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A Study of Congestion Aware Adaptive Routing Protocols in MANET

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Abstract

Routing protocols for mobile ad hoc networks (MANETs) have been explored extensively in last few years. Much of this work is targeted at finding a feasible route from a source to a destination without considering current network traffic or application requirements. Routing may let a congestion happen which is detected by congestion control, but dealing with congestion in reactive manner results in longer delay, and unnecessary packet loss and requires significant overhead if a new route is needed. Routing should not be aware of, but also be adaptive to, network congestion. Adaptation to the congestion helps to increase both the effectiveness and efficiency of routing. These problems are solved by the congestion-aware routing protocols in certain degree. These protocols which are adaptive to congestion status of mobile ad-hoc network can greatly improve the network performance. In this paper, we present the survey of congestion adaptive routing protocols for mobile ad-hoc network. Finally, the future direction of congestion-aware routing protocols is described.

Keywords: Ad hoc networks, congestion aware routing, Congestion metric, congestion adaptability

1. Introduction

Wireless ad-hoc network is usually defined as a set of wireless mobile nodes dynamically self organizing a temporary network without any central administration or existing network infrastructure. The node in the wireless ad-hoc network can serve as routers and hosts. So, they can forward packets for other nodes if they are on route from source to destination. Routing is important problem in wireless ad-hoc network. Traditional working protocols cannot work well in wireless ad-hoc network because of the characteristics of the wireless ad-hoc networks. Since, mobile nodes have limited transmission capacity they mostly intercommunicate by multihop relay. Multihop routing is challenged by limited wireless bandwidth, low device power, dynamically changing network topology, high vulnerability to failure. To answer these challenges, many routing algorithms in MANETs were proposed. There are different dimensions to categorize them: proactive routing Vs reactive routing or single path routing Vs multipath routing. In proactive protocols, route between every two nodes are established in advance even though no transmission is in demand. In reactive protocols, route is discovered when needed transmission and released when transmission no longer takes place. Congestion is one of the most important restrictions of wireless ad-hoc network. It may deteriorate the performance of whole network. In the current design routing is not congestion-adaptive. Routing may let the congestion happen which is detected by congestion control. But dealing with congestion in reactive manner results in longer delay and an unnecessary packet loss and requires significant overhead if the new route is needed. But, now there is another dimension for categorizing for routing protocols: congestion adaptive Vs congestion un-adaptive routing. Our motivation is that congestion is dominant cause for packet loss, long delay, and high overhead in MANETs.

These problems become visible in large scale transmission of traffic intensive data such as multimedia data where congestion is more probable and negative impact of packet loss on the service quality is of more significance. In this paper we studied congestion routing protocols like CRP(Congestion Adaptive Routing Protocol)[7],ECARP (Efficient Congestion Adaptive Routing Protocol)[11],CARP(Congestion Aware Routing Protocol),CADV(Congestion Aware Distance Vector)[12],CARA(Congestion Aware Routing plus rate Adaptation)[12],CARM(Congestion Aware Routing Protocol for Mobile Ad-hoc Network)[12].

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.

2. Algorithm

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

2.1 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.

2.1.1 Congestion Monitoring

When no. of packets coming to 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.

2.1.2 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 .

2.1.3 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.

2.1.4 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.

2.1.5 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.

2.1.6 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

2.1.6.1 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.

2.1.6.2 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.

2.1.6.3 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.

2.2. An Efficient Congestion Adaptive Routing Protocol for Mobile Ad Hoc Networks (ECARP):

An efficient congestion adaptive routing protocol is better than every other routing protocol during heavy traffic loads. The ECARP, routing protocol ensures high availability of alternative routes and reduce the rate of stale routes. ECARP is having mainly AODV as its base. This can be achieved by increasing the parameters of routing protocols (especially in AODV) that normally take more time for link recovery. These parameters are active_route_time-out, route_reply_wait_time, reverse_route_life, TTL_start, TTL_increment, TTL_threshold and delete_period.

ECARP Congestion Control Algorithm

This algorithm provides solution to improve routing protocols due to constrained environment.

Step 1: Check the occupancy of link layer buffer of node periodically. Let N_c be the congestion status

estimated.
Step 2: Compute N_c =*Number of packet buffered in buffer/Buffer Size*
Step 3: Set the status for congestion. It can be indicated by three statuses "*Go*", "*careful*", and "*Stop*".
["*Go*" indicates there is no congestion with $N_c \leq ½$], "*carefull*" indicates the status likely to be congested with $½ \leq N_c \leq ¾$ and "Stop" indicates the status already congested, $¾ \leq N_c \leq 1$.]
Step 4: Invoke congestion control routine when link failed event has occurred in data transfer with using active route or $¾ \leq N_c \leq 1$.
Step 5: Assume that neighboring will have alternate route or non-congested route to the destination.
Step 6: Make Query to non-congested neighbors for route to destination
Step 7: after obtaining the routes from the neighbors, select route with minimum hops.
Step 8: Once route is finalized start sending the data packets through non-congested route.
Step 9: If there is no alternative route to destination then start splitting the traffic to the less congested route.
Step 10: Traffic splitting effectively reduces the congestion status at the next main node.

2.3. 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.

2.4. 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.1
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

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

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

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.

2.5. 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:

$$E[D] = \frac{\sum Di}{n} L \tag{1}$$

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 send 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 maintainance 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 maintainance: 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 support 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.

2.6. Congestion Aware routing Protocol (CARP)

CARP is an on-demand routing protocol. It uses information gathered from MAC layer to discover congestion free routes. CARP uses combined weight matrix in its standard cost function to check for the congestion level. The multiple paths are computed during the route discovery. Calculate node weight matrix *NM* which assign a cost to each link in the network and select maximum throughput paths.

$$NM = (L_q * D_{rate})/(OH_{mac} * D_{avg})$$

1) *Route request*: Consider the route

$$S\text{-}P1\text{-}P2\text{-}P3\text{-}D$$

To initiate congestion-aware routing discovery, the source node S sends a RREQ. When the intermediate node P1 receives the RREQ packet, it first estimates all the node weight metrics.

The node P1 then calculates its node weight NMP1

$$RREQP1 \rightarrow P2$$

P2 calculates NMP2 and forward the RREQ packet

$$RREQP2 \rightarrow P3$$

Finally the RREQ reaches the destination node D with the sum of node weights

$$RREQP3 \rightarrow D$$

2) *Route Reply:* The destination node D sends the route reply packet RREP along with total node weight to the immediate upstream node P3

$$RREQD \rightarrow P3$$

Now P3 calculates its cost C based on the information from RREP as

$$CP3= (NM_{p1}+NM_{p2}+NM_{p3})-(NM_{p1}+NM_{p2})$$

By proceeding in the same way, all the intermediate hosts calculate its cost .On receiving the RREP from all the routes, the source selects the route with minimum cost value.

3. 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 .In ECARP some parameters of AODV such as TTL_start, TTL_increment are increased. So, it ensures the high availability of alternative routes and reduces the rate of broken rut removal process. 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.

4. CONCLUSION

It is clear from algorithms available for having adaptive solution for congestion in the network as due to vast pay load on networks, which may be due to flooding of packets or may be due to repeat requests on the basis of error correction techniques. Congestion metrics still remains a great challenge for the future work. It is quite important to obtain an optimal approach that combines related parameters collected from physical layer, MAC layer to measure congestion. Finally we can conclude that congestion is the problem associated with the network and has to be countered by having compromised solution rather than elimination.

REFERENCES

[1] D. B. Johnson, D. A. Maltz, “Dynamic source routing in ad hoc wireless networks,” Mobile Computing, pp. 153–181, 1996.

[2] Josh Broch, David A. Maltz, David B. Johnson, Yih-Chun Hu, Jorjeta Jetcheva. “A Performance Comparison of Multi-Hop Wireless Ad Hoc Network Routing Protocols,” The Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking, pp. 1-13, 1998

[3]Chen, X., H. M. Jones, A .D .S. Jayalath, “Congestion-Aware Routing Protocol for Mobile Ad Hoc Networks,” Vehicular Technology Conference 2007, pp. 21-25, 2007

[4] S. Ramanathan, M. E. Steenstrup, “A survey of routing techniques for mobile communications networks, mobile networks and applications,” Vol. 1, pp. 98–104, 1996.

[5] C. E. Perkins, “Ad hoc on demand distance vector (AODV) routing,” IEFT Internet Draft, November 1998,

[6] H. Raghavendra and D.A. Tran, “Congestion Adaptive Routing in Ad Hoc Networks (Short Version),” Proc. ACM Int’l Conf. Mobile Computing and Networking (MOBICOM), Oct. 2004.

[7] H. Raghavendra and D.A. Tran, “Congestion Adaptive Routing in Ad Hoc Networks” IEEE Transactions on Parallel and Distributed Systems, Vol. 17, No. 11, November 2006.

[8] D.A. Tran and H. Raghavendra, “Routing with Congestion Awareness and Adaptivity in Mobile Ad Hoc Networks,” Proc. IEEE Wireless Comm. and Networking Conf. (WCNC), Mar. 2005.

[9] Xiaoqin Chen, Haley M. Jones and Jayalath, "Congestion-Aware Routing Protocol for Mobile Ad Hoc Networks" IEEE 66th conference on Vehicle Technology, pp.21-25, October 2005.

[10] S. J. Lee and M. Gerla, “Dynamic load-aware routing in ad hoc networks,” Proceedings IEEE International Conference on Communications, pp. 3206–3210, June 2001.

TABLE I

Splitting probability distribution

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

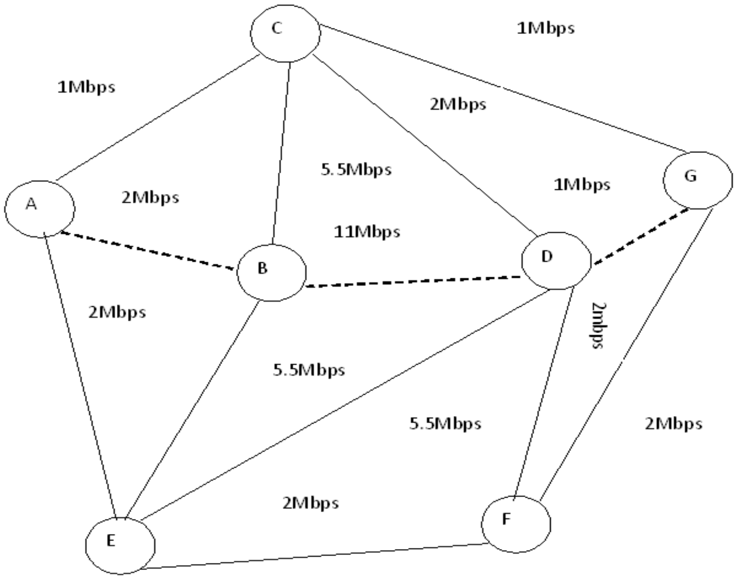
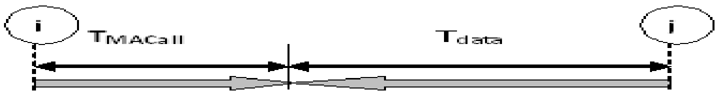
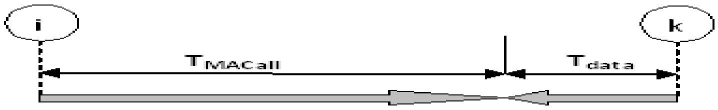


Fig. 1 An example of MDDR problem



Scenario 1: data rate =5Mbps, no congestion



Scenario 2: data rate = 11Mbps, with congestion

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

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