# Review of the Neural Network Based Congestion Control Methods of Wireless Sensor Network

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## ABSTRACT

WSNs are the widely used for the process of sensing and transmitting the data of any environment based on the application and they are mainly employed for the real-time applications. In the real-time applications, the WSNs are advantageous but the efficiency and the system performance are degraded because of the phenomenon termed as congestion. The occurrence of congestion affects the life-time of the nodes resulting in the poor throughput of the network. Thus, in order to enable effective transmission and to enhance the throughput of the network, an efficient congestion control method is required. Accordingly, the literatures present various approaches for the controlling the congestion that occurs in the network and it is very clear that the accuracy of the control mechanism is the outstanding issue at present. Therefore, the need for an effective congestion management system arises that outperforms the current approaches in terms of accuracy, congestion rate, and the packet drop rate. Thus, this review article presents the detailed review of 17 research papers that present the recommendation approaches based on neural networks, fuzzy-logic model, hybrid method, and learning-based models. Additionally, the detailed discussion of the survey taxonomy in terms of the simulation tools and performance metrics are clearly reviewed and analyzed. The research issues of various conventional methods are presented in the literature section along with the description of the methods that promote the researchers towards a better contribution of the congestion control mechanism.

## I. Introduction

Wireless Sensor Networks (WSNs) is the network comprising of a number of the minute, cheap, and battery-operated sensor nodes that are interconnected to each other wirelessly. The major role of the WSNs is to sense an environment within a particular sensing area and the main components of the WSNs are the processor, memory, transceiver, sensors, and battery [1]. The sensor nodes possess the capacity to collect the data and store it for further processing associated with the process. The major risk criteria of the sensor nodes is the energy such that the life-time of the nodes are affected when there is no sufficient energy as they are battery-operated [4]. Followed by any event, the sensors are activated so that they collect the data and they are transmitted or stored based on the application. The life-time of the nodes is affected due to the available network errors and traffic persisting in it. Moreover, the issues like the many-to one convergent nature [2] of upstream traffic and limited wireless bandwidth occurs in the network leading to congestion. All these factors influence the degradation in the performance of the network. Thus, it is essential to design and model an absolute congestion control mechanism that mitigates the occurrence of congestion [6].

Congestion is the process of seeking the more resources than is available in the network such that the performance is degraded and the delay in the network increases [2]. The presence of congestion can be determined based on the rate of the incoming data packets and the outgoing data packets. The two types of the congestion, namely the node level and the packet level congestion occurs in the network. The node level congestion occurs in the nodes whereas, the packet level congestion occurs in the transmission of the data packets [8]. The presence of congestion in the network degrades the energy, causes the packet loss, and affects the throughput of the network [11]. There are a number of the congestion control methods that offers energy efficient transmission and offers effective throughput in the network. The mostly prevailing methods include, fuzzy-logic, neural networks, and so on [12]. The efficiency of the neural network-based congestion control depends on the selection of the network parameters. Lot of methods based on neural networks are improper in dealing with the congestion in the network as the optimal selection of the weight-bias combination [16].

The main aim of the paper is to present a detailed survey of the various techniques present for controlling the congestion in the network. The review presents the existing methods of the congestion control that highlights the importance of the controlling the congestion. The survey is carried out in terms of the various simulation tools and the performance metrics used for implementation. The congestion in the network affects the nodes causing inefficient energy routine in the network. The methods of congestion control are categorized into four, namely the methods based on fuzzy-logic, neural networks, hybrid

model, and learning-based models. The existing methods have been categorized into various approaches and they are surveyed to present the research gap and issues. Thus, it serves as the motivation for the future extension of the congestion control.

The paper is organized as: Section 1 gives a brief introduction to the paper, Section 2 presents the literature review of the existing works, and Section 3 elaborates the analysis and discussion of the survey and section 5 concludes the paper.

## II. Review of Literature

In this section, we present the review of the congestion control method that follows the neural networks, fuzzy logic, and other learning-based methods. The review deeply discusses the methods with the issues of the methods, which would serve as a motivation for the future studies in the topic of congestion control in the networks.
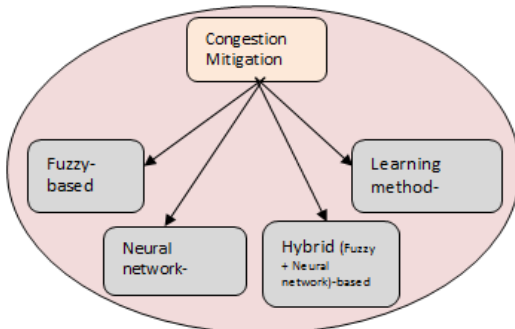


**Figure 1. Taxonomy of the congestion control methods.**

Whenever the packet rate of the incoming data packets exceeds the physical size of the queue in the nodes, congestion occurs. The method for controlling congestion in the network is categorized as four: The methods based on neural networks, fuzzy, hybrid models, and learning methods. The main achievement of the neural network based methods rely on the learning algorithm used for training the network for the selection of the network parameters and the fuzzy methods are based on the fuzzy rules.

**2.1 Neural network based methods for congestion control:**

This section briefs the congestion control methods that operate using the neural networks based on various learning algorithms and controllers. Parisa Bazmi and Manijeh Keshtgary [3] proposed a congestion control mechanism based on the neural networks that acts as an adaptive controller of congestion and remits the current status of the network.

In other words, prior to the instance of transmission, the presence of the congestion in the network is predicted and the route is cleared and the method is found to improve the throughput of the network. Moreover, the method is able to control the queue overflow leading to the reduction in the packet drop rate but this method requires the IP address of the host. However, the selection of the appropriate parameters is of huge concern.

Prakul Singhal and Anamika Yadav [4] developed the artificial neural network-based congestion control of the network that uses the number of participants, buffer occupancy, and traffic rate as input to generate the level of the congestion in the network. The Neural Network Based Congestion Detection (NNBCD) protocol developed in [4] determines the congestion level accurately upon the occurrence of the packet drop due to the training of the Bayesian regularization algorithm (Trainbr), which minimizes

the error but the time consumed to determine the exact weight and bias combination is large.

B. Subramani and T. Karthikeyan [9] modeled a method termed as Expert-Control based Intelligent Multicast Congestion Control (ECMCC) for enabling congestion control using the Radial Basis Function Neural Networks (RBFNN) that employs the knowledge base. The method offers improved throughput even when the pocket loss is higher but also there is small oscillation in the throughput for the increase in the congestion rate

A. B. M. Alim Al Islam and Vijay Raghunathan [11] proposed a method of congestion control using the neural networks that offered no network overhead and enabled the reliable transmission of the data over the network but faces much problem in training of the neural networks and the convergence of the network to a solution consumes more time.

Mehdi Mohtashamzadeh and Mehdi Harizi1 [13] used neural networks for inferring the congesting status of the network and thereby, preserves the QoS of the network. The method uses the Reno controller for deciding the congestion status of the network through incrementing or decrementing the sending rate of the network. The main drawback of the method is that the method avoids multiplicative decrease and is applicable only for the high traffic networks.

J. Alan Bivens et al. [14] used the feed-forward neural network to infer the severe congestion in a network. The method enables a better way of providing the control in the network through an effective learning and it enables the detection of the congestion in the network before it occurred. Once the congestion is controlled by dropping the packets, the congestion window of the sender is reduced but faces lot of problems in dealing with the larger networks mainly, at the point of communication.

Hyun C. Cho et al. [15] employed the AQM technique using the dynamic neural network based on the Back-Propagation (BP) algorithm. The function of the dynamic neural network is to improve the robustness of the adaptive feedback controller, which maintains the actual queue size in the network. The QoS of the network is improved but is not applicable for the noise disturbance networks and for the variable data streams.

**2.2 Learning based methods of congestion control:**

In this section, the learning methods used for minimizing the congestion in the network is presented. Pierre Geurts et al. [2] employed the machine learning technique for the control of congestion in the networks. The main impacts of congestion are heavy loss in the networks hence, the machine learning methods solves the problem through the development of the automatic loss classifier using the database from the random network topologies. This boosting classifier is found to enhance the bandwidth usage in the wireless networks and no deterioration is noted in the wired network.

Sudip Misra et al. [12] presented a method to solve the curb down congestion that occurs in the network as a result of the network's traffic, which enables large amount of energy consumption at the sensor nodes. The method Learning Automata-Based Congestion Avoidance Algorithm in Sensor Networks (LACAS) adaptively designs the processing rate of the network but this method is applicable only for the stationary environments.

Maciej Zawodniok and Sarangapani Jagannathan [17] proposed a decentralized, predictive congestion control

(DPCC) for wireless sensor networks (WSN) that permits the adaptive mechanism through the use of adaptive flow and adaptive back-off interval selection schemes. The usage of the fair scheduling algorithm maintains the effective QoS but this method is not applicable for real-time.

**2.3 Fuzzy-based method of congestion control:**

The fuzzy –based methods and the drawbacks of each methods modelled for avoiding the congestion in the network is depicted in this section. Jutan Wei, Bing Fan, and Yi Sun [1] proposed a method to control congestion that is based on the fuzzy logic and the method gains more advantage over the current buffer occupancy and congestion index (CI), which determines the congestion level of the individual nodes present in the network. The main goal of the fuzzy logic theory relies on the determination of the congestion degree that is essential for managing the traffic rate of the network such the status of the network is adaptively adjusted to minimize the packet loss and delay of the transmission. However, the randomness of the channel causes the overflow and the delay in the downstream node.

Saurabh Jaiswal and Anamika Yadav [5] developed a congestion control strategy of the network using the fuzzy concept that enables adaptive control of congestion. A Fuzzy-based Adaptive Congestion Control (FBACC) intake buffer occupancy, participants and traffic rate and establishes a smart method of dropping the packet in case of the congestion and regulates the traffic through a feedback mechanism. The energy and the time required for the re-transmission of the data packets is low but it discards the lost packets.

Saad A. Munir et al. [6] proposed a model for estimating the congestion of the network that is based on the fuzzy-logic. The proposed QoS Management and Control module is enabled at teh node level and the sink level such that it solves the congestion and finalizes the problem of insufficient memory and buffer capacity thus, providing efficient transmission. However, this method is better for the high traffic networks.

Cagatay Sonmez et al. [7] proposed a fuzzy-based control of congestion in the wireless sensor networks. The sensor fuzzy-based image transmission (SUIT) presented in this paper is the solution to solve the high volumes of data that mitigates the congestion by decreasing the quality of the image, which seems to be the drawback of the method.

The packet drop mechanism of the method is based on the weights of the packets and the image quality is reduced using cross-layer information exchange method and a quality adaptation technique.

Lyes Khoukhi and Soumaya Cherkaoui [10] presented an intelligent solution for solving the congestion issues available in the network. The intelligent system comprises of the fuzzy-logic system and Fuzzy Petri Nets for managing the threshold buffer and analyzing the decision making regarding the QoS. This method possesses the ability to adapt to the dynamic conditions of the network and provides better QoS support.

**2.4 Hybrid method using fuzzy-logic and neural networks of congestion control:**

Hybrid model uses both the fuzzy and the neural networks for avoiding the congestion that occurs in the network due to the traffic in the data packet arriving the nodes during the transmission process. Chung-Ju Chang et al. [8] designed a control mechanism based on the fuzzy/neural techniques that consists of pipeline recurrent neural network (PRNN) interference predictor, a fuzzy performance indicator, and a fuzzy/neural access probability controller for

regulating the traffic in the network. It enabled the intelligent prediction of the congestion in the network but the reservation packets are subjected to corruption using the contention packets.

Rekha Chakravarthi [16] used the fuzzy-logic and the neural network for regulating the packet drop in order to control congestion in the network. The soft computing based congestion control technique decides the dropping rate of the data packets in the network and the network takes Priority, Buffer Overflow and Loss rate as input to train the network that is trained using the back propagation based learning that offered better accuracy.

**III. Analysis using Research papers**

This section presents the analysis of the papers using the various simulation tools used for implementation and the performance metrics used for the implementation. The discussion is deliberated below.

**3.1 Simulation tool:**

The various simulation tools used for the implementation of the congestion control mechanism are listed in the table 1. The tools used include the OPNET, NS-2, ndnSIM, MATLAB, GloMoSim, Solaris 5.6, and Omnet++. The research paper [17] implemented the control mechanism in both the MATLAB and NS-2 for undergoing the comparative analysis of the performance. The tool OPNET is used in the research papers [1] and [7]. The MATLAB is an easy environment to implement the network topology and analyzing the performance and it is used to simulate the network in research papers [4], [5], and [17]. The research paper [13] employs the tool termed as Omnet++.

**Table 1. The simulation tools used in the research papers**

| Tools | Research Papers |
|---|---|
| OPNET | [1], [7] |
| NS-2 | [2], [4], [6], [10], [11], [17] |
| ndnSIM | [3] |
| MATLAB | [4], [5], [17] |
| GloMoSim | [12] |
| Solaris 5.6 | [14] |
| Omnet++ | [13] |

**3.2 Metrics utilized**

The various performance metrics used in the research papers for analyzing the superiority of the methods are depicted in the table 1. The main metrics that contribute towards the congestion avoidance are packet drop rate, congestion level, average delay, and throughput that are

**Table 2. The performance metrics used in the research papers**

| Metrics | Research Papers |
|---|---|
| Packet drop rate | [1], [2], [3], [4], [5], [6],[8] |
| Throughput | [1], [9], [10], [11], [12], [13], [17] |
| Congestion rate | [5], [8] |
| PSNR | [7] |
| MSE | [7] |
| Average delay | [10] |
| Energy | [12], [17] |
| Queue size | [15], [17] |
| Accuracy | [16] |
| Corruption rate | [8] |
| Utilization | [8] |
| Collision rate | [12] |

utilized by the research papers [1-13], [17]. The prediction accuracy of the method is discussed in the paper [16]. The main concept is that whenever the delay and the packet loss of the network increases, the throughput of the network is

affected and the network performance is said to yield a better performance whenever the transmission of the data packets are performed with the maximum value of the throughput.

**IV. Conclusion**

Advancement in the technologies and the information systems caused the heavy traffic in the networks that drags enormous attention towards the efficient congestion avoidance mechanism. The method for controlling congestion is essential as it makes energy-efficient transmission and increases the throughput of the transmission in the network. It is clearly known that the throughput is improved when the packet drop and the delay of the transmission are reduced. This paper presents a survey taxonomy that categorizes the various approaches based on the techniques presented in the research paper. The main intention of this article was about to study and review the various congestion control methods used assisting the networks to undergo a congestion free transmission. The review and analysis is carried out using 17 research papers, which is grouped into four methods and the analysis is performed based on the performance metrics and the tools used. Despite the fact, promising results have been reported on literature, and the results are presented that is based on packet drop rate, congestion level, Queue size, average delay, PSNR, MSE, and so on. Based on analysis, we have concluded that more number of researchers has used neural and fuzzy-based techniques for congestion avoidance mechanism.

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