Performance Analysis of Linear Topology Wireless Sensor Network in Oil and Gas Industry

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Abstract. Oil and gas industry is one of the largest corporations in the world. The process and machinery involved for the petroleum product to be extracted, refined and transported are usually critical and complex. Hence, it is crucial to have a stable and reliable system to control, monitor and manage the security of the industrial assets. Since Wireless Sensor Network (WSN) can sense, process and communicate, it is one of the best and popular solutions to the problem existed in the oil and gas industry. In this paper, a detailed performance analysis of AODV, DSDV and FIXRT with 32 and 128 packet size is presented by using linear topology in accordance with IEEE 802.11 standards by using ns2.35 simulator. The results showed that FIXRT protocol increases the overall performance of the network by almost 30%.

Keywords—Wireless Sensor Network (WSN), Oil and Gas monitoring, Packet Size, Linear Topology, IEEE 802.11 standards, ns2.35 Simulator

1. Introduction
WSN is a group of sensors each has the capability to sense, communicate and process, but form a network which mutually monitors the state of the physical world when deployed in a group. Each of these sensors has the ability to gather and process data while communicate with each other wirelessly [1]. This technology will affect the industry world especially the oil and gas since the procedure and environment involved in this industry are usually complex dangerous. With the capability of WSN is undoubtedly significant, the application of this technology is unlimited from agricultural sector, acoustic sector, environmental management and even oil and gas [2, 3, 4, 5].

Oil and gas industry are known for their dangerous and critical procedure to ensure the assets are in perfect condition. The operation is separated into three main levels, upstream, midstream and downstream. Upstream is where exploration occurred while midstream is the storage and transportation of the crude oil. Downstream, on the other hand, is where the refining and marketing process took place. The common transportation for the products is pipelines, ship or truck.

As predicted by U.S. Energy Information Administration Office [6], the future demand of energy will increase by 7% per year from 2018 to 2020, which is greater than the 4% average growth rate form the year 2005 to 2015. The report also forecasted that by 2030, natural gas plant liquid (NGPL) production will have a shocking increment by 38% compared to 2018 level. Figure 1 illustrates the subdivisions of oil and gas industrial operation.
1.1. Challenges in Deployment of WSN

Despite having such advantages, there is no perfect solution in this world. There are several challenges and obstacles in deploying WSN. The energy consumption is the most common problem faced by the researches and it is the most critical issues faced by WSN. This is due to the network lifetime is a major criterion, especially to the linear topology deployment as energy, are needed to gather, process and transmit each data packets. The energy consumption increases as the size of the network are increased. Since WSN are deployed to work with limited human intervention, any person can attack the network and the entire system will be disrupted [7]. Other than the mentioned challenges, the reliability and Scalability of the network are also a serious problem faced by the researches. In the oil and gas industry, a consistent communication system is vital. When unpredictable event is detected, the nodes are required to gather and sent the data within a period as failure to do so will lead to calamitous accidents. Figure 2 describes the overall view of challenges faced in the deployment of WSN.
1.2. Network Characteristic

To reduce the risk involved in the deployment of WSN, several techniques are applied. One of the popular techniques used is the manipulation of the topology. A network topology is referred as the way nodes are linked to one another in a network. Since the main focus in this paper is linear topology, the architecture of a multi-hop linear topology is classified into two major structure which is the flat one-tier topology and the hierarchical multi-tier topology as illustrated in Figures 3 and 3 [8].

The other manipulation that can be considered is the wireless standards. The wireless standards have a significant influence in term of performance and outcome to the nature of topology implemented. The two standard devices that are potential for a real scale implementation on linear topology is IEEE 802.11 and IEEE 802.15.4. The brief technical operation of both standards is as shown in Table 1.
Table 1. Comparison between IEEE 802.11 and IEEE 802.15 standard.

| Parameters          | Wifi  | ZigBee | WirelessHART | Z-Wave |
|---------------------|-------|--------|--------------|--------|
| IEEE standard       | 802.11a/b/g/n/ac | 802.15.04 | 802.15.04 | 802.15.04 |
| Operational frequency | 5GHz(a,ac)/2.4GHz(b,g)/2.4GHz-5GHz(n) | 2.4 GHz | 2.4 GHz | 868.42MHz |
| Nodes per maste     | 2007  | > 65000 | 500          | 232    |
| Range               | 100 meter(a,b,g)/250 meter(n) | 1600 meter | 250 meters | 100 meters |
| Data rate           | 11Mbps(b)/54Mbps(a,g)/450Mbps(a,c)/600Mbps(n) | 250 kbps | 250 kbps | 100 kbps |
| Battery Life/Cost   | Days-weeks High | Months-years Low | Months-years Moderate | Months-years Low |

2. Previous Study and Research

Lately, remote monitoring of pipeline using WSN are becoming a trend due to the speedy improvement of technology on communication protocols, efficiency, capability and implementation cost on the various application [9, 10, 11, 12]. Since the characteristic of the network layout is unique, consequences such as network destabilization, throughput unfairness, high delay and power consumption are formed. The authors in [13] proposed an algorithm which combines the advantages of both clustering and Compressive Sensing-based strategy. The authors also stated that the reason for WSN lifetime to be reduced is mainly because of Hot Spot Problem and the alternation of the role for Cluster Head. To overcome this, the authors suggested that a Backup Cluster Head along with a new mechanism to replace the role of Cluster Head which is called Energy-Efficient Compressive Sensing-based clustering Routing (EECSR). This study showed that the EECSR has better power efficiency and lifespan compared to the existing clustering algorithm.

In [14] the authors proposed a system that cartels JenNet network with IEEE 802.15.4 standard. This proposed system can be used on different network topologies such as linear, tree and star. To increase the robustness of the network, the proposed solution has a self-healing feature. To tackle the power limitation, this system contains sleep mode capability. To make the workers emergency maintenance easier, a wind sensor is added in the system to indicate the wind speed and other information.

The authors in [8] proposed a novel routing method, Odd-Even Linear Static Routing Path (OE-LSRP) to achieve noteworthy improvements in overall network performance. By splitting the node into two different paths, the snowball effect towards the destination nodes are reduced and this gives the performance of the network a significant boost. The authors tested the proposed solution in accordance with the IEEE 802.11 standard and the architecture of the nodes are in linear topology.

Next, the authors [15] presented a method which is called SimpliMote. This system uses IEEE802.15.04 standard to detect leakage in oil and gas pipelines. The author combined a low power custom sensor board with algorithms that detect leakages, localization, actuation and parameter sensing. A testbed of 3-meter-long pipeline that is filled with pressurized fluid is prepared to simulate the oil and gas pipeline. To create a real-life leak, valves are used.

3. Result and Discussion

In this research, certain parameters are being considered. The number of nodes that are being simulated is 200 nodes with 50m distance each and 125 m of communication range. The simulation was run with five cycles where the seeds number varies. The bandwidth used is 2 Mbps and two packet size are considered which are 32 and 128 bytes. The protocols involved are AODV, DSDV and FIXRT. The simulator that is being used is NS2.35 and the topology that is being considered is linear topology.

The results shown in Figure 5 indicates that DSDV with 128 packet size has a better delivery ratio compared to AODV protocol. The network with different sizes suffers from data loss but this problem...
is reduced by DSDV with 128 packet size. However, with FIXRT protocol, we can clearly see that the delivery ratio of the network has significantly increased to almost 30%.

![Graph on Delivery Ratio over Number of nodes](image)

**Figure 5.** The graph on Delivery Ratio over Number of nodes.

This results can be validated with Figure 6 which indicates that FIXRT with 128 packet size has the highest throughput value. With higher delivery ratio, the network will have a higher throughput. Since the network capacity for packet size 128 is higher, a better delivery ratio is produced.

![Graph on Throughput over Number of nodes](image)

**Figure 6.** The graph on Throughput over Number of nodes.

In Figure 7, it is clearly shown that the passive nodes for AODV with 128 packet size are higher compared to others. Since AODV has higher passive nodes, the delivery ratio of the network will also be affected. This result has clearly indicated that FIXRT has significantly reduced the number of passive nodes hence increasing the overall network performance of the WSN.

The results in Figure 8 indicate that packet size 128 has a higher routing overhead compared to 32. However, among the routing protocols that has 128 packet size, AODV is higher compared to DSDV. When the routing overhead is high, network recourse wastage will occur. When routing overhead is increasing, the usage of bandwidth is limited, and this will increase the queuing factor of the network.
Packet or data loss will occur more frequent and this will reflect on the performance of the network. However, among the 3 routing protocols involved in the comparison, FIXRT showed the most promising result as it has the lowest value of routing overhead over number of nodes.

*Figure 7.* The graph on Passive Nodes over Number of nodes.

This will reflect on Figure 9 which indicates that AODV has lower fairness index compared to DSDV and FIXRT. Among the packet size, 32 packet size has lower fairness index compared to 128 packet size. With lower fairness index, higher passive nodes will be produced, and this will affect the delivery ratio and the overall performance of the network.

*Figure 8.* The graph on Routing Overhead over Number of nodes.
4. Conclusion

Wireless Sensor Network (WSN) technology has the potential to provide a proper and efficient monitoring system, especially in the oil and gas industry where all the information is critical to avoid unpredictable disaster. The main challenges faced in the industry are mainly energy consumption, security, reliability, robustness and scalability of the WSN.

As a conclusion, the major attribute that is being focused on this paper to evaluate the overall performance of the network is delivery ratio. This is due to the main function of the WSN is to deliver information. As presented above, the FIXRT has a higher value of delivery ratio compared to other protocols with almost 30% improvement. This result is supported with higher value of throughput and fairness index. The passive nodes and routing overhead for FIXRT is also lower compared to AODV and DSDV protocols.

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