An ECN Approach to Congestion Control Mechanisms in Mobile Ad hoc Networks

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Abstract

Explicit congestion notification (ECN) mechanism capture network congestion status by using feedback based mechanism. It determines the level of congestion more accurate than pure end-to-end schemes with an ECN-like marking scheme. The purpose of the ECN bit is to notify TCP sources of an incipient congestion and mark packets before losses occur. ECN is a binary indicator which does not reflect the congestion level and its convergence speed is relatively low due to insufficient congestion feedback. In this paper, we proposed a novel approach to handle congestion in MANETs. The same is tried to resolve by using concept of explicit congestion Notification (ECN) bits which is an extension to transmission control protocol (TCP). It allows end to end notification of network congestion without dropping packets which is done conventionally in TCP/IP networks with a bit difference of additional bit. This additional bit allows more flexibility to adjust window size to handle congestion, in comparison to a single ECN bit. Aforesaid concept is tries to simulate and performance of the same has been evaluated with appropriate environment and parameters.

Keywords: Explicit Congestion Notification (ECN), Mobile ad hoc Networks (MANET), Congestion control, Congestion window Transmission Control Protocol (TCP).

1. Introduction

Mobile ad hoc network is complex distributed system of mobile devices which is dynamically and self organizing. MANET devices are independent to each other and it can move freely in communication range of network and take part in communication, devices which are outside the communication range of network cannot take part in communication. The devices can communicate using intermediate nodes which act as router for forwarding packets .it means that each device in MANET not only act as end system but also as router for forwarding route request, and reply data packets and acknowledgement to help in communication. MANET can have many application especially including military and emergency services. Because it reduces the cost and time of network setup and administration. The dynamic nature of MANET with sharable resources that can vary with time, such as topology dynamism and limited bandwidth is a challenging problem. Each network device manages queue space for storing incoming data packet and routing information, if the packet in not instantaneously   transferred then creates a bottleneck link. One bottleneck link in communication path can reduce the performance of whole network. In highly congested condition, the quick changes such as decreasing congestion window after successful transmission or doubling congestion window after a collision, cause bandwidth wastage and high variation in delay.

Varity of TCP variants have been proposed to solve congestion problems. They can be classified into two categories according to the mechanisms used to obtain congestion feedback: explicit network feedback based schemes and pure end-to-end schemes. Explicit network feedback based schemes usually perform better than pure end-to-end ones, but many of them require modifying IP header to carry additional feedback information. This incurs complicated computation in routers and makes them unpractical in real networks. For example, the XCP protocol can obtain accurate feedback, achieving high efficiency, fairness and fast convergence speed; but their additional feedback overhead also makes it difficult to deploy them in real networks. We propose an effective ECN-based congestion control scheme. This scheme is based on the network load factor ρ which can be estimated very easily at each router and is associated with following illustrated ECN bits in the IP header for feedback. We are making the sender aware about the state of congestion of link in the network. This is done in our scheme through explicit feedback from the network in the form of explicit congestion notification (ECN). Depending on the feedback from the network, the sender act accordingly sudden increase/ decrease the

congestion window. By using two ECN bits, it gives more convergence to adjust window size with added options to RED queue to handle congestion more effectively.

This paper is organized as follows: existing work described in section II, followed by proposed methodology is described in section III, simulation and result present in section IV, finally, we conclude this work in section V.

2. Existing Work

The new queue management scheme is designed [8] to help the monitoring the global congestion situation of an autonomous system. In order to observe the congestion situation of the system, traffic is generated between routers and a centralized unit. Routers are send packets according to current output queue levels. The central unit monitors overall view of congestion and update their random early detection parameters according to the congestion notification of the control unit [8]

Strategical (RED) Random early detection method is proposed in [4] which use queue parameter. By monitoring the queue parameter according to current queue condition and reduces the queuing delay and increase the throughput. Delay time can be reduced substantially if network length is more and sender and receiver are at sufficient distance and increase the throughput. Exiting RED uses a mechanism early detection of Packet drop without waiting to queue overflow, this mechanism inform the sender to reduce the packet transmission rate and also inform the receiver to not to send excessive acknowledgement packets. In strategical RED parameters are varied according to current queue availability which send excessive acknowledgment and solve above problem.

In [2] this paper an ECN-based congestion control algorithm called APCC is presented. In this algorithm using both wireless channel load and buffer length as compound congestion indicator. It provides more stable and higher efficient TCP congestion control and achieve time fairness and higher total network goodput. [5] Also presented an ECN scheme with new response strategy that is more aggressive in the short term, but preserve TCP behavior in long term without modifying the router marking rate. An effort [7] is tried to present distributed ECN-based congestion control protocol to which we refer as Double-Packet Congestion Control Protocol (DPCP).this scheme provide more accurate feedback compare to variable structure congestion control protocol (VCP).by extracting the router information into series of packets .it is capable to notify three level of congestion in two ECN bits. In [9] explicit congestion notification accurately improves the efficiency of TCP without harming its performance.

The Probabilistic Congestion Notification (PCN) is designed in [6] to help determine the exact level of congestion at each intermediate queue. This scheme use single bit explicit congestion notification (ECN) in the IP header. The source to estimate the exact level of congestion at each intermediate queue. By knowing this, the source mitigate its sending rate or choose an alternative roots. The estimation mechanism makes use of time series analysis both to improve the quality of the congestion estimation and to predict, ahead of time, the congestion level which subsequent packets will encounter [6].

[3] Have presented a new Code point mechanism that replace the current ECN mechanism and reuse the assigned bit in the TCP header. In order to observe the congestion situation and provide a better accuracy against losses of packets. This code point scheme performs well in internet link scenario and provides more accurate ECN feedback. By reusing the ECN TCP header bits without allocating further option space.

In this paper [1], an innovative VCP-BE method is presented. That uses available end-to-end bandwidth estimation to provide more accurate congestion feedback. With estimated available bandwidth and ECN feedback window adjustment, the algorithm convergence fast and to improve the network performance. But this algorithm suffers from overestimation of bandwidth and difficult computation in routers.

3. Proposed Approach

In this piece of work, concept of Explicit congestion notification is used, but in a bit different manner to increase flexibility to handle congestion. Here, unlike other practices, two ECN bits are used to notify congestion by intermediate nodes or receivers side which ultimately leads sender's side to adjust its window size accordingly. By using two ECN bits, it gives more convergence to adjust window size with added options to RED queue to handle congestion more effectively.

Conventionally, size of sliding window is decided upon successful delivery acknowledgement of packets and it gradually increases and decreases accordingly. In earlier works, RED queue was administered by two values of minimum and maximum threshold value, but here in this work RED queue is managed by introducing two more threshold value which are depicted by slow decrement and fast decrement along with similar vice versa pattern, due to highly dynamic nature of MANETs.

The network state is based on the network load factor ρ_l which can be estimated very easily at each router and is associated with following illustrated ECN bits in the IP header of each data packet. In our approach, for every time interval t_p a router observes its input traffic and calculates the load factor ρ_l as-

$$\rho_i = \frac{\lambda + k.q}{\gamma.C.t_p}$$

Where λ and q represent the amount of input traffic and the persistent queue length during the perion tp, k controls how quickly the persistent queue length can be reduced to zero. γ Denotes the target utilization and C indicates the channel capacity.

To adjust size of sliding window, an IMP will maintain a RED queue with four threshold level i.e. min, slow min, slow max, max which when get overburdened and crosses the max threshold level, set both ECN bits which signifies to reduce the window size significantly (let's say, four times) and if RED queue signals slow max threshold level, it reduces the size of window but less than aforesaid case (let's say two times). Below illustrated table expounds the behavior of RED queue which leads to change in ECN bits and adjustment in window size to handle congestion.

Following the aforesaid approach, as and when congestion experienced, the sliding window size is accordingly handled by the control bits sent by intermediate router to the source node. The novelty of this work lies in the fact that, congestion is handled bit in an efficient and swift manner, instead of slashing down the window drastically, which sometimes is not needed, at least to the extent it has been reduced or increased. As we are using the Mobile ad hoc network platform which is highly dynamic in nature and connectivity of any node changes abruptly, which sometimes leads to sudden increase/decrease of window size, but sometimes the same is needed to lesser extent, and such situation is handled in a better way in the proposed approach.

Table 4.1: Behavior of RED queue and ECN bits

RED queue threshold level	ECN bits status	Action to be taken at senders side
Slow $(0 \le \rho_l \le 0.7)$	00	Increase window size significantly (4 times)
Slow min $(0.7 \le \rho_l \le 0.9)$	01	Increase window size gradually (2 times)
Slow max $(0.9 \le \rho_l \le 1.0)$	10	Decrease window size gradually (2 times)
Max $(\rho_l > 1.0)$	11	Decrease window size significantly (4 times)

4. Simulation and Results

To evaluate the effectiveness of the proposed approach, aforesaid concept has been implemented over a simulation environment using NS2 simulator. In the simulations, we use the 400*400m2 gride and set the data packet size as 512B. The basic setting is an 11Mbps link with a 80ms RTT where the forward and reverse path each has 5FTP flows unless stated otherwise. RED is always used with ECN enabled at the routers. All simulations are run for at least 120s.

The effectiveness of the approach is being justified by comparing our approach with drop tail approach in literature work illustrated on the basis of Goodput, which is the application level throughput, i.e. the number of useful information bits delivered by the network to a certain destination per unit of time. The amount of data

considered excludes protocol overhead bits as well as retransmitted data packets. This is related to the amount of time from the first bit of the first packet sent (or delivered) until the last bit of the last packet is delivered.

Another metrics is average queue length which is a crucial count to measure congestion. A low value of average queue length a better congestion control mechanism is being used.

Lastly, loss rate is being considered for the same which is defined as the successfully delivered packets to the total sent packets.

Following mentioned graphs illustrate the effectiveness of our approach as compare to its counterpart drop tail.
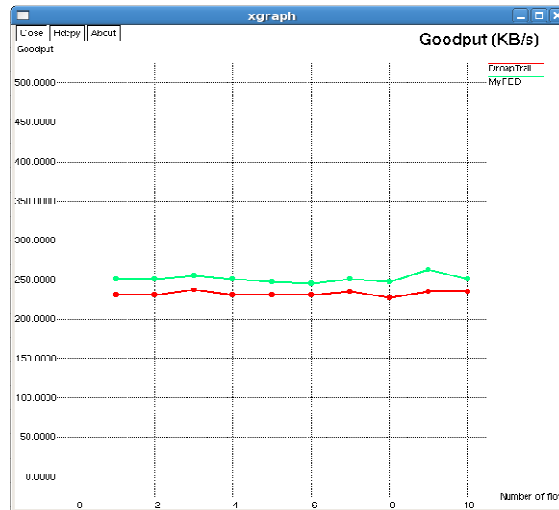

Figure 5.1 Goodput comparison of proposed approach

From figure 5.1, it is clearly depicted that our approach named "MyRED" is performing better consistently over increasing number of flows.
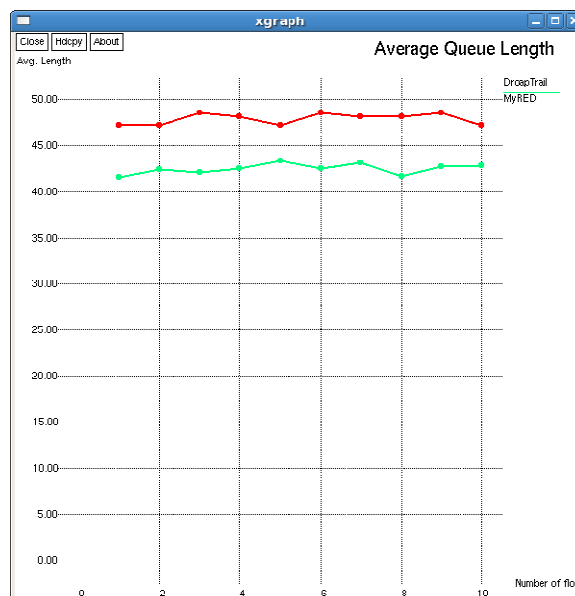

Figure 5.2 Average queue length comparison of proposed approach

Figure 5.2 expounds comparison of average queue length between proposed approach v/s drop tail and here also, our proposed approach MyRED is showing better results than its counterpart. Although it is fluctuating too much but still it is too low when compared to Drop tail approach.

Figure 5.3 Loss rate comparison of proposed approach

Lastly the loss rate observed in simulation setup is also far better (lesser) in our approach in comparison to that of Drop tail approach.

5. Conclusions

In the aforesaid study and evaluation of approach, we found our approach more effective and suited for congestion prone networks to handle the same using ECN bits associated with load factor. In all above expounded parameters, MyRED approach is performing better than its variant. The work can be extended and enhanced by implementing it in real hardware to study its strength and flaws in more practical settings.

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