Comprehensive Study on Congestion Control Mechanism for Increased Throughput in Wireless Sensor Network

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Abstract: In recent years the advancement of wireless senor network (WSN) have paid more attention for efficient communication among wireless devices for transferring data through wireless links from sensing area to data collection centre or base station (BS). As wireless system progress towards smart computing architecture, new protocols are developed to improve network efficiency. One of these protocol is transmission control protocol (TCP), used in data intensive application to transfer data efficiently. TCP has been the default choice for various application due its unique feature like control transmission bit rate, data reliability, congestion control and cumulative packet acknowledgement. To ensure quality of service (QoS) end to end congestion control mechanism should be considered most important parameter for fair sharing of network resources as future network becomes more complex. Congestion in the network is caused due to factors like packet collision, buffer overflow, interference, channel unavailability, low power links and many-to-one transmission. Congestion affects various network parameters and increases communication overhead. Therefore it is challenging issues in WSN that require developing advance techniques to detect and avoid congestion control. This paper presents a comprehensive study on classical and soft computing congestion control mechanism for WSN, different methods of congestion detection and avoidance have been investigated. Finally we highlight the realistic challenges for future research directions.

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I. INTRODUCTION

Wireless sensor network (WSN) comprises of tiny sensors nodes deployed in an area to sense the physical event and report to data collection node or base station (BS). Sensors are embedded with processor, radio transceivers, battery operated which are capable to operate efficiently to collect, compute and communicate data. Applications of WSN are widely used such as military, smart cities, health care and object detection. Sensor nodes are resource constrained with limited battery power [1].Senor nodes are designed to operate in a hostile environment with minimum manual interference and should have ability to possess fault tolerance and self healing behaviour for different scenarios [2]. Each node in network has short communication range for transmitting data through intermediate nodes which collaborates each other to forward data to base station (BS) through multihop. While forwarding data to BS, nodes in the network faces many constrains like interference, packet loss, attacks and congestion. Congestion is evitable in network due to various causes and no network can be proclaimed as congestion free, which has been a crucial task in degrading the network performance. Congestion in WSN occurs when resource demands exceeds the available capacity such as queue length, channel capacity, interference level and retransmissions. Different traffic patterns can be derived from the sensing environment and type of applications to achieve desire Quality of Service (QoS) [3-5].High degree of unfairness and traffic load fluctuation occurs when the traffic load exceeds the available capacity. Transmission control protocol (TCP) was designed to detect packet loss caused due to communication channel, interference, congestion and mobility [6]. TCP employs cumulative acknowledgments (ACK) during packet transmission to indicate packet was received at receiver successfully and expecting the next packet. TCP ensures end to end congestion control and increases overall network performance.TCP uses pre-defined set of rules whenever a packet loss is detected and controls congestion by adjusting congestion window (CWND) according to round trip time (RTT).Therefore congestion control is one of the challenging issues in WSN, failure of small number of nodes can bring down the network performance therefore it is essential to implement congestion detection and control mechanism to achieve QoS [7]. In this article existing congestion detection and avoidance methods for WSN have been summarised.

Paper organisation

The structure of paper is as follows. In Section II describe the motivation. Section III describes the causes of network congestion. In section IV describes the related works carried out on classical and soft computing congestion control methods. Section V describes the performance metrics to be evaluated. Section VI describes the summary and insight of the survey paper. And finally we draw the conclusion of the survey at section VII

II. MOTIVATION

With the emergence of smart computing and IoT (Internet of Things), WSN has driven attractive integration of physical real-world connection to many day-to-day life applications. Gathered data should be efficiently processed and forwarded to data clouds, base station or sink node without any packet loss. Congestion in the network causes huge loss of data and consumes more resource. Congestion detection and avoidance techniques have to be formulated to adapt complex and dynamic network. However, still some research has not been given attention to classify congestion control mechanism, layer-based congestion control and optimization addressing congestion issues. Considering this thought as primary concern motivates us to survey latest congestion control methods.

III. CAUSES OF CONGESTION IN NETWORK

Absence of central controller node

Absence of controller node in the network makes the nodes unable to get updates on the congestion occurrence or other information. Nodes in the network may have different configured communication protocols and heterogeneity that may cause problem in detecting congestion at appropriate location and time.

Event-based

Event based detection applications sense and process data based on event, during sensing the load of information gathering at same time result in congestion. Example military battle field, object detection and tracking, where each node becomes active when an event is detected.

Network with limited resource

Nodes are embedded with tiny sensors which are capable to compute smart functions and data processing. These sensors are limited to resource, power, bandwidth, energy, memory and computation.

Dynamic network change

Mobile nodes keep changing their position in network resulting in frequent topology changes. In some scenario nodes are deployed in random fashion and to operate without human intervention. Nodes are susceptible to get fault by physical damages and unexpected link failure, unstable links and channel fading while moving from one place to another.

Channel contention and many to one communication

Congestion is likely to occur when multiple sensors tries to access transmission medium at MAC layer. Simultaneous access to MAC creates a big packet collision and channel gets blocked causing packet drop. When node communicates many to one, it causes bottleneck situation to grab channel simultaneously such that packet transmission will be huge.

IV. RELATED WORKS

Classical routing aware congestion control mechanism

Any congestion control mechanism in the network consist of three phase in solving congestion problem. First phase is congestion detection phase, is a procedure to identify and investigate the cause of congestion occurrence points [8].There may be various parameters for the cause of congestion such as buffer occupancy, channel condition and packet loss. Detection phase is used as indicator to detect congestion on various parameters [9-10]. Congestion notification is a second phase, upon detection of congestion the upstream nodes in the network has to be informed to perform appropriate approach against it and the information can be explicitly or implicitly propagated. In explicit notification the congestion notification information to upstream nodes are sent through additional control packets, whereas in implicit the congestion notification is sent through piggyback congestion information between other nodes in payload packet header [11]. Finally the third phase is congestion control phase, in this phase the congestion is controlled through different mechanism by adjusting the sending traffic rates, assigning priorities to packets and increasing resources, queue size, and bandwidth. In [12] author proposed dynamic routing aware congestion for WSN constrained by considering traditional flooding and gossip algorithm. This protocol aims to traverse packets through alternate route whenever congestion is detected. Congestion is detected based on the available buffer space, the free buffer space is computed by defining the threshold value. If the buffer is fully occupied by packets and the threshold value exceeds then the retransmission counter is halved at the send side to decrease packet loss. The alternate paths are selected based on the buffer space availability, bandwidth, residual energy and hop distance. This scheme detects congestion and routes through alternate congestion free path from source to destination, this scheme fails to consider mobile nodes. In [13] author proposed multipath routing aware congestion avoidance protocol based on CA-RPL (Congestion avoidance-Routing protocol for low power and lossy network) to minimize the routing delay and paths are computed based on four metrics. CA-RPL was designed to route data packets to sink node reliably when nodes detect sudden events in monitoring are for emergency scenarios. CA-RPL combine routing metrics with delay root to calculate optimal paths to forward data to sink. This scheme can alleviate congestion caused by huge data traffic and balances the network load. This scheme has more transmission overhead making this as a disadvantage. In [14] author proposed priority based routing protocol by considering the limitation of widely used existing protocol, in this protocol the network resources are shared based on the real time data transmission and types of traffics. The traffic flows are categorized based on their service and assigning priorities like high priority real time traffic, high priority non real time traffic, medium priority non real time traffic and low priority non real time traffic. Delay sensitive traffic are considered as high priority traffic and low priority traffic is considered as not delay sensitive. Adaptive Random early detection (A-RED) is integrated to queue management scheme to detect congestion. This scheme achieves higher throughput by assigning packet priorities with lower packet loss, but this scheme fails to discover optimal paths. In [15] author proposed congestion aware routing to reduce congestion caused while forwarding traffic in MAC layer to increase throughput and minimize delay. In this routing scheme the intermediate node selects the forwarding relay nodes based on two conditions: 1) optimal path selection and 2) congestion aware forwarding. In optimal path discovery the relay nodes are selected based on their geography locations by considering minimum hop and in congestion aware the relay node are selected based on the channel availability. The use of two strategies while selecting forwarding relay nodes ensures efficient data transmission and reduces transmission delay, however this scheme is only designed for link level congestion. In [16] author proposed congestion aware routing to alleviate congestion by selecting the alternative parent node and makes the decisions based on multi criteria routing metric for selecting best parent node. Based on the traffic conditions this scheme adapts threshold to detect congestion by determining the current queue size being occupied to eliminate congestion situation. Parent node change is triggered when congestion is detected and alternate path is selected towards the root. This scheme improves throughput, packet loss ratio but has higher transmission overhead. In [17] author proposed fast congestion control scheme using hybrid optimize routing algorithm by considering nodes mobility. This routing scheme consists of two phase, in first phase the next hop node is selected based on multi-input time to optimize task with minimum queuing delay and in second phase the energy efficient route between source and destination is selected based on gravitational search algorithm to choose nodes with higher residual energy. The proposed hybrid routing scheme can resist congestion and aims to achieve higher routing efficiency in order to select best next hop node but has limited scalability. In [18] author proposed congestion aware cluster based routing (CCR) protocol to mitigate congestion. The main aim of CCR is to increase the performance metrics like throughput, delay and increase network lifetime considering limitation caused due to congestion which drains the battery dependency and storage capacity. CCR selects optimal primary and secondary cluster head which reduces the network overhead by performing two stages by dividing the network into groups and creating equal clusters. During data transmission different cluster head transmits data to sink node simultaneously which may results in congestion. To avoid congestion this scheme utilizes optimal bandwidth usage and load among the clusters are equally distributed to balance the network energy. CCR also integrates fault tolerance method to detect and rectify any faulty nodes in the network and increases packet delivery ratio but has higher computational overhead in updating nodes position. In [19] proposed an adaptive cross-layer method to control congestion in mobile sensor network. This scheme utilises packet drop classification paradigm to detect congestion and channel are efficiently utilised. The congestion notification packets are sent remotely or locally to make decisive information. The congestion in each flow is detected and adapts different transmission rates to improve channel utilization. In [20] author proposed cross layer approach to control congestion and packet recovery. This approach reduces congestion and contention problems occurred in data link layer and transport layer and ensure superior performance. TCP congestion window mechanism is adapted for packet recovery by storing the copy of packet. Packets with higher priority are maintained to access channel and adjustment of flow rates when congestion is detected. The link contention is determined by variance of contention round trip time per hop and contention window situation is observed. Higher packet delivery ratio and throughput is achieved but energy is not optimized. In [21] author proposed novel TCP congestion method for wireless network for explicit loss notification (ELN), this approach considers negative acknowledgement (NACK) to differentiate packet loss caused due to congestion or wireless link issues. This approach integrates small protocol packet that will prevent misinterpretation of packet loss caused due to link unstable or due to congestion and achieves better performance. The corrupted packets are retransmitted by adapting explicit loss notification without reducing congestion window (CWND). This approach fails to achieve real time communication for variable traffics.

Soft computing based congestion control mechanism

In [22] author proposed an optimization based congestion control by considering limitation of existing algorithm problem of having high computation overhead due to retransmission and control of congestion through optimal rate. Retransmission consumes more energy which is the one of the important constrain of WSN and realized nodes consuming more energy. To overcome this issue author proposed multi-objective optimization algorithm based on Particle swarm optimization gravitational search algorithm (PSOGSA) to control congestion and minimize the energy consumption of nodes. PSOGSA regulates rate optimization on arrival of data from child node to parent node. The energy of the node was considered to calculate nodes fitness for multi-objective functions and routing. This approach regulates data arrival based on priority, available bandwidth and energy to optimize resource and channel capacity and mitigates congestion. In [23] author proposed adaptive rate adjustment cuckoo search algorithm for congestion control. This algorithm aims to recover packet loss and avoid congestion for sensor network for different traffic loads by optimizing function that comprise of bandwidth, resource and priority. The rate share of the child node is adjusted within the service rate of parent node to avoid congestion. Cuckoo search algorithm neutralises the congestion when the parent node traffic exceeds the available queue size. In [24] author proposed hierarchical cluster based congestion control among sensor node, imperialist competitive algorithm is used to form clusters. The master node is responsible to gather information from each cluster and forward it to sink node. This approach uses threshold value to investigate congestion status of available buffer space of each node. If the threshold value reaches 50% then the buffer of each node is noticed, on reaching 80% the master node diffuse a message to downstream nodes and re-clustering process is initiated such that new master node is elected. In [25] author proposed congestion control based on deep reinforcement learning to control congestion by mapping receiver feedback which reflects the past network condition and traffic flow to adjust the next sending rate. The deep reinforcement learning helps to investigate timely applications and assures to assist resource control and modulating traffic flows based on the network capacity. This approach enables the training of different data traffic and conditions at achieve state of art performance for real time traffic. In [26] author proposed fuzzy based sliding mode congestion control algorithm (FSMC). Cross layer congestion between MAC and transport layer is designed and applied to TCP wireless channel to calculate signal-to-noise ratio (SINR). FSMC regulates queue length and adapts to adjust the queue buffer using sliding mode to control of congestion. FSMC effectively improves network performance and avoids congestion by reducing the queuing time.However this scheme fails to achieve effectiveness on WSN based IoT real time automation applications.

V. PERFORMANCE METRICS TO BE ANALYSED

It is required to evaluate performance metrics to be analysed after conception of congestion control methods to evaluate its efficiency. Various performance metrics to be analysed are:

Throughput: is the number of data packets received at the receiver per unit time and measured as kilo bytes per second. Higher the packet received at receiver more efficient is the algorithm.

Packet Delivery Ratio (PDR): is the total number of generated packets at the source to the total number of packets received at destination and measured in terms of percentage.

Average end-to-end delay: is the time taken to reach destination from source, i.e., sent time minus arrival time. Shortest the time taken indicates efficiency of algorithm and measured as milli seconds.

Hop-by-hop delay: is the metric to measure algorithm efficiency in terms of congestion and overhead between two nodes to reduce high queuing delay.

Communication Overhead: is the ratio of total number of control packets generated to the total number of data packets received.

Fairness: is the sharing of resources effectively among nodes by distributing available bandwidth across multihop

Energy Consumption: indicates the nodes energy consumption since nodes are energy constrained, less energy consumption increases the overall network lifetime and guarantees energy efficiency.

VI. SUMMARY OF THE PAPER

In this paper we reviewed various methods of congestion control for WSN based on classical and soft computing approaches. We found some recent works have been tackled to avoid congestion issues and performance metrics to achieve QoS. However some approaches cannot fulfil to achieve required performance for real time application and network scalability and may not be profitable. Hence the application based congestion control mechanism has to be designed based to control congestion for different applications.

VII. CONCLUSION

WSN is considered as an effective way to communicate and process information wireless and its use in various applications has evolved to benefit in fields of IoT, industry, military, education, health care and unmanned aerial vehicles (UAV). The primary challenge to deal with WSN is congestion problem, which can significantly reduce the overall network performance. Controlling congestion is observed as research gap and a challenging issue to authors given the limitation and constrains of WSN. In this article we study the classical and soft computing congestion control mechanism to mitigate congestion. From our observation we found classical congestion control mechanism has higher computational cost compared to soft computing. However soft computing mechanism also need to be improved in terms of energy efficiency while training the data. It is concluded that effective congestion control mechanism has to develop based on application specific and network scalability which can have robustness for dynamic network conditions.

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