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A Review of Congestion Control Techniques in Mobile Ad-hoc Network

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Abstract- A mobile ad-hoc network (MANET) is a temporary network that can change locations and configure itself on the fly. MANETs use wireless connections to connect various networks. The mobility and the easy use of mobile devices have motivated researches, to develop MANET protocols to exploit a reliable data transmission facilities provided by the mobile nodes. There are number of issues such as medium access control, routing, resource management, congestion control and power control which affects the reliability of secured communication in MANET. Due to the dynamic network topology, congestion control is an important issue in MANET. Congestion can occur in any intermediate node often due to limitation in resources, when data packets are being transmitted from the source to the destination nodes. The occurrence of congestion results in high data loss, long delay and waste of resource utilization time between mobile nodes. Hence the congestion control technique for detecting and overcoming of congestion is an important research work in MANET. The primary goal of congestion control is the maximum utilization of resources and keeps the load below the capacity. There are several techniques have been proposed for detecting and overcoming congestion in the MANET. This research paper reviews the various proposed congestion control techniques to control congestion in mobile ad-hoc network.

***Keywords*: MANET, Congestion, Congestion Control.**

I.INTRODUCTION

A mobile ad-hoc network (MANET) is a temporary network, where the nodes are arranged whenever necessary. Mobile ad-hoc network is a collection of independent nodes which forms a temporary network without any fixed infrastructure or central controller [8]. Each device in a MANET is free to move independently in any direction. MANET is completely different from other network since it provides various characteristic such as dynamic topology, node mobility and self-organizing capability. MANET provides several advantages which includes low cost, easy network maintenance and convenient service coverage. MANET is used in various applications such as military, virtual classroom, conference, emergency operations, business applications and vehicular ad-hoc network (VANET).

Due to the dynamic topology, the field of MANET is rapidly growing and changing. In a network, many devices sharing a common resource compete for link bandwidth which leads to network overload. To avoid network overload each sender has to adjust its data sending rate. In ad-hoc network each node (mobile device) acts as a router, which helps in forwarding packets from a source to destination. When more data packet arrives at the router, the un-serviced packet gets dropped. The dropped packets have to be retransmitted, which in turn leads to pumping of more packets into the network, resulting in congestion which degrades the network throughput [10].

Congestion may occur in a network, if the load on the network is greater than the capacity of the network [17]. Network congestion can cause many problems such as packet loss, long delay and reduce network throughput. To preserve the packet loss among the nodes from congestion, a congestion control is required which satisfy certain sort of requirements to ensure proper functioning of network capacity and link stability for data transmission from source to destination nodes. The goal of congestion control is to minimize the delay for packet delivery, packet loss and maximize network throughput. Thus the development of an effective congestion control technique for detecting and controlling the congestion in MANET is an important research work to establish a reliable communication between nodes in correct time with minimum overhead and maximum network throughput. However, development of a congestion control technique for MANET has been a challenging task due to the various characteristics of MANET such as: dynamic change in the network topology because of mobility of nodes, resource constraints, limited bandwidth and limited battery power. The various techniques that are used to control congestion are exponential back off, TCP congestion control, priority schemes and queue management techniques.

This research paper reviews various congestion control techniques to achieve a non-congested routing between the mobile nodes in MANETs. The structure of this paper is organized as follows. Section II describes the concept of congestion in MANETs. Section III presents the congestion control in MANET. Section IV concludes this research paper.

II. CONGESTION IN MANET

Secured data transmission is a challenging task in MANET. A secure MANET environment should provide confidentially, integrity, authenticity, availability and non-repudiation. The vulnerabilities that make MANETs highly insecure are: dynamic nature of wireless communication, node security and tampering, limited power in node, congestion control routing and absence of infrastructure. Detecting and controlling the congestion is an important activity to minimize the delay for enabling the network to perform faster data transmission towards the secured communication between mobile nodes.

MANET enables the transformation of information among the multiple disconnected network or mobile users. In MANET each mobile device works as a router and help each other for successfully delivering the data. In real time network environment each link capacity is finite and aggregate demand of the resources may exceed as compared to the available capacity. In such situation, link becomes overloaded and when this happens it becomes congested. This congestion may be permanent or temporary. In case of temporary congestion, packet arrived abruptly in burst. Solution to temporary congestion is possible by providing a considerable buffer space in router for allowing packets for out-bound link to spend short period before being forwarded to next link [14].

Congestion is a situation in MANET, which too many packets are available between sources to destination nodes in a part of the subnet. Congestion is a problem that occurs on shared networks, when multiple users want to access the same resources (bandwidth, buffers, and queues) and demand of this resource become greater than the capacity of network. The intermediate nodes are responsible for forwarding the data packets, if not able to deliver all the packets with the same arrival rate make a queue for storing the packets for short period of time. Thus packets can wait for their transmission between nodes [14]. The congestion can occur based on the various factors such as: (i) when the number of packets send to the network is greater than the number of packets a network can handle (ii) to perform bookkeeping tasks such as queuing buffers, updating tables (iii) when the input traffic rate is equal to or exceeds the capacity of the output lines (iv) when the increase in the resources such as bandwidth increase, traffic splitting over multiple routes. Congestion leads to packet losses, long delay, bandwidth degradation, route failure, node link losses and high overhead in a network [17]. Thus congestion control techniques are required to overcome the problem of congestion in MANET.

III.CONGESTION CONTROL IN MANET

Congestion control concerns the controlling of network traffic to prevent the congestive collapse between intermediate nodes such as packet loss, long delay and waste resource utilization time in MANET. Based on the current load condition of the network, the congestion control is done through controlling the sending rate of data streams of each source which is helpful to prevent congestion and also leads to high utilization of the available bandwidth [14]. A congestion control scheme ensures that the nodes place only as many packets on the wireless channel as can be delivered to the final destination. Congestion control techniques allow controlling congestion by determining the order in which packets are sent out an interface. Congestion control necessitates the formation of queues, allocation of packets to those queues based on the specification and scheduling of the packets. By using congestion control techniques, packets build up at an interface are queued until the interface is free to send them. The router regulates the packet transmission by controlling which packets are placed in which queue and how queues are serviced with respect to each other.

Congestion control refers to techniques that can either prevent or remove congestion. In general, congestion control techniques can be either rate based congestion control or buffer based congestion control [8]. The rate based congestion control algorithms are used during router. The several proposed congestion control research works such as drop tail (DT), random early detection (RED), random exponential marking (REM), BLUE, CHOKe use active queue management techniques (AQM) to eliminate network congestion. AQM technique is a router-based congestion control technique wherein routers notify end-systems of emerging congestion. The main idea behind the AQM is to provide a buffer in the network in order to manage or eliminate the problems arising out of possible congestions [1]. AQM techniques control the congestion by measuring congestion. The two approaches that are used for measuring congestion in AQM are queue based and flow based [12]. In queue based AQMs, congestion is measured by queue size and action is taken by maintaining a set of queues by internet routers. In flow based AQMs, congestion is observed and action is taken based on the packet arrival rate.

The various proposed congestion control techniques in the literature are described as follows:

A. Drop tail (DT)

Rade Stanojevic et al., [13] have proposed drop tail algorithm to avoid congestion for internet. This queue management algorithm sets a predefined value for the maximum length of the queue and when this value is reached, new packets are discarded, until the next vacant buffer space to accept new packets. When using the DT mechanism, all the packets in the traffic are treated identically, regardless of the type of traffic which it belongs to. Packet loss can cause the transmitter to reduce the number of TCP packets sent before receiving the acknowledgment. It also impacts on the efficiency of network bandwidth utilization. The throughput of a given TCP session will then reduce, until the transmitter start again to receive acknowledgments and begin increasing the size of its congestion window. This algorithm allows single connection or few flows to control queue space. The advantage of this algorithm are less packet loss within nodes and suitable for decentralized environment. This algorithm also has the disadvantages such as lack of fairness, less link efficiency and non-responsive flow.

B. Random early detection (RED)

Floyd and Jacobson [7] have proposed random early detection technique to avoid congestion in the network routers/gateways. This algorithm solves the traditional problems of queue management techniques and use probabilistic discard methodology of queue fill before overflow conditions are reached. RED maintains an exponentially-weighted moving average of the queue length which it uses to detect congestion. When the average queue length exceeds a minimum threshold, packets are randomly dropped or marked with an explicit congestion notification. When the average queue length exceeds a maximum threshold all packets are dropped or marked. By detecting incipient congestion early and to convey congestion notification to the end-hosts, allowing them to decrease their transmission rates before queues in the network overflow and packets are dropped. This algorithm helps to prevent the global synchronization in TCP connections sharing a congested router and to decrease the bias against burst connections. This technique is suitable for detecting and responding for long term traffic patterns and not suitable for short term traffic load changes. The advantages of this algorithm are less packet loss and high link utilization. The disadvantage of this algorithm is that it relies on queue length as an estimator of congestion.

C. Robust Random Early detection (RRED)

Changwang et al., [3] have proposed robust random early detection algorithm to detect congestion for long-term traffic patterns. RRED is a queuing discipline for a network scheduler. The RED algorithm and its variants are found vulnerable to the low-rate denial-of-service (LDoS) attacks. The RRED algorithm increases the efficiency of TCP throughput which can significantly improve the performance of TCP against LDoS attacks. The RRED algorithm detects and filters out attack packets at a faster rate than RED. The advantage of this algorithm is to improve the performance of TCP under low-rate denial-of-service attacks and the disadvantage is that it cannot detect congestion caused by short term traffic load changes.

D. Weighted Random Early Detection (WRED)

Cisco [4] has proposed weighted random early detection technique to anticipate and avoid congestion rather than control congestion through queuing strategies. By randomly dropping packets precedence to periods of high congestion, WRED uses the packet source to decrease the rate of its transmission. WRED drops packets built on IP precedence. Packets with a higher IP precedence are less expected to be dropped than packets with a lower precedence. WRED can selectively discard lower priority traffic when the interface begins to get congested and provide differentiated performance characteristics for different classes of service. WRED avoids dropping large numbers of packets at once and minimizes the chances of global synchronization. The advantages of this algorithm are low delay and greater fairness to all flows on an interface. The disadvantage of this algorithm is that it is sensitive to parameter settings.

E. Adaptive Random Early Detection (ARED)

Sally Floyd et al., [16] have proposed adaptive random early detection algorithm to avoid congestion in the network routers/gateways. ARED overcomes the limitations of the RED. ARED configures its parameters based on the traffic load. ARED algorithm avoids congestion based on the observation of the average queue length. ARED changes the probability according to the observation of average queue length. This algorithm maintains a predictable average queue size and reduces RED's parameter sensitivity. The advantages of this algorithm are setting of parameters in response to the altering load, low delay and high link utilization. The disadvantage of this algorithm is the choice of the target queue size to network operators.

F. Fair Random Early Drop (FRED)

Woo-june kim and Bycong Gi Lee [19] have proposed flow random early drop algorithm to control congestion in network routers. This algorithm modifies the RED algorithm. FRED algorithm focuses on the management of per-flow queue length. This algorithm uses per-active flow accounting to make different dropping decisions for connections with different bandwidth usages [2]. FRED uses a global variable to track the average per-active-flow buffer usage. It maintains the number of active flows based on the count of buffer packets. FRED achieves the fairness and high link utilization by share the buffer size among active flows. The cost of FRED is proportional to the buffer size and independent of the total flow numbers since it keeps track of flows that have packets in the buffer. The advantages of this algorithm are: penalizing non-adaptive flows by imposing a maximum number of buffered packets, low bandwidth connection and provide fair sharing for large numbers of flows. The disadvantage of this algorithm is that large number of non-responsive flows.

G. CHOKe algorithm

Rong Pan et al., [15] have proposed CHOKe algorithm to control congestion based on the fair queuing policy. This algorithm investigate the problem of providing the fair bandwidth allocation to each n flows that share the outgoing the link of a congested router. In this algorithm, whenever the arrival of a new packet takes place at the congested gateway router, a packet is drawn at random from the FIFO buffer, and the drawn packet is then compared with the arriving packet. CHOKe algorithm supports the discriminate against the flows which submit more packets/sec than is allowed by their fair share. The advantages of this algorithm are: approximate fair queuing policy, controls misbehaving flows with minimum overhead and high link utilization. The limitation of this algorithm is the lack of fairness when the number of flows is huge when compared to the buffer space and hardware implementation.

H. BLUE algorithm

Debanjan Saha et al., [6] have proposed BLUE to resolve the drawbacks of RED by using the hybrid control approach with queue size congestion measuring scheme. BLUE controls congestion with a minimal amount of buffer size. This algorithm uses flow and queue events to modify the congestion notification rate. This rate is regulated by packet loss from queue congestion and link utilization. BLUE maintains a single probability (P_m) to mark or drop packets. If the queue is continually dropping packets due to buffer overflow, BLUE increments (P_m) and send back congestion notification. Conversely, BLUE decreases its marking probability, if the queue becomes empty or if the link is idle. This allows BLUE to learn the correct rate it needs to send back congestion notification. The advantages of this algorithm are less packet loss, no queuing delay, avoid global synchronization of sources, maintain high link utilization and remove biases against burst sources. The disadvantage of this algorithm is that it permits non-responsive flow.

I. Adaptive virtual queue (AVQ) algorithm

Kunniyur and Srikant [12] have proposed AVQ algorithm to control congestion through virtual queue. Adaptive virtual queue algorithm maintains the capacity of the link and the desired utilization maintains a virtual queue at the link. The capacity and buffer size of the virtual queue is the same as that of the real queue. At the arrival of each packet the virtual queue capacity is updated [9]. When a packet arrives in the real queue, the virtual queue is also updated to reflect the new arrival. Packets in the real queue are marked/dropped when the virtual buffer overflows. The virtual capacity at each link is then adapted to ensure that the total flow entering each link achieves a desired utilization of the link. The advantages of this algorithm are high link utilization; minimize packet loss and minimum delay. The disadvantages of this algorithm are does not suitable for the varying traffic pattern at flow in the network.

J. Dynamic congestion detection and control routing (DCDR)

Senthilkumaran and Sankaranarayanan [17] have proposed dynamic congestion detection and control routing algorithm to detect and control routing in ad-hoc networks. This algorithm detects congestion based on the estimation of the average queue length at the node level. By the assessment of average queue length, a node detects the probability of congestion and sends a warning message to its neighbors. When neighbors received the warning message they try to search the alternative congestion free path to the destination. If the path is available, then predecessor node starts further communication through alternative path. DCDR uses a non-congested path discovery mechanism to prevent network congestion, hence packet loss rate is decreased and by which end-to-end delay is reduced. The advantages of this technique are reduction of delay and improvement in packet delivery ratio. The disadvantages of this technique are:

K. EXACT

Chen et al. [5] have proposed EXACT to control congestion with standard TCP compatibility for MANET environment. EXACT adopts rate based approach and in this technique all the intermediate nodes dedicate itself for monitoring the packet flow through them. These intermediate nodes determine and share the current bandwidth information with their neighbors. When a packet arrives at intermediate node, it checks for the rate information, if the rate is lower than the rate specified, the rate information in the header of the packet is modified before forwarding it. This helps the destination node in updating about the bottleneck rate. This technique is implemented using two different header fields, one field contains the current rate of the sender and the other is the rate requested by the sending application. This technique also helps in managing the flow rate at router and also informs the sender probable increase/decrease its transmission rate. In case of route failure, a safety window prevents the sender from overloading the network. In EXACT there are no retransmission timers, instead it uses SACK scheme. When a packet is not acknowledged by the receiver or if the received acknowledgement sequence number is too apart from the highest acknowledged packet then it is retransmitted.

L. Wireless explicit Congestion control Protocol (WXCP)

Su and Gross [18] have proposed WXCP to detect and control congestion for Wireless Multi-hop Network.

This technique is a window based approach involving rate based element in it. This technique uses multiple congestion metric and explicit feedback within the network. These values are computed at each intermediate node. The three metrics, the local available bandwidth, length of the queue and average number of retransmissions are computed at WXCP enabled intermediate node. The average number of retransmissions is computed to avoid the disturbance caused within the flow. The feedback is a function of relative influence of these three metrics. In this technique separate decisions are taken for congestion fairness control. Fairness controller achieves time fairness among flows rather than throughput fairness.

M. Multi-Agent Routing Protocol

Kazuya NISHIMURA and Kazuko TAKAHASHI [11] have proposed a multi-agent routing protocol to reduce network congestion for MANET. This research work uses two kinds of agents such as routing agents and message agents. These agents are used to store the routing table at each node data and move the data between nodes. In this work, a route is evaluated based on the evaluation function. The limitations of this work are: the identification of positional relationships between source and destination nodes, time frequency for sending packets.

Most of the proposed congestion techniques control congestion with various levels such as routing, TCP and handled the issues related to packet loss, link efficiency and throughput degradation. MANET has limited bandwidth and are more prone to error and also impose limits the amount of data that can be sent between nodes. The limited bandwidth of MANET can cause traffic overload related problems because of unfairness in traffic flow control. Hence a suitable congestion control for MANET is necessary for a stable network with better performance.

IV. CONCLUSION

Due to the dynamic topology, the field of MANET is rapidly growing and challenging. The various issues the needs to be faced by the MANETs are resource constraints, cooperation and congestion for secure communication. In order to carry out the effective communication within a MANET, an efficient congestion control is required to prevent the packet loss and long delay between dynamic nodes. This research paper has given a review of various congestion control algorithms in MANETs. The various congestion controls reviewed in this paper defend against congestion at a certain level with limitations. Hence, further research is needed to develop effective congestion control algorithm to detect and control congestion in MANETs for secured data transmission between mobile nodes.

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