# A Survey of Intelligent Traffic Control Algorithm in Wireless Sensor Networks

Tshimangadzo M. Tshilongamulenzhe
*Department of Information Technology*
*Tshwane University of Technology*
Pretoria, South Africa
tshilongamulenzhetm@tut.ac.za

Topside E. Mathonsi
*Department of Information Technology*
*Tshwane University of Technology*
Pretoria, South Africa
MathonsiTE@tut.ac.za

DP DuPlessis
*Department of Information Technology*
*Tshwane University of Technology*
Pretoria, South Africa
DuplessisDP@tut.ac.za

***Abstract*— Traffic control algorithms have been comprehensively studied and applied in WSNs, however, this is the first attempt to put in viewpoint the numerous efforts in form of a survey. In order to provide an inclusive survey of the existing literature. This paper examines current state of the art traffic control algorithms according to their common methodology applied in order to reduce packet loss and packet delay in WSNs. Additionally, this paper presents a clear understanding of the active research area, by identifying a clear classification and guidelines used when traffic control algorithms are designed. Furthermore, this paper outlines the strength and weakness of existing solutions and highlight the key open research areas for further development. This comprehensive survey act as a basis starting point and a guide for everyone enthusiastic to explore into research on traffic control algorithms in WSNs. Finally, the study presents the conclusion.**

**Keywords:** WSNs, packet loss, packet delay, Traffic control, Methodology.

## I. Introduction

In recent years, the use of wireless technology is becoming more popular all over the world [1, 2]. Wireless Sensor Networks (WSNs) has been growing in virous areas which includes Healthcare, Military, Smart cities, Smart irrigation and others which has increased the number of Sensor Nodes (SNs) and Access Point (APs) that communicate directly with each other without human intervention [3, 4]. SNs, are used to monitor and gather all types of information within different areas in a network [2, 5, 6].

WSNs have a wide range of benefits in applications [7-9]. WSNs are characterized as a new technology which allows many different devices to connect to the internet while segmenting their packets transferred by these devices in order to improve the quality of life. Moreover, WSNs brought benefits such as ease of access, data monitoring and automation and control. However, this also creates many challenges such as packet congestion which is caused by buffer overflow, node level congestion, transmission rate, among many others [10]. This paper will focus on link-level congestion caused by many-to-one data transmission scheme in WSNs. The link-level congestion normally occurs when there is contention, interference, and bit error rate within WSNs [11, 12]. Furthermore, link-level congestion increases the packet service time and decreases both link utilization and overall throughput during packet transmission in WSNs.

The remainder of this paper is structured as follows: In Section II, this paper presents the overview of WSNs. In Section III, the routing and traffic modelling protocols in WSNs is presented. In Section IV, the congestion in WSNs is presented. The related work is presented in Section V, and the conclusion is in Section VI.

## II. Overview of Wireless Sensor Networks

A WSNs is a new generation that recognized worldwide, and it presented the real-time embedded systems with different communication constraints from the traditional networked systems [13]. Moreover, WSNs uses autonomous devices which include sensors to monitor physical or environmental conditions. These autonomous devices are link to other devices (routers and a gateway) using wireless connection. Fig 1 below, illustrate the overview of WSNs.

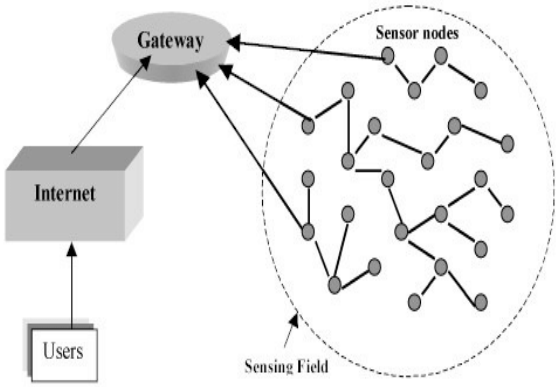


Fig 1: Overview of WSNs architecture.

The transmission of packets initiated by the SNs, which are collecting packets from the sensing field and forward those packets to the Gateway as demonstrated by Fig 1. The Gateway transmit the packets to the Internet so that the Users can be able to access the information using their devices. In Fig 1, different types of connection implement in WSNs architecture such as wireless and wired connection are

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displayed. Moreover, all nodes are connected in order to share information among each other in WSNs.

## III. Routing and Traffic Modelling Protocols in WSNs

There are various applications of WSNs which use routing protocols to improve their performance demand within a network environment [14-17]. WSN routing protocols is a good starting point. In this paper, the details of some of the important traffic modelling protocols existing in WSNs are discussed.

(a) Routing protocols

Routing protocols specify how routers communicate with one another by sharing information from source to destination within a reliable and efficient energy routine to increase the lifetime and improve the overall performance of the network. There are various types of routing protocols which include both static and dynamic routing protocols. Dynamic routing protocols are used in large networks environment so that routers can share information about the network with other routers. This allows them to select the best path for reaching a destination. Fig 2 illustrates the various characteristics of dynamic routing protocols.

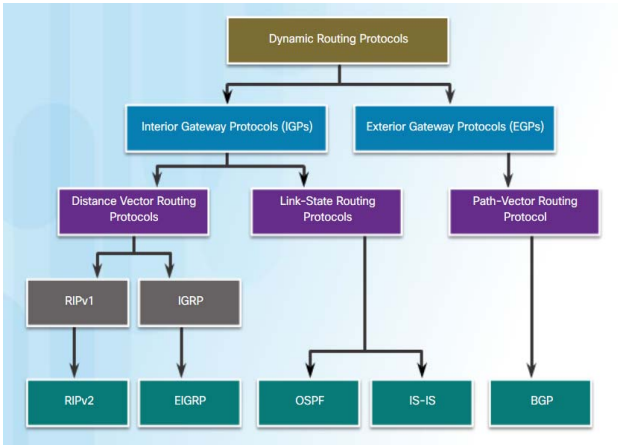


Fig 2: Characteristics of dynamic routing protocols [18]

The routing protocols on WSNs have the following features [19]:

- SNs do not have internet protocol (IP) addresses as in the traditional networks. Therefore, IP-based routing protocols cannot be applied to WSNs.
- The design of protocols must be scalable.
- Protocols should manage the communication among many nodes and forward the data to the destination.
- The protocol should meet the resource constraints of the node (limit power, low-bandwidth, low storage).
- Issues such as efficiency, fault tolerance, fairness, and security, should be achieved under the design of the network protocols.

Static routing protocols demand manual configuration and selection of a network route, usually managed by the network controller [20]. Hence, static routing protocols are implemented in situations in which the network parameters and environment are expected to remain constant. The static routing is only optimal in a few situations within a network environment.

(b) Traffic modelling protocols

Traffic modelling is a method that manages the network bandwidth, which delays some or all packets in bringing them into compliance with the desired traffic profile. The traffic modelling method is used to optimize or guarantee performance, improve latency, and increase usable bandwidth for some kinds of packets by delaying other kinds.

## IV. Congestion in Wireless Sensor Networks

A WSNs is defined as a group of devices called SNs that work together to form a wireless network [21]. These nodes transmit environmental information from the monitored area to the sink node in one or multiple hops through wireless links communication.

However, due to the resource constraints of WSNs, there are several deployed nodes that are an event-driven nature of WSNs [22]. Hence, there is many-to-one communication, and a high traffic of SNs. WSNs in some applications like event-driven applications face significant challenges due to a huge amount of transmitted data from the nodes in the event place. This large amount of data might lead to traffic congestion [11, 13]. There are various types of WSNs congestion, which is based on how packets are lost, namely: node-level congestion (buffer overflow), and link-level congestion (see Fig 3).

(a) Node-level congestion: refers to the packets that cause the buffer overflow on a specific node within a network [23]. Therefore, the overflow that causes the congestion in a network occurs when the packet arrival rate is higher than packet service time. This type of congestion causes packet loss and increasing queuing delay. The packet loss must be retransmitted, which decreases the network lifetime [24].

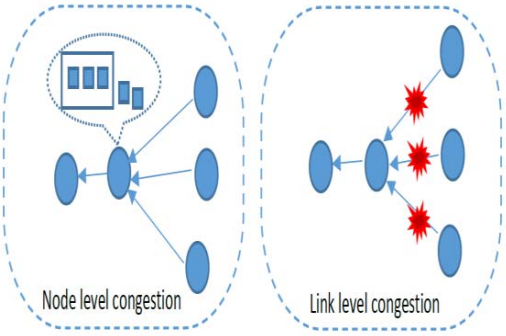


Fig 3: Common Congestion in WSNs [25]

(b) Link-level congestion: This type of congestion occurs when multiple active SNs share the same wireless channel; each one tries to send packets in the same transmission medium [11]. A collision might occur, and the transmitted packets may fail

to reach the destination node because of the collision between the packets. This type of packet collision increases the packet service time, and decreases the link utilization [13,17].

## V. Related Work

This section presents a portion of related work that has been conducted on link-level congestion within WSNs over the past decades. Many researchers have contributed to this area and provided their solutions.

A hybrid cluster based congestion aware (HCBCA) was proposed by [26] to overcome the link-level congestion by monitoring the traffic that affects the continuous flow of data in WSNs. The proposed HCBCA further displayed and monitors the arrival of data from the source to destination delay time, avoid packet losses and energy consumption process. The authors demonstrated that the proposed HCBCA reduces the energy wastage and as well as improves the receiving of data and collection of data from their member sensor nodes. Network Simulator-2 (NS-2) simulation tool was used to test and evaluate the effectiveness of the proposed HCBCA. The simulation results shown that the proposed HCBCA managed to improve packet lose, delays and energy consumption. However, the proposed HCBCA does not consider the network performance based on network throughput within WSNs.

An intelligent opportunistic routing protocol (IOP) that used a machine learning technique was proposed by [27] in order to select a relay node from the potential forwarding nodes to improve the reliability within the network. The objective of the proposed method was to connect several network devices in a better way and provide good services within WSNs. Furthermore, the routing of packets is the most important part when packet is distributed from one device to another. NS-2 simulation was used to test the effectiveness of the proposed IOP method. The simulation results shown that the proposed IOP method managed to select a relay node to improve the network performance within the WSNs. However, the proposed IOP does not consider the packet delay during the distribution of packets in WSNs.

[28] introduced a unique energy-aware and layering-based clustering and routing algorithm (EA-CRA) to split the field into a number of layers, with the breadth of each layer decreasing not just as it approaches the base station. The authors demonstrated that the proposed algorithm does not only shortens the communication distance between nodes, but also decreases the amount of communication overhead required for setting up clusters. The MATLAB simulations was used to test the effectiveness of the proposed EA-CRA. EA-CRA's is demonstrated by comparing its findings to those acquired from earlier relevant algorithms. However, the proposed algorithm does not consider the throughput during the routing process in WSNs.

A congestion control algorithm based on the multi-objective optimization algorithm named PSOGSA was proposed by [29] for rate optimization and regulating arrival rate of data from every child node to the parent node. The authors outlined that the optimization strategy governs the arrival rate based on priority and the output available bandwidth is based on the energy of the child node. MATLAB R2016a was used to test the effectiveness of the proposed PSOGSA. The proposed PSOGSA was compared with existing Cuckoo Search (CS) and Adaptive Cuckoo Search (ACS) algorithms during the simulation process. The simulation results shown that the proposed PSOGSA managed to outperformance other algorithms that was compared with during the simulation results. However, the proposed PSOGSA does not consider the delays of packets within the network.

An intelligent traffic control system was proposed by [30] to collect information based on the road traffic and the availability parking space within the smart cities. The authors demonstrated that the proposed system implemented the innovative services by allowing the clients to view the traffic rate and the available parking spaces to their destination remotely using virous wireless devices so that they avoid traffic jams to their destination. The proposed system integrates three different smart subsystems such as crossroad management, parking space management, and a mobile application to connect clients to a smart city using WSNs. MATLAB simulator was used to test and evaluate the effectiveness of the proposed system. The simulation results demonstrated that the objective of the proposed system was archived. However, the proposed system does not consider the end-to-end delay during the collection of information using WSNs in the cities.

An Intelligent Traffic Management (ITM) algorithm was proposed by [2] in order to avoid the packet congestion which normally caused by Buffer overflow. The authors stated that the packet congestion can leads to the decrement of network throughput, packet drop, and high end-to-end delay during packet transmission from and to different nodes. During the development of proposed ITM algorithm, the Modified Neural Network Wavelet Congestion Control (MNNWCC) algorithm and Tree-based Congestion Control (TACC) algorithm were integrated. NS-2 simulation tool was used to test and evaluate the effectiveness of the proposed ITM algorithm. The simulation results demonstrated that the proposed ITM algorithm produce better network throughput by 97.1 %, reduce packet drop by 32%, and end-to-end delay minimized by 27% when compared with MNNWCC algorithm and TACC algorithm. However, the proposed ITM algorithm does not retransmit the packets that are dropped within the network.

## VI. Conclusion

The WSNs is dominant and fast-growing worldwide. WSNs is a self-organized network system formed by the collection of different nodes that are capable of sensing, monitoring, processing, and communication in an autonomous manner. Furthermore, WSNs become more attractive to most network users for their daily

communication by sending and receiving information using different nodes. Hence, congestion avoidance is required to prevent packet congestion during packet transmission in WSNs. This research study did not take the security implementation into consideration within WSNs.

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