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A Model to Improve Packet Transportation in Wireless Sensor Networks

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Abstract: Wireless Sensor Networks (WSNs) are existing technology consisting of spatially autonomous devices using a large number of sensors to observe the environmental conditions and delivers sensed information to the network user. WSNs, during 21st century, gained more popularity as compared to wired network. The wireless technology used in this study consists of a collection of nodes organized into a corporate network. These nodes contain chips with processing capability which can control multiple types of functions within a network. Furthermore, these technologies are spatial displays that tend to be better clustered than wired networks. They have much higher path length appearances with potential low cost solution to variety of real world issues. However, this technology experiences congestions resulting in packet loss, end-to-end delay, low throughput and poor Quality of Service (QoS) in a network. This study, proposes Packet Bandwidth Scheduling (PBS) algorithm that lessen the packet collision, packet loss and end-to-end delay while improving QoS in WSNs. The designed algorithm complies with IEEE 802.11 wireless standard. Network Simulator-2 (NS-2) simulation result showed reduction in packet congestion, packet loss and end-to-end delay when compared with History-Based Increment Backoff (HBIB) algorithm and Packet Scheduling Algorithm (PSA).

Key words: Wireless sensor network, quality of services, gateways, PBS, PSA, HBIB

INTRODUCTION

In recent years, Wireless Sensor Networks (WSNs) have been one of the key technologies for enabling wireless technology more affordable to network users because of its low cost, ease of deployment and adaptability of WSNs (Liu *et al*., 2016; Levesque and Tipper, 2016). These technologies are normally used to observe the environmental conditions, surveillance processes and home or business automation (Dong *et al*., 2016; Thorat and Deshpande, 2016; Kassan and Chatelet, 2017; Prabhu *et al*., 2017; Mittal *et al*., 2018). These networks are formed by a large number of sensor nodes and they use radio frequency to perform operations, allow the fast setting up of sensing tools and access to the information in the locations wherein it seems impossible or quite expensive to have wired connections.

Each node is equipped with the sensor to sense the physical phenomena such as pressure, light and heat (Khan *et al*., 2016; Sarada and Surendra, 2017; Damaso *et al*., 2017). WSNs facilitate wireless communications for short and long range communication through radio signals. WSNs can be randomly deployed in any place and nodes have the potential to move around within a network (Yuan *et al*., 2017; Ahmed *et al*., 2018; Rani *et al*., 2017). Furthermore, the network users in these networks are able to access the network in any location as long as there is network coverage. Sensor nodes have the potential to sense, measure and gather information from different environments (Chen *et al*., 2017a, b; Jiang *et al*., 2017; Das, 2017).

The sensor nodes are small with limited processing power and computing resources. These nodes are inexpensive compared to traditional sensors. The nodes can sense, measure and gather information from different environments based on local decision process. Hence, these nodes can transmit the sensed data to the user (Yick *et al*., 2008). This technology is recognized as a dominant solution in the collecting and processing of data in different sectors by using low-cost and low-energy consumption (Joshi *et al*., 2017). However, in WSNs there are packet transportation problems which normally lead to network bottleneck and as a result, the network produces poor Quality of Service (QoS). Poor packet transportation happens due to contention caused by concomitant transmission, buffer overflows and

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increases on the incoming traffic from different nodes (Aguirre-Guerrero *et al*., 2014; Zhang *et al*., 2017). This further affects the continuous flow of packets leading to packet drops while increasing the end-to-end delays (Hull *et al*., 2004). The poor packet transportation in WSNs leads to communication breakdown and reducing the speed of packet transportation in the network. These issues are mostly increased when multiple nodes sender transmit packets to single receiver simultaneously for a very short period of time (many-to-one manner) (Cheng *et al*., 2016; Liu *et al*., 2017). The primary cause of this is that nodes simultaneously send large packets which require high bandwidth for communication and cause end-to-end delay, network throughput, packet-delivery ratio and packet loss.

Therefore, the packet transportation ought to be controlled in order to improve QoS in WSN (Thiagarajan and Rani, 2015; Singh and Singh, 2018; Shaukat *et al*., 2017).

To overcome the packet transportation issue in WSNs, this study proposes an algorithm that intends to improve the packet transportation and flow of information which guarantees a certain level of QoS in terms of network throughput, end-to-end delay, packet delivery ratio and packet loss during the transmission of packets.

Overview of wireless sensor network: Wireless Sensor Networks (WSNs) is based on IEEE 802.11 standard and is comprised of multiple number sensor nodes connected to each other in order to share the available services and resources (Khan *et al*., 2016; Abish and David, 2017). The sensors have the potential to sense and transmit information to the relevant location, however that depends on physical proximity. The communication between sensor nodes is through Access Points (APs). The communication with other networks is through gateways. The purpose of sensor nodes is to monitor the physical or environmental circumstances such as monitoring environmental conditions (Anbarasi and Gunasekaran, 2015; Chen *et al*., 2012).

All sensors share a single communication channel through multiple access protocols (Yaakob *et al*., 2016; Xu *et al*., 2018).

Figure 1, shows the communication between different nodes sharing network service and resources wherein more than one sensor nodes are sending packets through a single Access Point (APs). The APs also share the information among themselves to deliver a fast and proficient communication in the network, thereafter, the access point sends to gateway. In this type of network, there is more than one access point as illustrated in Fig. 1 to deal with the delivery of packets on a given area and size or monitor the flow of packets from one point to another.

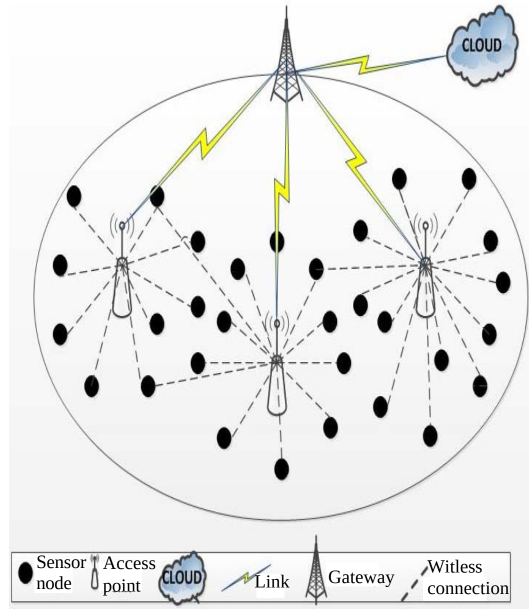

Fig. 1: Wireless sensor network architecture

Hence, APs contrast based on the deployment parameters, each access point has a technical limitation of 128 clients based on the bandwidth allocation as stated by IEEE 802.11 standard (Balasubramanian *et al*., 2016; Sharon and Alpert, 2018; Ravindranath *et al*., 2017).

The purpose of using APs is for packets broadcasting in order to have better communication in the network. As shown in Fig. 1. the sensor nodes send the packets to the APs. Once, the APs receives those packets, that APs send it to gateway thereafter, delivered to cloud.

Furthermore, WSNs are designed in different forms and those are structured and unstructured WSNs (Sharma *et al*., 2015; Mehta and Pal, 2017). With unstructured WSNs there is a large collection of tiny sensor nodes (Sharma *et al*., 2015; Chawla and Sachdeva, 2018). It is difficult to maintain this type of network. In a structured WSN, sensor nodes are deployed in a pre-planned manner (Sharma *et al*., 2015; Chawla and Sachdeva, 2018). Hence, it requires the distribution of nodes before deployment and in addition, this structure is cost-effective to maintain.

Literarure review: Over the previous years, lot of research has been directed in improving the packet transportation in WSNs. These researches focused on different mechanisms that are discussed below based on WSNs.

Artail *et al*. (2016) proposed the node detection approach to minimize the packet delay in WSNs by using the aggregates measurement data on the way to the sink node (base station). The algorithm that they used contains two phases: which are initialization and testing for faulty conditions using the Markov Chain Controller (MCC). They implemented and tested their results by using the Network Simulator-2 (NS-2). The results showed at least 98% detection rate at the cost of reasonable detection delays. However, there is still the possibility of some nodes that are damaged (node which is not functioning) that may go undetected if one or more nodes malfunction in a short period of time may course end-to-end delay within a network. This is because their proposed solution can only be able to detect gradual degradation in the sensor's ability to correctly sense the environment. This study, strongly considers this node detection method as part of improving packet transportation and quality of services.

Enhanced bandwidth sharing scheme was designed and implemented by Mathonsi and Kogeda (2014) to improve the network performance which was affected by link congestion and the high number of lost packets. The algorithm used, enhances the spectrum bandwidth allocations for network users. In the model, they integrated a transferable payoff coalitional game theory and standard Dijkstra algorithm in order to come up with Dijkstra-Transferable Payoff algorithm to improve QoS and reduce link congestion, end-to-end delay and packets loss in a network. They implemented and tested their results by using the Network Simulator-2 (NS-2). However, their algorithm improves the link congestion and end-to-end delay while the number of packets lost still remains the problem. This study focuses on improving the packet transportation in WSNs because packet transportation is most considered for metrics performance.

Liu and Tsai (2016) proposed a dynamic multi channel allocation framework for adaptive reliable and energy efficient communication in IEEE 802.15.4-based wireless multimedia sensor network. The simulation result verified that the available bandwidth-based dynamic multi-channel allocation mechanism realizes the trade-off between energy efficiency and dynamic QoS requirement. However, single system decision-making based on bandwidth allocation still remains a problem to guarantee the overall performance on QoS and energy consumption. This study strongly supports the decision-making of bandwidth allocation to maintain the travelling of packets within the network. The Packet Scheduling Algorithm (PSA) was proposed by Yantong and Sheng (2016) in order to overcome the problem of node-to-node communication packets transport delay as well as the starvation of real-time packages. In order to enhance the node communication, the algorithm that they use is categorized in three different methods, i.e., as follows: higher priority queue stores real-time communication packages while priority queue stores non-real time data packets and lower priority queue stores non-real time packages whose destination is local node. Their simulation results showed that the proposed algorithm improves the node-to-node communication packages transport delay for a single queue. However, the packet-delay in the nodes still remains the problem when there are a different number of queues for node-to-node transmission in a network.

Jandaeng *et al*. (2011) also proposed the use of packet scheduling algorithm to schedule all packets that are from application and network layer in order to reduce network congestion and avoid packet loss that occurs in WSNs. The algorithm indicates that when implemented, the packet collision will be minimized while increasing the throughput in WSNs. Their simulation results were implemented and tested by using different simulation tools to solve broadcast scheduling problem. The solution results showed a decrease in broadcast scheduling problem.

Aggarwal *et al*. (2016) proposed the hierarchical routing techniques to provide the reliable path from the source node to their destination in a network. The technique was implemented to improve life, time and energy consumption based on the routing of packets. The hierarchical routing includes the tree-based routing, cluster-based routing, chain-based protocol and grid-based routing. Their results showed that the scalability, energy efficiency and QoS are well managed in a network. However, due to the increases of data usage, the interaction between the cluster member and cluster-head is still a problem based on the way they share data. This study, strongly considers the process of hierarchical routing techniques when it transmits the packet because it avoids the broadcast process between the nodes.

The hierarchical routing algorithm based on Virtual Mobile Node (VMN) was proposed by Yan *et al*. (2016). The purpose was to find the quick optimal path in the diverse VMN domains and between any two nodes in the VMN domain limit. The method improved the performance on VMN failure and VMN message delivery within the two nodes when they communicate. Their results showed that they can obtain magnitude better performance by HRA-VMN compared to Hierarchical State Routing (HSR) and non-hierarchical routing approach. However, their solution does not consider the amount of WAVE flooding which can obstruct the application of the HRA-VMN algorithm. This study, strongly considers the communication process between the nodes by using the hierarchical routing algorithm because it avoids the use of broadcast method when transferring the packets from one node to another.

The History Based Increment Backoff (HBIB) algorithm was proposed by Manaseer and Badwan, (2016) to overcome the issue of network throughput and end-to-end delay with various numbers of nodes and different traffic loads. They assess the performance of the algorithms using Network Simulator-2 (NS-2). Their results indicated that the proposed algorithm perform well in network throughput and end-to-end delay compared with other algorithms with the packet rates of 6, 10 packets. However, their proposed algorithm achieved the improvement of network throughput and end-to-end delay-there is a problem of packet drop in a network. This study strongly support the algorithm used to improve network throughput and end-to-end delay by the researchs.

The use of two novel positioning schemes was proposed by Chen *et al.* (2012) which uses two generalized geometrical localization algorithms to achieve the accurate estimation based on the Time-of-Arrival (ToA) amounts without time synchronization. The mechanism that they used in order to improve the network performance and limitation of network addresses was based on the mobile anchor to utilize effectively and design two attractive movement strategies for the mobile anchor. Their results are implemented by using the traditional Trilateration method by extensive simulations and it was also validated. However, the proposed scheme does not require the sensor nodes for radio transmission. This study, considers the time of arrival of transmitted packets to avoid delays in a network which also improve the packet transportation.

Thorat and Deshpande (2016) proposed the distribution of bandwidth to the nodes as per distance from sink when transmitting the packets as part of reducing the congestion in wireless sensor network. The algorithm that they used in order to reduce the possibility of congestion and energy utilization of all nodes in a network is Adaptive Bandwidth Control (ABC) algorithm. Their simulation results showed that energy as well as traffic fairness is improved. However, the packets drop rate and network throughput still remained the problem on their proposed solution. Hence, this study integrated packet scheduling algorithm with history based increment backoff algorithm in order to solve the issue of collision, packets drop and throughput in wireless sensor network while improving the QoS.

The congestion control algorithms based on AODV routing protocol was proposed by Grover *et al.* (2015) to overcome the packet congestion in the network. The research use AODV routing protocol to implement routing in the network. The congestion control algorithm is responsible for preventing the occurrence congestion and also lessening the impact on network congestion throughput if it occurs. Network Simulator-2 was used to implement and test their solution. The solution results showed that their solution reduced the occurrence congestion. However, their solution did not solve the issue of the packets loss when there is a high load on a network which is greater than the capacity of the network. This study, consider the congestion control that they implemented. This is because without the control of packets congestion it leads to poor QoS in a network.

This study, adopted and combine two algorithms which are Packet Scheduling Algorithm (PSA) and History-Based Increment Backoff (HBIB) algorithms in order to come up with Packet Bandwidth Scheduling (PBS) algorithm in order to improve the packet transportation and improving QoS in a network.

Previous studies mostly focused on scheduling of packets, node detection and use of routing protocols. The proposed algorithm will be designed to improve on packet transportation where the PBS algorithm controls the packets movement on MAC layer. Additionally, the HBIB algorithm improves the end-to-end delay and throughput while PSA worked on network topologies to schedule all packets from different layers in order to reduce network congestion. The proposed algorithm also addresses the issue of packet delay in a network. The key contribution of this study is to derive a fair packet travelling from one node to another without any delay and using the right allocated bandwidth.

MATERIALS AND METHODS

Packet Bandwidth Scheduling (PBS) algorithm: Packet Bandwidth Scheduling (PBS) algorithm is an integration of two existing algorithms called packet scheduling and algorithm, History-Based Increment Backoff (HBIB) algorithm with the aim to improve the packet transportation and improve Quality of Service (QoS) in WSNs. Packet Scheduling Algorithm (PSA) is one of the algorithms that schedules all the packets from the application layer to network layer of the OSI Model in order to overcome the packet collision in the data link layer to avoid the delays of the packets in the network.

The scheduling algorithm consists of the set of packets in the nodes N = {N_1 N_2, ... , N}. Therefore, the PBS can achieve the combination by coordination the travelling of the packets in order to achieve the common objective. Any combination P⊆N represents the agreement between the exchanges of packets within the nodes in P to act as a single packet or entity. The packets P_i for (I = 2≈N) starts delivering the packet to the P_x immediately after P_{i-1} completes its step. Therefore, all network nodes are allocated bandwidth according to the amount of the nodes within the network. However, some network nodes use high bandwidth than others where $CW_{next} = Cw_{prev} *2^a$ for all P⊂N Eq. 1:

$$Y = \left\{CW_{next} = CW_{prev} * 2^a \forall P \subset N\right\} \tag{1}$$

The outcome of this algorithm is the vector. This study, let $x(S) = \sum_{i\in s} x_i$, therefore, it represents the packets delay P. Packet scheduling algorithm was designed to reduce the packets congestions in MAC layer leading to reduce the overall of packet collision in the system.

This study, added new features on the adopted algorithms in order to improve the packet transportation in WSNs. In this study packets with 100 bytes upwards were classified as the one with high-priority of traffic that cause poor packet transportation or packets delay while packets with 50 bytes downwards were classified as low-priority traffic to cause packet collision or packet delays.

Route discovery process: As reflected on Fig. 2 in this study routing discovery process shows how packets are been forwarded from source to destination. Every node when it needs to send packets to another network devices it uses the hierarchical routing table for a route. Therefore, the node continually updates an opposite route to the destination IP address in the routing table. The process of routing discovery in hierarchical routing significantly increases the scalability of routing process in wireless sensor networks by increasing the strength of nodes when packets are being transferred from the source to destination.

If a route to the source IP address already exists it is updated only if either the source sequence number in the route request is higher than the destination sequence number of the source IP address in the route table or the sequence numbers are equal.

In this study, the hierarchical routing concept is used for enabling or enhancing the mechanisms used to transfer packets in differentnodes within the network.

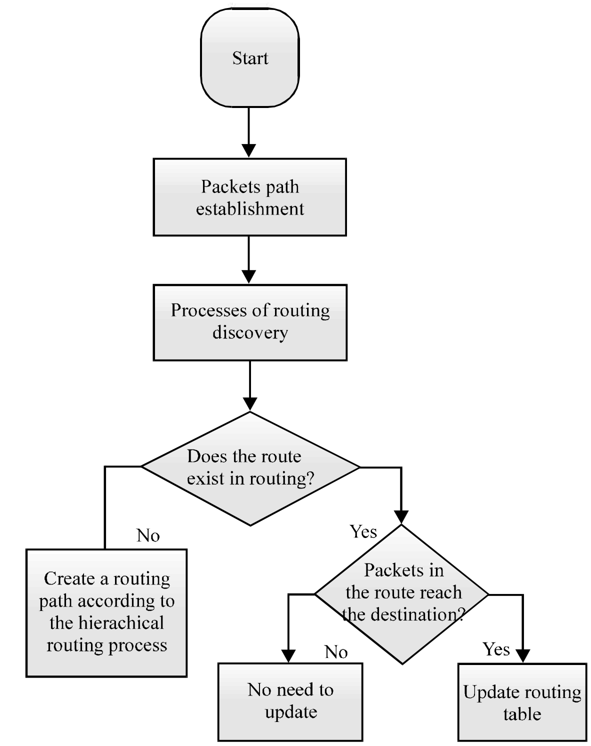

Fig. 2: Process of routing discovery

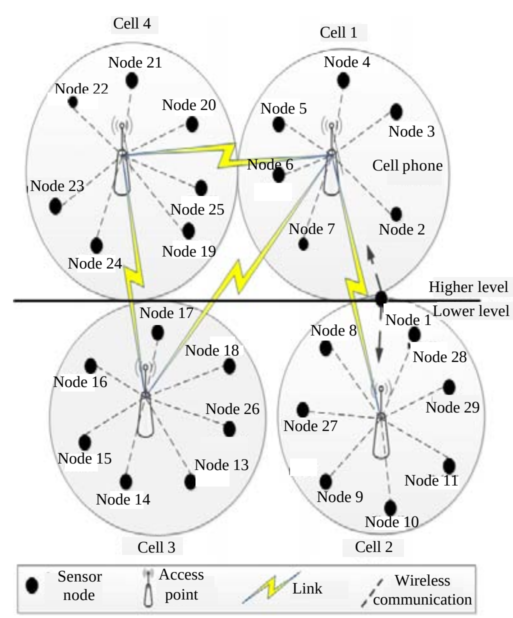

Fig. 3: Proposed system architecture for WSNs

Hence, the service discovery process is provided and to evaluate the packets transportation in this study. The flow chart showing the processes of routing discovery is demonstrated in Fig. 2.

Furthermore, Fig. 2 illustrates the process of routing discovery by using the hierarchical routing concept which optimizes the route and service discovery process and enables the optimization of the network by means of the communication path within different nodes.

System design and architecture: This study integrated packet scheduling algorithm with history-based increment backoff algorithms in order to improve the transportation of packets from source node to destination node. The integration of packet scheduling algorithm and history-based increment backoff algorithms was done in order to allow the proposed algorithm to transmit packets properly and orderly without any delay of packet. When applying the packet scheduling algorithm, this study prioritized the packets where high priority traffic had high priority over low priority traffic. This method decreases the packet delays for high priority traffic to improve the Quality of Services QoS.

A network traffic is presented as graph, G = (N, L) where N is set of finite nodes and L is a set of initially undirected links. This study, assumes that each node i∈N has a unique node Identifier (ID) and each link (I, j)∈L allows full duplex communication. A proposed system architecture for WSNs it contains of four cells as shown in Fig. 3.

Figure 3 indicates that a network node consider the simple path search on the metric network to be able to communicate with the other node in a different cell. The network node uses hierarchical routing process to communicate to each other in different levels (i.e., lower and higher level). Hierarchical routing will divide the network into levels namely: lower and higher level (Lower level is when the node starting the path for communication from the bottom of the hierarchical routing process and progressing to the upwards) and (the higher level of the hierarchical routing process is node that dispatched the process such as transferring the information to the destination node).

The lower level area in the proposed system architecture are those who are below cell 1 and 4 as indicated in Fig. 3. Higher levels are those who are above cell 2 and 3. This is illustrated by the node1 on cell 2 which is at lower level area which is close to another cell that is on a higher level area. Node 1 is between cell 1 and 2, this node uses access point which is on cell 1 for communication. Therefore, node 1 will use the hierarchical routing process to send information to lower level cell which will route the information to higher level cell. Therefore, if node 1 fails to access the signal from lower level, it can also use the higher level area to access information. This process reduces the high end-to-end delay, packet collision, and high percentage of packets lost during the packet transmission in the network.

RESULTS AND DISCUSSION

Simulation and results: The simulations tool is align with the IEEE 802.11 standards developed using Network Simulator 2 (NS2) V 2.35. The virtual machine running Linux 12.04 operating system with 512 RAM was used and NS2.35 was installed. Tool Command Language (TCL) script was used in NS2 to simulate network topology and C++ was used to simulate the proposed packet bandwidth scheduling. The network topology is stretched up to 700×600 m with 6 randomly situated nodes per each cell that is used to compare the algorithms.

Constant Bit Rate (CBR) traffic type with 10, 40, 60, 80, 100, 120 and 150 packet sizes was configured between the communicating nodes. The simulation was configured to start transmitting CBR packets at 0.3 sec and stop transmitting at 150 sec. The algorithms were compared using the performance results gained and recorded in sprit named out.nam. This was done in order to get the average of end-to-end delay, packet loss and network throughput during transmission after several simulations.

This study compared the proposed algorithm with packet scheduling algorithm and history-based increment backoff algorithms. The two algorithm was chosen because packet bandwidth scheduling does not consider the packets delay and packet drop. However, the packet bandwidth scheduling uses packet scheduling algorithm and history-based increment backoff algorithms to improve the packet transportation in a network. Within the simulations, the performance metrics are analysed as follows:

- Network throughput: is a measure of the total amount of the data which are successfully transmitted from source to destination at a given time
- Number of packets loss: the number of packets loss during the process of packet transmission
- End-to-end delay: it shows the time which packets took to reach the destination from the source

Network throughput: This study analyse the effectiveness of the network throughput based on the performance of the three algorithms. This study examine the performance of the three algorithms when the network throughput is for 14 nodes. Figure 4 shows the simulation results of those three algorithms which produce the similar network throughput when traffic load is low at 10 packets/sec.

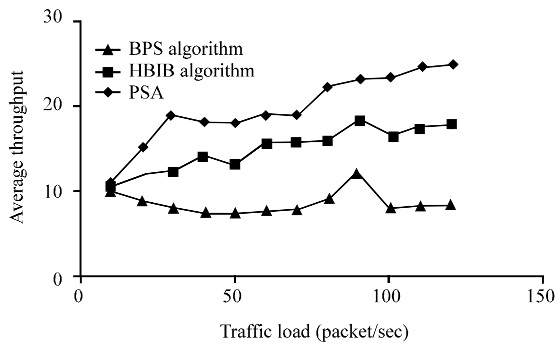

Fig. 4: The average of network throughput

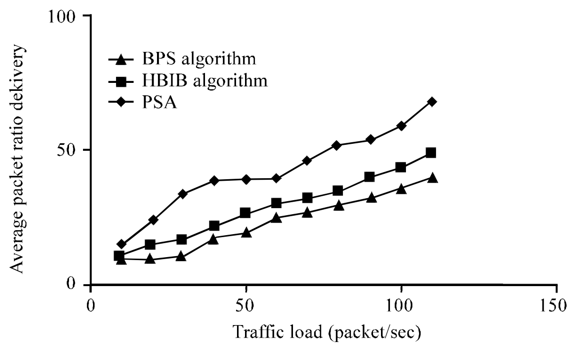

Fig. 5: Average of packets loss

The average network throughput for this algorithms are monitored and were compared under numerous packet sizes: 10, 50, 100, 150, 250 and 512 bytes. The packets bandwidth scheduling algorithm outperforms both packet scheduling algorithm and history-based increment backoff algorithms algorithm when the traffic load increases. The packets bandwidth scheduling algorithm improved the network throughput because the high bandwidth traffic had the high significance over low bandwidth traffic and it resulted in a better Quality of Service (QoS).

Number of packet loss: Packet loss is when the packet from source node does not reach its destination node. However, if the bandwidth is available and correctly allocated between the commutation users and the path is consistently selected, then the QoS is guaranteed and there will be less chances of packet loss within a network. The simulation results of those three algorithms showed the similar average number of packets lost when the simulation started.

Average percentage of packets were lost during the transmission of the algorithms which were monitored and compared under numerous packet sizes 10, 50, 100, 150, 250 and 512 bytes. Figure 5 shows the number of packets loss during the transmission (Fig. 6).

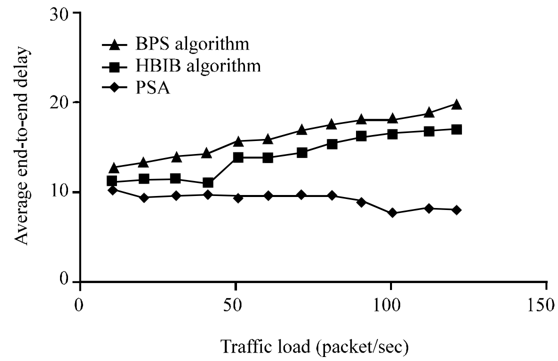

Fig. 6: Average of end-to-end delay

When the traffic load increased, packets bandwidth scheduling algorithm produced the lower average percentage of the packet lost while the other two algorithms (Packet scheduling algorithm and history-based increment backoff algorithms) produced high average percentage of the packets lost during the transmission of packets. Therefore, this gave better QoS that the network produced because the packet loss is optimized.

End-to-end delay: End-to-end delay showed the time taken by a packet within a network to flow from one to another node. Packets delay is a main concern on a different types of networks because every network has some kind of delay within it. It is always skilful to reduce the delay in a network as low as possible as it increases the network throughput.

The average of packets end-to-end delay slowed down during the packets transmission as indicated in Fig. 5. The algorithms performance of both algorithms were monitored and compared during the simulations under the numerous packet sizes: 10, 20, 100, 150, 200 and 512 bytes.

This study realized that when the load of traffic increased, the packets bandwidth scheduling algorithm executed better than packet scheduling algorithm and HBIB algorithm by decreasing the end-to-end delay. Therefore, the packets bandwidth scheduling algorithm outperformed the other two algorithms because the packets were spread over the reliable path while high priority traffic had high priority over the low priority traffic.

CONCLUSION

This study presented the design of packets bandwidth scheduling algorithm by integrating packet scheduling algorithm and history-based increment backoff algorithms. The packets bandwidth scheduling algorithm improves the packet transportation based on end-to-end delays, network throughput and packet loss WSNs was facing when transmitting the packets. Our proposed solution uses packet scheduling to first find a consistent path that packet will use when packets are transmitted from the source node to destination node in order to produce the preferred QoS in a network. The packets bandwidth scheduling algorithm also uses history-based increment backoff algorithms to allocate the packets between the nodes for communicating where high bandwidth traffic had high priority over low bandwidth traffic. This ensured that high priority traffic had short delay and this reduced the packets lost during packet transmission. In order to validate the performance of the packets bandwidth scheduling algorithm, simulations were carried out using different number of nodes. The simulation result displayed that the packets bandwidth scheduling algorithm improved the packet transportation based on end-to-end delay, packet loss and network throughput during the packet transmission. This also improved the Quality of Service QoS in a network.

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