Comprehensive Survey Congestion Control Mechanisms in Wireless Sensor Networks: Comprehensive Survey

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Abstract
Wireless sensor network (WSN) occupies the top rank of the widely used networks for gathering different type of information from different avatars. WSN has nodes with limited resources so congestion can cause a critical damage to such network where it limited resources can be exhausted. Many approaches has been proposed to deal with this problem. In this paper, different proposed algorithm for congestion detection, notification, mitigation and avoidance has been listed and discussed. These algorithms has been investigated by presenting its advantages and disadvantages. This paper provides a robust background for readers and researches for wireless sensor networks congestion control approaches.

Keywords: WSN, Congestion Control, congestion mitigation, congestion detection, sink channel load, buffer load.

1. Introduction
Wireless sensor networks have arisen in latest years as one of the most popular research topics which gain higher attention. Enhancements in the field of micro electric and mechanical systems technology stimulate wide smart sensor deployment. Wireless sensors have small memory, processing and power resources. These sensors can be used to gather different types of information for different purposes like weather, environments, health monitoring, military,..., etc. This gathered data is forwarded to central base station where it forwarded to remote users for analyzing and storing[1]. Figure 1 shows the wireless sensor networks main components

![Wireless Sensor Network Components](image)

Figure 1: wireless sensor network components

The infrastructure of the WSN varies based on the distribution of the sensors, these ten or even thousands of sensors are communicating with each other is a specific manner to collect data and information for the deployment region. Sensors can be divided into two categories: structured and unstructured. In structured sensor network, sensors are distributed in a preconfigured structure, the number of distributed sensor is limited based on the structure and can be easily maintained and managed.

Where in unstructured sensors network, the network contains high number of sensors deployed in an ad-hoc architecture in their target region[2]. This high number of sensors result in higher difficulty in management and maintenance.

The main task of Sink nodes in the WSN is to receive gathered data from sensor nodes. If the coverage of sensor node and mobile sink doesn’t allow a direct connection between them, then the sensor node forward his gathered data in a multi-hop manner. So some network nodes works as a relay for other sensor nodes to forward data. So if multiple sensor nodes try to transmit data on the same time using a single channel a congestion can occurred which result in packets loss and bandwidth reduction. Congestion can also occur if the mount of the received traffic exceed the node capacity[3].

2. WSN Congestion
Wireless sensor nodes has small computation resources and communicate with each other using a low power transmitters in a limited range. The communication between sensors nodes form a multi-hop network to deliver collected data efficiently. Network congestion is considered as one of the biggest challenges for sensor nodes communication in WSN where it result in destructive performance reduction. Energy efficiency and QoS parameters of the sensors nodes is highly impacted, the number of packet loss is increased and the overall network throughput is decreased. This effective problem of WSN has motivated researchers to provide solution to detect and avoid a network congestion[4].

WSN congestion can be divided into two different classes: node related and link related congestion. Node...
related congestion occur when the receiving data rate is higher that the receiving ability of the sensor node which result in receiver buffer overflow, It is more common in multi-hop sensor networks where nodes close to the sinks have higher load than other sensor nodes. Node related congestion cause packets delay sense it has to wait until the buffer can handle more packets for each sensor node. This also can increase packet loss and delivery delay? Retransmitting of dropped packets also increase the energy consumption which is very vital for sensor networks. Figure2, 3 show the difference between two classes of wireless sensor network congestion.

Link related congestion is happened when two or more neighbor nodes try to transmit data simultaneously. This class of congestion result in minimizing channel utilization, decrease network throughput and increase packet delay[5]. Energy wasting for retransmit dropped packets also can be one the congestion sequence.

In this paper, a comprehensive survey of the latest and the most significant congestion control has been presented. It discussed the characteristics of each approach and highlight its pros and cons. It discussed the different issues of congestion control mechanisms including the detection of the congestion, congestion notification, and congestion mitigation and congestion avoidance.

This paper presented the trends for congestion control for readers to better understand the current situation and the future trends for developing and designing new algorithms for congestion control.

3. Congestion Control

The task of congestion control in WSN is considered a very vital problem for the designing and implementation of the wireless sensor networks. The nature of WSN make the network congestion differ than other congestions in other types of network. Proposed algorithms which are designed to control the congestion can be classified into four main stages as shown in figure 4, these four stages include congestion detection, notification, and avoidance and congestion mitigation algorithms.

4. Connection Detection

The process of congestion detection related to steps required to discover the existence of congestion and then to locate the congestion in WSN. To perform this process, various parameters and objects need to be monitored and checked to detect congestion. These objects include packet delivery time, available buffer size, channels loads and a combination of buffer and channels load.
Wireless sensor nodes should be notified if a congestion occurred at the network. This notification is very critical for sending nodes or nodes intent to send data. This notification allow nodes to deal with expected congestion in the best manner. These notification approaches can be divided into two approaches: implicit and explicit [15].

This mechanism mainly depends on data rate reduction on congested nodes, this reduction is continue until the congestion eliminated. This mechanism has an effective drawbacks related to decreasing network performance in particular when dealing with sensitive and critical data [20].

Different research has been proposed based on this mechanism and provides different algorithms to handle its drawbacks. Congestion control from sink to sensors (CONISSE) [21] algorithm used an adaptive control for data rate. It control the reduction of data stream to utilize the available bandwidth. Fairness-Aware congestion control (FACC) [18] maintained fair bandwidth for different data flows. Enhanced congestion detection and avoidance (ECODA) [22] was designed to use two threshold for buffer and difference of weighted buffer to detect congestion. Then it utilize queue scheduler based on the priority of packets to control the congestion and if the congestion persist it use node based source transmitting. Algorithm proposed in [23] implements a distributed mechanism for congestion control for tree based WSN communication. It provides each node with an efficient data rate. Each one of these node monitor its receiving and sending rate and based on the difference between these two values, it make a decision to optimize using bandwidth. In [24] source output rate is calculated based on the link capacity cost and energy for the trajectory to the sink node. Then the data rate is adjusted based on the flow capacity and energy in addition to sink feedback.

2 - Resource Control
To overcome the shortage of traffic control approach related to affecting data rate, resource control approach has been proposed as alternative approach [10]. In this approach, when node level or link level occurs, data packets start to look for alternative trajectory which are not congested and use it to reach sink node. The pros of this approach that the data traffic rate is not affected and data has higher chances to reach sink without any performance degradation.
3- Priority Aware Control

This approach requires special consideration related to packet travel time and mechanisms to avoid loops. Different application take advantages of both traffic control and resource control by implementing both approaches in a single network.

Different algorithms have been proposed based on resource control approach. Topology Aware Resource Adaption TARA implements various multiplexing methods for WSN traffic based on the WSN topology, it didn’t only depends on buffer status but also monitor channel loading for collision detection also it optimize energy consumption and enhanced network performance, on the other hands, in large networks it add a massive overhead and load which make this approach not scalable. Learning Automata based on Congestion Avoidance Schema LACAS implement a learning automata based approach to avoid congestion. It preserve input and output data rate constant for all internal nodes. Packet drop rate is used as an indication for congestion and if congestion happens it use alternative internal nodes to avoid congestion. One of the main advantages of this algorithm is its ability to learn from older behaviors and act accordingly. This approach doesn’t consider link congestion and cause high energy consumption.

Hierarchal Tree Alternative Path HTAP[6] implement an alternative path based on hierarchal structure. It alleviate congestion using resource control approach. Alternative path include various nodes which are not member of the first shortest path that has been selected. Using these nodes result in consuming balanced energy and maximizing network life time.

The main methodology of this algorithm depends on four stages: neighbor discovery, alternative paths formulation. Hierarchal tree creation and finally handling nodes with exhausted batteries. One of the most disadvantages that it is not efficient with energy consumption. Flock based congestion Control Flock-CC[10] is a self-adaptable and solid congestion control. This algorithm implements Swarm intelligence model, this model is designed based on how bird’s flocks communicate and guided. In this algorithm a guide packets lead data flow to the sink and a void any congested links or paths. Flock-CC can be implemented easily and requires minimal rate of node data exchange. Experiments shows that this algorithm is very effective where it balance network load and available resources. It is also very scalable and optimize delay and energy but it doesn’t guarantee resource fairness.

Wireless Congestion Control Protocol WCCP[25] is designed to fit multimedia requirements. It mainly depends on both source congestion protocol and destination congestion protocol for source and relaying nodes. These two protocols control the source node sending rate and distribute the send packets. It also enhanced the quality of multimedia traffic received by base stations by compressing multimedia traffic in case of congestion and ignore other frames so it has high impact on multimedia traffic enhancements. WCCP doesn’t efficiently consume energy.

4- Priority Aware Control

In this approaches, proposed algorithm provides nodes in congested area with higher priority to transfer data. This prioritized data rate can help congested nodes to recover and process data transferring. Different algorithm has been proposed based on this approach. Priority aware congestion control protocol PCCP[17] determines the congestion status by comparing time of packet arrival and packet service. PCCP implements rate control algorithm to support node weight fairness. It utilize different classes of priority where nodes in higher class has the ability to use more bandwidth and send more traffic. PCCP is implemented to support both single and multiple path routing. On other hands, PCCP priority assignment is ambiguous and it provides extra queueing delay and packet retransmission. Cross Layer Active Predictive Congestion Control (CL-APCC)[26] is implemented to enhance network performance by using queueing mechanism to test data flow for nodes on the basis of memory status. It also examined the trends of network data exchange to adjust nodes data rates. CL-APCC updates IEEE802.11 based on different factors including waiting time, node neighbors and data priority to guarantee network fairness but it ignore energy consumption efficiency.

Adaptive compression-based congestion control (ACT) [27] mechanism is implemented to minimize the number of sending packets when congestion happened. It also deploy a compression methods like discrete wavelet transform (DWT), Run Length Coding (RLC) and adaptive differential pulse code modulation (ADPCM). ADPCM is used minimize the size of data which result in reduction in packets number. ACT utilize DWT as priority based congestion control where it provides data groups with different priority classes. So it adaptively control the queue based on congestion state. ACT also doesn’t optimize energy consumption so it is not energy efficient.

4- Queue Length Control

Queue length control mechanism adjust congestion based on nodes queue control. It mainly depends on simple rate control methods like additive incrementing additive incrementing multitive decrementing AIMD to adjust queue length to the least possible values. This type of congestion control provides efficient energy consumption. Multiple of powerful algorithms based on queue length control has been proposed. Interference Aware Fair Rate Control (IFRC) algorithm depends on rate assignment based on...
distributed manner. It detects congestion based on the queue status and notifies nodes about congestion based on overhearing technique. Nodes collect information about data rate from their neighbors, which also results in extra communication overhead. The main disadvantage of this algorithm is its stability complicated parameters where its parameters need to be assigned before network deployment.

Decentralized, Predictive Congestion Control (DPCC) [28] implements adaptive interval selection for both flow and back-off. This results in efficient energy consumption and distributed manner of power controlling. DPCC detects congestion by checking queue load and channel utilization. Mitigate congestion it starts an adaptive control of flow to adjust suitable data rate. It associated flow with weights to confirm fair resource allocation when congestion occurs. By weighted approach fairness is confirmed and guaranteed.

The algorithm of Queue based congestion control protocol with priority support (QCCP-PS) [29] utilizes the length of the queue as an indicator for congestion status. It implements congestion control based on node priority. It proposed an optimization for Priority based congestion control protocol (PCCP) to achieve better utilization of data for queue. The congestion level control the speed data transmitting rate, it also depends on the priority value of the node.

Congestion Control protocol based on Trustworthiness of nodes using Fuzzy logic (CCTF) [30] proposed algorithm for congestion control by minimizing the number of less important data packets and maximize buffer size. This procedure overcomes congestion and recovery from it.

Grid based Multipath with Congestion Avoidance Routing (GMCAR) [31] is built using grid model and provides efficient routing for QoS sensitive data. Grid master node for each grid takes care of data retrieved from internal grid nodes and communicates with other grid masters. This master node also has multiple trajectories to the sink node. It also continuously checks the available buffer size to avoid node congestion and when the size reaches a predefined threshold value, it raises a congestion alarm and starts avoidance steps by retargeting incoming data packets to other standby trajectories.

Healthcare aware Optimized Congestion Avoidance and control protocol for wireless sensor networks HOCA [32] algorithm which is active queue management based algorithm to control congestion was implemented to deal with healthcare data properties. This algorithm mainly focuses on energy consumption, network lifetime and end-to-end delay. It mainly tries to avoid congestion by implementing multiple paths with QoS characteristics. If the congestion occurred, HOCA depends on optimized congestion control algorithm to overcome its impact. HOCA divides the data traffic into two types: sensitive and non-sensitive and each type has specific mechanisms to deal with and apply its requirements.

7. Congestion Avoidance

Algorithms in this category expect congestion and provide steps to avoid it. Mechanisms used to mitigate congestion can be used to avoid it like traffic and resource management. Mechanisms for congestion avoidance which work to prevent congestion instead of reacting against its occurrence. Extra mechanisms other than used for congestion mitigation can be used including: Virtual sink where mobile sink is moved to high load areas [33], enhanced MAC layer provide MAC layer with extra enhancements to minimize congestion probabilities [34]. For learning automata approach, nodes can behave smartly by doing smart actions (automata). These nodes can control the data rate for data flows between internal nodes [35].

8. Summary

This paper presents a survey for the latest algorithm related to congestion control which is one of the most critical challenges for wireless sensor networks. Congestion impact of WSN can be distinctive where it can cause higher energy construction, minimized throughput and data loss and add extra end to end delay. These consequences can lead to decreasing network lifetime and resource exhausting. This paper investigated the state of the art researches in the field of congestion detection, notification, mitigation and avoidance.

References


