The Challenges that Frustrate the Deployment and use of Wireless Sensor Networks for Oil Pipeline Monitoring in the Niger Delta Region of Nigeria

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Abstract:- The deployment and use of Wireless Sensor Networks, an IEEE802.15.4 standard enabled devices in pipeline and oil infrastructure monitoring has gained global recognition over the years. Wireless Sensor Networks make it possible for data to be collected from distant and remote fields in real time because of its capability of robust and reliable multi-hop communication thus eliminating using other technologies which are generally wired technologies and easily vandalised. The deployment and use of Wireless Sensor Networks in pipeline and oil facilities surveillance in the Niger Delta notwithstanding, incidences of pipeline vandalization and consequent oil theft are still rife. Employing the technology is thus frustrated by a myriad of challenges. This paper seeks to x-ray and also proffers solutions to the various challenges that have frustrated the effective deployment and use of the technology in the Niger Delta hitherto.

Keywords:- *WSN, Fields, Pipeline, Multi-hop, Technology, Standard.*

I. INTRODUCTION

From the year 2001to 2010, Nigeria lost 7billion USD annually to the stealing of crude oil and about 2,550 souls perished from fire incidences that emanated from crude oil stealing activities. In this interval, the volume of crude oil that was poured into the surrounding was more than 35,000 barrel [1]. A publication of the journal of Health and Pollution in 2018 reveals that over 12,000 mishaps wherein oil was spilled happened in the Niger Delta from 1976 to 2014. Over 50 percent of these mishaps are adduced to pipeline corrosion and tanker accidents. Others are credited to operating blunders, mechanical flops, and vandalism especially from violent gangs. These caused irreparable damages to the environment giving rise to serious environmental degradation including the pollution of underground water /wells; thus, posing serious health challenges resulting in death of the people of the region and also annihilating aquatic organisms and causing irreparable harm to the regional ecosphere because real time data was not available to personnel for possible actions to be taken to curtail such spills and minimise the attendant effects. Spill incident data provided by Shell Petroleum Development Company (SPDC) on a monthly basis from 2013 till date show that majority of these spills come from vandalism; just a small number resulted from operational error. Again, the data depict that the quantity of products spilled due to vandalism is more than the quantity of product spilled due to operational error.

Before 2005, oil establishments that are in operation in the region relied on conventional wired network technologies such as fibre optics and wireless technologies which include satellite and radio communications for monitoring their vast oil wells and facilities. But on account of the prohibitive high cost of deployment and maintenance, ineffective/delayed detection of pipeline problems and leakages, incessant destruction done to the components of these technologies among other shortfalls of these technologies, many of these oil concerns have embraced the wireless sensor networks as the technology for monitoring their vast facilities scattered over the region. Wireless Sensor networks is an IEEE802.15.4 standard enabled devices with the capability of robust and reliable multi-hop communications thereby making it possible for data to be collected from distant and remote fields in real time. Utilizing this technology, notwithstanding, the rate at which pipelines are vandalised has remained unabated thus raising lots of concerns relating to the usage of the technology for the surveillance of pipeline and infrastructures. For example, Nigeria lost over 1.35bn USD from losing barrels of crude oil totalling 22.6 million to theft and pipeline vandalisation in the first quarter of 2019 [2].

Scores of research work concerning some challenges in the deployment and use of this technology are already concluded and many others are ongoing. Many of these challenges are viewed with the presumption that WSNs do not have fixed infrastructure[3][[4][5][6][7]. Nevertheless, the WSNs required for monitoring straight structures, e.g. pipeline are an ordered interconnected structure wherein every node for sensing is spread out in a straight line.

This work x-rays and also proffers solutions to the challenges that stymie the effective deployment and use of Wireless Sensor Networks in oil pipeline and infrastructure monitoring in the Niger Delta region of Nigeria. They include security, technical, and routing challenges.

II. SECURITY CHALLENGES

Security challenges are generally well known as the paramount drawback to the successful deployment and utilization of WSNs in the monitoring oil facilities in the region. The security challenges which are essentially attacks against the successful utilization of WSNs deployed in oilfields are:

- Denial-of-Service (DoS) attacks.
- Compromised or Malicious node attacks.
- Physical attacks.

Physical attack has been identified to be the most malignantly serious and rampant type of attack against sensing nodes of the wireless network used in the vast oil fields in the region [8]. The multinational Oil enterprises that are working in the region have invested heavily in providing protection for data to assures that the data emanating from the WSNs have privacy, and reliability but these efforts notwithstanding, vandalisation of pipelines bearing oil and gas and other infrastructure has remained unabated. This results from attacks/vandalisation on/of sensor nodes of the WSNs themselves which are meant to carryout surveillance and transmit status report on the pipelines and infrastructure being monitored to the base station for onward transmission to the control room of the company. It is has been established that the moment the nodes of the WSNs have been physically compromised, the security cryptographic solutions inside the nodes can be ripped off and the codes used to harm the whole deployed WSNs. Consequently, the equipment and pipelines they were meant to guard will therefore become vulnerable to the vandals.

To remedy the security challenge, the three following solutions are proffered to totally safeguard and boost the effectiveness of wireless sensor networks employed in the monitoring of any environment especially the vast oil environment of the region:

- Operational/Communication Security.
- Information/Data Security.
- Physical Security.

A. Operational/Communication Security

According to [8], operational security assures that WSN is always available. Operational security overcomes attacks on the Network's Physical layer protocol stack. The following cause of action are suggested to assure operational/communication security [8]:

- Safeguarding of WSN's communication links from attacks like halting WSNs signal; a situation called jamming and all forms of Denial-of-Service (DoS) attacks aimed at depleting the network's power source with the sole aim of disrupting the accessibility of the WSNs network. As a means of preventing malignant nodes from invading the network with the aim of upsetting it, all communication links should be encrypted.
- Utilizing spread spectrum frequency hopping to prevent bulk of the malignant nodes from invading the network to assure accessibility at all times. This is aimed at restoring the network even after an invasion.
- Employing geographic path hopping to safeguardthe routing technique level of the network to push off routing related intrusion opposing the network's running efficiency.

B. Information/Data Security

The increased need for real-time information has made the deployment and use of WSNs by the various oil enterprises in the region more expedient. WSNs often than not utilize multi-hop communication system to get over possible restraints. The paramount issue of multi-hop communication is the attack that is targeted at the source node and node's identity amid hopping. In a WSN with very limited resource having a source node transmitting data to a destination node via many intermediary nodes, there is the likelihood of intrusion, tracing of identity by an enemy, acquiring and even altering of the info from the source by the intermediary node.WSNs often than not function in very unfriendly regions, thus can be exposed to varieties of invasions like side channel attacks, namely differential power analysis. Here, the enemy observes the system, replicates the same procedure and carefully obtain measurement of the energy expended per cycle so as to retrieve the key or perturb utilized in the perturbation. As a measure to prevent this,in[9] a scalar binding is often employed in countermeasures that are set on cryptographic protection.The scalar computation is blinded utilizing integer m, where m stands for the order of the point P∈Eq, in order that mP ¼ 0. To illustrate, rather than compute Q ¼ kP mod q, Q ¼ k þ mðÞ P mod q is computed.

C. Physical Security

It has been established by several authors that the issue of physical security in which case all or some of the network's components are vandalised, thereby rendering the system ineffective, hitherto is the biggest of all the challenges that frustrate the implementation and use of WSNs in monitoring pipeline in the region[8].

To guarantee the sustained utilization of the monitoring technology employed in the monitoring o pipeline, to guarantee accessibility, distant, and instantaneous monitoring coupled with the safe functioning of the pipelines, humans are engaged to physically guard and patrol oil pipeline and infrastructure. This measure also helps in the surveillance and assessment of pipeline to locate the regions that have flaws, and get an exact measure of the flaws in order that relevant actions to forestall additional damage can be taken expeditiously. Petroleum and Product Marketing Company (PPMC), Host Communities' Leaders, and a collaborative squad of Cops and vigilante groups render guard services to watch over the pipelines in the region. Frequent airborne surveyance of very important segments of the pipeline and infrastructure is as well done by Petroleum and Product Marketing Company/ Nigerian National Petroleum Corporation (PPMC/NNPC) [10].

III. TECHNICAL CHALLENGES

Other than the challenge of security, technical issues are also being faced on a daily basis by the oil industries in the region when WSNs are implemented and used.

The following technical challenges are discovered to pose problems to plant handlers and WSNs technicians working in the oil fields within the region:

- Interoperability and scalability problems: WSNs wares from diverse manufacturers having diverse protocols and systems are very knotty to be integrated or be scaled. Since WSNs must exist side-by-side with other technologies like Wireless LAN (WLAN), Wi-Fi, Bluetooth to mention but a few, addressing the issue of interoperability and scalability is an imperative. Right now, research findings are giving rise to possible solutions to these issues. For example, Spread-spectrum Frequency Hopping has been found to have the potential to resolve the issue of interoperability.
- Technical know-how: Highly skilled workers are required for the effectual and thorough implementation, use, and management of the technology (WSNs) in addition to different wireless technologies and their capability to interoperate. Training and reorientation of personnel are an imperative to handle the issue of practical knowledge.
- Energy concerns: The issue of energy such as sensor node battery usage, performance, and optimization causes a number of technical challenges to WSNs utilization. These concern which are mainly the perpetuation and optimization of the battery are of date being seriously researched on.
- Latency problems, Nodes being too much, Node breakdown,the issue of network efficiency etc also cause additional class of challenges that are technical. The distribution of WSNs using either mesh or star topology coupled with spread spectrum frequency hopping scheme are helpful in lessening energy dissipation in addition to simultaneously helping to retain an operative network following the breakdown of nodes.

The other challenges discussed in this work are generally encountered when WSNs are deployed and utilized.

IV. ENERGY MANAGEMENT FOR LINEAR TOPOLOGY WIRELESS SENSOR NETWORK

Energy is among the prominent and scarce resources in operating Wireless Sensor Networks (WSNs). The WSNs' sensor nodes normally operate on small capacity battery. Giving that replacing the batteries after the distribution of the sensor nodes is a strenuous duty, it is very important to duly control their energy usage so as to attain the highest working lifecycle for the WSNs. The first challenge for a distant linear topology WSNs is developing an energy efficient communication protocols to enable the sensor nodes to effectively interface with each other and with the data sink of the wireless sensor network. As a consequence of the topology that is linear, the communication among nodes is restricted by directional transmittance through the route of sensor node dispersion. These protocols dictate when communication should be initiated premised on a least energy concept and the way nodes organize the data transmittance inside the immediate domain and with distant sink that will allow the sensor network to boost their lifespan whilst reducing the overall deployment cost.

V. ROUTING CHALLENGES

Energy saving routing technique is among the main difficulties for a distant straight topology WSNs. That is so, as routing techniques that are found in [6][7] carry out their route detection and sustenance employing an array of schemes like flooding, and multi-dimensional distribution. Flooding procedure is expensive in employing vital implements that are sparse in the wireless terrain like energy needed on-board, node handling capability, and space. Furthermore, it results in time lag in path discovery and sustenance. However, routing techniques which have been modelled for straight sensor network will not require utilizing expensive method for route detection. Actually, the fact that the network is linear could be exploited to either get rid of or excessively limit the route detection technique. For instance, an addressing strategy may be employed so as to realize the routing without requiring route detection. Furthermore, route sustenance may be carried out automatedly at the intermedial nodes by employing the data in the node location to subdue nodes flops. It is essential to be mindful that node position allocation is carried out just once when the network is being initialized.

VI. LOCALIZATION CHALLENGES

Several implementation of WSNs demand that sensor nodes should be acquainted with their total or approximate locations. This position info is utilized to achieve application definite duties and networking tasks effectively. For instance, a node functioning in a set-up is generally not only needed to send a report of an outcome of concern but it is also needed to give a report of the exact position of such an outcome of concern. Therefore, the node must possess the capability to measure the present position automatically. The assessment of the node's position by the node in a structural layout arrangement is called localization [11][12]. Localization in sensor networks is pivotal in aiding position aware operations, item tracking, position premised routing, and collective signal processing. Several localization schemes as reported in [12] may be grouped as direct approach, and indirect approach.

Direct approach: This approach is also called absolute localization. The approach is further broken into manual configuration, and GPS-based localization. The manual configuration technique is complex and costly. It is impracticable, and not scalable for vast WSNs. While in the localization technique that is based on GPS, each one of the nodes gets a GPS transceiver. It is very uneconomical to provide every sensor with a GPS transceiver as WSNs are implemented in countless number scattered all over the field being monitored.

Indirect approach: This method known as relative localization because the nodes are positioned relative to themselves in their surroundings. In this method, a minute quantity of nodes within the network known as beacon nodes are either provided with GPS transceiver to calculate their position or are modelled manually with their position. The beacon nodes then transmit streams of signals conveying their position to the other nodes within their surroundings. Using the sent signal made of the location info, the rest of the nodes calculate their various positions. This method perfectly decreases the cost brought about by the method based on GPS. Algorithm for determining nodes in straight topology WSN may be effortlessly designed by exploiting the linear configuration. In a bid to assist in this aspect, an upper level addressing strategy that contains information concerning nodes' position in the address could be utilized.

This scheme could immensely boost the potential of the network to readily, speedily, and accurately locate nodes.

VII. CONCLUSION

Wireless Sensor Network (WSN) will undoubtedly remain the choicest technology for monitoring oil bearing pipeline and facility because of its capability support real time, rugged and dependable multi-hop communications even from distant locations. Different challenges that frustrate its use in oil pipeline and infrastructure monitoring in the Niger Delta have been x-rayed and solutions have been accordingly proffered in this piece.

The employment of these solutions will greatly contribute to making Wireless Sensor Network (WSN) a more potent and reliable technology to efficiently monitor oil pipeline and infrastructure in the region. An efficient monitoring will abate if not totally eliminate the incidences of the stealing of crude, and environmental pollution as pipeline vandalization or accident will be reported in real time to enable suitable actions to taken promptly.

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