Performance Evaluation of Grid Wireless Sensor Network with Different Packet Size for Pipeline in Downstream of Oil and Gas Industry

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Abstract. In the past few decades, sensed data such as wind, vibration, temperature, and humidity were sent through the costly wire cable. With recent advancement and innovation in the wireless field, wireless sensor network (WSN) has emerged to benefit many industries in different aspects primarily in term of cost. WSN has been widely used in various applications due to its wide coverage area, particularly in oil and gas facility monitoring. Hence, the usage of grid WSN fits the wide coverage area mainly in the pipeline of downstream of oil and gas process. The main objective of this paper is to give a better understanding of the impact of different packet sizes, routing protocols, and the number of nodes towards a grid WSN as well as to provide open research issues in this field. Two types of routing protocols have been presented in this paper; reactive (AODV) and proactive (DSDV) with different packet sizes using a grid node arrangement. The simulated results have shown that with the increasing size of the network, more performance degradation occurred regardless of the packet size used. This issue can be seen through the packet loss and throughput loss in the network prominently after the deployment of 80 nodes and above. Apart from that, DSDV has shown a better delivery ratio, less number of passive nodes existence and less routing overhead produced in the network as compared to the AODV routing protocol.

Keywords— Wireless Sensor Network (WSN), Oil and Gas monitoring, Packet Size, Routing Protocols, Reactive (AODV), Proactive (DSDV)

1. Introduction
Numerous industrial, scientific, and environmental applications demand real-time data of physical events such as humidity, temperature, or pressure. Such events, in the past few decades, were collected and sent to the collecting point through costly, cumbersome cables. In recent years, WSN has emerged with a more promising return with its cheap, simple yet sophisticated solution to most of the industries. WSN has proved its capability in collecting, processing and communicating in various application particularly in the oil and gas industry [1].

WSN has been used in oil and gas facilities in upstream, midstream and downstream sectors to monitor health issues, to monitor pipeline integrity, and to enhance production. As shown in Figure 1, the upstream sector is where the discovery and extraction of raw materials process take place either from the underground or underwater [2]. Midstream is where the extracted material is stored and transported to the downstream process usually via truck, barge, rail or pipelines. Downstream, on the other hand, is where the transported materials are processed, refined, marketed and commercialized.
There are two types of pipeline distribution which are linear (midstream) and spread out distribution (downstream) as shown in Figure 2. This paper focuses on the WSN application of pipelines in the downstream sectors where the coverage area and the pipeline distribution fit the grid node arrangement. Since most of the assets were placed in remote locations, continuous remote monitoring in these three sectors is highly required to protect the assets and to maintain the production in the oil and gas industry.

The nodes deployed in the oilfield environment utilize sensors such as pressure or leakage sensor that gather crucial industrial data allowing new intuitions for plant operations and advanced solutions. It also helps in reducing downtime, operating and production costs, optimizing operations, enhancing platform safety by hindering problems and tolerating any errors. For example, in pipeline transmission, the operations usually dealing with harsh environments, highly flammable material and high pressure of liquid material. Hence, any failure during these operations could cause a tragic incident to the people surrounding and to the environment as well as critical financial loss. This is where WSN comes in handy where it reduces the intervention of humans in oil and gas operation.

In wireless communication, there are 7 layers in the Open Systems Interconnection (OSI) model as
shown in Figure 3 and this paper presents the performance evaluation comprising the network layer where the routers operate. In this layer, the data is packaged into IP datagrams consisting of destination and source IP address [3]. IP datagrams are responsible for the data forwarding process across the network. A routing algorithm or routing protocol determines how the data is routed in the network to exchange information. The aim of this paper is to evaluate the performance of the existing WSN routing protocol as well as implementation of different packet sizes towards the routing protocols and to present the lacking factors that affect the performance of the network as the network grows with an arrangement that mimics the spread-out distribution of the pipeline in downstream sector of oil and gas industry which is the grid node arrangement.

![Figure 3. The 7 layers in the OSI model.](image)

1.1. Routing protocols
With the high demand and fast-emerging technologies in WSN, several challenges stem out and created more opportunity window for researchers to solve. Packet loss, throughput loss, and high routing overhead have contributed to the performance degradation primarily in a high-density network. These issues could be caused by the congestion in the network, hence making routing one of the tangible issues that need to be solved. In the network layer or routing layer, different types of routing protocols have been used [4] as shown in Figure 4.

![Figure 4. Three routing protocols in the network layer.](image)
The proactive routing protocol is often known as a table-driven approach making the routing in pre-defined mode [5]. With this feature, the delay for packet forwarding is reduced by but the network resources will deplete due to the route update and maintenance for the routing table. One of the examples of proactive routing protocol is Destination-sequenced Distance Vector (DSDV) routing protocol. Reactive routing protocol, on the other hand, uses an ad-hoc method of routing where the path will be discovered only when needed [6]. This has caused the delay in the data forwarding but fewer routing overhead will be drawn. One of the examples of proactive routing protocol is Ad-hoc on Demand Distance Vector (AODV) routing protocol. Hybrid routing protocol combines the best features in the proactive and reactive routing protocol. One of the examples of the hybrid routing protocol is the Zone Routing Protocol (ZRP). There are more examples of routing protocols that have been proposed by past researchers which can be seen in the next section.

2. Related research

The researchers in [7] have presented a routing overhead of the reactive routing protocol study based on Wireless Multihop Networks (WMhNs). The network performance has been improved by implementing routing overhead monitoring methods to Dynamic Source Routing (DSR), AODV, and Dynamic MANET On-demand (DYMO) routing protocol. As a result, the researchers have found that AODV shows the best performance during high-density traffic by considering scalability. On the other hand, the DSR routing protocol shows the lowest end-to-end delay and control packets. The researchers also highlighted that DSR works best in a network with a fewer number of hop.

The researchers in [8] have proposed a Novel Hybrid Distance Vector (NHDV) routing protocol which combines AODV and DSDV routing protocols to reduce route discovery time, reduce congestion, and provide better scalability in the hybrid mesh network. NHDV uses clustering by appointing the gateway as the cluster head by using the Hello packet. As a result, NHDV has improved the network performance from the clustering technique and has enhanced the path quality from the implementation of DSDV.

In [9], the researchers have investigated the disadvantage Multicast Ad-hoc On-demand Distance Vector (MAODV) and with that, the researchers proposed a new routing protocol MAODV-BB (Backup Branches). MAODV-BB is the routing protocol that combines tree and mesh topology. The tree structure uses low network resources, efficient in forwarding but has poor robustness while the mesh structure helps in load handling during high load network. MAODV-BB has shown a significant improvement in the Quality of Services (QoS) during high load networks.

The authors in [10] have proposed Neighbors Perception ZBR (NP-ZBR) routing protocol, a novel ZigBee Routing Protocol (ZBR). As known by many, ZBR has good average hop, delay, and transmission rate. However, ZBR uses a high amount of network resources which then increases the load and energy consumption due to congestion. With NP-ZBR, a better performance resulted in terms of hop average and transmission delay while maintaining the same average end-to-end delay, throughput, and transmission rate as in ZBR.

In conclusion, there are few kinds of research that have been done on grid topology and none of the researches showed an implementation of high number of nodes in the network. Thus, this has led to the study of different numbers of nodes, packet size, and routing protocols towards the performance of grid WSN.

3. Simulation

In the oil and gas industry, there are two types of pipeline distribution which are linear and spread-out. This paper focuses on the spread-out distribution, hence the usage of grid node arrangement. It is important to simulate the network in order to determine the lack in the network using the specified environment which in this case, grid topology with a varied number of nodes. Table 1 shows the parameters as well as the routing protocols used in the simulation using Network Simulator 2 (NS2).

The resulted performance metrics such as delivery ratio, throughput, passive nodes, routing overhead, and fairness index from the simulation have been recorded to show the behaviour of the simulated network. Some statements from a few research papers were included to support the reasoning behind every presented result.
Table 1. Parameters used in the simulation

| Parameter          | Value                                                                 |
|--------------------|----------------------------------------------------------------------|
| Routing protocol   | AODV, DSDV                                                            |
| Bandwidth          | 2Mbps                                                                |
| Transport agent    | TCP                                                                   |
| Packet size        | 32, 128, 512                                                          |
| Topology           | Grid with nodes formation of 6x4, 8x6, 10x8, 12x10, 14x12, 16x18 and 18x16 |
| Number of nodes    | 24, 48, 80, 120, 168, 224, 288                                       |
| Node distance      | 50 m                                                                  |
| Propagation model  | Two ray ground                                                       |
| Simulation time    | 500 s                                                                |

3.1. Simulation results

As the network size increases, the delivery ratio decreased as illustrated in Figure 5. This indicates more packet loss, as well as the throughput degradation (as in Figure 6) in the network as the number of node increases mainly after 80 number of nodes onwards. This is due to the overloaded traffic which causes congestion in the network as the network density and size increases [11]. Apart from that, the queue length factor plays an important role in this case. In the simulation, the queue length is 50 and the queue type is tail drop queue, hence, without considering the time to live of a packet, any packet after the 50th enqueued packets will drop causing a packet loss. From the results, although the trend in Figure 5 shows a similar pattern, it can be said that DSDV shows a better delivery ratio as compared to AODV. In addition, the usage of 32 bytes of packet size causes fewest packet loss and 512 bytes of packet size causes the most packet loss in the network.

Packet loss issue that affects delivery ratio as shown in Figure 5 has contributed to the throughput degradation which can be seen in Figure 6. There is a control mechanism known as the TCP congestion control mechanism. In order to reduce the traffic load, the congestion control mechanism reduces the transmission rate or drops the packet [12]. This issue causing packet loss and throughput degradation. As shown in figure 6, a slight throughput reduction shown for packet size 32 and 128 bytes. However, for packet size 512 bytes, the throughput clearly starts to degrade after 80 number of node onwards.

Figure 5. Average delivery ratio over number of nodes.
Theoretically, the smaller the packet size, the more routing overhead the network has and vice versa [13]. This statement can be proved by observing the results shown in Figure 7, 32 bytes of packet size produced the most overhead as compared to 128 and 512 bytes. To be well described, the packages delivery using a truck is more cost saving as compared to the delivery using a standard car due to the fewer fuel consumption and fewer number of trip. For example, to send a big machinery equipment to a place, a truck would only take at most two trips, but a car would take more than that. It can be said that the truck utilize less fuel (routing overhead) consumption to deliver the equipment as compared to the car.

Apart from that, it can be clearly seen that the AODV routing protocol produced more routing overhead as compared to the DSDV routing protocol. Studies in [14, 15] have shown that AODV produces more routing overhead as compared to DSDV. Since AODV is on-demand protocol, the routing overhead will increase as the number of nodes increases. Due to high traffic, queue factor and time to live of the packet, ad-hoc routing protocol has to retransmit the dropped packet during congestion at cost of rebroadcasting of unwanted packets. Eventually, routing overhead will increase cannibalizing the network capacity. While for DSDV, during an event of packet drop, all of the required information is already stored in the routing table. Hence, the source does not have to rebroadcast the unnecessary packets to re-establish the path to the destination during high traffic. The packet loss through the delivery ratio of AODV and DSDV as shown in Figure 5 reflects the amount of routing overhead as shown Figure 7.
7, showing the drawback of packet retransmission by both AODV and DSDV routing protocols as the network grows.

With the increasing number of overhead in the network, the network resources will be used up and causing severe unfairness in the network [7, 16]. As shown in Figure 8, there are no significant differences in the fairness index trend between AODV and DSDV routing protocols. However, it can be seen that 32 bytes of packet size produced the worst fairness index and 512 bytes of packet size produced the best fairness index in the network. These situations can be said that by using smaller packet sizes, more network resources will be consumed as discussed on the routing overhead topic earlier.

Figure 8. Fairness index over number of nodes.

Apart from the fairness issue, passive nodes’ existence also one of the drawbacks of resource wastage. The network resources were not allocated equally, hence, some of the nodes had the chance to transmit or receive the data and some do not have the chance. As illustrated in Figure 9, the number of passive nodes increased as the number of nodes increases. AODV routing protocol produced more passive nodes as compared to DSDV routing protocol. This is due to the consumption of resources by AODV is more as compared to DSDV by taking routing overhead as an indicator to this issue (Figure 7). Passive nodes also existed the highest when the network is using 512 bytes of packet size and the fewest when using 32 bytes of packet size. Due to the unfairness and the presence of passive nodes, the delivery ratio as well has been affected. As can be seen in Figure 5 and Figure 9, the degradation in the delivery ratio and the passive node existence started to occur from 80 number of nodes onward.

Figure 9. Passive nodes over number of nodes.
4. Conclusion

WSN has shown its capability in various application mainly in the oil and gas industry. There are three processes involved in the oil and gas industry which are upstream, midstream, and downstream processes. In this paper, the pipeline in the downstream sector is the focused sector since the spread out distribution of the pipeline suits the grid node arrangement. In order to investigate the lack in the performance of such configuration, a simulation has been done using an increasing number of nodes. The results showed that most of the performance metrics start to degrade after 80 number of nodes onwards. The delivery ratio is high if a smaller packet size is used and a better transmission rate will the network has. Hence, fewer packet loss will occur if a smaller packet is used. The throughput of the network totally depends on the packet sizes; higher the packet size, the more throughput. However, as the network size increases, the throughput will degrade prominently after 80 number of nodes onwards. Apart from that, the usage of a smaller packet will cause more routing overhead to be drawn in the network, making the network resources to be wasted and causing the severe fairness issue in the network. In addition to that, more passive nodes will be resulted due to resource wastage. On the other hand, in terms of routing protocols, DSDV shows a better delivery ratio, routing overhead and number of passive nodes as compared to AODV routing protocol. Thus, DSDV outperforms AODV by three performance metrics out of five as the network grows by considering the grid node arrangement.

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