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CONGESTION AVOIDANCE AND CONTROL IN WIRELESS SENSOR NETWORKS A SURVEY

Er. Vaibhav Eknath Narawade[1], Dr. Uttam D. Kolekar[2]

[1]*Research Scholar, Faculty of Engineering,*

Pacific Academy of Higher Education and Research University, Udaipur

[2]*Professor & Principal, A. P. Shah Institute of Technology, Thane*

ABSTRACT

A wireless sensor network (WSN) has its application in various fields such as temperature monitoring, pressure monitoring, health monitoring, defence system etc. In wireless sensor networks, congestion occurs because of the inadequate resources like low processing power of the sensor node. The performance of the WSN is degraded by the congestion as it leads to the wastage of energy, reduction in throughput and huge information loss. To avoid this condition, numerous congestion avoidance methods for lossless data packet transmission can be employed. The objective of this survey is to investigate some of the existing congestion avoidance and control methods to categorize them and to examine their advantages and disadvantages. Accordingly, various congestion avoidance mechanisms are reviewed and the major issues are addressed in this paper.

Keywords: Congestion Avoidance, Congestion Control, Energy Efficiency, Optimization, Wireless Sensor Networks

I. INTRODUCTION

Wireless sensor networks have several sensor nodes based on its application. Since all the nodes are battery powered, it is necessary to use the limited resources effectively. Congestion in wireless networks may occur because of several aspects such as contention due to concurrent transmissions, overflow in buffers and time varying wireless channel condition. Congestion detection is a technique in which the abnormalities in the usual traffic is been made out. i.e., while transferring a data packet from one node to other node, quandary events may occur. Some of the techniques for congestion control are, Detecting and Avoiding congestion, Event to Sink Reliable Transport, Congestion control and Fairness etc.

In wireless sensor networks, source nodes send the packets to sink node (base station) in hop-by-hop or multi-hop manner. It has two kinds of sink such as static sink and mobile sink. When an event happens, then a huge amount of data traffic is sent from the corresponding sensor nodes to the sink node. Sometimes congestion arises in the network, which may leads to the missing of data packets with important data in the network. So, congestion problem in WSN must be solved efficiently to avoid wastage of energy and to increase the networks' lifetime. This will increase the throughput of the network. Even though there are several protocols to handle the

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congestion issue in the WSN, finding an effective way for congestion avoidance and control is still a challenging task.

Two types of congestion are Link-level congestion and Node-level congestion. Node-level congestion happens when the buffer at the sensor node is overflowed. All the incoming packets after overflow are simply dropped. Also the queuing delay is also increased. In case of link-level congestion, all the nodes attempt to send traffic on the link simultaneously. It results in packet collisions. Furthermore, due to link-level congestion, the link utilization is reduced. To avoid all the above mentioned effects of congestion, congestion must be controlled or avoided in an effective way. As a result of this, there exist two different research areas such as congestion control and congestion avoidance. Congestion control learns resumption from congestion methodologies and avoids collapsing in the network, whereas congestion avoidance investigates the techniques to prevent congestion.

In this paper, some of the congestion control mechanisms from the literature are discussed and classified based on several criteria with their advantages and disadvantages.. The goal of all the congestion management schemes is to increase the QoS of the network. All schemes help to increase the parameters like network throughout, packet delivery ratio. Also, it increases network lifetime. The organization of the paper is as follows: The taxonomy of the congestion control and avoidance protocols is given in section 2. Section 3 reviews the several congestion control and avoidance protocols. Research gaps and issues are presented in section 4 and section 5 concludes this paper.

II. TAXONOMY OF CONGESTION AVOIDANCE AND CONTROL MECHANISMS IN WSNS

The taxonomy of the congestion control and avoidance protocols is given in figure 1. The congestion control protocols are classified into traditional protocols and soft computing based protocols. Several traditional protocols present in the literature are based on rate control, random early detection, priority, class and grid.

Soft computing techniques are intellectual techniques which enhances the effectiveness of the wireless networks. Soft computing techniques optimize the power consumption and challenges in the network. Soft computing techniques such as fuzzy logic are applied to different applications of wireless networks.

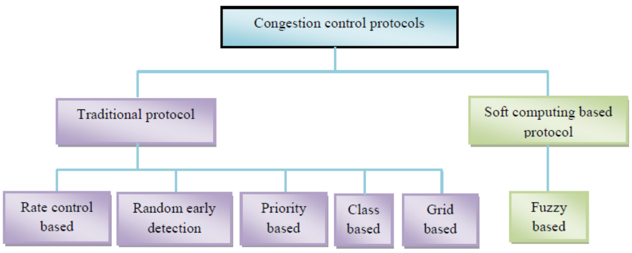

Figure 1. Taxonomy of Congestion Control and Avoidance Protocols

A. Traditional Protocols

In [1], congestion prediction approach using probabilistic method and congestion control using rate control method is proposed. The probabilistic approach for congestion prediction in a node is constructed by means of data traffic and buffer occupancy. The rate control methodology make use of a back-off selection approach and also rate allocation approaches, such as rate regulation (RRG) and split protocol (SP), to enhance throughput and decrease packet drop. A back-off interval selection approach is launched together with rate reduction (RR) and RRG. The back-off interval selection approach considers channel state and packet transmission without collision to avoid congestion. Experimental results were evaluated with decentralized predictive congestion control (DPCC) and adaptive duty-cycle based congestion control (ADCC). The results illustrates that the probabilistic method and the rate control method reduces congestion and improves performance. But, after a successful transmission, state information indicating the actual contention level is not maintained.

In network systems with limited bandwidth and heavy traffic, the communication quality are ensured by ATRED (adaptive thresholds random early detection) congestion control algorithm [2] to avoid congestion and manage the resources is proposed. In ATRED, the control parameters are not statically organized, but it is dynamically configured by the adaptive mechanism. In combination with the adaptive strategy, ATRED reduces the difficulty in tuning RED (random early detection) and provides a superior control on managing the queue, and achieving a better performance than RED under changing network conditions. The stability of the network system is assured with the proper design of the adaptive mechanism. Simulation results demonstrate that ATRED algorithm achieves a good performance and provide more reliable service in changing network conditions. RED based algorithm may cause intense oscillation of queue at the router and leads to serious variation in delay. Congestion control based on backpressure routings and service differentiation is presented in [3]. Back pressure routing algorithm does not calculate the routes in advance and the next step is selected dynamically. Each node sees its own queue backlog and its neighbour's queue backlog and adjusts its own rate and selects routes based on queue backlog of its neighbours. Dynamic prioritization is also used for service differentiation when there are two or more data with same condition in backpressure routing. The network should do most efforts to deliver data packets with instant or high priority.

In [4], Dynamic Alternative Path Selection Scheme (DAlPaS) for congestion avoidance and control is proposed. DAlPaS is an easy and efficient approach for congestion control whereas keeping the overhead as minimum. The function of this approach depends on the resource control rather than control on the sending rate at the source. The performance of DAlPaS is experimented by comparing with other well-known schemes and the results proved that the performance of DAlPaS is better than other schemes. But, the computational complexity is high and requires complete idea about network-wide per-wavelength link-state. In [8], a data centric congestion management protocol using AQM (Active Queue Managements) for healthcare applications is presented. It deals with end to end delay, energy consumption, lifetime and fairness. The proposed HOCA (Healthcare Aware Optimized Congestion Avoidance) protocol prevents congestion in the routing phase by means of multipath and QoS (Quality of Service) aware routing. If it is not possible to avoid congestion, then it will be alleviated via an optimized congestion control algorithm. Experimental results designated that HOCA can attain its objectives. But, the computing power to analyze the packets and throttle the speeds is higher for QoS techniques.

A congestion management data driven scheme for healthcare wireless sensor network applications with stationery patients is proposed in [7]. This scheme contains service differentiation and congestion avoidance and control (congestion management) units. The service differentiation unit aids in three types of traffics such as sensitive, non-sensitive, and control packet. The congestion management unit attempts to prevent congestion by multipath routing with different stages such as request dissemination, event report, route establishment and data forwarding. In data forwarding stage, the data traffic with high priority is transmitted via the shortest path route to satisfy the low delay service requirements. The data traffic with less priority and the control traffics are forwarded through the other routes. If congestion occurs, the proposed congestion control method allocates a new rate for source traffics. The proposed methodology considers the parameters such as end to end delay, energy consumption, networks' lifetime and its fairness in consuming energy. But the packets will suffer from high delay when they pass through longer queues.

To alleviate congestion, a topology-aware resource adaptation (TARA) scheme was proposed in [9]. TARA offers several advantages such as topology awareness, energy efficient, and distributed. By using a capacity analysis model, TARA determines the required topology. This approach is developed by means of graph colouring problem. The results established that the performance of TARA is closer to an ideal offline resource control algorithm, by means of both fidelity satisfaction and conservation of energy. But, the level based congestion avoidance is missing in this protocol. In [11], a Dynamic Resource Control Protocol (DRCP) for controlling congestion in WSN is introduced. DRCP controls congestion by using multiple resources. It minimizes the congestion by controlling the transmission power. Experimental results demonstrate that the proposed method enhances the throughput of the system, and reduce packet dropping, while conserving more energy. But, the priority consideration of the nodes is not considered.

In [12], Grid-based Multipath with Congestion Avoidance Routing protocol (GMCAR) is introduced. It utilizes the concept of dividing the sensor network field into grids. Within each grid, one sensor node is choose as a master node. The master node delivers the data generated by any node in the grid and forward the data received from other master nodes in the neighbour grids. For every master node, multiple diagonal paths which connect the master node with the sink node are stored as routing entries in the routing table of that node. The main idea here is integrating the grids densities together with the hop count into the routing decisions. A congestion control protocol is proposed in such a way to alleviate the congested areas if congestion occurs. The proposed approach demonstrates its enhanced performance by attaining superior utilization to the available storage. But, it suffers with heavy delay and the computational power is also high.

B. Soft computing based protocol

Fuzzy Based Adaptive Congestion Control (FBACC) is proposed in [6]. The proposed algorithm presents a fuzzy logic based congestion estimation, which drops the data packet on occurrence of congestion up to a tolerable level and it controls the traffic rate. FBACC performs well than the existing approaches in terms of detecting congestion, packet loss, end-to-end delay and consumption of energy. FBACC accurately sense the congestion in the network and also adjusts to present traffic rate relating to the product of previous participants with previous traffic rate to decrease the packet loss. FBACC conserves energy of retransmission since the packet loss is reduced because of traffic adaption. But, the product of traffic over participants is increased if the network is low congested or else remains unaltered.

The flocking behaviour of birds aids in the implementation of a robust, scalable and self-adaptive congestion control protocol in WSNs [5]. This approach takes on a swarm intelligence paradigm enthused by the collective behaviour of bird flocks. The major concept here is to 'guide' packets (birds) to form flocks and travel on the way to the sink (global attractor), while attempting to prevent congestion regions (obstacles). The direction of motion of a packet flock is determined by the repelling and attracting forces between the packets, and the field of view and the artificial magnetic field in the direction of the artificial magnetic pole (sink). The implementation of the proposed approach is easier at the individual nodes, with reduced exchange of information. Flock-based Congestion Control (Flock-CC) method balances the load by efficiently utilizing the allotted network resources and transferring the data packets to the sink. Also, the proposed method attains the potential in opposition to failing nodes, scalability in different network sizes and performs well than usual techniques. The performance in terms of power and including the power in the desirability function is a difficult task in this work.

III. REVIEW AND ANALYSIS

Table 1 reviews the literature of congestion avoidance protocols and the major advantages of the method.

Table 1. Literature review

Authors	**Methods**	**Advantages**	**Disadvantages**
R. Annie Uthra*et al.*,[1]	Back-off interval, Rate control	Per-node throughput is increased and the energy in the network is reduced by preventing packet drops. As the buffer occupancy is minimal, the rupture of data traffic is well maintained.	The state information after the transmission of packets, representing the real contention level is not maintained.
Zhi Liu *et al.*,[2]	ATRED congestion control algorithm	Tuning difficulty of random early detection (RED) is decreased and has superior control on managing the queue, and attains much better performance.	RED algorithm leads to serious queue oscillation in the router and delay variation

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Akbar Majidi*et al.*,[3]	Backpressure routing and dynamic prioritization for congestion control (BDCC)	This algorithm does not pre-calculate routes and next step is selected dynamically.	Network should do most efforts to deliver data packets with instant or high priority.
CharalambosSergiou*et al.*,[4]	Dynamic Alternative Path Selection Scheme	It is an easy and efficient approach for congestion control whereas the overhead is maintained as minimum.	The computational complexity is high and requires complete idea about network-wide per-wavelength link-state.
Pavlos Antoniou *et al.*,[5]	Congestion control and avoidance based on Bird flocking behavior	Robust way to avoid the congested area and dead node zones.	Difficult to include power in the desirability function
SaurabhJaiswal*et al.*,[6]	Fuzzy Based Adaptive Congestion Control	Better technique to to drop data packet up to a tolerable level and can control traffic rate.	The product of traffic over participants is increased if network is less congested or stay unaltered
Abbas Ali Rezaee*et al.*,[7]	Class Based Optimized Congestion Management Protocol(COCM)	This algorithm is more efficient in terms of packet loss, energy efficiency, end-to-end delay and fairness.	Higher delays suffered by packets when they go through longer queues.
Abbas AliRezaee*et al.*,[8]	Optimized Congestion Avoidance and control protocol	Considers the parameters such as end to end delay, energy consumption, lifetime of the network and fairness in energy consumption.	computing power to analyze the packets and throttle the speeds are greater for QoS techniques

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J. Kang et al. [9]	Topology-Aware Resource Adaptation to Alleviate Congestion	Traffic control and resource control	The congestion level-based avoidance is missing
P. Antoniou et al. [10]	flocking behavior of birds	Attains robustness against failing nodes, scalability in different network sizes and performs better than conventional approaches	QoS parameters are not considered
Nazbanoo Farzaneh et al. [11]	Dynamic Resource Control Protocol (DRCP)	enhance throughput of the system and reduces packet drop, whereas energy saving	The priority consideration of nodes are not considered
O. Banimelhem and S. Khasawneh et al. [12]	Grid-based multipath with congestion avoidance routing protocol	suitable in attaining superior utilization with the available storage	It suffers with heavy delay and computational power

IV. RESEARCH GAPS AND ISSUES

One of the common problems in WSN is congestion which causes because of carrying more data to be transferred through network. Consequently, it increases the queuing delays and causes information loss which is absolutely degrading the quality of service (QoS) by decreasing the lifetime of the network and also the disintegration of network topology in multiple components [5]. The congestion happening over the network wastes the limited energy due to more number of retransmissions and packet drops, and also obstructs the event detection reliability [3].

Due to the undesirable situation of congestion in network, various congestion control algorithms was applied in order to mitigate congestion, such as ATRED congestion control algorithm, Backpressure routing and dynamic prioritization for congestion control (BDCC), Dynamic Alternative Path Selection Scheme. But, these algorithms find the difficulty of further overhead to the previous intense loaded environment, which ultimately causes resource depletion. The traditional algorithms results in serious oscillation of queue at the router and leads to high delay variation. Also, those algorithms do not consider the data packets delivery with instant or high priority. In [7 and 8], congestion control was carried out by finding the optimal rate which is found out after solving the optimization problem. But, this optimization problem was not solved using the popular heuristic methods. In [7], they utilized a simple Poisson process but the heuristic methods offers better rate suggestion than the simple Poisson process.

V. CONCLUSION

The literature review of congestion control and congestion avoidance algorithms in the wireless sensor networks circumstance is presented in this paper. In this survey, the congestion control and avoidance mechanisms are investigated in terms of their appropriateness in congestion detection and inform the related nodes with the intention that a proper control can be taken. Based on the usage, several methods are applied to manage the congestion. To satisfy the application requirements, either traffic control by throttling the node rates or resource control by utilizing the unused resources are used. Different issues and challenges regarding the congestion control protocols were studied which will be useful for further research in this field.

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