes warns of presence of chemical or biological and provides reaction time. This can help to reduce casualties.
- Army commanders and formation leaders can attach wireless sensor network to their troops, vehicles and ammunition to gather and give status report on them. This can also be implemented for timely information gathering by the army.

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2.4.2. Medical and Health

- Used to store patients data such as identification, medical history and treatment option to ensure quick retrieval during emergency.
- Monitoring human vital organ and accident recognition
- Care of the elderly, sensor nodes are attached to remind them of their daily activities such as exercise, taking of medication and meals [Puccinelli & Haenggi, 6].
- In hospital, sensor nodes can be attached to medication with the right prescription and composition to minimise wrong medication.
- Tracking and monitoring of doctors and patients especially those in mental hospital. The sensor nodes are attached to the patients and doctors, this enable location of doctors and patients and also help detect heart rate and blood pressure in patients.

2.4.3. Environmental Monitoring

- Monitoring of pressure and temperature of pipeline carrying petroleum products [Imad Jawhar et al., 5].
- Detection of oil spillage, pipeline vandalisation, leak and rapture in water supply and pipeline block to reduce maintenance cost [Ivan Stoianov et al., 7].
- Deployed sensor nodes can be used to detect forest fire and relay the exact location and origin to the base station to enable quick intervention.
- Flood detection where sensor nodes provide information on rainfall, water level and weather condition and alert the base station for proper analysis of the data gathered.
- Bio complexity mapping of the environment which include spatial spectral and temporal resolution at geometric decline cost per unit area [Akyildiz et al., 13].
- Precision agriculture where sensor nodes are deployed to monitor the pesticide level in the drinking water, the level of soil erosion and level of pollution in real time.
- To monitor the microbial contamination of water used for irrigation and swimming and allow remote testing and relaying the result to the base station [Ajmal & Allen, 16].
- Wireless sensor nodes can be deployed to test the quality of water in developing countries especially in rural areas.

2.4.4. Home Application

- Integration of smart sensor nodes and actuator into home appliances such as vacuum cleaner, microwave ovens, refrigerators and video players that can interact with each other internally and externally through internet to allow users to manage home devices remotely.

2.4.5. Commercial Applications

- Environmental control of office buildings where a distributed wireless sensor networks integration can be used to control air flow, temperature and to reduce energy consumption.
- Can be deployed in museums to provide paging and locations in the museums.
- Wireless sensor nodes are being deployed in cars to help detect and identify threats within geographical area and report these threats to remote end user for proper analysis.
- Structural health monitoring system for detection and localisation of damage in building, bridges, ship and aircrafts [Ning Xu et al., 8].

III. PIPELINE VANDALISATION AND OIL SPILLAGE MONITORING: WIRELESS SENSOR NETWORKS AS VIABLE ALTERNATIVE

The wireless sensor network technology has established itself as a viable alternative in target monitoring and detection. The use of human resources and security agencies (Police, civil defence and military) in pipeline monitoring and detection of oil spillage has become a huge burden on the government due to the expensive nature of the system. Even the alternative sensing technology such as oil spillage trajectory model which is a model that predict the number of days it will take oil spill to get to the coast line of Nigeria proposed by Egberongbe et al., [1] has not save the difficult task. They pointed out that, it will take an average of 5.5 days to detect oil spillage at Nigeria coastline. This is long time for destruction of huge magnitude to occur in the environment. Another techniques that has been deployed by oil and gas industries in Nigeria [Egberongbe et al., 1] is the establishment of Nigeria Sat-1 Satellite that provides oil spillage position and serves as oil spill model inputs. There was also the creation of regional spill response centre along coastline but this has not provided the best method in oil spillage monitoring.

The use of wireless sensor networks in target monitoring has gained prominence in recent years. These include wireless sensor network for steamflood and waterflood pipeline monitoring developed by SunHee Yoon et al.,–[17], oil and gas monitoring in the United Arab Emirate [Imad Jawhar, 5], Development of Wireless sensor networks for detection of topological changes [Farah et al., 18] to mention but a few. Nigeria can tap onto these developments and applications of wireless sensor network to monitor oil and gas infrastructure and promptly detect and respond to damages in pipeline carrying petroleum products. There are number of reasons why wireless senor networks have been deployed in target monitoring. This section of the paper will explain the advantages of wireless sensor networks over other traditional

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sensing technologies in pipeline vandalisation monitoring and oil spillage detection in Nigeria.

Stanlava [19] in his research on the application of wireless sensor networks, noted that four technologies have driven its application and acceptance. These technologies include Radio Frequency Identification (RFID), Global Positioning System (GPS), General Packet Radio Service (GPRS) and Wireless Local Area Networks (WLAN/802.11). Wireless sensor networks rely on existing low powered Radio Frequency Identification services. RFID is widely used for device tracking and to keep track of sensor nodes deployed in oil and gas fields. To ensure effective location of target such as leaking pipeline, vandal positions and exact location of existing defective infrastructure, wireless sensor networks deploy emergency response application, Global Position system (GPS) with camera as a supporting technology. Data collected by wireless sensor network can be appropriately presented over the internet using the General Packet Radio Service (GPRS). This enhances the time it takes to transmit data to appropriate decision maker to take actions. Stankovic further noted that the data can be transmitted over the internet through wireless local area network (WLAN/802.11) while the same data can be presented to mobile phone format using Bluetooth technology.

Autonomy is another attractive feature of wireless sensor network technology [Chanin & Hollaran, 20]. When the nodes are deployed in oil and gas field, the microprocessor can automatically initiate communication with other nodes to form wireless mesh networks and relay information to each other through the central node. The above feature has made wireless nodes to be deployed in any location.

Other advantages of wireless sensor networks as enumerated by [Chanin & Hollaran, 20; Huen & Sohu, 21] which has made it sought after technology in target monitoring and detection are:

- Uses inexpensive and low-powered microcontrollers and transceivers making it affordable to many organisations.
- The mesh networking employed to transmit data from one point to another consumes less energy than the traditional sensing technology.
- Ad hoc nature of the network allow addition of wireless nodes when required [Bhattacharyya et al., 22].
- The technology offer better coverage than centralised sensing network as more wireless nodes can be deployed in large area.
- Considerable reduction in data loss due to remote sensing and monitoring, and data are collected in real-time.
- Negative environmental condition cannot affect pipeline monitoring as that can be done remotely especially in inaccessible area.
- The technology can allow many user to view and manipulate the data transmitted simultaneously as data are retrieved from remote site. The data can be automatically analyse and appropriate action taken when phenomenon of interest occurs.
- Sensor nodes are self-healing, nodes can be added or removed without bringing the network to a halt. The network can reconfigure itself and determine the best route to the base station. This is important if any node die during vital operation.

The above feature and advantages derivable from the application of wireless sensor networks has expose the reason behind the adoption of this technology as a veritable tool in infrastructure monitoring. Organisations in oil and gas and environment has deployed this important development, and Nigeria cannot be an exception to this. There is need to enlighten industrial player, government and researchers on the benefits of wireless sensor networks in pipeline vandalisation monitoring and oil spillage detection. This will enable these organisation to appreciate the technology and work towards its implementation.

IV. Conclusion and Future Works

The effects of pipeline vandalisation and oil spillage in the environment are enormous. Despite its negative consequences, it is a frequent occurrence in Nigeria. Monitoring of pipeline infrastructure is a costly task, therefore devising a more effective means that is less expensive is very important. Wireless sensor networks which has been used in other countries to monitor and detect defective infrastructure. To obtain timely information on pipeline vandalisation and oil spillage can help in mitigating their negative effectives on the environment. This research has effectively outline the benefits of using wireless sensor networks in oil and gas sector in Nigeria. Further research of this work will look at the implementation requirement, implementation and development and quality of service provisions for wireless sensor networks, deployed for pipeline vandalisation and oil spillage monitoring and detection in Nigeria.

References

[1] F.O.A Egberongbe, Peter C. Nwilo & Olusegun T. Badjo (2006), "Oil Spill Disaster Monitoring along Niger Coastline", Online at www.fig.net/accra/papers/ts16-06-egberongbe-et al.pdf.

[2] Society for One Nigeria (2012), "A Radio Awareness Campaign on the Impact of Oil Bunkering and Crude Oil Theft", *Federal Radio Corporation of Nigeria*.

[3] O.C. Okpo & R.C Eze (2012), "Vandalisation of Oil Pipeline in the Niger Delta Region of Nigeria and Poverty: An Overview", *Studies in Sociology of Science*, Vol. 3, No. 2, Pp. 13–21.

[4] A.O. Benedict (2011), "Tragedy of the Commons: Analysis of Oil Spillage, Gas Flaring and Sustainable Development of the Niger Delta of Nigeria", *Journal of Sustainable Development*, Vol. 4, No. 2, Pp. 200–210.

[5] Imad Jawhar, Nader Mohamed & Khaled Shuaib (2006), "Framework for Pipeline Infrastructure Monitoring using Wireless Sensor Networks", Online at www.ieeexplore.ieee.org.

DOI: 10.9756/SIJCSEA/V7I4/03010010202
ISSN: 2321-2381

[6] D. Puccinelli & M. Haenggi (2005), "Wireless Sensor Networks Applications and Challenges of Ubiquitous Sensing", *IEEE Circuits and System Magazine*, Pp. 19–29.

[7] Ivan Stoianov, Lama Nachman & Sam Madden (2007), "PIPENET: Wireless Sensor Networks for Pipeline Monitoring", Online at www2.imperial.ac.uk/infrasense/pdf-files/p264-stoianov.pdf. (Accessed: 26/05/2014).

[8] Ning Xu, Sumit Rangwala, Krishna Kant Chintalapuda & Deepak Ganessan (2004), "A Wireless Sensor Network for Structural Monitoring", Online at www.escholarship.org/uc/item/7694/52g.pdf.

[9] C.O. Iwendi & A.R. Allen (2011), "Wireless Sensor Networks Nodes: Security and Deployment in the Niger-Delta Oil and Gas Sector", *International Journal of Network Security and its Application (KJNSA)*, Vol. 3, No. 1, Pp. 68–79.

[10] Bhaskar Bhuyan, Hiren Kumar Deva Sarma, Nityananda Sarma, Avijit Kar & Rajib Mall (2010), "Quality of Service Provisions in Wireless Sensor Networks and Related Challenges", *Journal of Wireless Sensor Networks*, Vol. 2, No. 11, Pp. 861–868.

[11] A.K. Shukla, S. Tripathi, C. Eapen & A. Ashok (2012), "Ambient Data Collection with Modelling and Implementation of QoS in Wireless Sensor Networks", *International Journal of Engineering and Advanced Technology (IJEAT)*, Vol. 1, No. 6, Pp. 280–286.

[12] K. Akkaya & M. Younis (2003), "Energy-Aware QOS Routing Protocols for Wireless Sensor Networks", *Proceeding of the IEEE Workshop on Mobile and Wireless Networks (MWN2003).*

[13] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam & E. Cayiru (2002), "Wireless Sensor Networks: A Survey", *Journal of Computer Network*, Vol. 38, Pp. 393–422. Online www.elsevier.com/locate/comnet.

[14] E. Egea Lopez, J. Vales Alonso, A. Santos Martinez, P. Pavon Marino & J. Garcia Haro (2005), "Simulation Tools in Wireless Sensor Networks", *Proceedings of the Summer Simulation Multiconference–SPECT-2005*. Pp. 2–9.

[15] Jennifer Yick, Biswanath Mukherjee & Dipak Ghosal (2003), "Wireless Sensor Network Survey", Online at www.costfocus.org.pdf.

[16] T. Ajmal & B. Allen (2012), "Wireless Sensor Network for Water Monitoring", *Research Proposal to the Institute of Research in Applicable Computing*. Online at www.beds.ac.uk/irac.

[17] SunHee Yoon, Wei Ye, John Heidemann, Brian Littlefield & Cyrus Shahabi (2011), "SWATS: Wireless Sensor Networks for Steamflood and Waterflood Pipeline Monitoring", *IEEE Network*: *The Magazine of Global Internetworking*, Vol. 25, No. 1, Pp. 50–56.

[18] C. Farah, C. Zhong, M. Worboys & S. Nittel (2008), "Topological Changes using a Wireless Sensor Network",– *Proceeding of the 5th International Conference on GIscience*, Vol. 5266, Pp. 55–69.

[19] S. Stanlava (2009),–"Medical Applications based on Wireless Sensor Networks", *Transaction on Internet Research.* Online at http://vipsi.org/ipsi/journals/journals/tir/2009/July/paper05.php.

[20] J.I. Chanin & A.R. Hollaran (2009), "Wireless Sensor Network for Monitoring Application". Online at http://www.wpi.edu/Pubs/E-project/Available/E-project-030708-030227/unrestricted/Wireless_Sensor_Network_for_Monitoring_Applications.pdf.

[21] I. Huen & G. Sohu (2007), "The Environmental Application of Wireless Sensor Networks", *International Journal of Contents*, Vol. 3, No. 4, Pp. 1–7.

[22] D. Bhattacharyya, T. Kim & S. Pal (2010), "A Comparative Study of Wireless Sensor Networks and their Routing Protocols", *Journal of Sensors*, Vol. 10, Pp. 10506–10523. Online at http://www.mdpi.com/1424-8220/10/12/10506/pdf.

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