A Review on Congestion Adaptivity and Congestion Aware Routing Protocols in MANET

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Ad-hoc networks are useful for providing communication support where no fixed infrastructure exists and movement of communicating parties is allowed. Mobile ad-hoc network shows unexpected behavior with multiple data streams under heavy traffic load when it is send to common destination. Congestion is one of the most important restrictions of wireless ad-hoc networks. Because of congestion the problems like long delay, high overhead and low throughput occurred. To overcome these problems in certain degree many congestion aware and congestion adaptive routing protocols are proposed. These protocols can greatly improve the network performance. In this paper, we present a survey of congestion aware routing protocols for mobile network.

Keywords:
Mobile ad hoc network, Routing Protocols, Congestion, congestion Adaptability.

I. INTRODUCTION

MANET i.e. mobile ad-hoc network is an autonomous system of mobile nodes connected through wireless links. It does not have any fixed infrastructure .MANET is quite different from distributed wireless LAN and wired network nodes in the MANET keep moving randomly at varying speeds, resulting in continuously charging network topology .So it is quite difficult for any single mobile host to have an accurate picture of topology of whole network .Nodes in the ad-hoc network serves as routers as well as hosts. So, they are able to pass packets for other nodes if they are on route from source to destination .Routing is important problem in wireless ad-hoc network because of limited bandwidth, low device power, dynamic network topology etc. One of the major technological challenges of such routing protocols are classified as *proactive* or *reactive* depending upon whether the keep routes continuously updated or whether they react on demand. Demand approach is more efficient in that route discovery is there only when needed for transmission and released when transmission no longer takes place. Mobile ad-hoc network shows unexpected behavior with multiple data streams under heavy traffic load such as multimedia data when it is send to common destination. The main reason for packet loss, protocol overhead, and delay to find new route in MANET is due to congestion. So, In order to deal with all these issues, the routing in MANETs needs to be congestion adaptive due to these problems service quality is affected. So, to address these issues in present scenario many congestion aware routing protocols are there. In this paper we studied congestion aware protocols like CRP(Congestion Adaptive Routing Protocol)[7], CARP (Congestion Aware Routing Protocol) , CADV (Congestion Aware Distance Vector) [11], CARA(Congestion Aware Routing plus rate Adaptation) [11] ,CARM(Congestion Aware Routing Protocol for Mobile Ad-hoc Network) [11], QMRB(QoS Routing with traffic distribution) [12] , CARE(Congestion Aware Scheduling Algorithm)[10]. The remaining part of the paper is organized as follows: In section II we provide the studied congestion aware routing protocols. In section III comparison between these algorithms is presented. In section IV we concluded the paper.

II. ALGORITHMS

There are many routing algorithms in mobile ad-hoc networks for routing and congestion free networks. Some of them are explained below:

A. Congestion Adaptive Routing Protocol (CRP): Congestion Adaptive Routing is a congestion adaptive unicast routing protocol for mobile ad-hoc network.CRP protocol tries to prevent congestion from occurring in the first place. In CRP, every node appearing on a route warns its previous node when prone to be congested. So, CRP uses the additional paths called as “bypass” for bypassing the potential congestion area to the first non congested node on the primary route. It reduces packet delay. But, at the same time CRP tries to minimize bypass to reduce protocol overhead. Hence, the traffic is split over bypass and primary and adaptively to network congestion. Hence, 1) power consumption is efficient.2) Congestion is resolved beforehand and at the same time there is small packet loss rate. CRP is on-demand and consists of the following components. *1) Congestion Monitoring:* When no. of packets coming to

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the node exceeds its carrying capacity, node becomes congested and its starts losing packets. Various metrics are used for node to monitor congestion status. Main parameters are percentage of all packets discarded for lack of buffer space, the average queue length, the no. of the packets timed out and retransmitted, average packet delay. In all these parameters, rising number indicates growing congestion.

TABLE I. SPLITTING PROBABILITY ADJUSTMENT

Congestion	Bypass status=green	Bypass status=yellow	Bypass status=red
Next primary node is green	P:=p+(1-p)/4	P:=p+(1-p)/3	P:=p+(1-p)/2
Next primary node is yellow	P unchanged	P unchanged	P:=p+(1-p)/4
Next primary node is red	P:=p-(1-p)/2	P:=p-(1-p)/4	Find another bypass

2) Primary Route Discovery: Sender discovers the route to the receiver by broadcasting the REQ packet toward receiver. The receiver responds REQ by sending the REP packet on same path that the REQ previously followed. This is called primary route and nodes on this are called primary nodes. To reduce traffic due to the primary route discovery and better deal with

Congestion in the network, 2 strategies are adopted 1) REQ is dropped if arriving at a node which is having congestion status as “red” 2) REQ is dropped I arriving at node already having a route to destination .

3) Bypass Discovery: A primary node periodically broadcasts a UDT i.e. update packet. This packet contains the nodes congestion status and set of tuples [destination D, next green node G, distance to green node, n] for each node appearing as a destination in primary table. For this reason is when node P receives an update packet from next primary node $P_{next,}$ about the destination D, P will be aware of congestion status of next. This causes the congestion to know about the next green node of P which is n hops away from primary route. But if the next hop is yellow or red, congestion will be there if data packets continue to be forwarded on $P \rightarrow P_{next}$. But, CRP tries to keep congestion from occurring in the first place, P node starts to select bypass route toward G-the next green node of P known from the UDT packet. This bypass search is similar to primary route search, except that 1)the bypass request packet’s TTL is set to 2*m and 2)bypass request is dropped if arriving at node already present on primary route. It can be also possible that no bypass is found. So, in such situation packets are delivered to destination by following primary route.

4) *Traffic Splitting and Congestion Adaptability:* When the bypass at a node is found, data packets coming to this node are not necessarily spread over bypass and primary route. To avoid the bypass from being congested no packet is forwarded on bypass unless any primary node is red i.e. congested. The basic idea behind traffic splitting is that when primary link consists of less congested node, traffic on primary link should be increased, otherwise it should be reduced. Bypass and primary routes cannot include more than 2 common nodes, but different bypass paths can share common node. This increases chance to discover a bypass. But, because of this bypass node may become congested if it has to carry large loads of bypass traffic. But, this can be solved, by splitting probability adjustment for congestion adaptation. The probability adjustment is as shown in TABLE I.

5) *Multipath Minimization:* To reduce the protocol overhead, CRP tries to minimize using multiple paths. If the probability p to forward data on a primary link approaches 1.0, this means the next primary node is far from congested or the bypass route is highly congested. In this case, the bypass at the current node is removed. Similarly, if the next primary node is very congested (p approaches 0), the primary link is disconnected and the bypass route becomes primary. To make the protocol more lightweight, CRP does not allow a node to have more than one bypass. The protocol overhead due to using bypass is also reduced partly because of short bypass lengths. Each bypass connects to the first non-congested node after the congestion spot, which should be just a few hops downstream.

6) Failure Recovery: CRP is able to quickly resume connectivity after a link breakage by using bypass routes currently available. There are 3 min cases of failure

Primary link failure: When one of link on primary route fails, the initial node sends a DISC packet towards sender along route. This DISC goes on recording nodes and it stops at node having bypass. This node if finds that its bypass destination is there in DISC, that bypass is not used and DISC is forwarded upstream towards sender till it finds a node with bypass and not having failed node as its destination. If both these cases are not there DISC is sent to the sender and it will find new primary route.

Bypass link or node fails: In this case bypass node which finds this failure sends a BPS_DISC packet through bypass route to primary node and that bypass is removed.

Primary node fails: If node on the primary route fails, its previous node sends DISC packet along primary route. If the bypass node detects some failure, it will also send BPS_DISC packet along bypass until reaching a primary node. When primary node received both these packet, it removes bypass and DISC packet is forwarded along primary route. Then this is handled same as first case. If BPS_DISC packet doesn't arrive at the primary node on time that bypass is used as primary route. But, if it comes late, it is ignored. But, route remains broken but it will recover soon because another DISC packet will be sent back.

To evaluate the performance of the CRP following parameters are used:

Packet delivery ratio: Percentage of data packets received at the destination out of the number of data packets generated by the CBR traffic sources.

End-to-End delay: It is the accumulative delay in data packet due to buffering of packets, new route discoveries, queuing delay, MAC-layer re-transmission, and transmission and propagation delays.
Routing Overhead: The ration of the amount in bytes of control packets transmitted to the amount in bytes of data received.
Normalized power consumption: The ratio of the amount in bytes of both control and data packets transmitted to the amount in bytes of data received.

B. Congestion aware routing plus Rate Adaptation (CARA):

The base use of CARA protocol is DSR. The route discovery mechanism of DSR is modified. This protocol mainly aims to find the bypass route for congested zones or nodes. This can be achieved by combining the average MAC utilization and the instantaneous transmission queue length to indicate the congestion level of nodes in the network. When source wants to transmit data to the destination node, it broadcasts RREQ packets. When intermediate code receives RREQ, it checks its congestion level. If the congestion level is higher than it discards the RREQ. When RREQ arrives at the destination node, though destination node is congested or not it handles the RREQ and replies RREP. So, route without congested node is established.
CARA uses two metrics to measure congestion information first is average MAC layer utilization. The instantaneous MAC layer utilization is considered as 0 only when the medium around the node is available at the beginning of a transmission and as 1 when the node is not idle. (e.g. detecting physical carrier or detecting or back off due to virtual carrier sensing.) As, the instantaneous MAC layer utilization is either 1 or 0 the average value with in the period indicates the use of wireless medium around the node.
Second metric used is instantaneous transmission queue length. If the node has many packets waiting in the queue, it causes long packet latency or even dropping of packets. So we can say that node is congested now.
The above mentioned metric can veraciously reflect the congestion conditions around the node. This protocol tries to minimize the congestion in two ways: 1) It forbids the RREQ packets to propagate in the congested area. 2) It guides the route around the congested area or nodes instead of across them.
As a result of this no conditional transmission burden generate in these areas.

C. Congestion Aware Routing protocol for Mobile ad hoc networks (CARM):

A congestion aware routing protocol for mobile ad hoc networks uses a metric incorporating data rates, MAC overhead and buffer delay to control the congestion. The CARM protocol introduces a new parameter called WCD (Weighted Channel Delay) to measure congestion level and adopts a route ELDC(Effective link Data-rate Category) to avoid the MDRR(Mismatched data-rate route) problem. The MDRR problem is shown in following fig.3

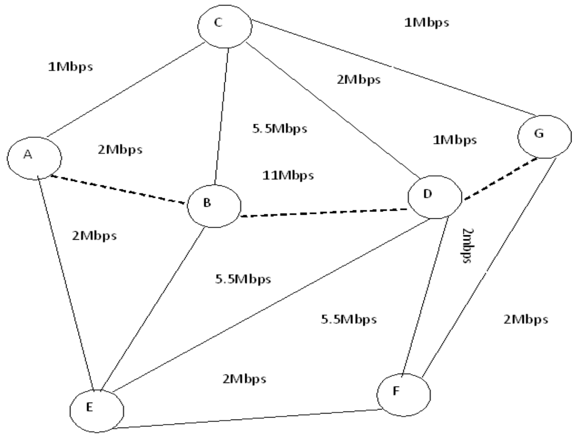

Fig. 3 An example of MDDR problem

The data rate of route shown by dashed (A-B-D-G) is limited by teaming fast link (B-D) with slow link (A-B and D-G).

As mentioned earlier, the CARM protocol introduces a new parameter called WCD (weighted channel delay) to measure congestion and it is given as

$$WCD=a\ \Sigma\tau Q + (1+b)T_{MACALL}+T_{data}$$

where Q is the number of buffered packets for this link. $T_{data}=L_{data}/\ R$ is the data transmission time, L_{data} is the length of data in bytes or bits and R is the data rate of the link. T_{MACALL} is total time spent at the MAC layer. The constants a and b are parameters with values between 0 and 1 which are used to weight T_{MACALL}. By weighting T_{MACALL} can avoid misjudgment of congestion as shown in fig.2

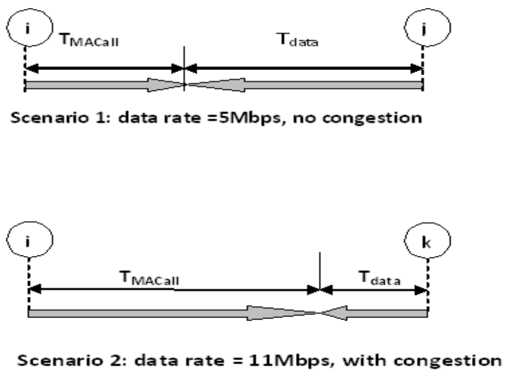

Fig. 2 Two scenarios with the same overall delay but different MAC and transmission delay due to different data-rates and congestion levels.

In CARM, source node broadcasts RREQ packets with ELDC and WCD information when it attempts to transmit data to the destination. Intermediate nodes compare source ID, source sequence, and ELDC of the RREQ packets they receive from neighbors, and drop the RREQ packets whose source ID and source sequence number are the same with that of other RREQ packets received earlier and ELDC is lower than the earlier RREQ packets'. Only the destination node can responds to the RREQ packets by sending RREP packets back to the source along the route from which they came. The route is established when the first RREP arrives at the source. The subsequent RREP packets are cached for the spare routes. The utilization of the congestion metric, WCD, is very special in CARM protocol. Because the priority of route packets is higher than data packets, the route packets can be forwarded without queuing. That is, the congestion level information inherent in queuing delays is lost. The author proposed a RREQ-delay scheme. An RREQ is forwarded with a delay of the WCD that is calculated according to the WCD information in the RREQ at the intermediate nodes. The lower the congestion level of link is, the smaller the delay of RREQ packets are, the earlier the RREQ packets arrive at the destinations. This scheme ensures that the RREQ packets of routes with lower congestion level arrive at the destination first and congested links are eliminated in the routes. This all causes high overhead. So, overhead in case of CARM is very high.

D. Congestion-Aware Distance Vector (CADV):

The CADV protocol is based on proactive protocol, DSDV. In a distance vector routing protocol, every host maintains a routing table contains a distances from itself to possible destinations. A mobile host in ad -hoc network acts like a single server queuing system. Delay in sending packet is related with congestion. In CADV, each entry is related with delay expected. This helps to measure congestion at the next hop. The expected delay is computed follows:

$$E[D] = \frac{\sum D_i}{n} L \qquad (1)$$

Where n is the number of sent packets & L is the length of MAC layer packet queue. *E [D]* estimates the time. A newly arrived packet has to wait before it is sent out. In CADV, routing decision is made based on distance to the destination as well as the expected delay at the next hop showed in (1) CADV gives the routes with low expected delay, higher priority. CADV tries to avoid congestion and tries to balance traffic by giving priority to a route having low expected delay.

CADV routing protocol consist of three components:
1) Traffic Monitor: It monitors traffic going out through the link layer. Currently it keeps track of average delay for sending one data packet in receipt period of time. Time period is specified by route maintenance component.
2) Traffic Control: It determines which packet is the next to send or drop. It reschedules packets if needed. It supports a drop tail FIFO queue and provides functionality to queue packets.
3) Route maintenance: It is the main component. It performs the work of exchanging information with neighbors, evaluation and maintaining routes. It manages the traffic monitor and traffic control component.

CADV better supports for QoS. The real time performance of CADV is good, and end to end delay was short. The over head of CADV is unacceptable when the network is large. Through put also decreases the performance of CADV is may be well in the small & steady wireless ad-hoc network.

E. QMRB
This protocol presents a new approach called quality of service mobile routing backbone over AODV for supporting QoS in mobile ad hoc networks. The mobile routing backbone (MRB) dynamically distributes traffic within the network and selects the route with the best QoS between a source–destination pair Nodes in real-life

mobile ad hoc networks are heterogeneous and have different characteristics. Based on these characteristics, our solution classifies nodes in a MANET as either QoS routing nodes (QRN), simple routing nodes (SRN) or transceiver nodes (TN). QRNs possess QoS guarantees, SRNs simply route packets through the network while TNs send and receive packets but cannot relay them. The MRB is formed by these different types of nodes while it is not essential that all nodes in the network join the MRB. Nodes not joining the MRB may still communicate with it through a working link. Node classification for the MRB is computed by the four QoS support metrics (QSMs) for each pair of nodes.

Static resources capacity (SRC): This is computed by the weighted sum of the size of the node packet queues, speed of the CPU, power of the battery and the maximum available bandwidth.

Dynamic resources availability (DRA): It indicates the current load in the resource usage of a node. The usage rates of the static resources are used to calculate the available dynamic resources.

Neighborhood quality (NQ): It is the number of nodes in the neighborhood of a node which can successfully forward packets

Link quality and stability (LQS): It is the power of signal received and the statistical stability of its links.

The node aptitude is computed based on the node classification by following the formula:

$$MN_{aptitude} = \mu SRC + \acute{\eta}\, DRA + \text{б}NQ + \omega LQS + \Phi BW$$

Where: - μ, ή, б, ω and Φ are coefficients BW is the available bandwidth.

Once the MRB is set up, route discovery is initiated using RREQs along the MRB. The main advantage of QMRB is a better use of the available bandwidth by distribution the traffic through the network and by reducing the number of control messages needed to establish a route from a source node to destination node.

F. Congestion Aware Scheduling Algorithm for Manet (CARE)

Mobile ad-hoc network scheduling algorithm differs significantly from traditional wireless network. In MANET, when a node has data packets for transmission, it need to observe its own queue as well as neighbor's. Here is given a detailed description of scheduling scheme and its implement with AODV routing protocol. Investigation is currently on AODV, but the scheme is general in nature and it can be easily extended to fit other routing protocols.

1) Congestion Indicator: In MANET, because of the dynamic changing of topology and scarceness of bandwidth, the scheduling algorithm should response to the change as soon as possible. So we choose load information as congestion indicator, which is defined as the ratio of periodically measured arrival rate (input) and service rate (output):

$$LOAD = \frac{\text{Input rate}}{\text{Output rate}}$$

2) Scheduling Table: For all passing flows, each node maintains a scheduling table (ST) that contains the information about their load and priority. The highest priority flow is the one whose next hop node has the lowest load. Each entry of the ST is associated with a unique flow, sorted according to their priority in descending order. Each ST entry consists of the following fields: Flow_id, Dest_node, Load, Priority and Time-stamp. Flow_id is the id of the current flow. Dest_node is the id of the next hop node to which the flow will be sent. Loads reflect the neighbor nodes' congestion degree, which is computed by the original node according to expression (3). The priority field presents the priority value of the flow, which is mainly determined by load information. The Time-stamp records the flow's arrival time. The Load field is an important parameter used for calculating the priority of a flow that has entries in the ST of the node. Hence, a node needs to keep track of the load information of all neighbor nodes. This is achieved by means of a feedback mechanism.

3) Scheduling Scheme: Every incoming flow is assigned an id and related to an entry in ST. At the beginning of every frame, the scheduler firstly classifies the incoming flows according to their next hop address and then sorts them in descending order according to their priority values in ST. During each frame, the scheduler picks packets and inserts them into the output queue from high priority flows to low priority ones. The node will update the priority of all the flows at the end of each frame, which can be achieved by part of the route protocol.

We modify the format of RREQ and RREP messages. There is one field to taking load information added in both RREQ and RREP.

The modified RREQ format is:

<source_addr, source_sequence_#, broadcast_id, dest_addr, dest_sequence_#, hop_cnt, Load>

The modified RREP format is:

<source_addr, dest_addr, dest_sequence_#, hop_cnt, lifetime, Load>

When a node initiates a route discovery in the first time, it will broadcast its load information to its neighbors by the RREQ message. Accordingly, neighbor nodes that receive such load notification will create a new entry in their STs for the node. If a node has already been a part of active route, load information can be transmitted by HELLO message. A node offers connectivity information by broadcasting local hello which is implemented by RREP. By this means, the load information can be broadcasted to its neighbors. When receiving HELLO message, the neighbor node initiates a feedback, through which the information about its load can be conveyed to the source. During the frame, if one node doesn't receive any message from its neighbors, it will delete those neighbor s' entry in its ST. Because the routing packets are very important for the connectivity of network and they contain the load information, we still give them high priority over data packets in the same class. If two different flows have the same priority, we schedule them in FIFO order. When the buffer is full, the packets belonging to the lowest priority flow are dropped first to make room for high priority flows packets.

Scheduling Algorithm: Router side: Initiate scheduling table

At the beginning of each frame

1. Classify the flows according to the next hop address
2. Schedule packets according to the Rules

At the end of each frame

1. Send Load Requests to neighbors
2. Update the scheduling table

Neighbor side

1. Compute its load according to expression load=input rate/output rate
2. Notify its load information to previous hop node.

III. COMPARISONS

Congestion is a dominant reason for packet drops in ad hoc networks.CRP sends packets on both bypass paths and primary routes simultaneously. So, incoming traffic is distributed on primary and bypass route depending on current congestion status of network. Congestion is subsequently better resolved. QMRB, as compared with AODV and DSR outperforms both protocols in packet delivery ratio. The main benefit of QMRB is that it makes better use of available bandwidth by distributing traffics through the network and by reducing the number of control messages needed to establish path from a source to destination when compared with AODV. CADV is not congestion adaptive. It offers no remedy when the existing route becomes heavily congested. So, CADV improves AODV in delivery ratio only. The real time performance of the CADV is good and the End-to-End delay is short. The disadvantage of the CADV is that since, each node maintains all the routes to the nodes in the network and changes the route information periodically, the overhead for maintaining the routing tables is huge. The overhead of the CADV is unacceptable when the network is large or the topology changes frequently. The throughput decreases sharply at the same time. So, CADV may perform well in the small, steady wireless ad -hoc network. By studying the algorithms of CARM, CARA and CADV it is conclude that overhead of the CARM and CADV are higher than CARA, the delay of CADV is shorter than the other two. CARE gives priority to help constructing routes when the network is not congested. CARE can also helps to decrease the arrival rate at the congested node and balance the load among network.

IV. CONCLUSION

In today's era of wireless mobile ad hoc network congestion is the main cause because of which the performance of wireless ad hoc network deteriorates. For building the promising features for ad hoc connections the congestion aware routing protocols will play vital role. So, here we tried to study congestion aware routing protocols which will help to relive the influence caused by congestion in mobile Ad-hoc network.

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