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A Survey on Congestion Control Algorithms in MANET

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ABSTRACT *Mobile Ad hoc Network (MANET) is a temporary network in which the nodes move without any fixed infrastructure. In a MANET, nodes communicate with each other over multiple wireless links and also change network topologies due to mobility of the nodes. In MANET, routing is a challenging issue since it depends on several factors like router source, topologies, etc. Congestion control is a significant challenge in MANET. The network gets congested whenever the number of data packets transmitted in the network exceeds beyond its potential. Due to congestion of data, packets get dropped and thereby the network performance is decreased. In this paper, various literature is reviewed for understanding different congestion control algorithms and techniques proposed to avoid congestion. This paper analyses various congestion control schemes which are based on diverse concepts. The present review of the comparison table concludes that, parameters such as end to end delay, packet drop, routing overhead and packet delivery ratio (PDR) are improved due to the application of congestion control techniques.*

KEYWORDS : *Congestion control, Mobile Ad hoc Network (MANET), Routing protocol, packet delivery ratio (PDR)*

1. INTRODUCTION

Mobile nodes connected using wireless links are called Mobile Ad hoc Network (MANET). It has no fixed infrastructure and works in constrained bandwidth. Due to changing network topology from time to time, the nodes are allowed to move arbitrarily. The mobile node performs both routing and hosting functions and every gadget must go about as a switch for transmission of packets to each other (Saleh Ali et al, 2010). The main difference between MANET from other wireless networks node mobility. Owing to unique characteristics of the mobile nodes, there are many issues and challenges in designing MANET networks. Currently, there are several routing protocols in multipath networks. A mobile node transmits a packet to a sink via intermediate nodes (Azvine, 1997). Every node in MANET is considered important for assessing Quality of service (QoS) because the performance is degraded even if a single midway node is affected. MANET is applicable where no preset infrastructure is available. In Ad-hoc networks, there is no altered framework and system switches and hence, the portable nodes act as switches. In an ad - hoc network, topology change transpires when the nodes move, resulting in congestion of routing. This is one of the major limitations in MANET. This paper study clarifies what steering strategies are utilized to expand the QoS execution assessment with the assistance of relative examination.

2. CONGESTION CONTROL IN MANET

Congestion is a situation that is occurred in communication networks in which there is a huge number of packets in a part of the network. Congestion arises when the number of packets sent to the network (load in the network) is more than the network capacity (number of packets network can handle). Congestion results in packet losses and bandwidth degradation and wastage of time and energy on congestion recovery process (Chen et al, 2007). Owing to the shared communication medium of the MANET, congestion not only overloads the mobile nodes but it also impacts the whole network coverage area (Zaini et al, 2012). Some of the issues that occur due to the congestion are as follows.

Delay: When the congestion is high, it results in more delay. Hence, an alternate route has to be discovered to avoid long delay. However, the existing on-demand routing protocol delays the route searching procedure.

Overhead: High processing and communication procedures are carried out to find alternative routes. Whenever multipath routing is used, extra efforts are required to maintain the multiple paths.

Packet losses: Packets are lost due to congestion in the network. This can be minimized by reducing the packet sending rate or decreasing the traffic load. Due to high packet loss, throughput is reduced.

3. REVIEW OF LITERATURE

The major aim of congestion control is to lessen the delay and buffer overflow created due to congestion in network and thus allow the network to perform better. In wired networks, congestion control is executed at the transport layer and is designed distinctly from the tasks of other layers. But, those congestion control mechanisms are not applicable to MANET, which has its unique issues such as restricted bandwidth, energy constraint, path failures due to mobility of node and restricted buffer size. As number of packets sent through a network is more, the congestion in network yields high packet loss rate, unstable re-routing, energy and bandwidth loss, and retransmission of lost packets. This loss affects the performance of the network. Thus, various congestion control schemes were proposed to alleviate this issue.

A hybrid technique based on rate control or resource control was introduced by Sharma et al, (2016) to overcome congestion. The RREQ is distributed throughout the entire network as every node forwards it to the next node till it reaches the destination node. This process overlooks the congested node by choosing an optimal alternate path among multiple paths. Congestion detection is performed by perceiving warning in control messages received at every node, since congested node informs a flag to the nodes requesting for path. This system satisfies the fidelity requirements and improves the efficiency of the network in terms of delivery ratio, packet drop, routing load, etc.

3.1 TCP based congestion control

Congestion control is associated with the traffic inside the network and is used to eliminate network failure when the network is slower than the traffic source transmitting the data. To avoid congestion, the sender must adjust the transmission rate according to receiver's needs. The TCP sender possesses a variable window to estimate the number of packets it can transmit into the network before receiving acknowledgement. This variable dynamically differs over time to restrict the sending rate.

Sunitha et al., (2014) presented a cross-layer oriented method for enhancing the TCP performance. A triggering method initiates congestion when the channel occupied ratio (COR) attains the high threshold limit and the received signal strength is below the least threshold value. Then, the congestion control method controls the data sending rate of the sender by calculating the available bandwidth, delay incurred in the link and COR. Additionally, an optimal resource allocation was designed. Results of simulation proved that the efficiency is improved in terms of throughput, delivery ratio and delay.

Congestion control is linked with traffic control in a network. The efficiency of end-to-end Transmission Control Protocol (TCP) reduces with increased load in number of hops. To overcome this issue, Kumar, H., & Singh (2014) developed effective TCP Congestion Control AODV routing that contains a congestion monitoring mechanism based on queue length and traffic rate. The entire congestion status is estimated in congestion monitoring. While establishing route, congestion control in the particular channel, queue length of packet, traffic rate based overall congestion standard, packet loss rate and packet drop ratio are taken into consideration for monitoring the congestion status. Then, congestion less routing is recognized to lessen the packet losses, overhead and delay. The simulation results highlighted that this method achieves better throughput, Packet Delivery Ratio (PDR, decreased end-to-end delay and minimal overhead than the normal TCP based AODV routing.

Sreenivas et al., (2013) introduced a design of link-layer congestion control protocol by measuring capacity information such as bandwidth and delay at every node along the path. The destination node computes the new window size based on the values, and sends this detail to the sender node as feedback. Accordingly, the sender behaviour is transformed suitably. This method is also compatible with standard TCP. This technique introduced an extra module inside the protocol of the mobile node that allows adjustment of the outgoing data stream depending on capacity measurements by computing Round Trip Time (RTT) and modification of congestion window size.

3.2 Congestion control based on Active Queue Management (AQM)

An enhanced version of RED algorithm called (IRED) was developed by Simaya et al., to improve the efficiency of MANET. RED protocol utilized an Active Queue Management (AQM) concept to recognize the congestion at an early stage and this information is forwarded to the destination host. IRED is a Priority Queue based AQM scheme in which packets were dropped depending on two factors (i) arrival rate of packets and (ii) queue length. Thus, the effect of network congestion is reduced and also the packet loss rate is reduced.

The traditional on demand route discovery techniques apply flooding technique to rebroadcast received route request (RREQ) packets till a path to a particular destination is established. This results in broadcast storm problem and congestion in intermediate node when data is transmitted from sender node to receiver node. Hence, they incur high packet loss and long delay that result in reduced network efficiency.

In the early detection of congestion and self-cure AODV routing protocol (EDCSCAODV), the queue status of every node in the prime route is computed at node level. The node is able to detect the congestion at an early stage and transmits an alert message to its neighbouring nodes. Upon listening to this, the neighbour nodes employ automatic cure algorithm to get a substitute path without congestion for transmitting data. Therefore, this algorithm (EDCSCAODV) increases the network efficiency by minimizing routing overhead, delay and improves PDR without experiencing any extra cost. The performance of EDCSCAODV revealed that EDCSCAODV outperformed the conventional AODV routing schemes.

In early congestion detection and optimal control routing (EDOCR), the network is segregated into dense and sparse regions by applying mean of neighbours to discover non-congested alternate path. In EDOCR, initially the network is divided in to dense and sparse regions to find an alternate route without congestion by using average neighbours. After splitting, it starts an optimal route discovery procedure to identify a path to destination. This optimal route discovery minimizes RREQ overhead incurred in the route discovery operation. All the prime path nodes compute their queue-status at node level in regular interval. When, a node recognizes a congestion which is probable to occur, it transmits an alert message to neighbours. Thus, EDOCR uses the non-congested predecessor node of a congested node and initiates optimal route discovery procedure to identify a substitute non-congested path to the destination. EDOCR improves performance in terms by minimizing routing overhead, delay and improves PDR. Similarly, early congestion detection and adaptive routing (EDAPR) techniques prevent congestion by non-congested two-hop neighbours (NHN).

Dynamic congestion detection and control routing (DCDR) is a unicast routing protocol in MANET which analyses the network dynamically. Whenever a source node needs to send a data packet, a congestion-free set (CFS) of nodes is constructed containing one-hop and two-hop neighbours of source node. The source then starts the route discovery process by applying CFS to know the congestion-free path to the destination. If a CFS is not found owing to the network congestion, then DCDR does not start the route discovery procedure. But, once a new route has been established, the transmission of data packets will resume. It decreases network congestion by minimizing the excessive flooding of packets and identifying congestion-less path among the source and destination. Hence, packet loss and end-to-end delay are reduced and throughput is improved. In this technique, congestion at MAC layer due to buffer overflow is predicted and then the traffic is adapted in the network layer by identifying a non-congested path.

3.3 Mobility based congestion control mechanism

In MANET, Sheeja et al (2013) introduced an effective congestion avoidance scheme (ECAS) to eliminate congestion. The packet loss is large due to the mobility of nodes in MANET. ECAS is a mobility based congestion control method which involves three stages. Initially, congestion status is obtained by complete monitoring. Following this, congestion detection is done based on three factors namely queue length, channel contention and total congestion standard. Finally, a congestion free routing is developed to choose a route from source to destination node. This method provided good throughput, delivery ratio and minimal delay.

3.4 Congestion control using adaptive load balancing

Load balancing in multi-path routing is improved than the single path routing in ad hoc networks, thus decreasing the congestion by distributing the traffic in numerous paths.

Multipath load balancing technique for congestion control (MLBCC) in MANETs was developed by Mallapur et al (2015) to efficiently balance the load among the multiple paths to minimize congestion by executing two main tasks during the transmission procedure. Initially, congestion detection was performed by computing the arrival rate and outgoing rate at a specific time period. Next, a gateway node is chosen using link cost and the path cost to allocate the load efficiently which is achieved by choosing the most optimal paths. No deavailability degree standard deviation parameter is used as a correction parameter for an efficient flow of distribution. This factor prevents the declination of network performance due to insertion of data flow from nodes that are out of the path. The experimental outcome proved significant improvement in average end-to-end delay, PDR and packet drop than ad hoc on demand multipath distance vector (AOMDV) and Fibonacci sequence multipath load balancing protocol (FMLB).

M. Aliet al., (2012) introduced an adaptive multi-path routing protocol for achieving load balancing as well as congestion in MANETs. The multi-path route finding algorithm is based on Scalable Multi Path On Demand Routing protocol (STORM). It calculated many fail-safe paths, which provided all the intermediate nodes on the prime path with many routes to receiver node. The fail-safe paths are comprised of the nodes with minimum load and high bandwidth and residual energy. Whenever the average load of a node along a route exceeds a certain threshold or the on-hand bandwidth and remaining energy of the node reduced below a threshold limit, it allocates the traffic to many fail-safe routes to minimize the traffic load on a congested link. The simulation results demonstrated that the algorithm performed better than the conventional congestion control mechanism in terms of throughput and PDR and minimizes delay for CBR traffic [1].

In order to handle the bandwidth and delay necessities of real time traffic, rate control is performed at every node in a decentralized manner. The rate control mechanism helps in better utilization of bandwidth at network level. The rate of all best effort traffic and real-time traffic distributed across each channel is persistent below a specific threshold, for reducing the avoidable delay.

Soundararajan et al., (2012) presented a multipath load balancing and rate based congestion control (MLBRBCC) mechanism for MANET. To regulate the traffic rate in the network, the algorithm applies two methods namely, rate estimation and rate control. Initially, the node at source end sends the data packet to the node at the receiving end through intermediate nodes. On receiving the data, the channel utilization and the queue length are determined at every intermediate node according to which congestion status and estimated rate are determined and this information is sent as feedback to source node. The sender node carries out the rate control according to the estimated rate in the feedback packet. The outcomes of the simulation proved that MLBRBCC provide low end to end delay and better PDR values.

3.5 Mobile agent based congestion control mechanism

Sharma and Bhadauria (2012) presented a mobile agent based congestion control mechanism in AODV to alleviate congestion in ad-hoc network. Mobile agents were added in ad-hoc network that contain routing information and nodes' congestion status. The mobile agent traverses through the network and chooses a neighbouring node with minimal load as its next hop. Then, updation of routing table is carried out according to the node's congestion status through the mobile agents. Thus, the nodes obtain the dynamic network topology in time. This technique provided high delivery ratio and throughput and minimal delay.

Uthariaraj (2013) presented congestion detection and recovery technique where the congestion status of the nodes is calculated based on the factors like data rate, queue length and medium access control (MAC) contention. Then, it is compared with the maximum and minimum limit of these factors and the node congestion status is distinguished as normal, medium or high level. Whenever data needs to be sent, the intermediate nodes between sender and receiver node verify their congestion status. If the congestion status of a particular node is more or congestion status of more than one node is medium, an alert message is sent to the sender. The sender then chooses an alternate congestion less path for data transmission. The network simulation outcome revealed that congestion detection based route recovery technique minimizes the packet drop and delay while increasing the packet delivery ratio in presence of high traffic loads.

3.6 Cross layer approach based congestion control technique

Kamatam and Srinivas (2012) developed Stratified Cross layer Congestion Control and Endurance Routing (SC3ERP) protocol which is a route discovery algorithm, was developed from proactive routing protocol DSR. In this protocol, the congestion control mechanism is divided into three methods. The first part tackles congestion due to contention, congestion due to buffer overflow is handled by second method, and third method handled the link failure congestion. Congestion due to buffer overflow is resolved by controlling it at predecessor path node level. The failure of this node level is addressed by implementing at cell level and then at the network level. This consecutive procedure reduced the cost of energy and utilization. Node level path restoration used in congestion control technique supports induced data transfer against severe congestion due to contention and link failure. The packet overhead is reduced, however MAC overhead is high and path optimality is achieved greater.

Thilagavathe and Duraiswamy (2011) introduced a cross-layer oriented method to alleviate congestion at MAC and transport layer of MANET. The proposed technique was applied over Ad hoc on demand Multipath Reliable and Energy Aware QoS Routing Protocol (AOMP-REQR). This method employed additive increase and multiplicative decrease (AIMD) for rate based congestion control of transport layer protocol. At the transport layer, if the received packet rate is greater than the threshold limit, then the source reduces the sending rate. In MAC layer, if the expected received power at a particular time exceeds an exponential average received signal energy, then the signal interference is indicated and the link is predicted as congested. Whenever the source obtains congestion status details from MAC and transport layer concurrently for the same path, then congestion less path is found for transmitting data without doing the rate control procedure. The simulation results revealed that packet drop is low and delay is minimized.

4.COMPARATIVE ANALYSIS

To eliminate network congestions, numerous researchers have suggested many techniques. Some of them are based on the use of Active queue Management (AQM) strategies. The key idea behind this is to offer a buffer in the network to control or eliminate the issues arising due to possible congestions. There are certain solutions which are based on load balancing concept. Other techniques are based on TCP based solutions. However, most of the researchers focused on congestion control mechanism based on load balancing techniques.

Table 1: Comparative analysis of various congestion control mechanisms

Research work	Congestion Technique used	Parameters analysed	Conceptual Idea
Sharma, A and Pawar, K. (2016)	CRAODV	Improved PDR, low packet loss, less routing load	Based on rate control and resource allocation
Sunitha, et al., (2014)	TCP based congestion control mechanism	Improved throughput, and delivery ratio. Reduced delay.	Based on channel occupied ratio (COR) and received signal strength.
Mallapur et al (2015)	Multipath load balancing technique for congestion control (MLBCC)	Improved average end-to-end delay and PDR. Reduced packet drop.	Congestion detection based on arrival rate and outgoing rate, node availability for flow distribution
Kumar and Singh, (2014)	TCP Congestion Control and AODV routing	Improved throughput, packet delivery ratio, low end-to-end delay and overhead than the normal TCP based AODV routing.	Based on queue length and traffic rate
Simaya et al (2014)	Improvement of RED (IRED)	Low packet loss	Active Queue Management(AQM)

Uthariaraj (2013)	congestion detection and recovery technique	Minimizes packet drop and delay, improves packet delivery ratio at high traffic loads.	Based on data rate, queue length and medium access control (MAC) contention
Sreenivas et al (2013)	L2DB-TCP	Delay variation is less	Based on bandwidth and delay
S. Sheeja et al (2013)	Effective Congestion Avoidance Scheme (ECAS)	Improved throughput, PDR, less delay and less routing overhead	Based on queue length, channel contention and total congestion standard
Senthilkumaran &Sankaranarayanan,. (2013)	Dynamic Congestion Detection and Control Routing(DCDR)	PDR is high, Low delay, low routing overhead	Based on queue-status
Soundararajan, and Bhuvaneswaran (2012)	Multipath Rate Based Congestion Control technique	Throughput and PDR improved.	Based on traffic rate
Senthilkumaran, &Sankaranarayanan, (2013).	Early Congestion Detection and Adaptive Routing(EDAPR) in MANET	Minimal end to end delay, less routing overhead, better PDR	Based on queue-status
Ali et al., (2012)	Congestion adaptive multipath routing for load balancing	Improvement in throughput and PDR minimization of delay for CBR traffic	Based on load, bandwidth and residual energy
Sharma and Bhadauria (2012)	Mobile agent based congestion control mechanism in AODV	High delivery ratio and throughput and minimal delay.	Based on minimal load
Kamatam, and Srinivas (2012)	SC3ERP	Packet overhead reduced, MAC overhead increased, path optimality is high.	DSR based cross layer approach.
Thilagavathe and Duraiswamy(2011)	Cross-layer oriented method.	Reduced packet drop and delay.	Rate based method.

5. RESULTS AND CONCLUSION

In mobile ad hoc networks (MANETs), congestion happens in nodes owing to restriction in resources, when data packets are transmitted from the sender node to receiver node. Congestion in networks results in packet loss, delay and wastage of resources and time. Congestion control is a technique which minimizes the congestion incurred in network due to several reasons. Numerous congestion control mechanisms were proposed based on different concepts like load balancing based on traffic rate, signal strength, residual energy, etc. This paper reviewed the recent congestion control methods proposed for MANETs at different layers. A comparative analysis is provided highlighting the basic concept used and parameters improved.

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