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A Random Congestion Routing Protocol Based on Queue Latency and Link Reliability Estimation in MANETs

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Abstract

Objectives: The increased usage of wireless network communication and service demands for better quality services. This paper proposed a Random Congestion Routing Protocol (RCRP) based on the node data queue latency and its link reliability estimation in a mobile ad hoc network. **Methods/Statistical Analysis:** Wireless QoS mainly depends on efficient data routing with minimum latency, but due to high mobility and low resources make it's unreliable. Another factor which highly impacts the wireless QoS is the network congestion, it causes due to the increase in data traffic for the various services usage and the complexity of the mesh network. So, it is very important to manage delivery latency and link reliability in the congested network for efficient data routing. The proposed RCRP support in achieving efficient data routing with minimum latency through Queue Latency Estimation (QL) and provides are liable link with low energy consumption through Link Reliability Estimation (LR). **Findings:** The integrated approach can effectively manage the congested network and can provide better throughput. The experiment evaluation result supports the improvisation in throughput with low end-2-end delay and energy consumption for the proposal approach.

Keywords: Congestion Routing, Energy Consumption, Link Reliability, MANET, QoS, Queue Latency

1. Introduction

Mobile ad hoc network is dynamic and self-configured in nature. It communicates without infrastructure support which makes it differ from an infrastructure based wireless communication. The complete communication depends on intermediate nodes support and its resources[1-6]. It is very important for any routing protocol to utilize the intermediate node bandwidth and its resource efficiently to achieve a standard throughput. As the nature of communication flooding with a high number of data packets of different data type as text or multimedia, generally, congest a network. It is very important and challenging to handle this flooding communication to avoid the congestion loss and for better throughput. Most congestion control protocols[7-12] avoid the congestion through control the data input rates, but it affects the throughput and achieves high latency to complete a transmission. High latency makes a node be utilized for longer which impact the node resources specifically bandwidth and energy, and at the same time establishing the link reliability in mobility is a major concern in congested MANET[7,13,14].

Primal congestion management implements algorithms rules which control source traffics in control rates in a size of the window. Often this process largely depends on the feedback and basically, forms a closed loop management, TCP congestion control is an example of this kind of management. Queue management is another class of congested control studied in past[5,9], for managing the node overload. But it was observed that most existing protocols manage queue overload by controlling the input data rate[15]. In RED[16] and REM[17] implements queue man-

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agement algorithm which updates the congestion status implicitly and controls the quantifications of the source traffic to manage the congestion which provides network throughput potentiality.

Increasing traffic mostly overload nodes to perform more processing and utilizes a good amount of node resources especially in form node energy[5]. Persevering node energy in high traffic network is a challenging task. Most conventional energy-aware routing protocols[16,18] are evaluated in a low overhead scenario where traffic rate is constant. But in a congestion traffic, a node has to maintain a good amount of data packet in its buffer queue, which adds an additional utilization of energy and queue delay. So, it is equally important to estimates the current queue load and its latency along with its link reliability to effective manage the communication.

In the past few years, many researchers have tried to improvise the traffic congestion control system in MANET[7,18,19]. The objective of all congestion control algorithm is to balance the traffic to maximize performance through improvising the packet delivery ratio and decrease end-to-end delay and packet drops rate. In traditional routing protocols like DSR and AODV for wireless ad-hoc environments contain particular quality to minimize signaling overheads and link failure caused due to mobility[20-22]. These protocols will not calculate the minimum path cost, but they intend to choose the paths that will be lower in cost and less hop count to overcome the delay. They also adapted to give up energy for more efficient routing in integrated with link metric to work.

A detailed congestion investigation is presented in[23] about Congestion Detection and Avoidance (*CODA*). It performs the continuous monitoring of the wireless communication medium and the queue occupancy to detects congestion. After identifying the congestion it transmits a backpressure message to the sender nodes to reduce the data traffic to control the congestion. The choking of data rate affects the throughput performance and also long delay. In[24] integrated three mechanisms to present a congestion control techniques known as *FUSION*. In general, the transmission rate of the sender nodes is to reduce congestion by choking the traffic rate. However, the rate-limiting mechanism, continuously generating tokens when they identify that their parents are performing sending activities. The techniques perform the continuous monitoring which attains an expensive and consumes more energy.

In[25] proposed a congestion monitoring and efficient routing establishment scheme to avoid congestion known as Effective Congestion Avoidance Scheme (*ECAS*). It monitors the status of the queue length and packet loss to overall measure the congestion. The congestion standard is based on the long delay, reduce network congestion and packet loss to achieves good throughput performance and low end-to-end delay and network overloading. But this also suffers from high traffic rate and high packet loss.

In[26] proposed a node average queue length estimation to control congestion know as Dynamic Congestion Detection and Control Routing (*DCDR*). The estimation will identify the availability of congestion free sets in data routing from source to destination in a path. It's high traffic rate may fails to estimates the accurate congestion which causes high packet loss and high overload.

In[1] presents a Distributed Three-hop Routing (*DTR*) protocol for hybrid wireless networks. For the transmitting, it divides the message into segments and sends in distributed manner. It divides a source node message stream into segments and transmits them on their mobile neighbors, who continue the segments to their destination through a network infrastructure planning. It limits the path length to three, and always arranges for high-capacity data nodes to send. Unlike the existing protocols, it produced significantly low overhead by reducing the discovering and maintenance. It also has control algorithm for congestion avoidance and overloads on the central nodes in the case of distributions in unbalanced networks.

In[2,3] addresses two problems related to routing and dynamic resource in the multi-hop wireless network. A variety of end-to-end delay requirements for each stream, and then to create a new queue management system and the way down the length of the delay parameter to the destination nodes, the delay introduced by combining the two. Taking advantage of the delay parameter and the queue management system, this letter is a traffic control, routing and scheduling algorithm was proposed back pressure. The proposed algorithm is optimal throughput reaches close to one-way only, but also convenient adaptively selected according to each of the current delay constraints.

All protocols in relation to the congestion avoidance and quality of service requirements in high traffic do not make a clear distinction in their choice in the routing requirement. These proposed algorithms main objective is to improvise the quality of service irrespective of analysis of other factor impacting the performance. For the enhancing the congestion control routing, we propose a random congestion routing protocol (*RCRP*) based on the Queue Latency (*QL*) estimation and Link Reliability (*LR*) for the randomly route the data packets. The enhancement mostly targets to avoid the congestion efficiently and minimize the energy requirement through effectively estimating link reliability. The following section describes the proposed protocol in detail.

2. Proposed Random Congestion Routing Protocol

MANET is an interdependent and resource sharing network, where each sender node completely depends on the intermediate nodes to complete a task if they are not in direct range of destination. To complete a task source node always in completion to attain more bandwidth of their neighbor nodes. In the case of high network traffic neighbor node highly flooded with data packets and forms a long queue to pass through for the destination. An excessive packet arriving at a fixed bandwidth generally chock the bottleneck and cause congestion, in the result, it attains high packet drops[12]. Retransmission of these lost packets consumes an additional bandwidth and energy resources[10]. So, it is important to have a mechanism which can effectively manage both network traffic and resources. The proposed Random Congestion Routing Protocol (RCRP) focus both the issues solutions. RCRP implements two estimation techniques to resolve the issue as, *Estimation of Queue Latency* and *Estimation of Link Reliability*. Based on this estimation we perform a random routing to avoid congestion to minimize the energy resource consumption through identifying a reliable link for routing.

2.1 Estimation of Queue Latency

Traditional Queue management schemes[27], allows the incoming data packets to node queue until it can accommodate. It starts dropping the packets when it queues length get full. This is a generic problem as it doesn't implement any congestion and queue length estimation to control high traffic. This raises a serious concern for the dynamic and interactive network communication. We present a Queue Latency (*QL*) estimation based on queue length and queue delay computation.

We introduce a Congestion Controller Manager (CCM) which periodically monitors the neighbor nodes queue length and compute the probable latency for a new data packet if its join the queue. It will also compute the link reliability status for each neighbor node, which we will discuss in the following section.

To monitor the neighbor node queue length the CCM periodically sends an "*NQ*" control message to its neighbor nodes which are being discovered in the route discovery. It might be an additional overhead over the network but it supports to predict the node current overload status and also helps RCRP for computing *QL*. To compute *QL* we derived an estimation method using an Exponential Weighted Moving Average (EWMA)[14]. EWMA estimation is based on the statistically meaningful linear variations and a constant value of the moving average, it is simple and less source required in compare to another estimation method. We consider the queue length as varying factor and node moving average as a constant δ to compute the Queue Latency. We assume that a node *N* estimating the Queue Latency of forwarding node as $QL(f_k)$ as described in Algorithm-1.

Algorithm-1: Queue Latency Estimation

<u>Initialization</u> :

Control_Msg = "*NQ*"
Moving average constant ,$\delta = 0.6$;
(For a stable EWMA has δ = 0.6[14])
Queue_Latency,$QL(f) = 1$;
Queue Position→ ρ;

<u>Method</u> :*Compute_QL( )*

N gets First Hops from RouteTable → *NodeHops[ ];*
while*w=0; w<=NodeHops count* ***do***
Sends "*Control_Msg*" to*NodeHop[w];*
if *"NQ" reply received* ***then***
No. of data packets in Queue of NodeHop[w] $\rightarrow C_{len}$
for $\rho = 0, \rho <= C_{len}$ ***do***
$QL(f_k) = \delta * QL(f) + (1 - \delta) * \rho$;
$QL(f) = QL(f_k)$;
end for
N updates*QL* of *NodeHop[w]* → *QL(f);*
End while

Based on the computed *QL(f)* for each neighbor node CCM able to find the minimum and maximum congested node among them. Before making a decision of sending data packet CCM also make sure the link reliability based on their past monitoring response. In the section, the estimation of link reliability is discussed in detail.

A. Estimation of Link Reliability

The estimation of Link Reliability (*LR*) is to identify the most stable linkage for data transmission. It might be not true that a node which maintaining low *QL* may have a good link reliability. Because link reliability depends on the node mobility and link failures. So, it's important to identify the stable link node for the communication along with the low congestion for efficient throughput. *LR* estimation is perform using a regular monitoring the neighboring node through sending a «*Hello*» message, and for the moving mobility average, we considered the EWMA constant as $\delta = 0.6$. The computation process of *LR* estimation is presented in Algorithm-2.

Algorithm-1: *Link Reliability Estimation*

***<u>Initialization</u>* :**

Control_Msg = "*Hello*"
Moving average constant , δ = *0.6;*
(For a stable EWMA has δ = 0.6 [19])
No. of Control msg Transmitted→*T;*
No. of Reply Received → *R;*
Past Link Reliability*PLR(n) = 1;*

<u>Method</u> :*Compute_LR ( )*

N gets First Hops from RouteTable → *NodeHops[ ];*
while*w=0; w<=NodeHops count* **do**
T = NodeHop[w] Control_MsgTransmitted;
R = NodeHop[w] Reply Recieved;
Prob_LR(N,NodeHop[w]) = δ*
PLR(NodeHop[w])+ (1 – δ *) * R/T;*
PLR(NodeHop[w]) = Prob_LR(N,NodeHop[w]);
T = 0; R=0;
N updates*LR* of *NodeHop[w] → PLR(NodeHop[w]);*
End while

The estimation of reliable link minimizes the retransmission of data packets, which helps in reducing energy resource utilization. Based on these two *QL* and *LR* estimation the CCM decide a data sending route for a node. The mechanism for data routing based on CCM estimation to avoid congestion is being described in next section.

2.2 Data Routing with RCRP Mechanism

The main cause of congestion mostly due to the rate of variation in receiving and transmission[28,29]. We take a random mechanism to transmit data in various route base on our *QL* and *LR* estimation to effective manage the congestion and minimize the resource usage in RCRP. It eventually distributed data packets in a different route, the process is described in Algorithm-3.

Algorithm-3: *Data Routing with RCRP Process*

<u>Method:</u> *<u>Data</u> Routing()*

N gets First Hops from RouteTable → *NodeHops[ ];*
while*w=0; w<=NodeHops count* **do**
NodeHops[w]→ x ;
A_QL[]← getCompute_QL(x);
A_LR[]← getCompute_LR (x);
End while
//- - Sorting both QL and LR.
Top_Nodes[] = *Compute_Sorting(A_QL[], A_LR[])*;
// -- Choosing 2 Random Nodes for data Routing.
for*t=0;t < 2* **do**
N_{add} ← *Top_Nodes [t]*;
SendData_pkt (N_{add}*);*
endfor

The RCPR modifies the AODV routing protocol for route discovery and data routing. A *CCM* module is implemented in each node to estimates the *QL* and *LR* to decided the optimal node for routing as shown in Figure-1.

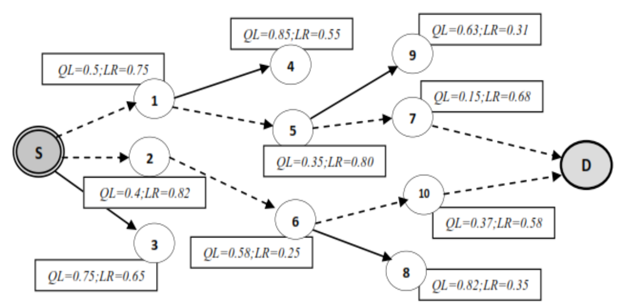

Figure 1. RCPR Data Routing Mechanism.

As per the Figure-1, a source node *S* has *3* first hop nodes. It randomly chooses maximum *2* nodes based on its *QL* and *LR* to data routing as illustrates in Table-1.

Based on the information of Table-1, source node *S*, choose node *1* and *2* to send data packet simultaneously as it shows low *QL* and high *LR*. This process continues until data packets are delivered to destination node *D*. A simulation experiment is performed to evaluate the proposed work as described in below section.

Table 1. Route table of each node

Node	F-Hop	QL	LR
S	*1*	*0.5*	*0.75*
S	*2*	*0.4*	*0.82*
S	3	0.75	0.65

3. Experiment Evaluation

To evaluate the performance we compare the obtained result with three similar protocols as, DTR[1], ECAS[25] and DCDR[26]. These all protocols focus on congestion control routing through queue and neighbor monitoring. The required parameter for the evaluation is discussed in below section.

3.1 Simulation Setup

We prepare a scalable network environment using the Table-2 simulation parameter in GloMoSim Simulator. It provides flexible and quick development environment for a different novel model with satisfactory evaluation results. The simulation is performed for a timeperiod of 1000 sec with varying traffic rates from 5 pkts/s to 30pkt/s in a Random waypoint (RWP) model mobility having a constant speed from 0-20m/s.

Table 2. Simulation parameters

Configuration	Parameter Values
Terrain Area	1000m X 1000m
No. of Nodes	100
Mobility Speed	0 - 20 m/s
Source-Destination Pairs	25
Packet Size	512 bytes
Traffic Rate (pkt/s)	5,10,15,20,25,30
CCM Monitoring Interval	2 sec

3.2 Results Analysis

The obtained results from simulation being analyzed to evaluate the performance. We analyze the Throughput, End-2-End delay, Avg. energy consumption and Packet Drop measure for the result analysis.

Throughput:Figure-2 shows the throughput comparison between RCRP and existing protocol. RCRP shows a better throughput in comparison to the other protocols. The variation of traffic rate 5 - 30 pkts/sec increases the traffic congestion rate, but RCRP shows an improvisation due to the accurately estimating the neighbor nodes for data forwarding based on *QL* and *LR* measures and also the randomly forwarding the data packets in multiple routes handle traffic congestion efficiently. Comparative protocols attain high packet loss and delay as the traffic congestion increases which affects their throughput performance.

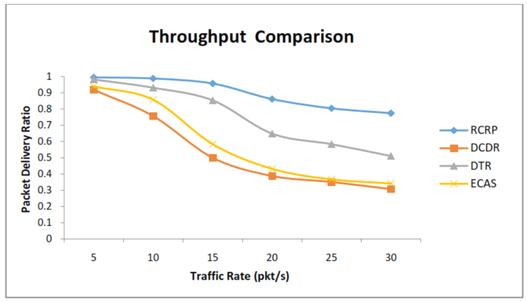

Figure 2. Throughput Comparison Result.

***End-2-End Delay*:** This is an important measure in evaluating congestion that highly impacts network performance. It is measured by calculating the difference in time from their origin and delivered packets. Figure-3 shows the end-to-end delay comparison between RCRP and other mechanisms. RCRP approach attains the lowest end-to-delay in compare to another mechanism due to the utilization of random routing mechanism through most RL links for sending a data packet, whereas other protocols generally slow down the rate of a data packet or waits for the node to get free. RCRP attains a 5% low delay at lowest traffic rate and 25% low at high traffic rate.

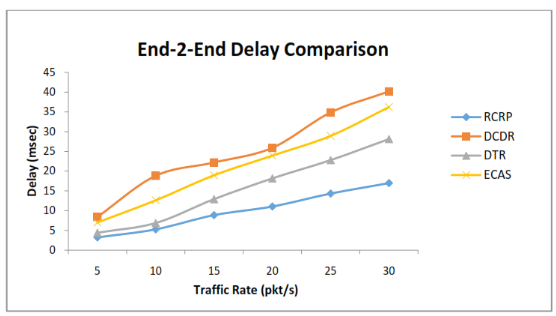

Figure 3. End-to-End Delay Comparison Result.

***Avg. Energy Consumption*:** The Figure-4 shows an Avg. Energy Consumption Comparison between the RCRP and other protocols. RCRP shows 10% low consumption of energy in compare due to *RL* estimation. The estimation assures that the forwarding node is highly reliable for data routing, which decreases the probability of retransmission of data packets. This makes RCRP in the reduction of energy consumption in compare to others. But multiple route data forwarding make use an addition energy usage, due to which it shows an increment with an increase in traffic from 15 - 30 pkts/s.

***Number of Packet Dropped*:** Packet drop or loss in a network is mainly caused due to denial of service, delay, link failure, packet collision and congestion. Figure-5 shows a packet drop comparison between RCPR and other protocols. RCRP shows a low packet drop in compared to others due to stable link identification using LR estimation. With increasing traffic rate from 15 - 30 pkts/s it also shows an increment, it is due to the unavailability of low QL and average LR intermediates nodes, as they are getting high congested with increasing traffic rates. In other protocols, long queue delay and also unreliable link routing makes the high loss of packets in different traffic rates.

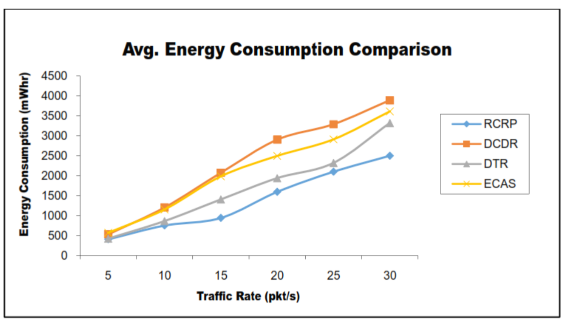

Figure 4. Avg. Energy Consumption Comparison Result.

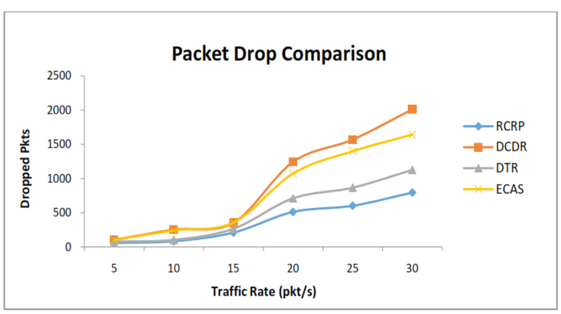

Figure 5. Packet Drop Comparison Result.

4. Conclusion and Future Works

The demands of stable and guaranteed communication in MANET is a key concern. The limitation of resources and high flooding of data and control packets creates a congestion-prone network, which impacts the data loss and network stability. This paper proposed a random congestion routing protocol (RCRP) based on the node data Queue Latency and Link Reliability estimation for the first-hop nodes. It implements a congestion controller manager (CCM) to compute the QL and LR periodically. The integrated approach effectively manages the congested network and shows an improvised throughput with low packet loss, energy consumption, and delay. The experiment evaluation with the existing protocols shows an extensive improvement of throughput and attains the lowest end-to-delay in compare. The throughput improvement is due to multi-hop data routing and low consumption of energy proves the objective of the proposed protocol. In future, it will explore this method for different data type prioritization and data security impacts on congestion and it performances.

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