

# Congestion Control for Wireless Sensor Network: A Study

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**ABSTRACT:** Modern Telecommunication, Computer Networks and both wired and wireless communications including the Internet, are being designed for fast transmission of large amounts of data, for which Congestion Control is very important. Without proper Congestion control mechanism the congestion collapse of such networks would become highly complex and is a real possibility. Congestion control for streamed media traffic over network is a challenge due to the sensitivity of such traffic towards. This challenge has motivated the researchers over the last decade to develop a number of congestion control protocols and mechanisms that suit the traffic and provides fair maintenance for both unicast and multicast communications. This paper gives out a brief survey of major congestion control mechanisms, categorization characteristics, elaborates the TCP-friendliness concept and then a state-of-the-art for the congestion control mechanisms designed for network. The paper points the pros and cons of the congestion control mechanism, and evaluates their characteristics.

**KEYWORDS:** Wireless sensor network; Congestion control protocol; Traffic control based protocol; Resource control based protocol. WSN - Wireless sensor network ,DRCP - Dynamic Resource Control Protocol, DAPS - Dynamic Alternative Path Selection, HTAP - Hierarchical Tree Alternative Path ,Flock – cc – Flock Congestion Control, GBCC - Generalization based Congestion Control ,DAIPaS -Dynamic Alternative Path Selection Scheme, TADR - Traffic Aware Dynamic Routing, CADA - Congestion Avoidance Detection and Alleviation, CAR - Congestion Aware Routing

## I. INTRODUCTION

Congestion control over network, for both of all types of media traffic, has been an active area of research in the last decade [1]. This is due to the flourishing increase in the audiovisual traffic of digital convergence There exists a variety of network applications built on its capability of streaming media either in real-time or on demand such as video streaming and conferencing, voice over IP (VoIP), and video on demand (VoD). The number of users for these network applications is continuously growing hence resulting in congestion. In networks, the packet loss can occur as a result of transmission errors, but most frequently because of congestion. TCP's congestion control mechanism reacts to packet loss by dropping the number of unacknowledged data segments allowed in the network. TCP flows with similar round-trip times (RTTs) that shares a common bottleneck to reduce their rates so that the accessible bandwidth will be constantly, distributed equally among them. Not all network applications use TCP and therefore do not allow the same concept of fairly allocation the available bandwidth. Thus, the result of the unfairness of the non- TCP applications did not have much impact because most of the traffic in the network uses TCP-based protocols. However, the quantity of audio/video streaming applications such as Internet audio and video players, video conferencing and analogous types of real-time applications is frequently increasing and it is soon expected that there will be an increase in the proportion of non-TCP traffic. In view of the fact that these applications commonly do not amalgamate TCP-compatible congestion control mechanisms, they treat challenging TCP-flows in an unreasonable manner. All TCP-flows reduce their data rates in an attempt to break up the congestion, where the non-TCP flows maintains to send at their original rate. This highly unfair condition will lead to starvation of TCP-traffic i.e., congestion collapse [2], [3], which describes the disagreeable situation where the accessible bandwidth in a network is almost entirely occupied by packets which are discarded because of the congestion before they reach their destination. For this reason, it is desirable to define suitable congestion control mechanisms for non-TCP traffic that are compatible with the rate-adaptation mechanism of TCP.

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These mechanisms should make non-TCP applications TCP-friendly, and thus lead to a fair distribution of bandwidth. Unicast is a one-to-one form of communication in networks where multicast is one-to many. Multicast is advantageous over unicast particularly in bandwidth reduction, but unicast is still the extensively used communication form network.

Advances in electro-micro systems, low power design have led to the development of small-sized, tiny sensors that have the capacity to sense the environmental changes like temperature, pressure and collaborate to fulfill a common task, such as environmental monitoring, data processing or tracking. These sensors measure environment surrounding itself and send information to the base station. Networks are built using collection of many sensor nodes together. In wireless sensor network, data from all sensor nodes gather by sink node and sink node communicates with the user through the internet as shown in fig. 1. Sink node serve as powerful entity it also work as gateway, storage center, human interface. For event based application in WSN When some event occurs at particular node, then that node able to sense environment changes and in query based application sink node send query and according to that all node proceed. Sensor nodes can be used possible for harsh environment, real world applications like disaster management, military and civil applications such as weather monitoring, security, detecting ambient conditions such as temperature, movement, sound [2]. Deployment of the nodes in such applications can be in a random fashion or it can be manually for instance, in a disaster management application a large number of sensors can be dropped from a helicopter [3]. Sensor node scatters around the area for specific applications so energy, memory, computational powers are limited, due to which congestion and also packet loss occurs. Congestion in wireless sensor network affects directly energy efficiency and application specific Quality of services [4]. The remainder of the paper is conveyed as follows: Part II we describe the congestion control in wireless sensor networks. Part III identifies the resource utilization based congestion control protocols in wireless sensor networks. Part IV shows the comparison of these protocols on the basis of several parameters. Part V concludes the paper with an indication of future scope.

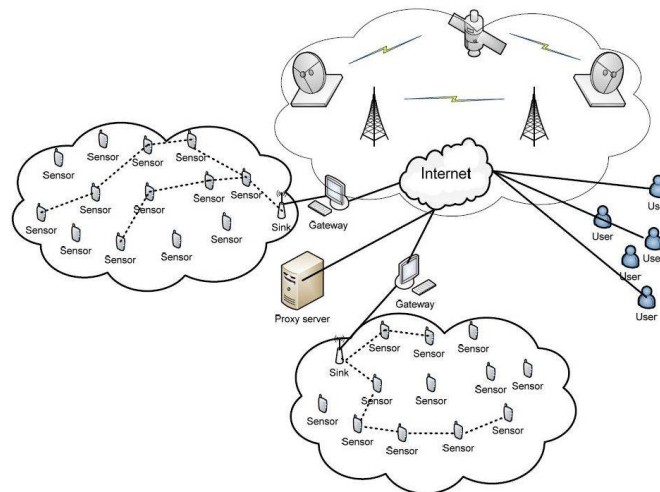


Fig1. Topology of Wireless sensor network

## II. CONGESTION CONTROL IN WSN

Congestion in wireless sensor network takes place when traffic load increases and available capacity at any point is limited. Congestion increases packet loss and worsens the throughput of the wireless channel. In wireless sensor network Congestion happens due to two reasons: Buffer overflows and link collision. Buffer overflows type congestion occurs when the packet transmission rate is higher than the packet receiving rate. That causes power loss and packet drop in network. Link collision type congestion is caused by competition, collision, and bit error due to which a node receives very few packets in comparison to the packets transmitted by its neighbour node [4]. Congestion algorithms in

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wireless sensor network classifies as Congestion Mitigation, Congestion Avoidance, and Reliable Data Transport. Congestion Mitigation again classifies as Congestion Detection, Congestion Notification, and Congestion Control. Congestion Detection and Notification may be a part of Congestion Control. Congestion Control Algorithm further classifies as Traffic Control, Resource Control, and Hybrid Method. Traffic based congestion control protocol shrinks congestion by reducing the traffic rate or increasing the window size according to the traffic. In the window based technique, sender node increasing a congestion window based on network bandwidth to handle traffic. Traffic rate based technique increases or decreases traffic rate, according to the requirement of controlling congestion. [4] Traffic control further classifies as Avoiding and Reacting manner. But in traffic control method only the source mitigate the congestion. Event based network generated when specific event at particular node occur. For event based network, traffic control based protocols are not sufficient. Event based networks are not used in a periodic manner and short term packet burst occurs for which resource utilization based protocol give better results as compared to traffic control protocol. Resource control based protocols use available resources such as nodes to solve congestion

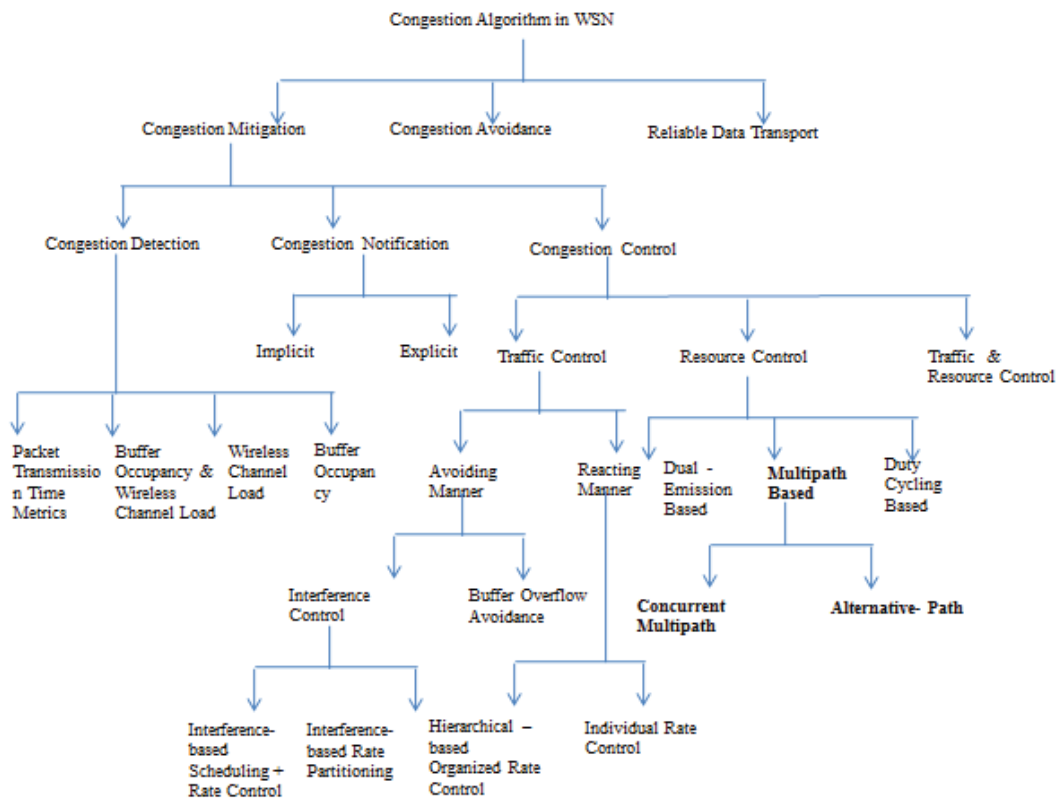


Fig. 2. Classification of Congestion algorithms in wireless sensor network.

### III. RESOURCE UTILIZATION BASED CONGESTION CONTROL PROTOCOL

Wireless sensor network contains many tiny nodes so resource utilization based congestion control algorithms use these nodes as extra resource for congestion control. Resource control based congestion control protocols are classified as Dual Emission Based, Multipath Based, and Duty Cycling Based. Multipath Based are further classified as Concurrent multipath or alternative Path [5]. This section reviews various multipath based resource utilization protocols for congestion control in wireless sensor network.

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## A. DYNAMIC RESOURCE CONTROL PROTOCOL(DRCP)

DRCP congestion control protocol utilizes multiple resources to mitigate congestion [6]. In DRCP, intermediate nodes to use available extra resources for transferring the packets. Each node able to increase or decrease transmission power. Increasing transmission power agrees to a node to discover wide range of neighbours that allows better resource utilization. Each node collects cost information of neighbours and computes the path cost for every neighbour. Cost information contains buffer level, number of packets in the queue, residual energy of node. After that each node selects a neighbor node based on the ranking of their costs. When a node detects the congestion level above threshold, it increases its resources i.e. transmission range, when the congestion decreases in future then a resource decreases procedure takes place to decrease the transmission range to its previous value.

## B. DYNAMIC ALTERNATIVE PATH SELECTION (DAPS)

DAPS [7] protocol for control congestion is simple and keep overhead minimum. This technique contains four stages Setup Phase, Topology Control Phase, Soft Stage Phase, and Hard Stage Phase. In the setup phase, after the random deployment of nodes each node discovers each other and built their neighbour tables where they keep information about their neighbours. Topology control scheme contains dynamic way to control the topology without adding extra burden to the network. For that every node observes neighbour table continuously, especially "LEVEL" field and find a node with lower level for data transfer. Soft stage Phase comes when a node receives data from more than one nodes. Receiving from multiple nodes is then prevented by sending back pressure message to the node from which it prefers to stop receiving data. Soft stage advised the nodes change their routing path. In case the node doesn't change its path then based on the flag value an alternative path selection process starts forcefully in hard stage phase.

## C. HIERARCHICAL TREE ALTERNATIVE PATH(HTAP)

HTAP [8] algorithm controls congestion by selecting alternative paths. Its alternate path selection decision based on local information such as the congestion state of its neighbours. It contains four stages Topology Control Phase, Hierarchical Tree Creation Phase, Alternative Path Selection Phase, and Handling of Powerless Nodes Phase. In topology control phase it uses Local Minimum Spanning Tree (LMST) to create an initial topology. In LMST each node builds its local minimum spanning tree by prims algorithm. Hierarchical tree creation stage contains level wise formation. The source node sends level discovery message to the neighbours if there is no upstream node for forward packet than node responds by NACK. After that connection is formed between each transmitter and receiver by using two way handshake protocols. Alternative path creation phase contains congestion detection algorithm, each node calculates the total receiving rate and compare it with its maximum transmission rate if total receiving rate larger than maximum transmission rate than that node select alternate path. During powerless nodes handling phase, a node broadcasts the message to the neighbor nodes in case its power reaches to the minimum power level.

## D. FLOCK CONGESTION CONTROL(FLOCK-CC)

The Flock – CC [9] protocol uses swarm intelligence which is motivated by behaviour of bird flocks. Flock – cc protocol guides packets to form flocks and flow towards the sink avoiding congestion regions. It is decentralized, robust, self adaptive and scalable. In this protocol every time current hosting node sent packet to new hosting node based on a decision process which consists of three stages 1) Selection of direction that is forward, sideways, or backwards using the field of view property and the magnetic fields. 2) Sorting of all nodes in the selected direction in decreasing order by their desirability 3) Probabilistic based (which is proportional to desirability) selection of the new hosting node. The position of sink play important role in evaluation of direction of movement of a packet. Congestion detection based on Queue loading and Mac layer collisions and retransmission in Flock cc.

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## **E. GENERALIZATION BASED CONGESTION CONTROL(GBCC)**

GBCC [14] protocol solve congestion by distributes traffic to over sensor nodes in a fair manner. For that traffic rate of data at each sensor node is taken as training set object. Average traffic rates of sensor nodes deployed around the event area and their standard deviation use to calculate fitness function. To construct the path from the sensor node to the sink node tree based routing protocol is used. Here when a sensor node is congested with traffic from child nodes then it distributes its traffic to its neighbour nodes. Level wise formation is used for classifying congested node from its neighbour node. Neighbour nodes mark as parent nodes if it is at same level or higher level from congested nodes. And it is ma lower level than mark as child node. Generalization based algorithm consumes more power at the initial state.

## **F. DYNAMIC ALTERNATIVE PATH SELECTION SCHEME(DAIPAS)**

DAIPaS [12] is a congestion avoidance and control algorithm that chooses an alternate path if congestion takes place. It contains Setup Phase and DAIPaS Mechanisms Phase. In setup phase, sink node broadcasts “HELLO” packet with its level id which is ‘level 0’ to its one hop neighbour nodes. Than after neighbour node update their level to 1 & this process continues until the level wise formation of all the nodes is not completed. DAIPaS consists of mechanisms two stages namely Soft stage and Hard stage. Each node comes in soft stage when a node receives packets from more than one flow. Thus in soft stage congestion condition is created which is solved by keeping each node receiving data only from one flow. But in the case of high traffic flow, soft stage fails, then it comes across the hard stage during which chosen forcefully alternate path to avoid congestion. That alternate path selection depends on Buffer threshold, Path cost, Node’s remaining energy.

## **G. PROBABILITY BASED HOP SELECTION APPROACH(PHSA)**

PHSA [16] for congestion control mitigates congestion by increasing the available resources on the path. For every node in the network the algorithm finds the path with appropriate cost between the node and every other neighbor node. Two techniques namely 1) Information Exchange 2) Send/Receive data are used for that purpose. Information exchange technique contains four subsections Compute and Exchange cost information, Path Cost Computation, Next Hop Choice, and Notification Phase. In Send /Receive data technique, data is send data to their neighbor nodes according to the selected hop. A node that has no data to send kept in sleeping state for that round. This protocol select next hop based on the minimum path cost which is the sum of transmitting cost of all nodes on the path. Congestion detection in the algorithm is done on the basis of MAC layer contention and queue overflow.

## **H. TRAFFIC AWARE DYNAMIC ROUTING(TADR)**

TADR protocol [13] directs packets around the congested areas avoiding there areas and distribute the packets along multiple paths where idle and under load nodes are appropriately utilized to alleviate congestion. It uses depth and queue length to find the shortest path for packets. The area used by TADR can be viewed as a bowl. The sink is placed at the bottom and if congestion is not there, then this protocol simply employs as shortest path routing. On contrary, in case of congestion algorithm finds the appropriate detour path without obstacles.

## **I. CONGESTION AVOIDANCE DETECTION AND ALLEVIATION(CADA)**

CADA [15] scheme alleviate congestion by dynamic traffic multiplexing or rate adjustment. It avoids congestion by choosing node based on a distributed node selection algorithm. This is a proactive method for congestion avoidance. In this technique, congestion level of specific node is measured on the basis of combination of buffer occupancy and channel load. CADA counts growing rate of buffer occupancy and if it reaches some specific threshold then that node is denoted as congested. If the packet delivery ratio decreases continually, in spite of maximum channel utilization, then it is considered a case of channel congestion. To mitigate congestion mitigation it uses both traffic control and resource control techniques. For that each node keeps track of state information of incoming traffic. If congestion



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causes at intermediate node than it mitigate by selecting detour path. Otherwise congestion occurred at hotspot node that is source or sink node then is controlled by rate adjustment.

### **J. CONGESTION AWARE ROUTING(CAR)**

In CAR [21] data is separated as high priority and low priority. If congestion occurs in the network then high priority data select path where congestion occur and low priority data select less congested nodes by selecting alternative path to transmit data. When the node has packet to transmit the sink node, it sends a RREQ to find the best path to the destination. Intermediate nodes maintain information such as source-id, packet seqno, and arrival time of previous visited node. Intermediate node receives RREQ then it calculates congestion of network. The congestion is calculated on the base of the density of the packets passing through the node.

### **K. QUALITY OF SERVICE ADAPTIVE CONGESTION CONTROL(QoS -ACC)**

QoS-ACC [17] maintains quality of service parameters like packet loss, delay, link utilization. Two queue maintain by this protocol that is, QRT and QNRT for real time and non-real time application data respectively and one backup queue QBACK-UP for storing unacknowledged non real time data at network layer. In this technique, congestion is detected based on the ratio of packet inter-arrival time and packet service time. For congestion notification it uses the implicit notification technique. For congestion mitigation, it employs two techniques 1) Short Term Congestion Control 2) Long Term Congestion Control. For short term congestion control, when a node encounters congestion then its intermediate previous sender node diverts traffic on the alternative node. For long term congestion control, it uses congestion avoidance technique that sends backpressure message to immediate sender node.

## **IV. PARAMETRIC COMPARISION**

Table 1 represents a comparative analysis on the basis of the parameter path selection method, congestion detection method, congestion notification, fairness, scalability, reliable data transmission provided or not, and the traffic direction method. Congestion detection method refers to the process of detecting and locating congestion in wireless sensor network. [6] For congestion detection different parameters are used that are packet loss, queue length, channel load, packet service time, and transmission delay. For notifying congestion can be of two types implicit or explicit methods. Fairness contains an equal distribution of load. The traffic direction method indicates whether traffic flow from source to sink or sink to a source. For efficient resource utilization, after encountering congestion path selection method chose an alternative path or multiple paths for distribution of traffic. Here GBCC, TADR, CADA, CCR distribute traffic along an multiple paths for controlling the congestion. On the contrary DRCP, DAPS, HTAP, FLOCK-CC, DaIPAS, PHSA, QoS-ACC use alternative path for congestion control.

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Protocol	Path selection method	Congestion detection method	Fairness	Scalability	Congestion notification	Reliable data transmission	Traffic Direction
DRCP	Alternative path	Buffer based and MAC layer contention	No	No	Explicit	Yes	Source to sink
DAPS	Alternative path	Buffer based and channel load	Yes	Yes	Implicit	Yes	Sink to source
HTAP	Alternative path	Buffer-based	No	Yes	Implicit	Yes	Source to sink
FLOCK-CC	Alternative path	Buffer-based	Yes	Yes	Implicit	Yes	Source to sink
GBCC	Multipath	Buffer-based	Yes	No	-	No	Source to sink
DaIPaS	Alternative path	Buffer based	No	No	Implicit	Yes	Sink to source
PHSA	Alternative path	Buffer based and MAC layer contention	No	No	Explicit	-	Source to sink
TADR	Multipath	Buffer based	No	No	-	No	Source to sink
CADA	Multipath	Buffer based and channel load	No	No	Implicit	No	Source to sink
CCR	Multipath	Buffer Based	No	No	-	No	Source to sink
QOS-ACC	Alternative path	Packet service ratio	No	-	Implicit	Yes	Source to sink

Table 1: Comparative Analysis of Resources utilization based congestion control protocols.

### V. CONCLUSION AND FUTURE SCOPE

In this paper, we analyse multipath based resource utilization congestion control protocols for wireless sensor network. We compared them on the basis of parameters like path selection method, congestion detection method, congestion notification method, fairness, scalability, reliable data transmission, and traffic direction. Event based applications use resource utilization based congestion control in which nodes used as additional resource to mitigate congestion. While several congestion control protocols have been introduced in this literature, no technique introduces security issue. Having energy constrained nodes, WSN also face energy consumption issue.

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