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Congestion Avoidance and Data Prioritization Approach for High Throughput in Mobile Ad Hoc Networks

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Abstract

In mobile ad hoc networks, congestion is one of the most important limitations that affect the performance of the whole network. Congestion control in mobile ad hoc network is quite different from the traditional networks. The approach of standard TCP congestion control is not properly adapted to the dynamic properties of MANET, which creates lot of difficulties in routing, due to resources and bandwidth limitations. Existing congestion control algorithms tries to ease the network congestion by reducing the delivery rates. However these algorithm approaches always minimize the throughputs. In this paper, we proposed a congestion avoidance and data prioritization (CADP) through the self congestion prediction (SCP) algorithm and data prioritization approach (DPA) to reduce network overload and improvise the overall throughput. It defines and identifies the data prioritization during data routing for effectively managing the route congestion control. An extensive simulation shows, the proposed protocol outperforms incomparable the existing routing protocols and is suitable for scalable and congest network.

Keywords - Congestion Prediction, Efficient Routing, Data Priority, Quality of Service, MANET

1. INTRODUCTION

The increase usage of wireless network application demands effective management of network traffic to avoid congestion. It has a negative impact on the performance, throughput and resource consumption. Traditional congestion problem is quite different from wireless network [5][2]. All the data flows in wireless communication are always irregular because of the random destinations which challenges in congestion control in wireless and also comes with some additional requirements. It is very difficult to detect congestion standard rate occurs due to node mobility and limited resources in mobile ad-hoc network that leads to link failure and data loss.

The information message generated during a critical scenario is of high importance and loss of such data can damage the purpose of deploying dynamic wireless network. In other words, the congestion control in wireless communication must not only be based on the network strength but also on the commitment required by the applications also. Many applications of wireless networks, such as vehicular and biomedical or any critical information, have diverse data traffic with different quality of service requirements and demands effective congestion control.

Ad-hoc network creates a dynamic network and acts themselves as routers are responsible for routing data packets. Most methods of congestion control are router or node centric [12] [14] [24]. Most of the previous research works on congestion control in wireless communication have only focused on the traffic control which includes end-to-end and hop-by-hop congestion. Traffic control schemes are effective to control congestion in conventional networks, and some of them are also suggested wireless network scenarios [3,9,13], but most of the proposal are restricted or even unsuitable for special purposes such as controlling source traffic during a crisis state is undesirable since it will significantly go against the requirements. It is better practice to control excessive incoming traffic during critical state by tuning the resources to accommodate the requirement.

But congestion in the ad-hoc network is due to the link failure that causes frequent packet loss. TCP approach for handling link failures and congestion control in ad-hoc turns bad result and unnecessary reduction of the transmission rate and degrade the network performance. Therefore, it should predict host mobility and congestion dynamically for maximum TCP performance impact [14] [18].

In this paper, we propose congestion avoidance and data prioritization (CADP) through the self congestion prediction (SCP) algorithm and data prioritization approach (DPA) for efficient routing and improvise the performance of route packets in congestion node and send packets along different path nodes where the less congested nodes are sufficiently utilized in response to congestion during reliability requirements. SCP algorithm predicts the likely delay of 1-hop nodes in advance to avoid delay in the routing path to avoid congestion and data prioritization approach (DPA) is for effective congestion control for betterment of quality of service in mobile ad hoc routing protocol. To consider the proposal we modify AODV [6] routing protocol that keeps track of the next hop for a route instead of the entire route.

The paper is organized in the following sections as follows. Section-2 describes the related works about congestion avoidance and data prioritization. In Section-3, we introduce the proposed approach for congestion avoidance and data prioritization. In section-4 we discussed the routing process using CDAP approach and Section-5 describes the experimental evaluation and performance study and analysis. Section-6 describes the conclusion and future work.

2. RELATED STUDY

Network congestion is a common attack which generally occurs in wireless network and also in ad hoc network is an important issue. The congestion caused by buffer overflow in node-level can result in packet loss and queue latency, where as link-level congestion is related to the channels shared in wireless network by several nodes as discussed in [11][12][13][14] using competitive MAC protocol. Optimization of TCP in MANET mechanism has been explored in several studies [5][16][21]. TCP mechanism specifically designed to handle link failures that it does not have the flexible mechanism for failure handling. Many researchers widely study on congestion control in wireless communication to improvise the network throughput and minimize end-to-end delay.

A. Congestion Avoidance Approaches

Congestion Detection and Avoidance (CODA) [8] presents detailed investigation on congestion detection and avoidance in wireless network. It detects the congestion by sampling the wireless communication medium and continuous monitoring of the queue occupancy. The mechanism of this work broadcasts a backpressure message to sender nodes As soon as a node detects congestion and then the sender nodes will choke the traffic volume to alleviate congestion.

FUSION in [9] presents three congestion control techniques to alleviate congestion. Basically, it mitigates congestion by choking the transmissions rate of the sender nodes. However, in its rate limiting mechanism, nodes to determine continuously, watch their parents' sending actions when they generate tokens. It is too costly and consumes more energy due to continuous monitoring.

Xu et al. [2] propose TCP unfairness problems caused by the average local share. This proposal improves TCP fairness through Neighborhood Random Early Detection (NRED). In NRED all nodes in the neighborhood, it shows each node can estimate the total number of packets in neighborhood. All these packets form a virtual, distributed neighborhood queue. In the case of the buffer queue length pass over the threshold queue limit, the packets begin to fall with increasing delay probability. NRED estimates the size of the neighborhood queue based on the use of the channels. So neighbors are overheard during transmission. It assumes an early congestion if usage exceeds a threshold limit. It calculates a drop probability and informs all neighbors in the area. Upon receipt of notifications each node calculates its own drop probability. Incoming packets are deleted if the total drop probability is above the threshold of the queue.

B. Data Prioritization Approaches

Ye et al. in [1] propose Congestion Aware Routing approach (CAR) which extends to spatially separate routing based on distributed congestion information. The majority of previous works in the congestion aware routing focus on TCP flows to interact with the congestion control mechanism. It evaluates the theoretical benefit of spatial separation by simulating known as centralized CAR (CCAR) approach. It assumes all nodes are fully aware of the source, destination and route of every single TCP stream. More realistic scenario is described as a decentralized distributed CAR approach (DCAR). It calculates a congestion weight for representing its local load situation and broadcasts to its neighbors. Route discovery choose a route which is based on the aggregated route weight. Destination node use minimal weight to send the route reply. It discovers the congested zone of the network to dedicate the portion of the network to forward primarily high-priority traffic that exists between high-priority data sources and the data sink.

D. Cordeiro et al. [10] works on Contention-based Path Selection (COPAS) protocol which focuses on TCP problem in MANET known as capture problem. COPAS have proposed extending a reactive routing protocol that can capture the medium unjustly and shows an improvement in comparison to others. During the route discovery process all possible routes to reach the destination are discovered from the source. It uses two disjoint routes to move upstream and downstream TCP traffic respectively, which avoid the effects in both directions to capture the medium. Route selection is performed based on the congestion during the discovery process. It has to wait for the medium to free to support the measure based on the back-off times. It updates constantly during the operation process and a new route is replaced with less congest.

An observation made in [1] [5] [11] [23] that, the packets on the congested path will experience a relatively large end-to-end delay and high packet loss. Undoubtedly, it is a negative impact in wireless ad-hoc network. It motivates us to propose a self congestion prediction (SCP) algorithm to overcome this loss in MANET and a data prioritization approach (DPA) for data prioritization in data routing, which objective is to provide efficient quality of services minimizing latency and improve throughput at different traffic types as discussed in section-3.

3. CONGESTION AVOIDANCE AND DATA PRIORITIZATION APPROACH

3.1 Congestion Avoidance Algorithm

Congestion can occur at any point of time in a network node, and then it becomes congested and starts losing packets. In an Ad-hoc network, node congestion mechanism used to measure the level of packet loss due to a lack of buffer space. Every second a node checks the residence of the packets in its queue, applying dynamic estimation technique for congestion [7].

A. Congestion Prediction

This section describes the Congestion prediction algorithms which work on novel delay estimation technique, as delay indicates the time required to send a packet from source to destination node. Let assume a delay on a specific one-hop link, denoted by *D*, and size of the queue is limited by the value *S*. A packet is dropped when a new packet arrives and S packets are already in the queue. To compute *D*, we need to estimate the following factors,

- *Queuing Delay* - which represents the interval between the times the packet enters in the queue from the link's sender and time it is waited for the packet it becomes the head of line packet in this node's queue. We denote it by *QD* and the number of packets arriving in the queue as P_{arrv}.
- *Contention Delay* - is the time interval between the packets arrives at the head of line and packet sent to the physical medium for transmission. We denote it by *CD* and the number of packets leaving the queue P_{leav}.

Therefore we have the relation, as

$$D = QD + CD \tag{1}$$

When $P_{leav} > P_{arrv}$, the transmission rate of the node is higher than the arriving process and there will be no accumulation in the queue involving a queuing and a contention delay will be *0*.

$$P_{leav} > P_{arrv} \Rightarrow QD + CD = 0$$

When $P_{leav} \leq P_{arrv}$. Let's denote by $p(n)$ the probability to have *n* packets in the queue $(n \leq S)$. A packet arrives with rate δa and exits with rate δr. So the probability,

$$p(n) = \frac{\delta a}{\delta r} \times p(n-1) = \left(\frac{\delta a}{\delta r}\right)^n \times p(0) \tag{2}$$

And, the mean number of packets Q in the queue is therefore:

$$Q = \sum_{n=0}^{S} n \times p(n) \tag{3}$$

Using queuing theory and according to Little's law, the parameter $QD + CD$ is equal to the mean waiting delay time as *D*.

$$D = (QD + CD) = \frac{Q}{\delta a} \tag{4}$$

B. Congestion Avoidance

In SCP, routing node predicts the 1-hop neighboring nodes delay information through congestion information (*CInfo)* messages. Every Δt second, each node locally estimates its waiting delay time (*D)* and includes this information in a *CInfo* packet using congestion prediction algorithm. The delay estimation allows SCP to predict the transmission delay rates at its neighboring nodes. The protocol maintains *1-hop Neighbor Table Info (HOP_NT_Info)* to keep *CInfo* of each node which discovered during routing process. It alleviates the congestion using *HOP_NT_Info* information to dynamically select the less congest node for routing to improve throughput. The following section describes the utilization of SCP for efficient routing.

3.2 Data Prioritization Approach

A data prioritization approach (DPA) [4] for routing using data priority level to avoid the network congestion through effective data flow control for improving reliability and throughput. A priority-based data priority control mechanism [17] to adjust the node traffic rates based to avoid congestion with different service priority for congestion control in wireless networks. Traffic is diverse and may have different requirements depending on the data priority [20][21][22].

To design the DPA approach with different data priority we classified data as follows:

1. **Low-Priority Data:** This data should be delivered without loss but can tolerate reasonable delay.
2. **Medium-Priority Data:** This data should be delivered within a deadline but may tolerate reasonable packet loss.
3. **High-Priority Data:** This data is of high importance and require delivery immediately.

The Framework of DPA approach as shown in Fig-1 consists of two main modules which are designed to devote for data prioritization based on the priority requirements as Neighbor and Queuing manager and its functionality is discussed below.

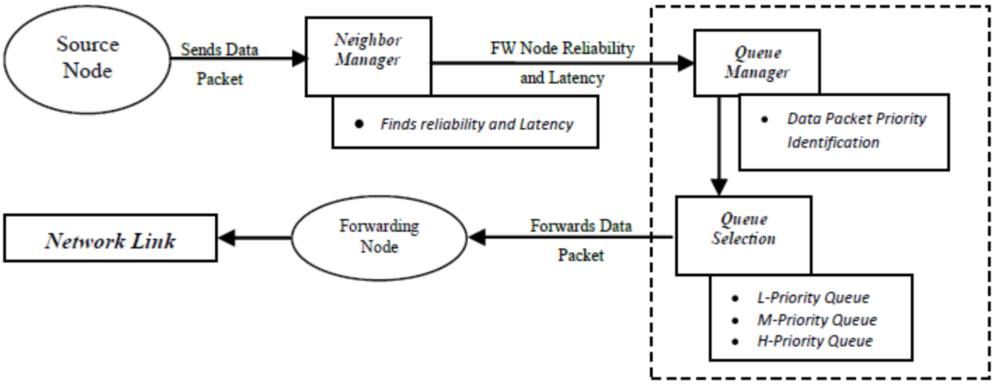

Fig.-1 Proposed Framework for DPA Approach

A. Neighbor Manager

The neighbor manger (NM) is responsible to find the reliability and latency of a forwarding node. It uses a neighbor table which includes all the information related to the neighbor nodes consisting of waiting time for each queue, transmission delay and packet delivery ratio. It regularly updates the neighbor table by sending a HELLO packet to the neighbor nodes. To estimate the node reliability NM uses Window Mean Exponential Weighted Moving Average (WMEWMA) estimation technique derived from Exponential Weighted Moving Average (EWMA) [15] estimation as shown in the Alogrithm-1.EWMA has the advantage of being simple and less resource demanding compared to other methods [19]. Still, it can react quickly to significant changes, while being stable and less influenced by sporadic, large deviated measurements. WMEWMA is very similar to EWMA but updates the estimated parameter in regular time intervals.

Algorithm-1: Neighbor Manger reliability estimation Using WMEWMA.

```
Reliability Estimation ($x_i$ ,$y_i$)
Where, $x_i$ - transmitting node and $y_i$– receiving node.
$\alpha$  - is a constant value of the node moving average.
(For a stable WMEWMA has $\alpha = 0.6$ [8].)

Initialization:
    Packet Reception Ratio ->$Prr_{(xi\,,\,yi\,)} = 1$;
    Number of packet Received ->$R = 0$;
    Number of packet dropped ->$D = 0$;
    Last packet sequence Number, $Sp = 0$;

    for each reception of data packets from $x_i$ do
        R=R+1;
        D=D+packet_seq_no – (sp+1)
        Sp = packet_seq_no;

        $Prr_{(xi\,,\,yi\,)} = \alpha \,.\, Prr_{(xi\,,\,yi\,)} + (1 - \alpha\,)\,R/(R+D)$;
            D=0;R=0;
  End for
```

Algorithm-2: Neighbor Manger Latency estimation Using EWMA.

```
  Each packets queuing delay ->$Qd(x_i)$.[data_pkt_type]
Time the packet is ready for transmission - >$t_0$
Time of the reception of acknowledgment ->$t_{ACK}$
The bandwidth ->$bw$
Exact waiting time of the packet - >$\beta$
Parameter of the moving average ->$\alpha$
```

```
Initialization: Transmission delay ->$Td(x_j)= 0;$

For each packet transmission do
If  $Qd(x_i).[data\_pkt\_type] = 0$ then
$Qd(x_i).[data\_pkt\_type] = \beta;$
Else
    $Qd(x_i).[data\_pkt\_type]=\alpha . Qd(x_i).[data\_pkt\_type] + (1 - \alpha) \beta;$
End if
End for

For each ACK receptions from $y_j$ do
If$Td(x_i) =0$ then
$Td(x_i) =t_{ACK} - size (ACK) /bw - t_0 ;$
Else
$Td(x_i) =\alpha .Td(x_i) + (1- \alpha) ( t_{ACK} - size (ACK) /bw - t_0 );$
End if
End for
```

Algorithm-2 illustrates the latency estimation. It is a EWMA approach which is employed and it is used for both transmission delay and queuing delay. Each node, x_i, estimates transmission delay, $Td(y_j)$, of outgoing link for each neighbor, y_j, as well as its queuing delay, $Qd(x_i)$.

B. Queue Manager

The queuing manager *(QM)* is responsible for implementing data priority identification for multi queuing strategy that will control congestion. It will identify the packet priority level and assign the data packet in queue through a multi queue priority policy described in Alogrithm-3.

To evaluate the proposal we use three different queues and send packets from highest to lowest priority level. The highest priority queue is used for high critical data packets where as second level data is consider for medium level priority queue and others as normal priority. It is possible in case of high number of high and medium priority data; lower priority data may be blocked for long. To overcome this timeout (pkt) policy for each packet is used to remove.

Algorithm-3: Queue Manger queue priority policy

```
For each packet reception, from NM do
        If pkt_type = High_Priority then
                Insert packet in High Priority Queue
        Else
If pkt_type = Med_Priority then
```

```
Insert packet in Medium Priority Queue
Else
            Append packet in Low Priority Queue
        End if
End if
Initialization: timeout(pkt);
End for

For each timeout(pkt) do
If expires then
Move packet to High_Priority
Else
Cancel timeout(pkt)
End if
End for
```

4. ROUTING PROCESS USING CADP APPROACH

We modify the AODV [6] with SCP and DPA to propose CADP approach to perform on-demand route discovery and alleviate network congestion for efficient routing and data prioritization. The CADP approach has two main process as: Multipath Discovery and Efficient Routing.

A. Multipath Discovery

When a source node has data to send, it broadcasts a route request (RREQ) to its neighbors. Each message RREQ defined on the basis of time to live (TTL) for the number of hops that should be transmitted. A RREQ identified based on group of the source address and the broadcast source Id number. Intermediate node receiving the RREQ, first determines the demand duplicity watching it request seen table. In case the RREQ is new and its lifetime is greater than 0, then it is append to their address to the path sequence value of the packet and retransmitted further. The process continues until it finds the destination address and reply.

Route reply (RREP) is a unicast process to the source. Destination node replies the RREQ along the reverse path containing the RREP message. Each node in the network for routing support maintains two tables, one for route information as *Route Cache (RC) Table* and other is *1-hop Neighbor Table Info (HOP_NT_Info)*. Route cache table is used for data routing and *HOP_NT_Info* is used for congestion prediction and efficient data routing.

B. Efficient Routing

In ad-hoc network source initiates the data forwarding by choosing an optimal path from the *RC Table.* But A-SCP approach select route which 1-hop node have the congestion delay below the threshold limit *(T),* computed using equation [6] and having minimum number of hops to reach the destination. Table-I below show the multipath routes discovered to reach the destination *(D),* number of hop and mean delay in seconds.

TABLE I. SOURCE (S) AND DESTINATION (D) NODE ROUTE CACHE TABLE

Route	*Route Path*	*First Hops*	*Congestion Delay for First hops (secs)*
R1	2,3,4,6,D	2	0.3
R2	**3,5,4,8,10,D**	**3**	**0.2**
R3	2,4,8,7,12,D	2	0.3
R4	4,5,8,6,10,D	4	0.2
R5	4,6,7,9,10,12,D	4	0.2

Based on the Table-I we can say that the Source node *(S)* has three 1-hop nodes as *2, 3 & 4*. Even though first route *(R1)* of the table is shortest to reach destination A-SCP protocol select second route *(R2)* for routing, because the first hop node of *R2* congestion delay is low compare to the first hop node of *R1* route. Here we assume threshold limit *(T)*, as 5 seconds.

TABLE II. INTERMEDIATE NODE-3 ROUTE CACHE TABLE

Prev Hops	*IM Node*	*Next Hops*	*Congestion Delay for Prev hops (secs)*	*Congestion Delay for Next hops (secs)*
2	*3*	4	0.3	0.2
S	*3*	5	-	0.4

Intermediate node *(IM_Node)* in AODV maintains the previous and next hop information as shown in Table-II. *IM_Node* as follows the same approach as source node does to further route the data. Table-II shows the Route Cache Table of *Node-3*. As per Table-II, *Node-3* has two next hops and two previous hop nodes. *Node-3* evaluates the congestion delay and based on the value it sends data packet to *Node-4* instead of *Node-5* as it shows high congestion delay.

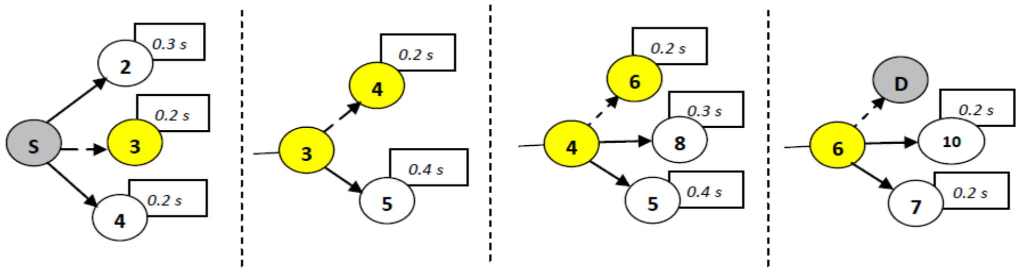

Fig.2. Data Forwarding based on Congestion Delay Prediction

This approach continues as shown Fig. 2 till data packet delivered to destination. This is the novelty being contributed in the approach which improvise the throughput and minimize the end-to-end delay.

5. EXPERIMENT EVALUATION

5.1 Simulation Setup

To simulate CADP with different data traffic based we extend the feature of Adhoc On-demand Vector (AODV) Routing protocol with SCP and DPA. We evaluated the effect of DPA protocol in different packet priority as Low Packet, Medium Packet, and High Packets levels. We simulate the proposal work with the following setup given in Table-1 to evaluate the performance using Glomosim Simulator.

Table-1 Simulation Parameters

Configuration	Parameter Values
Simulation Time	1000s
Simulation Area	1500m X 1500m
No. of Nodes	100
Mobility	RWP
Mobility Speed	0 to 20 m/s
Pause Time	30s
Packet Size	512 bytes
CBR Rate	4pkts/s
CBR Traffic Rate in milliseconds (ms)	500, 400, 300, 200, 100
PACKET-PRIORITY	0 (LOW), 1 (MED), 2 (HIGH)

We perform an extensive simulation run for a period of 1000 seconds varying the packet priority level from Low to High. We compare our proposed CADP approach with CODA [8], FUSION [9], CAR [15] and DPA protocols for performance measure. To evaluate the congestion metric we change CBR traffic rate form 500millisecond to 100 milliseconds at a rate of 4pkts/ms.

To measure the performance comparison of the protocols we compute the Packet Delivery Ratio, Control Overhead, Packet Drop Ratio and Avg. End-to-End delay, with varying the packet-priority and CBR traffic rate from 500 to 100 milliseconds with different traffic rate scenario. The obtain results are discussed in the following section.

5.2 Performance Evaluation

We initially evaluate our data prioritization approach (DPA) to observe the performance increment over the existing systems. The obtain results shows an better improvement over the compared systems. On integration with congestion avoidance algorithm (CAA) with DPA as a proposal known as CADP is further evaluation for achieving efficient throughput on high traffic rates. The obtain result are presented below.

A. Throughput Analysis

Throughput defines the Packet delivery ratio (PDR) as the total number of data packets received verses the total number of data packets originated. Throughput performances of the protocol are shown in Figure-3, 4 and 5 at different data priority with a varying traffic rates. DPA and CADP show almost similar throughput in low priority and a better improvisation in case of medium and high priority. The improvisation of CADP throughput is due to the efficient congestion prediction by individual node to alleviate the congestion where as other schemes computes the congestion on the entire route which cause long delay for route selection and a longer route. Even due to reliable node selection by the Neighbor manager for forwarding nodes and proper queue selection by Queue Manager Communication and maintains a minimum packet loss with a reasonable delay which achieve high throughput.

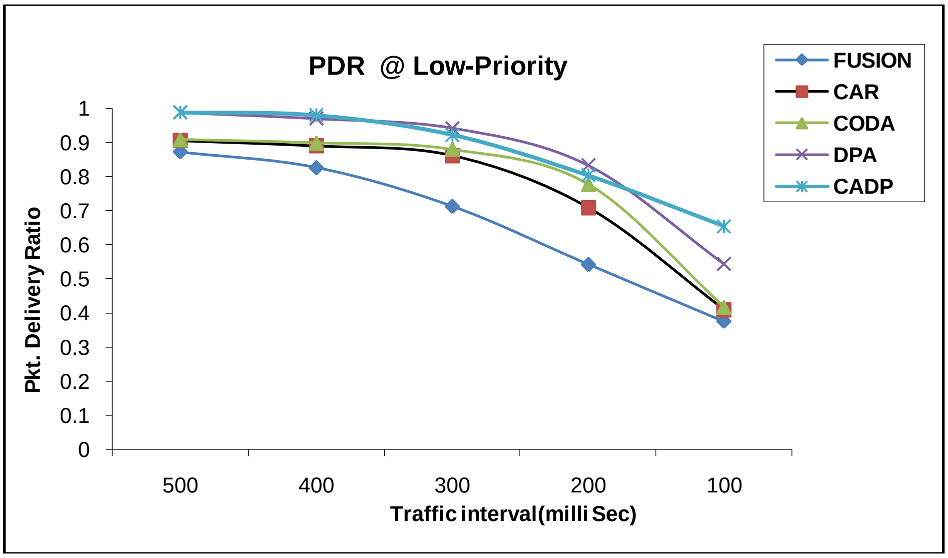

Figure 3: Throughput Performance at Low Priority Data

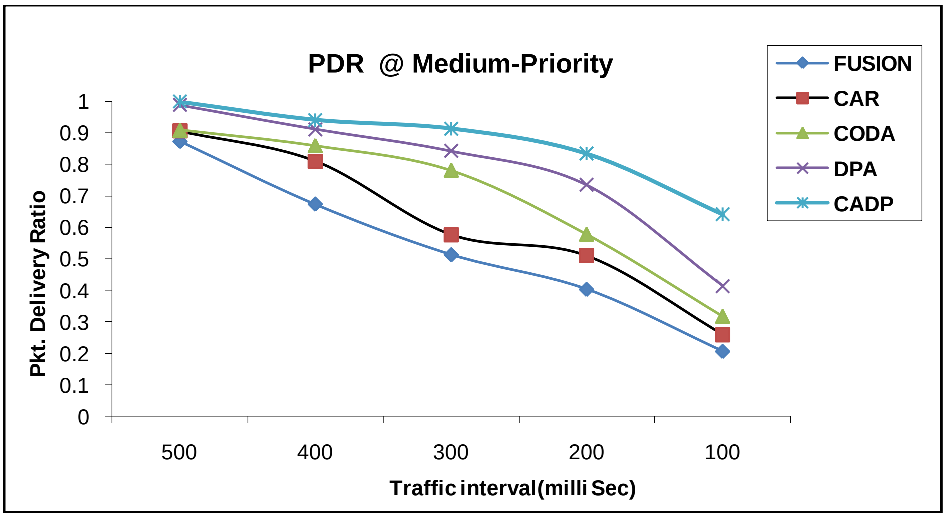

Figure 4: Throughput Performance at Medium Priority Data

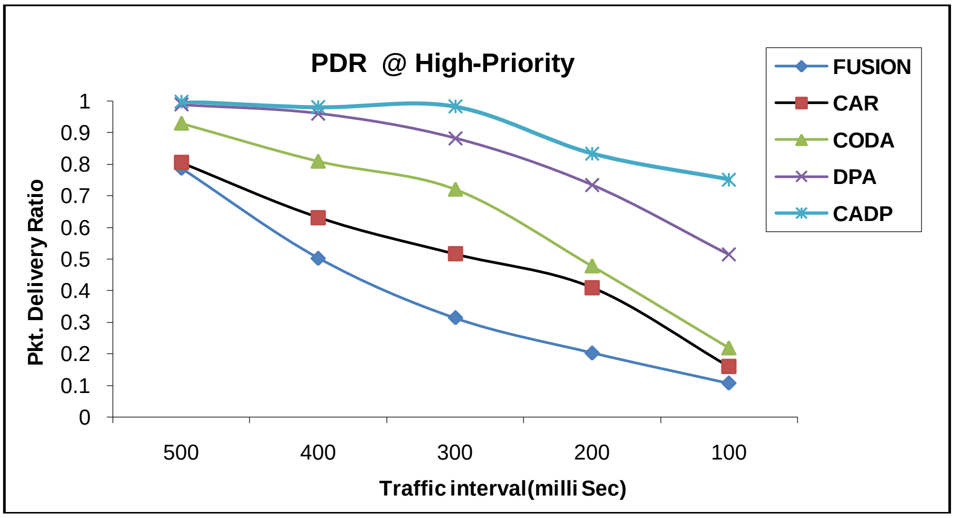

Figure 5: Throughput Performance at High Priority Data

B. End-to-End Delay Analysis

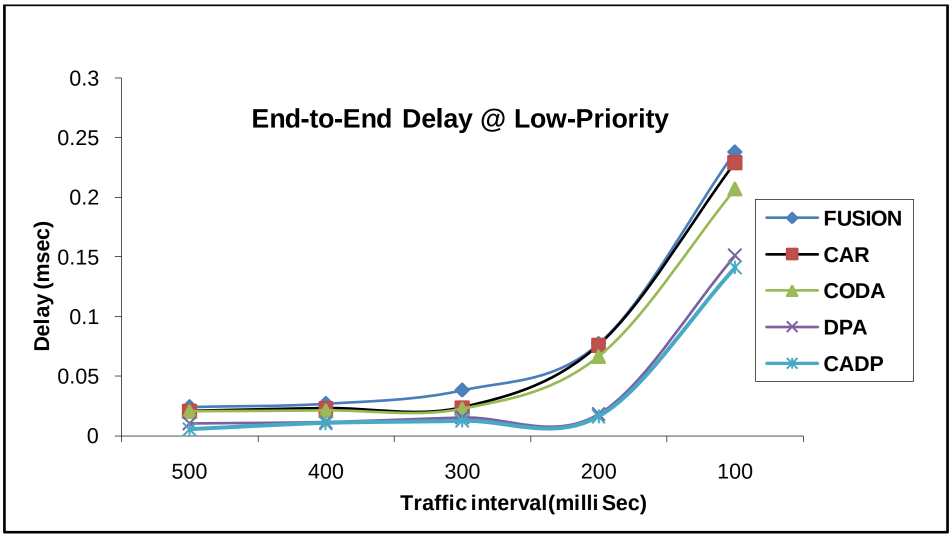

Figure 6: End-to-End Delay Performance at Low Priority Data

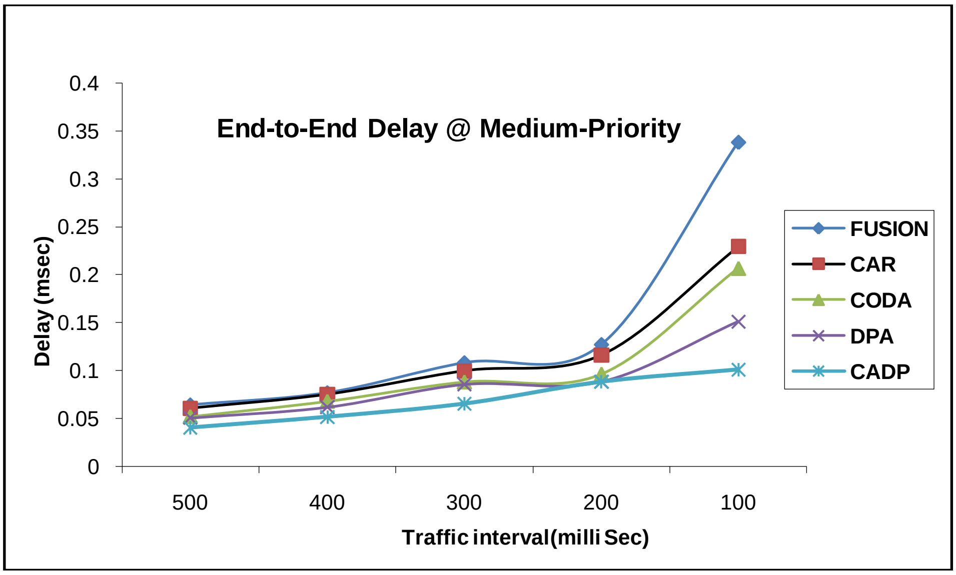

Figure 7: End-to-End Delay Performance at Medium Priority Data

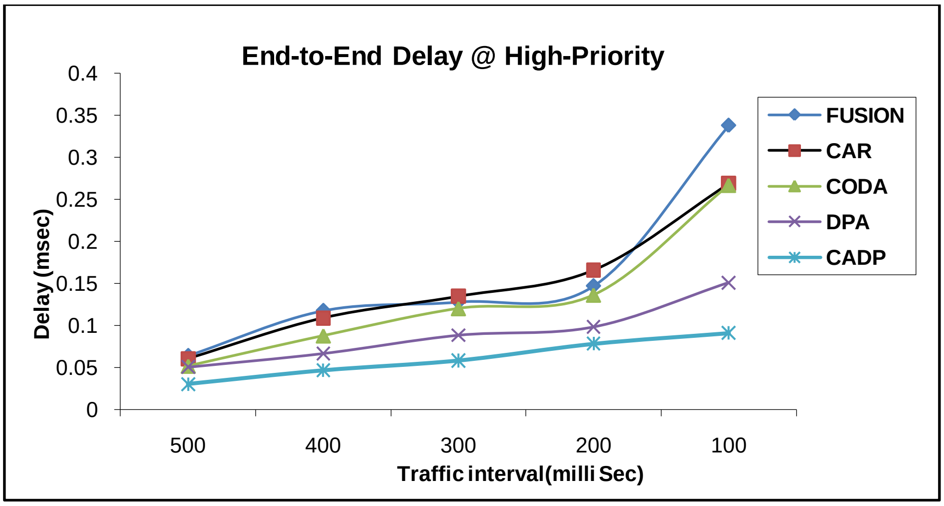

Figure 8: End-to-End Delay Performance at High Priority Data

End-to-End to delay is calculated based on the average of total time taken to deliver the data packets from source to destination in entire simulation process. Figure-6, 7 and 8 shows the end-to-end delay comparison results at different traffic level and packet priority show different performance. The end-to-end delay comparison results at different traffic level and packet priority shows a less delay in compare to other protocols and in compare to DPA it shows almost similar. All the protocols shows a steep increase in delay in high traffic rate, where as CADP shows a reasonable delay in case of all the priority data selection. The reasonable delay in CADP is due to the effective node Queue management by Queue manger for communication.

C. Packet Drop Ratio

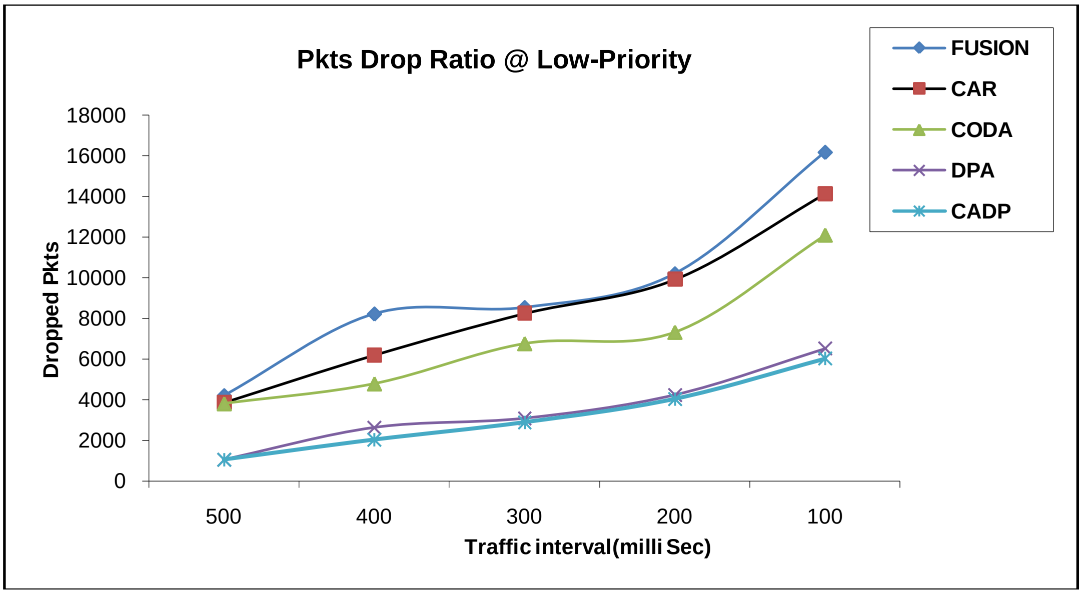

Figure 9: Packet drop ratio Performance at Low Priority Data

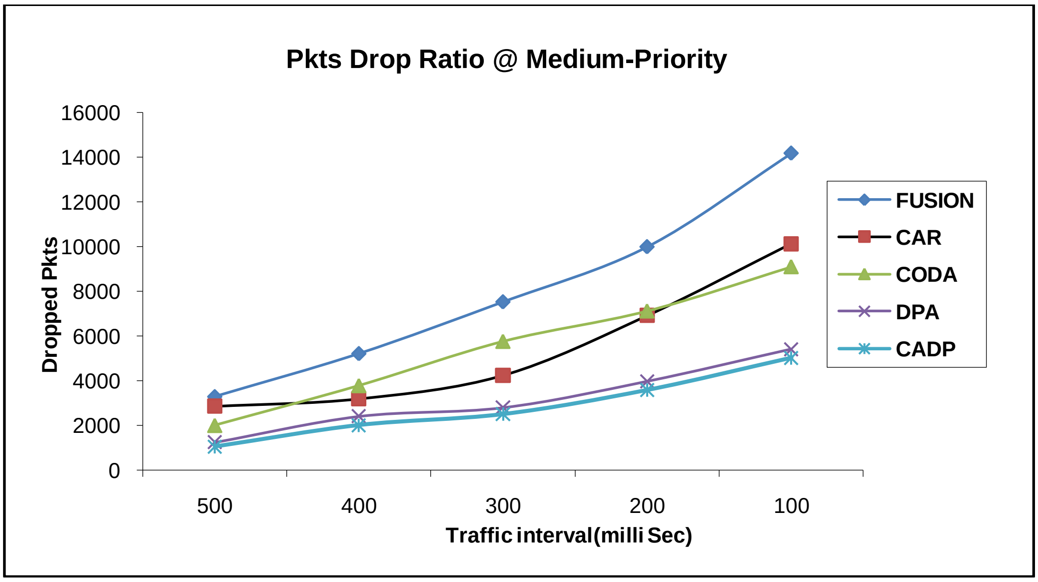

Figure 10: Packet drop ratio Performance at Medium Priority Data

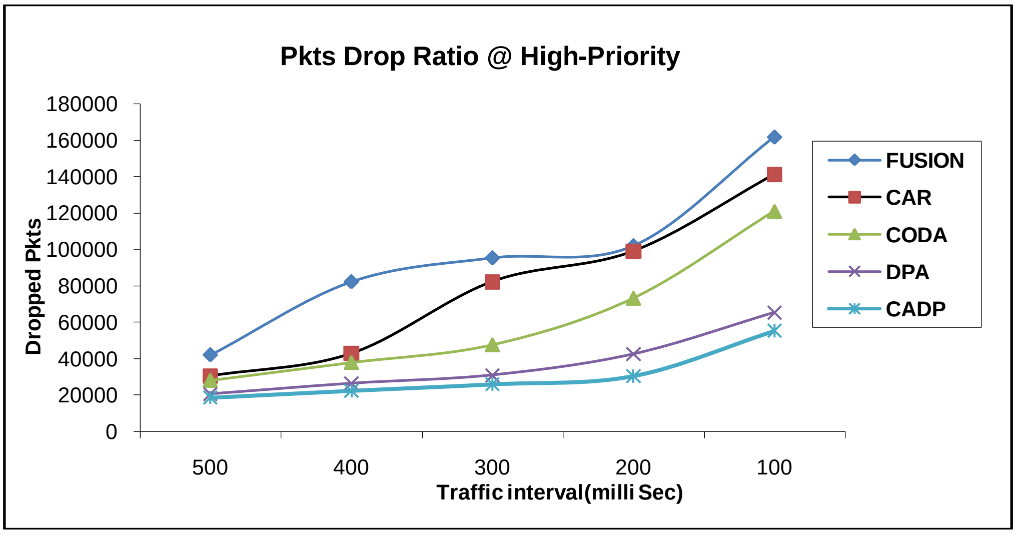

Figure 11: Packet drop ratio Performance at High Priority Data

Packet drop ratio calculated based on the total number of Packets dropped by the protocols during entire simulation process. Figure-9, 10 and 11 shows the packet drop ratio results at different traffic level and packet priority show different performance. All the protocols shows high packet drops in high traffic rate, where DPA and CADP shows a reasonable drop of packets in case of high priority data selection. The reasonable drop of packets in CADP is due to the effective node selection by Neighbor manger for communication which maintains less packet drop.

6. CONCLUSION AND FUTURE WORK

The real congestion control is able to reduce congestion, but difficult to meet the reliability required by applications in mobile ad-hoc dynamic and evolving environment. In wireless ad hoc network congestion control is different from tradition network. Most of the congestion control scheme alleviates congestion by minimizing the transmission rate which directly affects the throughput ratio. We proposed the congestion avoidance and data priority based routing to effectively control the congestion. The proposal takes different data packet type in accounts based on the data criticality. The design framework has Neighbor Manager and Queue Manager to handle the reliable node selection and appropriate queue selection for data routing. The simulation shows an improvisation in compare to existing congestion control protocols. The obtained results are very encouraging and show that the protocol ensures good quality of service and makes different traffic selection based on priority requirements. In case of high traffic and high priority the protocol may attend high latency. We have proposed a timeout method to overcome this but this might be a redundancy process. The simulation results indicate an improvement in throughput, efficiency, minimize the end-to-end delay, routing overhead and avg. packet loss rate in comparison to other protocols. One can explore this method for better time allocation for data priority in the future work.

REFERENCES

[1]. Z. Ye, S. Krishnamurthy, and S. Tripathi. Use of Congestion-Aware Routing to Spatially Separate TCP Connections in Wireless Ad Hoc Networks. In Proceedings of the 1st International Conference on Mobile Ad hoc and Sensor Systems (MASS), Fort Lauderdale, FL, USA, Oct. 2004.

[2]. Kai Chen, Yuan Xue, Nahrstedt K" On Setting TCP Congestion Window Limit in Mobile Ad-Hoc Networks",ICC '03, IEEE International Conference, pp. 1080- 1084, 2003.

[3]. M. Zawodniok and S. Jagannathan, "Predictive Congestion Control Protocol for Wireless Sensor Networks," IEEE Trans. Wireless Comm., vol. 6, no. 11, pp. 3955-3963, Nov. 2007.

[4]. Govardhan Reddy Kamatam, Podili V. S. Srinivas and K. Chandra Sekaraiah,"Data Prioritization Approach for Congestion Control in Mobile Ad Hoc Network", ELSEVIER, Proceddings of the Second International Conference on "Emerging Research in Computing, Information, Communication and Applications", ERCICA, 2014.

[5]. M.H. Yaghmaee and D.A. Adjeroh, "Priority-Based Rate Control for Service Differentiation and Congestion Control in Wireless Multimedia Sensor Networks," Computer Networks, vol. 53, no. 11, pp. 1798-1811, 2009.

[6]. C.E. Perkins, E.M. Royer, "Ad-Hoc On-Demand Distance Vector Routing", Proc. 2nd IEEE Workshop on Mobile Computing Systems and Application, New Orleans, Louisiana, USA, Feb. 1999.

[7]. Govardhan Reddy Kamatam, Podili VS Srinivas and Chandra Sekaraiah K, "Self Congestion Prediction Algorithm for Efficient Routing in Mobile Ad-Hoc Network", IEEE, International Conference on Control, Instrumentation, Communication and Computational Technologies (ICCICCT),978-1-4799-4190-2/14, 2014

[8]. C.Y. Wan, S.B. Eisenman, and A.T. Campbell, "CODA: Congestion Detection and Avoidance in Sensor Networks," Proc. ACM Int'l Conf. Embedded Networked Sensor Systems (SenSys '03), pp. 266-279, 2003.

[9]. B. Hull, K. Jamieson, and H. Balakrishnan, "Mitigating Congestion in Wireless Sensor Networks," Proc. Int'l Conf. Embedded Networked Sensor Systems (SenSys '04), pp. 134-147, 2004.

[10]. C. de M. Cordeiro, S. R. Das, and D. P. Agrawal. COPAS: Dynamic Contention-Balancing to Enhance the Performance of TCP over Multi-hop Wireless Networks. In Proceedings of the 10th International Conference on Computer Communication and Networks (IC3N), pages 382-387, Miami, FL, USA, Oct. 2002.

[11]. Wang, X.; Kar, K.; Cross-layer rate optimization for proportional fairness in multihop wireless networks with random access, IEEE Journal on Selected Areas in Communications, ,2006.

[12]. Raju Kumar, Riccardo Crepaldi, Hosam Rowaihy, Albert F. Harris III, Guohong Cao, Michele Zorzi, Thomas F. La Porta, Mitigating Performance Degradation in Congested Sensor Networks, IEEE Transactions on Mobile

Computing, Vol. 7, No. 6, June 2008.
[13]. T. Kathiravelu, N. Ranasinghe, A. Pears, "An Enhanced Congestion Aware Adaptive Routing Protocol for Opportunistic Networks", Proc. 6th Intl. Conf. on Industrial and Information Systems, Sri Lanka, Aug. 2011.
[14]. M. Radenkovic, A. Grundy, "Congestion Aware Forwarding in Delay Tolerant and Social Opportunistic Networks", Proc. 8th Intl. Conf. on Wireless On-Demand Network Systems and Services, Bardonecchia, Italy, 2011
[15]. A. Woo and D. Culler, "Evaluation of Efficient Link Reliability Estimators for Low-Power Wireless Networks," technical report, Univ. of California, 2003.
[16]. Y. Yang and R. Kravets. Achieving Delay Guarantee in Ad Hoc Networks by Adapting IEEE 802.11 Contention Windows. In Infocom, Anchorage, USA, May 2007.
[17]. M.H. Yaghmaee and D.A. Adjeroh, "Priority-Based Rate Control for Service Differentiation and Congestion Control in Wireless Multimedia Sensor Networks," Computer Networks, vol. 53, no. 11, pp. 1798-1811, 2009.
[18]. F. Bjurefors, P. Gunningberg, C. Rohner, "Congestion Avoidance in a Data-Centric Opportunistic Network", Proc. ACM SIGCOMM Workshop on Informatics-Centric Networking, Toronto, Ontario, Canada, Aug. 2011.
[19]. T. Roosta, M. Menzo, and S. Sastry, "Probabilistic Geographical Routing Protocol for Ad-Hoc and Sensor Networks," Proc. Int'l Workshop Wireless Ad-Hoc Networks (IWWAN), 2005.
[20]. Mi-Young Park, Sang-Hwa Chung, "Analyzing Effect of Loss Differentiation Algorithms on Improving TCP Performance" the 12th IEEE International Conference on,(ICACT), Vol.1 pp.737- 742, Phoenix Park 2010.
[21]. Kumaran, T.S. and V. Sankaranarayanan, Early detection congestion and control routing in MANET. Proceedings of the 7th IEEE and IFIP International Conference on wireless and Optical communications Networks (WOCN), Sept. 6-8,2010.
[22]. Mohammad Amin KheirandishFard, SasanKaramizadeh, Mohammad Aflaki, "Enhancing Congestion control to address link failure loss over mobile ad-hoc network", International Journal of Computer Networks & Communications (IJCNC) Vol.3, No.5, Sep 2011.
[23]. N. Thompson, S.C. Nelson, M. Bakht, T. Abdelzaher, R. Kravets, "Retiring Replicants: Congestion Control for Intermittently-Connected Networks", Proc. IEEE INFOCOM, San Diego, California, USA 2010.
[24]. M. Radenkovic, A. Grundy, "Framework for Utility Driven Congestion Control in Delay Tolerant Opportunistic Networks",Proc. 7th IWCMC, Istanbul, Turkey, 2011.