An Improved Mwsn Efficiency by Hybrid Traffic Aware Prescriptive Congestion Avoidance and Reducing Energy Utilization Using Fdnn Approach

By

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Abstract

In Mobile Wireless Sensor Networks (MWSN) has been employed to monitor the health conditions of remotely located patient's. It has different kind of networks challenges including service differentiation, detection and avoidance of congestion through the network while the traffic becomes higher than the aggregated channel capacity. For this case, specific considerations are required. As a result, a Dynamic Random Early Detection with Fuzzy Proportional Integral Derivative (DRED-FPID) controller based on Active Queue Management (AQM) technique has been designed to control the target buffer queue and sending rate of each node. However, some limitations are addressed in this technique such as it does not consider the service differentiation, traffic flow estimation at congested nodes, high energy consumption and packet loss that degrades the network performance. Hence, the major objective of this proposed work is to improve the network performance by detecting and controlling the congestion in the network.

Keywords—Wireless sensor networks, Congestion avoidance, DRED-FDNNPID, Load based allocation, Statistical time division multiple access.

Introduction

Wireless Sensor Network (WSN) is a type of spatially distributed autonomous network that has many sensor nodes for forecasting the physical and atmospheric conditions.WSN is deployed in medical areas for monitoring the patient's health conditions in a short duration. The collected data are broadcasted to the central unit of the network namely sink node (Gentili, C., et al. 2017). Such data transmission causes data explosion and congestion via intermediate nodes that affect end-to-end delay, packet loss, network lifetime, etc. As a result, congestion control or avoidance is the most crucial for broadcasting a patient's health information without any information loss and congestion through the network.Among those techniques, Dynamic Random Early Detection-Fuzzy Deep Neural Network based Proportional Integral Derivative with Congestion Avoidance (DRED-FDNNPID-CA) achieves better congestion reduction. This technique was performed according to the priority of data packets and adjusting the network traffic or transmission rate if congestion was detected in the network. However, the network energy consumption was high which causes network lifetime. Therefore in this paper, CA is enhanced as an Energy-aware Congestion Avoidance (ECA). In this proposed technique, the LBA method is introduced to allocate the medium resources shared by different sensor nodes in the network based on the STDMA technique. Here, time scheduler is used in the PID controller that collects the memory information, battery information and location information of each sensor node. Then, the dynamic timeslots and medium resources shared by nodes are allocated according to the collected information. Based on the allocated timeslots and resources, the data packets are transmitted to the destination node successfully. Thus, this technique reduces both congestion and energy consumption in the network efficiently.

The rest of the article is structured as follows: Section II presents the literature survey related to the energy-efficient based congestion control mechanisms in WSN. Section III explains the proposed methodology. Section IV illustrates the experimental results of the proposed mechanism. Finally, Section V concludes the research work.

Literature Survey

This chapter discusses the detailed information about the previous researches that are related to the AQM-based congestion control techniques, congestion detection and avoidance techniques and energy-aware congestion avoidance techniques in WSN/MWSN.

An optimized congestion management protocol (Rezaee, A. A., et al. 2014) was proposed for healthcare WSN. Initially, a novel AQM scheme was proposed for avoiding congestion and providing QoS by utilizing individual virtual queues on a single physical queue for storing the input packets from each child node according to the significance and priority of the source's traffic. If the incoming packet was accepted, then three mechanisms were used for controlling the congestion.

Congestion-aware routing and fuzzy-based rate controller were proposed (Hatamian, M., et al. 2016) for WSN. In this method, a novel congestion-aware routing was proposed by using greedy approach. This approach was used for finding more affordable paths. Then, a fuzzy rate controller was used for rate controlling that utilizes two criteria as its inputs with congestion score and buffer occupancy. Such parameters were according to the total packet input rate, packet forwarding rate at MAC layer, number of packets in the queue buffer and total buffer size at each node. Once congestion was detected, the notification signal was transmitted to the offspring nodes. Thus, they were able for modifying their data transmission rate. However, only two inputs were considered in this approach.

An AQM mechanism (Wei, Y., et al. 2016) was proposed for controlling the congestion in MANET. In this mechanism, the node's own ability and its significance in the network for deciding the queue threshold were considered. The node's buffer queue in different levels of congestion area probability was controlled by adjusting the upper limit and lower limits. Therefore, the node's responsibility of forwarding data packets was adjusted based on their own conditions.

Priority-based queuing and transmission rate management were proposed (Bouazzi, I., et al. 2017) by using a fuzzy logic controller in WSN. The main objective of this approach was introducing a fuzzy logic algorithm to solve the issues in maintaining the message latency, reliability and maximizing the battery life of sensor nodes. Here, a fuzzy logic scheme was employed for optimizing the energy consumption and minimizing the packet drops. The fuzzy logic was implemented in the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism by filling queue length and traffic rate at each node. However, the efficiency of this approach was less.

Proposed Methodology

This Proposed work focuses on improving congestion detection and control in the MWSN with reduced packet loss and energy consumption. The major contributions of the research work are given below:

- The first contribution is that proposing a service differentiation aware Dynamic Random Early Detection and optimized Fuzzy Proportional Integral Derivative (DRED-FPID) for AQM congestion control in MWSN that differentiates the traffic based on their priorities.
- The second contribution is that congestion avoidance aware using modified weighted fairness guaranteed that diverts the traffic to the non-congested nodes for reducing the packet loss in the network.
- The third contribution is that Dynamic Random Early Detection (DRED)-Fuzzy Deep Neural Network Proportional Integral Derivative (FDNNPID) based energy-aware congestion avoidance for MWSN that uses Load Based Allocation (LBA) mechanism for reducing the mean energy consumption and increasing the network lifetime.

Result and Discussion

This chapter provides the overall performance of different congestion detection and avoidance techniques such as DRED-FDNNPID, DRED-FDNNPID-CA, DRED-FDNNPID-ECA and compared with the existing technique i.e., DRED-FPID in terms of different metrics.

Simulation Environment

This experiment is conducted by using Network Simulator version 2.35 (NS2.35). The simulation parameters considered for this experiment is listed in below Table 4.1.

Table.4.1 *Simulation Parameters*

Parameter	Value
Network size	300×400 sqm
Number of sensor nodes	30
Number of sink nodes	1
Packet size	512 bytes
Packet rate	120 packets/sec
Node's initial energy	5000 Joule
Buffer size	100

Packet Loss Ratio

PLR is defined as the amount of packets lost during its transmission in a unit time and is computed as,

$$\text{PLR} = \frac{\text{Packet Loss}}{\text{Time Duration}}$$

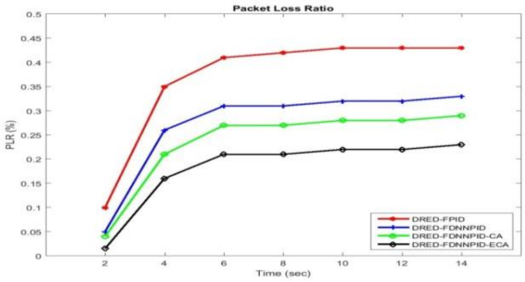

Figure.1 *Comparison of PLR*

Figure 1, a comparison of PLR in the network for both proposed and existing techniques is shown with respect to time. It is observed that when service is not yet differentiated, the PLR is high. Alternatively, as service differentiation process and scheduling mechanism are performed with congestion control and rate adjustment process, the PLR is reduced significantly. From the analysis, it is observed that the DRED-FDNNPID-ECA technique reduces the PLR compared to the other techniques.

Packet Loss Probability

The packet loss probability is computed as,

$$P_{loss} = \frac{\text{Number of packets lost}}{\text{Number of packets lost} + \text{Number of packets received}}$$

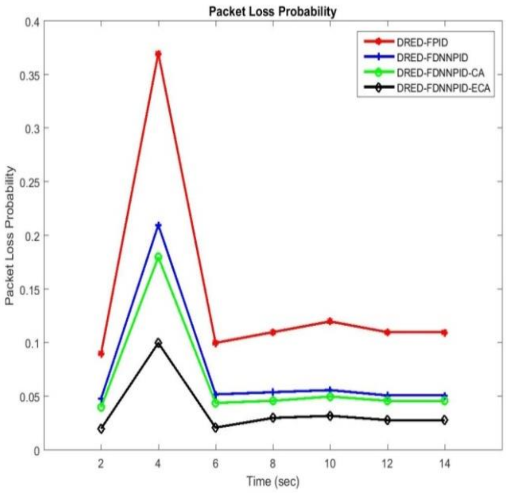

Figure.2 *Comparison of Packet Loss Probability*

Figure 2 shows the comparison of packet loss probability for both techniques. From the analysis, it is observed that the proposed DRED-FDNNPID-ECA technique has reduced probability of packet loss by using service differentiation and scheduling the timeslots to transmit the data successfullly without any congestion and maintain the minimum packet loss.

Mean End-To-End Delay

It defines the time between generation of data packets and reaching the destination.

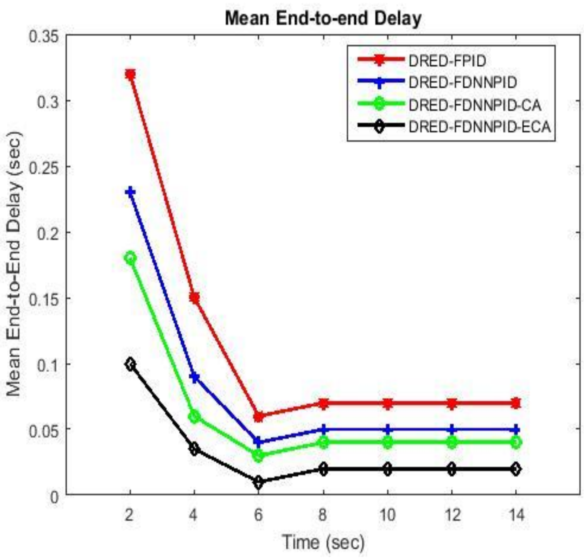

Figure.3 *Comparison of Mean End-to-end Delay*

Figure 3, a comparison of mean end-to-end delay in the network for both proposed and existing techniques is shown with respect to time. It is observed that end-to-end delay in the proposed DRED-FDNNPID-ECA scheme is decreased rapidly than the other techniques since the low delay is crucial for transmitting the packets containing patient's information without any congestion.

Mean Queue Length

The queue length is defined as the amount of packets in the queue and the mean queue length is the most essential criterion in delay measurement. When the packet inter-arrival time longer than the packet service time, the queue length is increased and thus a delay is increased in the network. It is based on the delay status and waiting time in intermediate nodes.

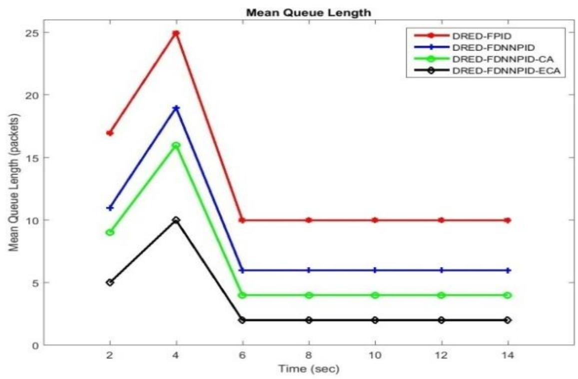

Figure.4 *Comparison of Mean Queue Length*

Figure 4 illustrates the comparison of mean queue length for both proposed and existing techniques with respect to time. It shows that the mean queue length of the proposed technique is less than 2packets/sec. Through the analysis, it is observed that the queue length of the proposed DRED-FDNNPID-ECA technique is controlled by differentiating the services and scheduling the traffic in order to avoid congestion in the network.

Transmission Rate Adjustment

The transmission rate is defined as the speed that data is being transmitted from source to destination in a given time duration. Rate adjustment is occurred from the node with congestion to the source node of the traffic in hop-by-hop manner. In addition, it is performed until the network congestion is removed and there is no notification transmitted to the source for adjusting the transmission rate.

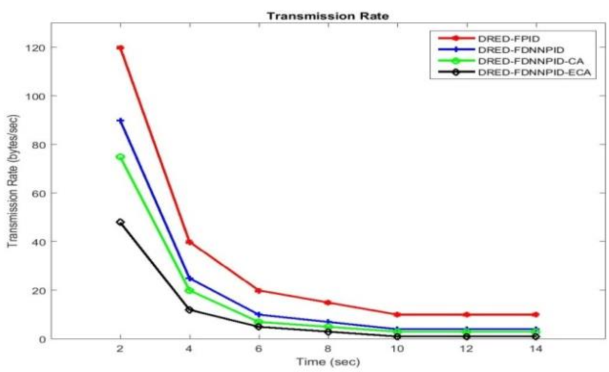

Figure.5 *Comparison of Transmission Rate*

In Figure 5, a comparison of the transmission rate in the network for proposed and existing techniques is shown with respect to time. It is observed that the transmission rate of the proposed DRED-FDNNPID technique in each time period is less than the other techniques resulting in the congestion through the network is controlled and avoided efficiently.

Mean Energy Consumption

It is defined as the amount of energy consumed by sensor node during transmitting the data packets from source node to destination node.

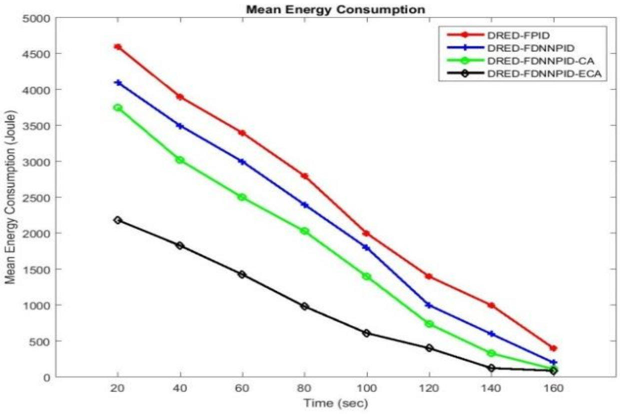

Figure.6 *Comparison of Mean Energy Consumption*

Figure 6 shows the comparison of proposed and existing techniques in terms of mean energy consumption for different time periods. From the analysis, it is concluded that the proposed DRED-FDNNPID-ECA technique achieves minimum energy consumption compared to the other techniques and so the network lifetime is improved efficiently.

Conclusion

In recent years, MWSN has emerged in medical industrial applications to remotely monitor the patient's health conditions. The most crucial challenges in these networks include service differentiation, congestion detection, avoidance and control when the traffic becomes higher than the aggregated channel capacity. For this scenario, specific considerations were needed to detect and control the congestion. As a result, a DRED-FPID controller has been designed based on AQM technique to control the target buffer queue and sending rate of each node. However, this technique has some limitations such as it does not consider the service differentiation, traffic flow estimation at congested nodes, high energy consumption and packet loss that degrades the network performance. Hence, this research has a major objective of improving the network performance by detecting and controlling the congestion through the network.

In the first part of this work, a service differentiation mechanism is proposed with DRED in which priority-based rate control is introduced based on the weighted load metric related to the queue status of the nodes. Initially, each traffic assigns different priority since ensuring a low delay bound is a significant issue for real-time traffic. High priority-based traffic is buffered in a separate queue along low buffer size and low priority based traffic is controlled by using the DRED algorithm. Moreover, the fuzzy inference system is enhanced based on the machine learning approach such as DNN known as FDNN which uses more inputs for the learning process. Thus, this improves the DRED-FDNNPID with self-adaptation to enhance the performance and optimize the average queuing delay.

In the second part of this work, a DRED-FDNNPID technique is further enhanced by traffic estimation and diversion techniques to avoid congestion efficiently. In this technique, network traffic estimation is performed by using modified additive increase decrease algorithm to quickly resolve the congestion. Based on this estimation, the traffic is diverted or packets are dropped along the alternative paths. Such traffic diversion is achieved for congestion avoidance due to lack of coordination with the rate adjustment and traffic estimation. Thus, the proposed technique avoids congestion by estimating the network traffic at congested nodes and diverting the traffic along the available alternative paths.

In the third part of this work, congestion avoidance is improved as an ECA. In this proposed technique, the LBA method is introduced to allocate the medium resources shared by different sensor nodes in the network based on the STDMA technique. Here, time scheduler is used in the PID controller that collects the memory information, battery information and location information of each sensor node. Then, the dynamic timeslots and medium resources shared by nodes are allocated according to the collected information. Based on the allocated timeslots and resources, the data packets are transmitted to the destination node successfully. Thus, this technique reduces both congestion and energy consumption in the network efficiently. Finally, the simulation results prove that the proposed techniques afford better performance with an improvement of DRED-FPID controller using service differentiation, traffic estimation and diversion and energy-aware congestion control efficiently.

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