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NETWORK PERFORMANCE OPTIMISATION USING ODD AND EVEN DUAL INTERLEAVING ROUTING ALGORITHM FOR OIL AND GAS PIPELINE NETWORKE

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ABSTRACT

Wireless Sensor Network (WSN) provide promising and resilient solutions in a broad range of industrial applications, especially in the pipeline of oil and gas midstream pipeline. Such application requires a wide communication coverage area because the pipelines are usually stretched over a long distance. To fit the requirement, the sensor nodes have to be arranged in a linear formation. Performance evaluation has been carried out using reactive (AODV) and proactive (DSDV) routing protocols during the initial phases of the research. The factors causing the overall network performance to degrade as the network density increases are identified. It is mainly due to the load's increment, which will inhabit the packet queue and clog the network. These will result in packet loss, throughput unfairness, higher power consumption, and passive nodes in the network. The AODVEO reactive routing protocol is proposed to reduce the routing instabilities by splitting the traffic into (1) even-path and (2) odd with the consideration of the x-axis. The proposed routing algorithm was then compared to AODV and DSDV routing algorithms in terms of network performance with node deployment of 20,40,60,80,100,120,140,160,180 and 200. The proposed routing algorithm has shown substantial improvements in the delivery ratio (19.07% more), throughput (9 kbps more), fairness index (0.06 more), passive node's presence (30% less), and energy consumption (0.038J less) when compared to AODV on 200 nodes deployment.

Keywords: *Wireless Sensor Network, Linear, Static, WSN, Routing Algorithm, Oil and Gas Pipeline*

1. INTRODUCTION

The oil and gas sector is divided into three main parts: upstream, midstream, and downstream. All three processes, as illustrated in Figure 1, are required to obtain commercial oil and gas.

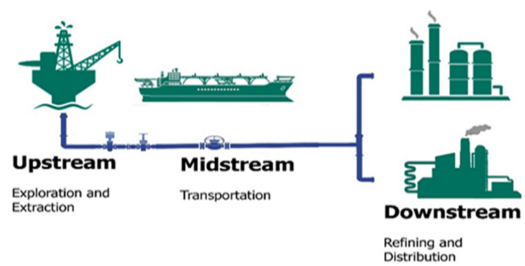

Figure1 : Overview of oil and gas industry section

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The process starts with industry discovery and field development in the upstream sector, where all crude oil exploration and extraction occur [1]. This section is usually located in the middle of the ocean. Three types of methods are generally used to extract the raw materials: primary recovery, secondary recovery, and enhanced recovery.

Before moving the raw resources to the next sector, they will undergo field processing and be stored temporarily. Several processes will be done, including the separation of crude oil, natural gas, and water. After the separation, the raw materials are stored in various containers accordingly. Besides processing and storage, midstream plays an active role in transporting crude oil via trucks, tanker vessels, or pipelines from upstream to downstream.

Upon entering the downstream sector, the raw resources are processed, stored, and converted into finished products before being marketed. The developed product undergoes various evaluations and tests before they are commercialised.

While there are plenty of ways of transporting the materials, pipeline transportation is a cost-effective and more practical way of transportation [2], [3]. However, issues such as leakage, corrosion, and sabotage led to unexpected disasters that damaged the economy of the industry and nature. On January 10, 2018, The Star reported that Petronas confirmed a leakage had occurred at the Long Luping section of the Sabah-Sarawak pipeline located in Lawas. This 600km pipeline connecting Kimanis in Sabah to Bintulu in northern Sarawak had a leakage that occurred at 1.45 am[4]. On January 13, 2020, another explosion was reported, and it is the fourth explosion recorded since June 11, 2014, along the same pipeline[5].

Furthermore, The Straits Times reported that two were injured during an explosion at Petronas oil and gas complex that occurred on April 12, 2019. The explosion harmed two local workers, and more than ten houses in Kampung Lepau were damaged [6]. These reports proved that the remote pipeline integrity monitoring system is essential to avoid any unforeseen disaster.

Thanks to its usability and cost-effectiveness, Wireless Sensor Network (WSN) has prevailed in the mobile tracking of pipeline's health in recent years [7], [8].WSN is a collection of sensors that can sense, process, and communicate, forming a network for monitoring the physical world [9]. WSN has been implemented in both ground and underwater pipelines integrated with sensors to detect irregularity of pipeline's health [10]–[13]. Ince radio frequencies (RF) communication is not appropriate for the underwater environment due to high-frequency wave absorption, the WSN for underwater detection uses acoustic communication [14].

Aside from WSN, there are other types of sensor networks, such as mobile ad-hoc networks (MANET), vehicular ad-hoc networks (VANET), and wireless mesh networks (WMN). There is two type topology which is linear and spread out. Since the pipeline in midstream usually covers hundreds if not thousands of kilometres [15], the topology focused in this paper is linear topology.

The classifications are separated into one-tier flat topology in linear topology, as shown in Figure 2 and multi-tier hierarchical topology.

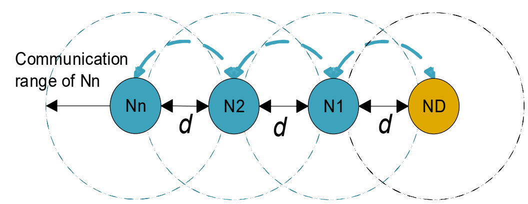

Figure 2 : Flat one-tier topology

Hierarchical topology usually involves a cluster head that will communicate with the nodes and forward the information to a higher cluster head level, as described in Figure 3.

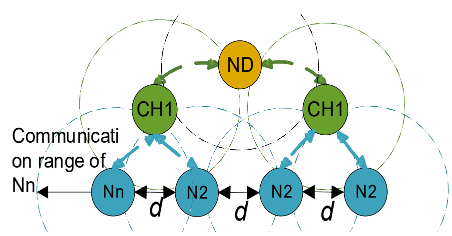

Figure 3 : Hierarchical topology

In addition to that, this paper also covers the IEEE 802.11 accordance wireless standard with the contribution on the network layer (routing layer) of the Open System Interconnection (OSI) model [16].

2. PROBLEM STATEMENT

In most of the applications, the data transmission technique used is similar, which is via multi-hop technique where the sender node will transfer the data to the receiver node[17]. However, as the number of nodes increases, problems related to (1) energy consumption, (2) communication reliability, (3) network scalability, (4) robustness, and (5) security arises[18].

In a deployment of WSN in linear topology, the lifetime of a network is a crucial factor that affects not only one particular node but the whole network, especially in restricted power supply applications [19]. A massive amount of power is needed for transmitting the data in a large-scale system. Even though the idea of preparing backup power for the nodes is applicable, but it is not suitable in underground or underwater nodes[20], [21].

In the oil and gas field, a secure contact network is necessary. If an anomaly is observed, the nodes are expected to collect and transmit the data or signal to the destination node within a specified amount of time since failure to do so will result in a catastrophic accident. The data collected are also crucial for monitoring the pipeline's health to avoid extra costs. Hence, a reliable communication and monitoring system is indispensable in this field.

The scalability of a network allows the network to achieve stable performance without being affected by the number of nodes. When the network expands, the number of nodes being deployed is increased. The network will generate more data, and more traffic will be created in the network. Consequently, the network becomes overcrowded, and the performance will degrade. The scalability can be affected by (1) capacity of a network, (2) queue threshold, and (3) range of source node to the destination node.

On the other hand, Robustness and security determine how flexible the network is to manage massive volumes of data, intrusion, or malicious attack. Since the nodes are implemented to decrease human interference, unauthorised personnel may attack the network by triggering a false alarm or manipulating the packets to obstruct the collection of data [22]. A routing protocol is deemed decent if it can adapt and deliver optimum performance in the network.

3. BACKGROUND WORKS

At the beginning of the studies, several performance issues were noticed, mostly because of the rising number of nodes. The deprivation of delivery ratio, throughput, and high energy consumption in the network reflected the network performance on the network layer, known as the routing layer. Hence, many researchers are attracted to routing to improve overall network performance. Routing is also known as a high-level decision-making mechanism in which information moves from source to destination nodes through an inter-network, whereby one or more transitional nodes could be located [23]. The efficiency of routing protocols is typically calculated from the perspective of link reliability among nodes, disconnection, and restoration of connections, an essential operation in a system where nearly all data packets may be missed. The three most popular routing protocols are reactive, proactive, and hybrid routing protocols.

Reactive routing protocols use an on-demand approach for discovering paths [24], which means the routes are dynamically changing, and the decision is based on the present network conditions [25]. The flooded messages and route tables are minimised because the network's status is not continuously monitored or updated [26]. However, the route discovery process will continuously occur, causing more time to establish the connection. As a result, the end-to-end delay will increase. The Ad-hoc On-Demand Distance Vector (AODV) routing protocol is one example of a reactive routing protocol. To manage the routes, AODV uses route request (RREQ), route reply (RREP), and route error (RRER) [27], [28]. The RREQ is used as a broadcast packet and the RREP as an acknowledgement packet. RERR, on the other hand, is sent to the source node during interruption of the link so that the source node restarts the route detection process if it still has data to transmit [28].

Compared to previous protocols, proactive routing protocols, also known as table-driven protocols, update the routing table regularly [29], [30]. The updates of information such as the following hop, number of sequences, hop figure, and destination are made permanent by sending control messages occasionally between all nodes in the network. As compared to reactive protocols, the proactive protocols have a more rapid establishment of routes, which indicates that the routes are always available. Since the routes are continuously updated, the will delay is minimised, and traffic in the network is more constant [25]. On the downside, the network is flooded with routing information (control packets and routing overhead), making the network congest due to the frequent updates of the routing table eating up all the network resources. The Destination Sequence Distance Vector (DSDV) is one example of a proactive routing protocol. In the case of DSDV, each node is needed to send a sequence number that

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is increased periodically and transmitted to all neighbouring nodes along with other updates [31], [32].

Hybrid routing protocols combine proactive and reactive protocols and utilise the advantages of both mentioned protocols. The hybrid routing protocols obtain correct path information to determine the optimum direction to the target node by updating routing information only when needed. The hybrid routing protocols are generally referred to as a DSDV and Link State Routing (LSR) routing combination optimised for rapid integration with lower power and memory consumption.

In general, network traffic should be denser in correlation to the number of nodes, regardless of the type of routing protocol chosen to be implemented in the network. This relationship occurred due to the increment of both control packets and data packets congesting the traffic of the network. All nodes are considered as sources in real-life deployment, and data are transmitted simultaneously. For each node in the linear network, the interface queue length is limiting the traffic queue, as shown in Equation (1).

$$NP=(CP_i+DP_i)+\sum_{j=i+1}^{x}(CP_j+DP_j)\leq IfQlen \quad (1)$$

Where,

$$x = n - 1 \quad (2)$$

Where NP is the total packets of the network constricted by the IfQlen limit, and n in Equation (2) is the total number of nodes in the network. CP_i is the sum of the control packets, and DP_i represents the sum of data packets for node i with the condition $1 \leq i \leq x$. CP_j and DP_j represent the control packets and data packets for the adjacent nodes j, respectively. As Equation (1) showed, when the total quantity of nodes raises, the total packets generated increases. As a result, several issues related to the performance of the network arise. Hence, the Ad-hoc On-Demand Distance Vector Even and Odd (AODVEO) routing protocol is proposed.

4. AD-HOC ON-DEMAND DISTANCE VECTOR EVEN AND ODD

The Ad-hoc On-Demand Distance Vector Even and Odd (AODVEO) routing algorithm were developed based mostly on the AODV routing algorithm. Dissimilar to the conventional AODV routing algorithm, which determines its path by selecting the shortest (by using hop count) and freshest (by using sequence number determination) route [33], the AODVEO establishes its path based on Even and Odd paths. AODVEO is designed to improve overall network performance for linear topology results compared to the conventional routing algorithm.

During the path discovery(forward route), the route request (RREQ) packages are flooded to all the nodes in the network. When a node with an odd number is forwarding the RREQ to its neighbouring nodes, only the node with an odd number will accept the RREQ and continue forwarding the RREQ and vice versa for an even-numbered node. This process will be continued until the RREQ reached its destination node, and RREQ will be dropped. Once RREQ is dropped, the destination node will generate and transmit route reply (RREP) in a reverse direction, and once the source node receives the RREP, the data packet will be forwarded using the established route

4.1 Packet Accumulation

Queue limit is a simple mechanism for controlling bidirectional packet movement within every node in the network. AODVEO also has a queue limitation, but the dual-path (Even and Odd) approach lessens the routing overhead by half and allows for better network traffic. The total packets accumulated in the network for Even nodes can be described as in Equation (3).

$$NPE = (CPE_i + DPE_i) + \sum^{y} (CPE_j \quad (3)$$

Where,

$$y = \begin{cases} \frac{x}{2}, & if: \\ x+1 & \end{cases} \quad (4)$$

X can be referred to in the previous section, and NPE represents the network packets for even traffic queues for x nodes in the network. CPEi represents the overall control packets, and DPEi is the sum of overall data packets for node i where $1 \leq i \leq x$. CPEj and DPEj are the control packets and data packets for the neighbouring nodes j with $i \leq j \leq N$ condition.

On the other hand, the total packets accumulated in the odd traffic can be described as in Equation (5).

$$NPO = (CPO_i + DPO_i) + \sum^{z} (CPO_j \quad (5)$$

Where,

$$z = x - y \quad (6)$$

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NPO represents the network packets for odd traffic queues for x nodes in the network. CPO_i is the overall control packets, and DPO_i is the sum of overall data packets for node i with the restriction of $1 \leq i \leq x$. Whereas CPO_j and DPO_j are the control packets and data packets for the neighbouring nodes j with $i \leq j \leq x$ condition.

The data that has been accepted by the receiver (destination node) is as described as Equation (7). Any package that comes in (data and control packets) with a queue length more than IfQlen is dropped from the network for both even and odd traffic.

$$TNP = NPE + NPO \qquad (7)$$

TNP represents the network packets accumulated in the network. Alternatively, NPE and NPO are the total numbers of packets available in even and odd traffic, as stated in Equation (3) and Equation (5), with the limitation of IfQlen bounds the equations. Figure 4 shows the developed algorithm to illustrate the third criterion used in the proposed AODVEO routing algorithm.

4.2 Number of Broadcast Packet Forwarding

Usually, when there is no present route available, a source node will have to commence a forward route discovery by flooding the RREQ packet to its neighbouring nodes. The neighbouring node with the freshest and shortest path to the destination node is selected as the following RREQ forwarder. As a result, the RREQ packets that are being broadcasted in the total network increase as the total number of nodes increases. As the size of the network increases, the source node will be further than the destination node. Hence, more information is required to be included in the RREQ packet. The forward routing table in the conventional routing protocol is presented in Figure 5.

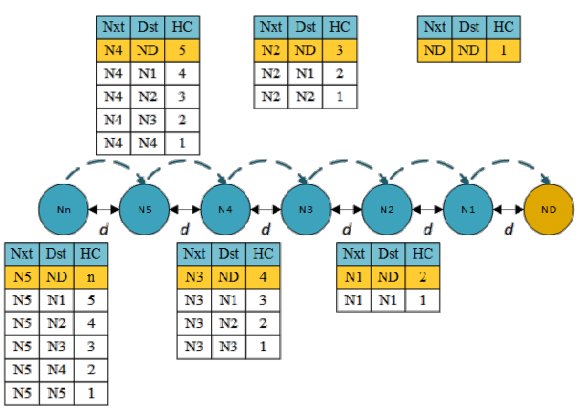

Figure 5 : Forward routing table in a conventional routing protocol.

Note that the further the node is to the destination node, the more information is required to be included in the RREQ packet.

Accumulation of RREQ packet being forwarded that particular traffic has to handle is illustrated in Figure 6.

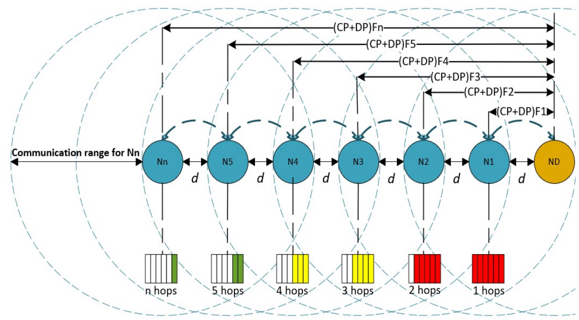

Figure 6 : Packet accumulation flow in a conventional routing protocol.

As described in Figure 6, all RREQ packets that are being forwarded in the network are handled by one traffic. For example, the total amount of RREQ packets being forwarded is six times. Since there is no traffic management mechanism in the conventional routing protocol, only one traffic is handling all the RREQ packets that are being forwarded. By assuming *rf* is the number of RREQ forwarders, the total number of RREQ forwarding in traffic could be concluded as in Equation (8).

$$N_{RREQ} = rf / Tn \qquad (8)$$

N_{RREQ} is the total number of RREQ forwarding handled by the traffic duing route discovery phase, and the Tn is the total number of traffic available in the network. By referring to this equation, the larger the network size, the higher the accumulated number of RREQ packets that the traffic must handle. As a result, the network would get exhausted faster in terms of network resources cousing more packet loss.

By splitting the network into two 1) Even path and 2) Odd path, a systematic and efficient traffic management is created. The total workload in the network is divided and hence, the information required in the RREQ packets is reduced. The forward routing table in AODVEO is presented in Figure 7.

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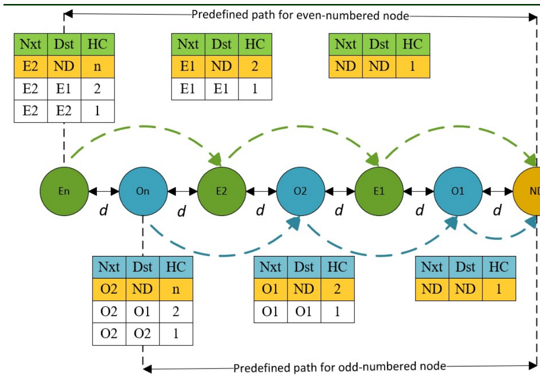

Figure 7: Forward routing table in AODVEO.

It is worth noting that the total information contained in the RREQ packet is drastically decreased over the same distance.

Similarly, the traffic workload is divided with the implementation of the Even and Odd criteria in the route establishment phase. Figure 8 shows the accumulation of RREQ packets in AODVEO.

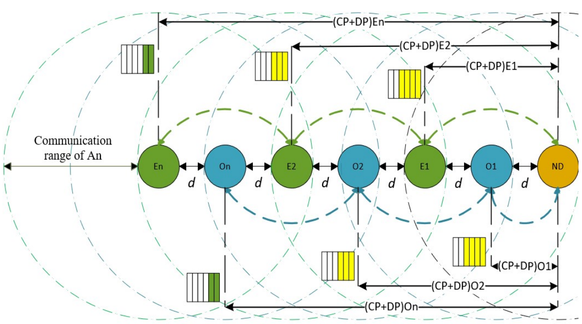

Figure 8: Packet accumulation flow in AODVEO.

By splitting the network traffic, both even traffic and odd traffic will share the network load. Hence, the packet accumulation in the network is assumed to be half as compared to the conventional routing protocol. Both Even and odd traffic will have the same number of packet accumulation as shown in Equation (9).

$$ON_{RREQ} = EN_{RREQ} \quad (9)$$

In conclusion, AODVEO routing algorithms have fewer RREQ forwarding than the conventional multi-hop linear routing algorithm such as AODV. The traffic splitting features reduce the traffic workload and congestion by offering more chances for the packets to en queue during high traffic. As a result, not only the total energy consumption is reduced, but also the number of packet losses, as well as the time required for a packet to reach the destination, are improved.

5. SIMULATION SETUP

The simulation was conducted using the machine equipped with Intel Xeon 3.2 GHz, 8GB memory, and 1.5TB of storage. The average time required to complete one set of results for each routing algorithm is two weeks. The simulation has been carried out using AODV (reactive), DSDV (proactive), as well as AODVEO (reactive) using Network Simulator 2.35. The best five results are chosen and averaged from seven randomly generated runs (seven seeds) to achieve a detailed performance evaluation with 500 seconds of simulation time. The distance between each node, denoted as *d,* is 50 meters. The transport agent applied is Transmission Control Protocol (TCP), while the traffic type is Constant Bit Rate (CBR). The nodes are aligned in a non-cluster linear architecture with the node formation of 20, 40, 60, 80, 100, 120, 140, 160, 180, and 200. The packet size for each executed packet is 512 bytes with a transmission rate of two packets per second. The queue length is set to the default value, which is 50. Increasing in the queue length will lead to heavier traffic and higher latency, while decreasing it may lead to more packet drops due to the reduced space for the packets to accommodate. The parameters are presented in Table 1.

Table 1: Simulation parameters

Parameters	Value
Routing algorithm	AODV, DSDV, AODVEO
MAC	IEE 802.11
Number of nodes	20, 40, 60, 80, 100, 120, 140, 160, 180, 200
Traffic type	CBR
Interface queue type	Drop Tail/PriQueue
Packet size	512 bytes
Packet queue length	50
Simulation time	500 seconds
Propagations model	Two ray ground
Simulation seeds	1 to 9
Node distance	50 meters

6. RESULT AND DISCUSSION

This chapter of the paper shows the overall performance of the network for the proposed AODVEO by comparing AODV and DSDV results using the predefined simulation model as illustrated previously. They are evaluated on the following metrics.

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6.1 Delivery Ratio

The delivery ratio is the correlation between the packets received successfully and the total sent packets. The delivery ratio is an important performance measure for the reliability of a given network. Since most implementations in the oil and gas sector are data-critical, any lost information is, therefore, an enormous value to the industry itself. The lower delivery ratio of the packets indicates more network packet loss.

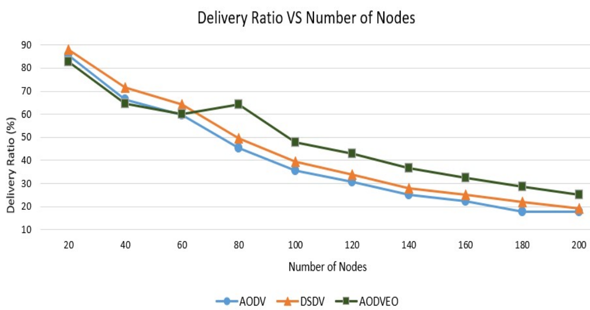

Figure 9 : Delivery ratio against the number of nodes

By referring to the above figure, the packet distribution ratio decreases as network size increases. At a smaller network scale with 20 to 60 nodes, the AODV and AODVEO delivery ratios are almost identical, while DSDV is slightly higher. Upon deploying 80 nodes, the proposed routing protocol significantly surpassed the AODV routing protocol by 19.07% and DSDV by 14.91%. Overall, the proposed technique delivers 1-19% higher delivery ratio when compared to AODV and 1-15% higher delivery ratio than the DSDV routing protocol. The result shows that when compared to both conventional routing protocols, AODV and DSDV, the proposed routing protocol is more efficient in preserving the packet sent to the target node. The packet queue in the network is minimised by separating the traffic into two distinct routes, and this eliminates congestion, and consequently, more data flow can be accomplished.

6.2 Throughput

Throughput is defined by the rate of received data (from the packet) transferred from source to destination in kilobytes per unit per second (kbps) in the network. Based on a consumer's viewpoint, throughput is more important if compared to the delivery ratio as a higher throughput within the available network resources means more significant network capacity. However, the delivery ratio is more critical from the designer's point of view as it helps to determine the problems that may lead to low network throughput.

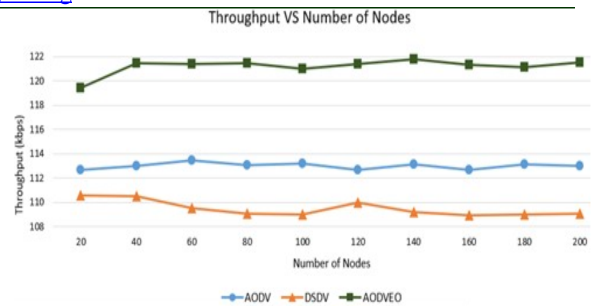

Figure 10 : Throughput against the number of nodes

Throughput in a network with AODVEO, as illustrated in Figure 10, outperformed both AODV and DSDV from a small-scale network size of 20 nodes to a large-scale network size of 200 nodes. When comparing AODVEO with AODV, the proposed routing protocol can deliver 6.79 kbps and 8.45 kbps more at nodes 20 and 200, respectively. Upon comparing AODVEO with DSDV, AODVEO shows 8.89 kbps and 12.43 kbps more with the deployment of 20 nodes and 200 nodes, respectively. Overall, the proposed technique demonstrates significant improvement with 6-9 kbps more than AODV and 8-13 kbps more than DSDV. The throughput trend in Figure 10 is a reflection of the packet delivery ratio trend (Figure 9). Upon data loss, the source node will attempt to re-transmit the data, and this would result in a lower distribution of delivery ratio and the amount of data that has been successfully received. The throughput will, therefore, be severely affected too.

6.3 Energy Consumption

Energy consumption is measured in Joule (J) and can be described as the overall energy utilised in a network over the total received packet. Energy management is an essential parameter in wireless in linear topology as a discontinuity in the communication connection can be created by single node failure. The power consumption closer to destination nodes is usually higher since more packets are being delivered. The high load area causes the line of traffic to congest, and when there is a package produced by or crossing through the node in the area, it is most likely to be dropped. Because of (1) the packet regeneration and (2) the packet hopping, issues such as energy waste are generated.

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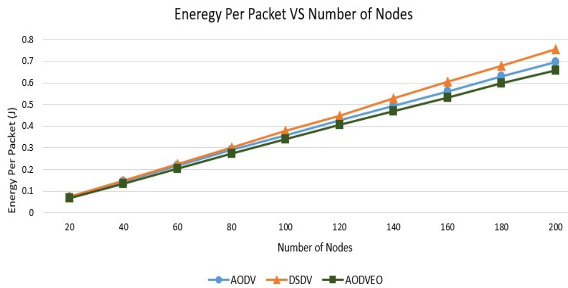

Figure 11 : Energy per packet against the number of nodes

By referring to Figure 11, the energy expenditure is also increased with the increasing number of nodes. Network with DSDV routing protocol consumed the highest amount of energy, while the proposed routing protocol consumed the least amount of energy. By contrasting the proposed routing protocol with AODV and DSDV, AODVEO outperforms both conventional routing protocols at a small network size of 20 nodes by 0.00402 J for AODV and 0.00540J for DSDV. The proposed routing protocol uses 0.03818J and 0.09578J less energy for AODV and DSDV in larger network sizes with 200 nodes, respectively. Overall, AODVEO outperformed AODV with 0.004-0.038J lower energy consumption per packet and DSDV with 0.005-0.096J lower energy consumption per packet despite having a higher throughput value.

6.4 Passive Nodes

Passive nodes are deemed to be nodes that do not transfer data to the destination node in the network. The passive nodes existed due to the unnecessary or unevenly shared bandwidth allocated for the network and mostly occurred in high traffic networks with a constrained energy source. The passive nodes cause a breakdown of communication between nodes, and this will affect the network's lifetime.

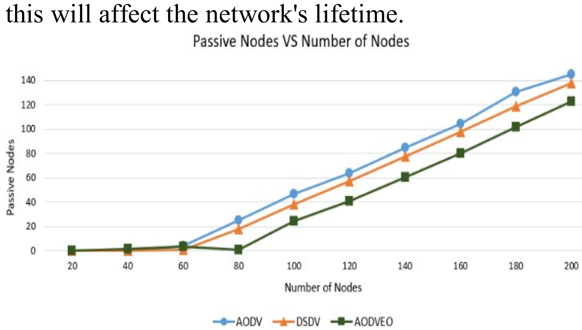

Figure 12 : Passive nodes against the number of nodes

As portrayed in Figure 12, the passive nodes in AODVEO and AODV only exist in the network with 40 node deployment, while DSDV has passive nodes at node 60. In a large-scale network with a 200 node distribution, the total number of passive nodes exits in the network with the AODVEO routing protocol is around 61.4% of the nodes deployed. In contrast, the total passive nodes that exist in the network with AODV and DSDV routing protocols is 72.6% and 68.9%, respectively. Overall, AODVEO has 1-30% lower passive nodes than AODV and 1-20% lower passive nodes than DSDV. Although AODVEO has a higher value of throughput, the passive nodes that existed in the network are still lower than both AODV and DSDV.

6.5 Routing Overhead

Routing Overhead can be defined as the ratio of the total number of routing packets to the total number of successfully received packets—a high number of routing overhead results in high consumption of network resources. In general, packets such as control packets and broadcast packets contribute to the increment of routing overhead.

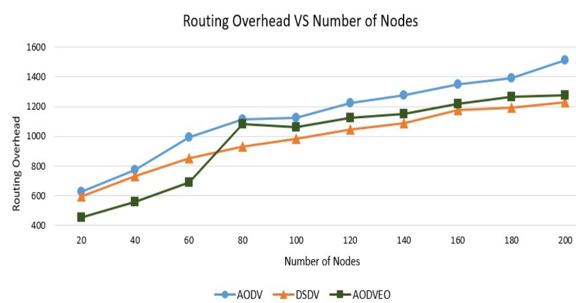

Figure 13 : Routing overhead against the number of nodes

As illustrated in Figure 13, DSDV has the lowest routing overhead compared to AODV and AODVEO due to the characteristic of proactive characteristic, as explained before. In a small-scaled network size of 20 to 60 nodes, AODVEO outperformed both AODV and DSDV by having 172.92-301.31 less routing overhead than AODV and 140.39-162.20 less routing overhead than DSDV. However, starting from 80 nodes deployment, AODVEO has 39.50-150.23 more routing overhead than DSDV but 31.90-235.51 less routing overhead than AODV. Despite having a higher value of throughput, AODVEO has a lower routing overhead compared to AODV and a slightly higher routing overhead compared to DSDV.

6.6 Fairness Index

The network fairness index or equality index is known as the network-wide measure of resource equality allocation. The closer the index number is to 1, the better the allocation of resources over the network. Network imbalances are an important factor with any protocol in linear wireless sensor networks.

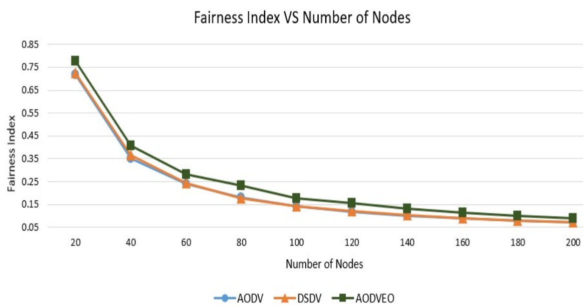

Figure 14 : Fairness index against the number of nodes

As indicated in Figure 14, the proposed routing protocol, AODVEO, outperforms all the other routing protocols starting from the deployment of 20 nodes by 0.06 for AODV and 0.05 for DSDV. Nonetheless, the fairness index for AODVEO is still below 0.5, beginning with 40 node deployment and getting worse as the number of nodes deployed increases. Overall, AODVEO achieved a 0.02-0.06 more fairness index than AODV and a 0.02-0.05 more fairness index than DSDV. However, the numbers in the graph indicate that the issues surrounding network fairness have yet to be fully resolved since the resources allocated are far from being equally distributed.

7. CONCLUSIONS

In a pipeline network, many interrelated factors affect overall network performance. Reactive routing protocols (AODV) and proactive routing protocols (DSDV) were simulated in the early stage of the research, and the network performance was reviewed. As the network size rises, numerous issues relating to network performance were identified. The proposed reactive AODVEO routing protocol is reliable and efficient. The proposed routing protocol improves the overall network performance of a wireless sensor network with linear topology. In the most extensive network configuration (200 nodes) as compared to AODV, the AODVEO routing protocol enhanced the network to deliver 8.89kbps more throughput and 7.284% more delivery ratio while having 0.03818J less energy and 11.2% less passive nodes. However, there is negligible development of the fairness index where the index point is still below par (0.5). The numbers reflected in Figure 14 indicated that the resource is not yet distributed equally through the network.

8. OUTLOOK

Generally, the overall performance of the network has been improved by applying the proposed methodology. However, the increment of the fairness index is still low. This indicates that the network resources are yet to be equally distributed. Future researches should consider to focus on this parameter in order to further improvise the network performance.

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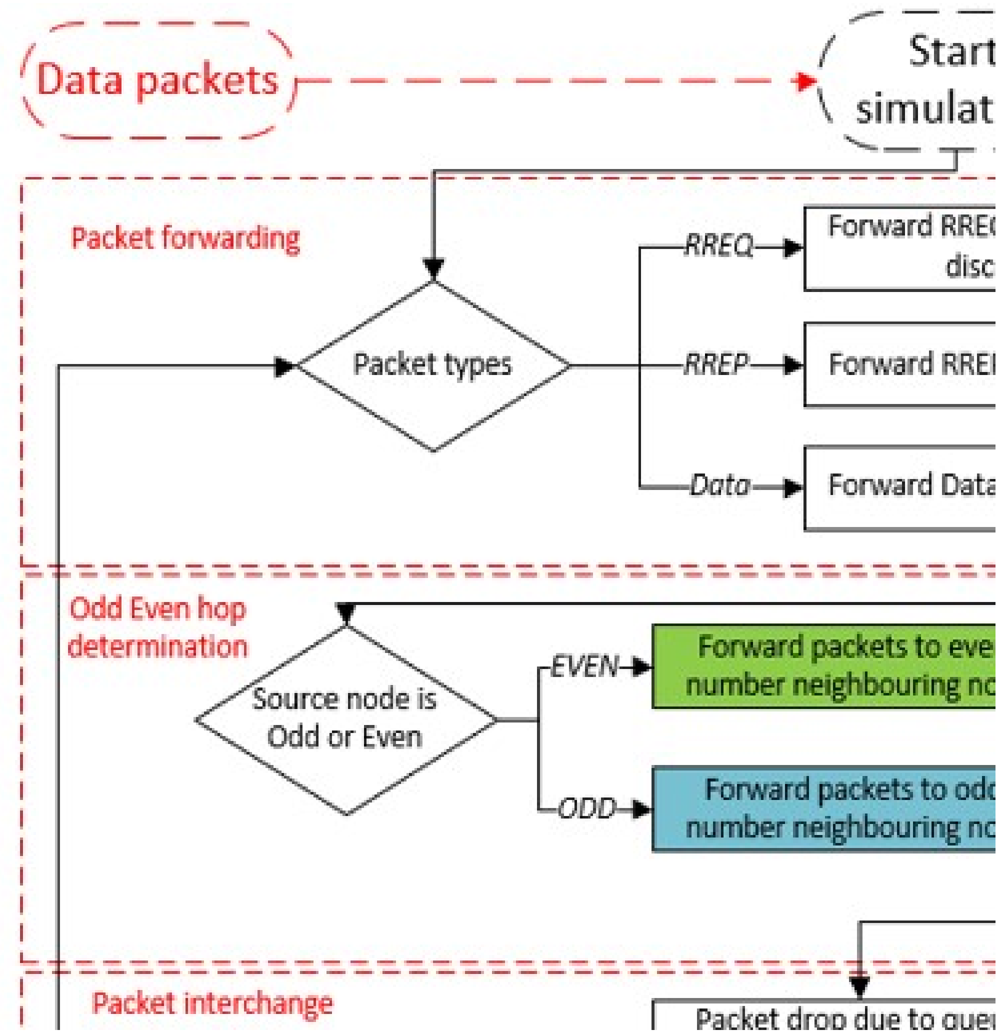

Figure 4 : AODVEO routing algorithm