Acta Scientific Applied Physics

Volume 3 Issue 9 September 2023

Review Article

A Comprehensive Analysis of Congestion Control Techniques in Wireless Sensor Network

Roland T Tweh[1]*, Edwin O Ataro[2] and George N Nyakoe[3]

[1] *Department of Electrical Engineering, Pan African University Institute for Basic Sciences Technology and Innovation, Nairobi, Kenya*

[2] *School of Electronics and Electrical Engineering, The Technical University of Kenya, Nairobi, Kenya*

[3] *Department of Electrical and Electronics Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya*

***Corresponding Author:** Roland T Tweh, Department of Electrical Engineering, Pan African University Institute for Basic Sciences Technology and Innovation, Nairobi, Kenya.

Received: July 26, 2023

Published: August 04, 2023

Abstract

Wireless Sensor Networks (WSNs) have over the years emerged as a vital technology for monitoring and collecting essential data from their deployed environment, however excessive network congestion can cause packet loss, network delays, low throughput, increased network buffering and retransmission thereby shortening the lifetime of sensor nodes. Congestion control is essential for WSN but efficient utilization of resources is vital in achieving maximum Quality of Service (QoS) of the network. In this paper, the researchers present a comprehensive analysis of recent congestion control techniques in WSNs. The aim is to examine how these congestion control mechanisms operate and highlight their weaknesses. In addition, this paper also aims at setting criteria that researchers should achieve when developing congestion control techniques in WSNs.

Keywords: Wireless Sensor Networks; Quality of Service; Congestion Control

Introduction

A Wireless Sensor (WSN) is a network of nodes that can sense, process, and communicate independently [1]. These tiny sensor nodes communicate with one another haphazardly to detect and monitor the environment of deployment [2]. Each node in WSN sends data packets via intermediate nodes to a sink/base station via a short-range transmitter [3]. These small sensor nodes are often deployed to sense and monitor many applications in dangerous and inaccessible areas.

Congestion is one of the major issues in WSNs that affects the QoS [4]. It is an unforeseen state that causes packet loss, decreased throughput, packet buffering, and retransmission resulting in the loss of vital data over the network [5]. Congestion must thus be controlled to avoid performance deterioration and network disruption. Congestion can occur as a result of suspicious occurrences or undesired network activity. Congestion also occurs when the number of incoming data packets at a single hub exceeds the number of exiting data packets.

Congestion control is important because it focuses on improving the QoS, maximizing network lifespan, and avoiding large traffic drops while making optimal use of resources [6]. It is important because it allows a regular flow of data and improves the overall performance of WSN allowing end-users to experience faster data transfer speeds and fewer network delays. Congestion control techniques are methods for controlling traffic and maintaining a

Citation: Roland T Tweh., *et al*. "A Comprehensive Analysis of Congestion Control Techniques in Wireless Sensor Network". *Acta Scientific Applied Physics* 3.9 (2023): 03-10.

steady volume of data within a network. These techniques deliver equitable high bandwidth utilization, quick and efficient fairness, a high level of responsiveness, and compatibility which reduces subsequent packet losses [7]. As a result, several techniques have been used to redefine the effectiveness and QoS in the network. Congestion control techniques are distributed into three types namely: Congestion mitigation, Congestion detection, and reliable data transmission as shown in figure 1.

Congestion mitigation is the reaction and control of congestion by performing MAC and network layer operations. Congestion detection is the prevention of network congestion. Reliable data transmission is controlling congestion and getting back lost information.

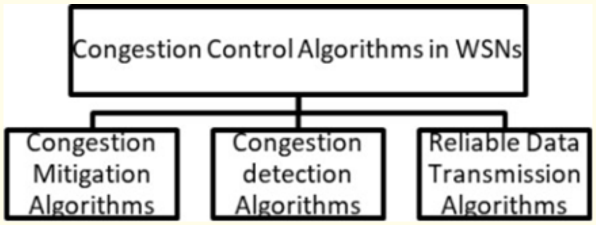

Figure 1: Congestion Control Technique [6].

In recent years, many researchers have provided support in the literature on the need for congestion control in WSNs. These researchers provided an analysis of studies focusing on the two common causes of congestion namely: Buffer overflow and Link collision [8] as shown in figure 2. Buffer overflow (node-level congestion) hurts the performance of the impacted node in the WSN. It causes energy loss due to a greater packet ratio and as a result, disconnects the affected node from the network resulting in certain routes being unavailable. This happens when the quantity of sent packets surpasses the packet handling ability of a single node (node A), resulting in packet losses and waste of node energy [9]. Link Collision (link level congestion) occurs when numerous vigorous nodes attempt to connect with a single node (node B) at the same time, resulting in packet loss due to struggle and incursion.

The contributions of this paper, the authors provide a comprehensive analysis of the significant number of congestion control techniques used for WSNs, address and discuss the characteristics of each technique as well as the strengths and weaknesses of each technique, provide specific criteria for the design and development of new congestion control technique in WSN.

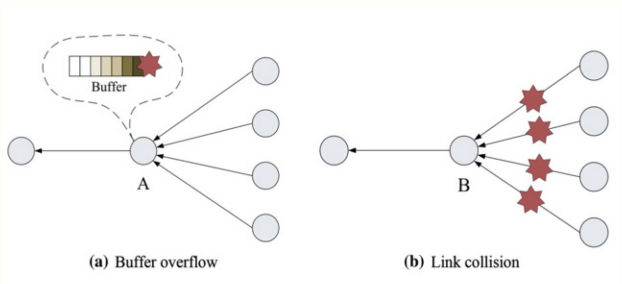

Figure 2: Typical Congestion Appearance Scenarios in WSNs [9].

The rest of this paper is arranged as follows

Design Issues and Challenges in WSNs

WSNs provide a wide variety of standout highlights. The one-to-many and many-to-one data flow patterns in WSN [10]. The next generation of WSNs has a large number of sensor nodes with low-performance CPUs, meager non-rechargeable batteries, lower bandwidth connectivity, and less memory. There are many limitations on the utilization and availability of sensor node resources as a result [11]. Next, a significant number of nodes must be deployed for the majority of WSN applications. Thus, the protocols' capacity to scale up and down is crucial [12]. Each node also has a large amount of data. It takes a lot of power, energy, and bandwidth to transfer this data to the sink node. By deleting unnecessary data from the network stream, this problem can be resolved. Certain precise features of WSNs should be concentrated to practice in real- world applications [8].

Memory requirements and minimal computation.

- Automaticity and self-organization.
- Energy efficiency.
- Scalability.
- Support for in-network data aggregation

Importance of Optimization in WSNs

The importance of optimization in wireless sensor networks is evident. A technique for achieving the best results in a specific circumstance is optimization [13]. Many optimization techniques are available and are utilized in networking to achieve desired goals. Solitary and multi-objective optimization fall within this classification [14]. In single-objective optimization, the optimizer's job is to reduce or take advantage of a single objective while working within a variety of constraints [15]. Whereas different objectives are simultaneously optimized in multi-objective optimization. Real-world issues have multiple goals, all of which must be improved at once [16].

Congestion in wireless sensor network

A node in a wireless sensor network is a compact embedded computer that interacts with sensors and actuators and uses short-range wireless transmitters for communication [3]. Data packets are routed hop-by-hop towards management nodes, which are commonly referred to as sinks or base stations, by these autonomous yet cooperating nodes to create a logical network [17]. A detected or monitored event causes sensor networks, which typically operate under light load, to suddenly become active, generating large, sudden, and correlated impulses of data that must be delivered to a small number of sinks without materially impairing the performance of the sensing application [8]. This unregulated, high pace of data packet production frequently causes congestion, which causes random packet drops and longer delays. These networks suffer greatly from dropped packets since they use a lot of energy [18]. Without protective measures, overloaded nodes may run out of power, leaving the network with routing “holes.”

Causes of congestion in wireless sensor networks

As the amount of data generated by source nodes close to sinks increases, the offered load outpaces the network’s capacity and causes congestion [19]. Buffer overflows, channel blockages, interference, packet collisions, and many-to-one flow patterns are some of the primary causes of congestion. When there are more incoming packets than there is buffer space for, this condition is known as buffer overflow. Between several flows and various packets in a flow, congestion develops. The simultaneous transmission of data via various network pathways by close nodes causes interference. Lower-level congestion results from packet collisions, which also cause packet losses [20]. Data communication between numerous sources and sinks is one-to- many, which causes a bottleneck at the sink. Packet collisions result in packet losses, channel quality degradation, packet loss per unit of time, and packet drops at buffers are all effects of congestion [21]. Congestion must therefore be addressed. Figure 3 depicts three causes of congestion in WSNs.

Congestion control techniques in WSNs

Congestion control technique refers to methods and systems that can reduce or completely remove congestion. It also refers to regulating the quantity of network traffic based on network capacity. Open loop and closed loop are the two types of congestion control systems [23]. The occurrence of congestion is prevented in the case of open-loop congestion control, which is a preventive or avoidance strategy. In this category, congestion management can be carried out from the source or destination locations. On the other hand, the objective of closed-loop congestion control is to get rid of the current congestion [24]. To address the congestion issue in WSNs, many techniques have been proposed in the literature. Congestion control, congestion avoidance, and dependable data transmission algorithms are three categories for the algorithms. Since many algorithms fall into more than one category, we strive to match each algorithm to the one that best matches it in this endeavor. Each category’s algorithms are arranged according to the year they were published. Using this classification, we aim to show how this research field has changed over time [25].

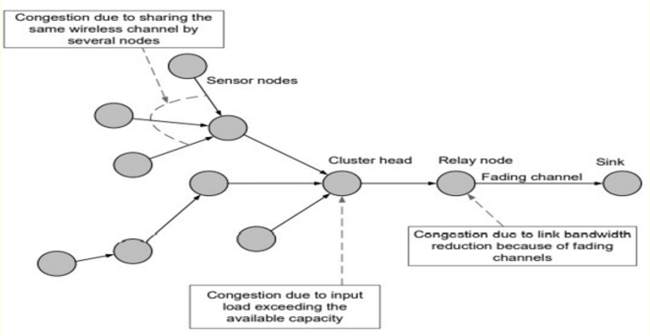

Figure 3: The causes of congestion in WSNs [22].

Congestion detection and avoidance (CODA)

In [26], the authors developed two mechanisms for event-driven WSNs: an open-loop, hop-by-hop backpressure method and a closed-loop, multi-source regulation technique. CODA detects congestion based on buffer occupancy and channel load, and the CODA method of coarse rate adjustment employs additive increase multiplication and decrease. Packet loss is a natural consequence of congestion management fairness, and sensor nodes expend more energy processing control packets like ACK and backpressure. The sink node broadcasts ACK packets in the direction of the nodes while the data transmission rate is being controlled.

Ant colony optimization algorithm and the tabu search algorithm (ACO-TSA)

In [27], the authors propose a congestion and traffic technique at the communication level due to the WSN's intrinsic constraints and a large number of scattered nodes. Congestion will cause an excessive number of packets to be lost, wasting energy and other network resources. In this technique, the most perfect manner to transfer data from the nodes to the CH is initially sought after using the ACO algorithm. The obtained path can then be saved using the pheromone evaluation, and after finding and saving the path, the WSN congestion control method will be initiated. When congestion is managed using the tabu search parameter. Find the routes that have the most transactions compared to other routes, evaluate their threshold, and add them to the prohibited list. When there is congestion on one route, a different route is chosen to send goods. The simulation results show that the suggested method is more energy-efficient and has a lower packet loss rate and shorter network lifetime than the alternative way.

Trust aware energy efficient fuzzy clustering protocol (TA-EE-FCP)

The authors in [28] present a novel proposal for a safe routing algorithm that is based on fuzzy cluster trust and is energy efficient. The proposed protocol is implemented with the help of NS2 and several assessment criteria, including an analysis of energy consumption, a packet delivery ratio, and delay. It is seen from the simulation results that the proposed strategy optimizes energy usage, raises the network's packet delivery ratio, decreases data transmission delay, and then lengthens the network lifetime.

Priority-based energy efficient, delay and temperature aware routing algorithm (PEDTARA)

Priority-based Energy Efficient, Delay, and Temperature Aware Routing Algorithm is an effective routing model for SDN-based WBAN that was created in [29]. The proposed PEDTARA model made use of an improved optimized MGCSMO algorithm for route optimization based on energy, queue length, link dependability, and path loss with consideration for the thermal dissipation of nodes for the forwarding node selection. Initial forwarding node selection in the proposed PEDTARA model is based on energy and temperature. To lessen the chance of overheating, the heated nodes are forced to rest for a few cycles. The best routing paths were then chosen using the fitness function, which was then developed and employed in MGCSMO.

Intelligent traffic routing algorithm (ITRA)

To monitor environmental factors like soil moisture, humidity, and soil temperature, the authors in [30] implemented WSNs in the agricultural environment. As a result, the proposed technique is very helpful and should be taken into account when implementing WSNs in the agricultural environment. Furthermore, this paper demonstrates that for network users to be able to monitor their agricultural environments across a variety of environments, they always need a good network performance. To create the algorithm, the LBRM and MLCC algorithms were combined, and Network Simulator 2 (NS-2) was used to evaluate the algorithm's performance.

Hierarchical tree alternative path (HTAP)

The authors of [31] propose HTAP, a hop-by-hop approach that manages congestion by generating dynamic pathways to the sink. In the topology control scheme, each node produces and updates its neighbour node. When there is congestion, HTAP reroutes the excess traffic to the sink via other paths, which include nodes not present in the original path. A hierarchical tree is formed, with the root node serving as the source node, and the powerless nodes informing the nearby nodes of the condition. It is simple, efficient, and achieves scalable resource control, according to the concept.

Congestion control based on adaptive integral backstepping (CCAIB)

To address the congestion issue for wireless networks, the authors of [32] developed a novel algorithm called CCAIB within the AQM framework. Several bottleneck routers are taken into consideration by CCAIB. The AQM problem is solved using a backstepping process, and the wireless packet loss ratios are evaluated using an adaptive method. CCAIB performs better in terms of queue length convergence time, queue packet loss ratio, and window size when compared to the H algorithm, another congestion control technique for wireless networks. Also, several network scenarios are used to test the viability and effectiveness of CCAIB.

Firefly algorithm optimized fuzzy-PID controller (FA-Fuzzy-PID)

Based on a Firefly-optimized Fuzzy-PID controller, the authors of [5] present a new and efficient way of controlling congestion in wireless sensor networks. A more precise and accurate result was achieved by applying the Firefly Algorithm to optimize the PID parameter increment from the Fuzzy-PID controller. The objective was to increase WSN performance overall and provide a regular data flow, enabling end users to enjoy quicker data transfer rates and fewer network delays. According to the results of the simulation, the suggested control strategy effectively reduces congestion in wireless sensor networks.

Congestion minimization of LTE networks (CMLTEN)

A supervised deep learning approach was developed by the authors of [33] to reduce congestion in LTE/LTE- A cellular towers. The technique estimates the number of users connected to each tower before estimating the congestion level's threshold. To reduce the congestion, the Genetic Algorithm (GA) and Block Coordinated Descent Simulated Annealing (BCDSA) were suggested.

Neuroevolution of augmenting topologies-transmission control protocol (NEAT-TCP)

There is evidence that the proposed scheme in [34] can adapt and function with various problems. With a 69% fairness percentage, a 66% latency reduction, and a 71% packet loss reduction, NEAT-TCP has demonstrated its viability in obtaining higher fairness. Yet we see that NEAT inhibits many activation processes that are involved in judgment.

Cuckoo fuzzy-PID controller (CFPID)

The PID method is applied to cluster head nodes in [35] to effectively collect sensor data while controlling queue size. Furthermore, a fuzzy control technique is used to address the issues with PID controllers, such as their weak adaptive capability, sluggish parameter optimization, and imprecise optimization. The quantization factor and PID parameter of a fuzzy PID controller are optimized via CFPID. The outcomes demonstrate that, in terms of real-time loss rate and instantaneous queue length, CFPID surpasses IBLUE and PID.

Rate aware congestion control mechanism (RACC)

A novel congestion control approach (RACC technique) was proposed in the study that was just presented in [36] to enhance delay performance by regulating congestion. It enhances the current single-node buffer occupancy-based congestion control method employing three separate levels. To guarantee the percentage of buffer occupancy, the queue length on each node is continuously checked. The results show that in terms of throughput, packet delivery ratio, normalized routing overhead, MAC overhead, and average end-to-end delay, the RACC method is more advantageous. When J-ERLB and RACC approaches are compared, energy still represents a compromise. The most effective modulation strategy is assessed to transfer data to remote sensor nodes as efficiently as possible.

Joint congestion control mechanism through dynamic alternate route selection (JCCM-DARS)

The author in [37] simulated and analyzed the cause of data packet loss due to link and node congestion. When the RED queue mechanism is used instead of the traditional Droptail, the QoS metrics are reported as high. The Location Aided Energy Efficient protocol is proposed as the dynamic alternate path routing algorithm in this work, with geographical position information of forwarding nodes and residual energy as routing metrics. As a result, stateless, one-hop neighbourhood tracking alone reduces network overhead and overall energy consumption. When the UDP/RED mechanism collaborates with the LAEER protocol, metrics such as PDR and average E-E delay are reportedly high. Based on simulation results, the LAEER protocol outperforms the AODV protocol in an IoT-based wireless sensor network.

A hybrid firefly algorithm with particle swarm optimization (HFAPSO)

In [38], the authors propose a hybrid LEACH-C algorithm that combines the Firefly algorithm with particle swarm optimization (HFAPSO) in order to increase network lifetime and decrease energy consumption. When choosing the most energy-efficient optimal cluster head, this method takes into account the residual energy and distance between the nodes. The proposed method is assessed, and the LEACH-C and Firefly algorithms and its performance are contrasted. The experimental findings demonstrate that, in terms of network lifetime, energy consumption, and the number of alive nodes, the proposed methodology outperforms the other algorithms.

Ant colony routing with cooperative game theory based for congestion control (ARCGCC)

In [39], the process of data transmission in wireless sensor networks is first examined. The new data transmission model is created based on data classification and priority. Additionally, a proposed mechanism for congested area control is based on cooperative games. The ant colony algorithm is combined with this congestion control mechanism. The heuristic value of the algorithm includes the degree of congestion and the QoS value. Congestion is avoided as much as possible during the routing finding and selection process. The best routing path is constructed. The sending rate is changed to reduce congestion once it is identified.

Automatic threshold based low control-flow communication protocol (TSDN-WISE)

The issue of energy consumption and control message overhead in SDWSNs was addressed in [40] by proposing a Software-Defined Wireless Sensor Networks (SDWSNs) architecture for monitoring applications and a threshold-based routing algorithm known as TSDN-WISE protocol. By implementing threshold values that are automatically calculated by the data values gathered from the network for a defined period, TSDN- WISE achieves its goal of reducing the control message overhead. It is possible to forward the Packet In message to the controller if the data value is equal to or higher than the threshold. This allows for the network's control of both data and control traffic.

Criteria for the design and development of new congestion control technique in WSNs

After critiquing various congestion control techniques in WSNs, the researchers have presented criteria that future researchers should follow in the design and development of new congestion control techniques in WSNs. In these criteria, Congestion control techniques must be

- Resilient to both internal disturbances and external stimuli.
- Scalable so that they can be adjusted for the number of sensor nodes.
- Self-adaptive to respond to unforeseen environmental changes, node additions, and node removals.
- Deployment considerations must be made in soft computing-based congestion control techniques.
- Potential for performance improvement with mobile agent strategies.
- Inclusive of both queue occupancy or buffer drops and wireless channel contention losses when determining if there is congestion. This is because wireless channel contention losses quickly rise with channel load and result in a rise in buffer drop, and queue occupancy alone is not a sign of congestion.
- Due to the current energy and memory restrictions placed on sensors in wireless sensor networks, easily implementable
- Experimental techniques to show its viability in real-life situations.
- Considerate of Security issues.
- Able to interact with different layers by introducing a cross-layer technique.

Conclusion

This paper discussed a wide range of congestion control methods for wireless sensor networks. There was a review of the detrimental impacts of congestion as well as various strategies for preventing it. Also, the strengths and shortcomings of the various approaches were assessed, along with an assessment of the relevant publications. Global user connectivity and the dramatic increase in data traffic have created new challenges and problems. Throughout the past few years, numerous control strategies have been examined and developed. To satisfy the demands of future networks, this study has suggested a set of criteria that researchers should try to implement to improve the existing procedures. We can conclude that good congestion management is crucial to enhancing a network's resilience and meeting future network requirements. We find that there is still room for development and that additional studies can be conducted to address specific issues and satisfy the requirement of future networks after analyzing the various relevant works and evaluating the network criteria. The study can be expanded in the future to include approaches for improving energy consumption and cross- layer techniques for reducing congestion between levels.

Bibliography

1. EH Kim. "Fan-Shaped Flooding in Wireless Sensor Networks". *International Journal of Electronics Engineering Research* 10.2 (2022): 225-229.

2. S Srinivasa Rao., *et al*. "A Novel Optimization based EnergyEfficient and Secured Routing Scheme using SRFIS-CWOSRR for Wireless Sensor Networks". *International Journal of Electronics Engineering Research* 10.3 (2022): 644-650.

3. R Bhaskaran., *et al*. "Replica Node Detection using Metaheuristic Algorithms in Wireless Sensor Networks". *International Journal of Engineering Trends and Technology* 70.5 (2022): 339-345.

4. C Sergiou., *et al*. "A comprehensive survey of congestion control protocols in wireless sensor networks". *IEEE Communications Surveys and Tutorials* 16.4 (2014): 1839-1859.

5. RT Tweh., *et al*. "A Novel Congestion Control Scheme using Firefly Algorithm Optimized Fuzzy-PID Controller in Wireless Sensor Network" 11.1 (2022): 44-53.
6. B Nawaz., *et al*. "Congestion control techniques in WSNs: A review". *International Journal of Advanced Computer Science and Applications* 10.4 (2019): 194-199.
7. J Wei., *et al*. "A congestion control scheme based on fuzzy logic for wireless sensor networks". *Proc. - 2012 9th Int. Conf. Fuzzy Syst. Knowl. Discov. FSKD 2012*.Fskd (2012): 501-504.
8. S Panimalar and TP Jacob. "A Comparative Study of Hybrid Optimized Algorithms for CongestionControl in Wireless Sensor Network". *Proc. 2020 IEEE Int. Conf. Commun. Signal Process. ICCSP 2020* (2020): 889-893.
9. S Qu., *et al*. "Cross-layer congestion control of wireless sensor networks based on fuzzy sliding mode control". *Neural Computing and Applications* 32.17 (2020): 13505-13520.
10. Y Shatnawi. "Congestion Control in ATM networks using PID Controller with Immune Algorithm". *2019 10th Int. Conf. Inf. Commun. Syst* (2019): 19-24.
11. URS Yalavarthy and VSKR Gadi. "PEM Fuel Cell Powered Electric Vehicle Propelled by PMSM Using Fuzzy PID Controller-A Research". *International Journal of Engineering Trends and Technology* 70.1 (2022): 63-74.
12. R Rajesh. "Energy-Resourceful Routing by Fuzzy Based Secured CH Clustering for Smart Dust". *International Journal of Electronics Engineering Research* 10.3 (2022): 659-663.
13. MA Kafi., *et al*. "A survey on reliability protocols in wireless sensor networks". *ACM Computing Surveys* 50.2 (2020).
14. SL Yadav., *et al*. "Traffic and EnergyAware Optimization for Congestion Control in Next Generation Wireless Sensor Networks". *Journal of Sensors* 2021 (2021).
15. V Dubey., *et al*. "Forest Fire Detection System Using IoT and Artificial Neural Network". International Conference on Innovative Computing and Communications 55 (2019).
16. J Lu., *et al*. "Artificial agent: The fusion of artificial intelligence and a mobile agent for energy-efficient traffic control in wireless sensor networks". *Future Generation Computer Systems* 95 (2019): 45-51.
17. H Abdel-Jaber. "An Exponential Active Queue Management Method Based on Random EarlyDetection". *Journal of Computer Networks and Communications* 2020 (2020).
18. S Silmi., *et al*. "Wireless Sensor Networks Simulators and Testbeds" (2020): 141-159.
19. N Thrimoorthy and T Anuradha. "Congestion Detection Approaches In Wireless Sensor Networks: -A Comparative Study". Early Years An International Journal of Research and Development 12.3 (2016): 59-63.
20. MR. Mundada., *et al*. "A survey of congestion in Wireless Sensor Networks". *2016 Int. Conf. Adv. Hum. Mach. Interact. HMI 2016* (2016): 144-148
21. UK Jigo., *et al*. "State of the art of survey on congestion control protocol in constrained networks" (2016).
22. S Shams Shamsabad Farahani. "Soft Computing-Based Congestion Control Schemes in Wireless Sensor Networks: Research Issues and Challenges". *Majlesi Journal of Electrical Engineering* 15.1 (2021): 39-52.
23. S Sunassee., *et al*. "A Comprehensive Review on Congestion Control Techniques in Networking". *Proc. - 5th International Conference on Computing Methodologies and Communication* (2020): 305-312.
24. DSV. "Automatic Spotting of Sceptical Activity with Visualization Using Elastic Cluster for Network Traffic in Educational Campus". *Journal of Ubiquitous Computing and Communication Technologies* 2.2 (2020): 88-97.
25. M Mahajan and S Kaur. "Congestion Control Protocols in Wireless Sensor Networks: a comprehensive Survey". *Proceedings of the Eighth International Conference on Management Science and Engineering Management 2020* (2020): 160-164.
26. CY Wan., *et al*. "Energy-efficient congestion detection and avoidance in sensor networks". *ACM Transactions on Sensor Networks* 7.4 (2011): 266-279.

27. SS Sefati. “Routing and Congestion Control in Wireless Sensor Networks using the Ant Colony Optimization algorithm and the Tabu search algorithm” (2023): 1-34.

28. B Krantikumar. “Trust Aware Secured Energy Efficient Fuzzy Clustering based Protocol in Wireless Sensor Networks” (2023).

29. O Ahmed., *et al*. “PEDTARA: Priority-based energy efficient, delay and temperature aware routing algorithm using multi-objective genetic chaotic spider monkey optimization for critical data transmission in WBANs”. *Electron* (2022): 11.1.

30. TM Tshilongamulenzhe., *et al*. “Intelligent Traffic Routing Algorithm for Wireless Sensor Networks in Agricultural Environment”. *Journal of Advances in Information Technology* 14.1 (2023): 46-55.

31. C Sergiou., *et al*. “Hierarchical Tree Alternative Path (HTAP) Algorithm for Congestion Control in Wireless Sensor Networks”. no. Cc (2019).

32. X Deng., *et al*. “CCAIB: Congestion Control Based on Adaptive Integral Backstepping for Wireless Multi-Router Network”. *Sensors* 22.5 (2020): 1-15.

33. A Albanna and H Yousefi. “Congestion Minimization of LTE Networks”. *IEEE/ACM Trans. Netw* PP.Icic (2020): 1-13.

34. KL Wallaschek., *et al*. “NEAT-TCP: Generation of TCP congestion Control through neuroevolution of augmenting topologies”. *2020 IEEE Int. Conf. Commun. Work. ICCWork. 2020 - Proc* (2020): 1-6.

35. L Lin., *et al*. “A novel fuzzy PID congestion control model based on cuckoo search in WSNs”. *Sensors (Switzerland)* 20.7 (2020).

36. A Grover., *et al*. “Rate aware congestion control mechanism for wireless sensor networks”. *Alexandria Engineering Journal* 61.6 (2022): 4765-4777.

37. J Thyagarajan., *et al*. “A joint congestion control mechanism through dynamic alternate route selection algorithm in iot based wireless sensor network”. *Advanced Parallel Computation* 41 (2022): 96-102.

38. B Pitchaimanickam and G Murugaboopathi. “A hybrid firefly algorithm with particle swarm optimization for energy efficient optimal cluster head selection in wireless sensor networks”. *Neural Computing and Applications* 32.12 (2020): 7709-7723.

39. Z Hu., *et al*. “Game Theory Based Congestion Control for Routing in Wireless Sensor Networks”. *IEEE Access* 9 (2021): 103862-103874.

40. SSG Shiny and K Murugan. “TSDN-WISE: Automatic Threshold based low control-flow communication protocol for SDWSN” 10.10 (2021): 1-11.