IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661, p- ISSN: 2278-8727Volume 12, Issue 3 (Jul. - Aug. 2013), PP 103-109
www.iosrjournals.org

Analysis of Rate Based Congestion Control Algorithms in Wireless Technologies

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Abstract: *In this paper, the congestion control algorithms in wireless technolologies are analysed. It has been found that TCP VEGAS is better than other TCP variants for sending data and information due to better delivery fraction and average end to end delay. But it has a consistent window size for packet transmission. Congestion Avoidance can resolve Congestion effectively and has higher average throughput than slow start due to the ability to deal with random loss. Cross layer Congestion Control require significant power and memory corresponding to network bandwidth. So to overcome all these problems, here we analyse the performance of AIMD, TFRC and TCP congestion control protocol. After observing simulation results, it is found that GAIMD is better than TFRC in terms of throughput and TFRC is better than GAIMD in terms of smoothness.*

Index Terms: *MANET, CONGESTION CONTROL, MULTIPATH ROUTING, TRFC, GAIMD, TCP.*

Submitted date 20 June 2013 **Accepted Date: 25 June 2013**

I. Introduction

MANET is an infrastructure less wireless network. There is no centralized management. It is the network that allows the node's mobility. Any no. of nodes can participate in data transmission. The objective is that the nodes are free to roam in and around the network and the same time the sender node is forced to update its path, frequently. They can form any topology. Route changes due to nodes mobility causes in steady packet delivery delays and packet loses. Mobile devices act as routes and data packet are forwarded by intermediate nodes to their final destination. MANET are independent systems of mobile nodes which form wireless network of sorts where mobile nodes dynamically structure a network to exchange information without making use of any preexisting fix network. A MANET is said to exist when a willing node sends data to another willing node who readily accepts it. These two nodes works as a host and a router. This helps in forwarding of packets for other mobiles nodes in a network that are beyond the transmission range of the mobile source node.

Mobile nodes in MANET have limited transmission capacity. They intercommunicate by multi-hop relay. Multi-hop routing have many challenges such as limited wireless bandwidth, low device power, dynamically changing network topology and high vulnerabilities to failure.

There are many routing algorithms, but these have problem of congestion which decreases the overall performance of the network.

To maintain and allocate network resources effectively and fairly among a collection of users is a major issue. The bandwidth is shared by no. of users. Packets are queued in these queues awaiting transmission. The nodes at center of a network may carry more traffic as compared to other nodes. When too many packets are contending for the same link, the queue overflows and packets have to be dropped. When no. of senders sends packets of data, and if no. of packets are more than the bandwidth then few of them are dropped and these dropped packets are sometimes retransmitted. If a packet is lost and sender receives a duplicate ACK then sender thinks that there must be a reordering of packets but if sender receives fourth duplicate ACK then he came to know that it can be the case of packet losses When such drops become common events, the network is said to be congested. This may affect the performance of network as delay increases; throughput and reliability may also be affected.

D.C. joy Winnie and N. Kesavan Nair [3] proposed that the network consists of no. of cluster nodes. A cluster head will identify the congestion periodically in the network .This cluster head will monitor about the congestion by using three factors or parameters:

- Round trip time
- Node's out link capacity
- Average queue size

The overall performance is evaluated with the help of delivery ratio and average throughput .The algorithm is highly effective in dealing with multiple inference flows and in achieving high delivery ratio and low delays compared to old approaches.

The major problems observed in MANET Congestion Control are:-

Route failures trigger inappropriate TCP congestion control reactions. The standard TCP retransmission timeout grows too fast in MANET environments. After rerouting, the new route can have very different properties like Random losses can occur on wireless links. The locally shared medium induces unfairness between TCP flows and has a long feedback path. Data and acknowledgment packets interfere on the shared medium. TCP oversaturated the network. On the shared medium there is intra-flow contention between successive data packets. The TCP acknowledgment scheme generates a lot of packets. TCP traffic is busty. TCP’s basic design decisions do not fit a MANET environment well.

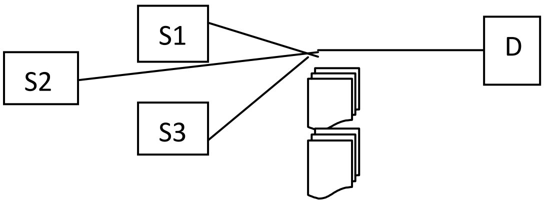

Fig 1: Dropped packets

To overcome the above problems, we have observed various mechanisms, parameters, techniques and control strategies.

The remainder of the paper is organized as follows:- Section II presents the review of literature. Section III presents the simulation setup in terms of congestion control on wireless technologies. Section IV finds out results that which congestion control protocol is better in terms of throughput and smoothness via graphs and finally section V concludes the paper.

II. Related Work

W.R. Salem Jeyaseelan *et al*. proposed that Congestion control mechanism has two basic classifications:

1. Congestion avoidance
2. Slow Start

Slow start means to avoid transmitting huge amount of data in a single path in network. It works by increasing the window size. Each time the acknowledgment is received. Here after every acknowledgment received, the CWND size is reduced to half. The size is calculated by estimating the congestion between the nodes. Now receiver sends information to sender, then sender maintains the congestion window size. As source receives ACK for every segment, the window grows exponentially until a timeout occurs or the receiver reaches its limits. This deals with how to adjust the window size. Window based congestion control (CA) can resolve congestion effectively and has higher average throughput than slow start due to its ability to deal with random loss[3].

Kai Chen, *et al.* [5] proposed that how to properly set TCP'S congestion window limit to achieve optimal performance. The author propose an adaptive CWL setting strategy to dynamically adjust TCP'S CWL according to the current RTHS (round trip hop count) of its path .TCP adjusts its congestion window according to its normal congestion control algorithm. It is observed that setting TCP and CWL to a large value in MANET would adversely affect its performance. In this we propose an adaptive CWL setting strategy to dynamically adjust TCP'S CWL according to its current path in MANET. TCP'S congestion control is window based that it keeps a congestion window to signal the availability of network bandwidth and adjust the window size according to the additive increase multiplicative decrease algorithm. In a typical TCP, the congestion window size is unbounded, which allows a TCP flow to obtain as much bandwidth as network permits [5].

To overcome the shortcomings of above, cross layer congestion control[6] focus on the parameters like:-

- Cost metrics that define the efficiency and performance of an ad-hoc network.
- The method to decrease the power consumption in MANET of ad-hoc network in manner to increase the longevity and maintenance of mobile ad-hoc network[6].

Here the different congestion control techniques are

- Hop by hop congestion control:-
- Adaptive routing technique
- Congestion monitoring
- Primary route discovery
- Bypass discovery
- Traffic splitting and congestion adaptability

- Multipath minimization
- Failure recovery

But this study has a shortcoming that the supporting nodes require significant power and memory corresponding to network bandwidth.

The concept of cross layer optimization is used in hop by hop congestion control schemes.

1**. HCCC**:-Packet loss in this HCCC is less than CODA and ESRT. Throughput of HCCC is much higher than others. Source transmission rate in HCCC is quite in stable level after the transmission process. Energy efficiency in HCCC is greater. More the sensor node in network, more the packet dropped. But HCCC is not suitable for large scale WSN.

2**. CODA** :-(Congestion detection and avoidance)

It guarantees that throughput satisfies the accurate request by adjusting rates in closed loop way.

3. **ESRT** (Event source reliable transport):- It controls the congestion by changing and transforming the network state. This uses a more accurate method to detect congestion than CODA.

4**. FUSION**:-It exploits three techniques to achieve cross layer processing.

a. Hop by hop flow control

b. Rate limiting source traffic

c. Prioritized MAC protocol

It assigns priorities to nodes. Guowei Wu, Fengxi, Lin Yao proposed that hop by hop uses cross layer optimization to detect congestion degree and mitigate congestion where nodes rate and flow are adjusted according to the priorities.

Few cross layer optimization schemes are:-

ANAR:-It combines transport layer congestion control and network layer routing protocol.

Cross layer prediction congestion control scheme for improving the performance of network applies queuing theory to analyze data flow of signal. But this wouldn't be able to work in multi-hop wireless mesh network.

For achieving fair and efficient congestion control for multi-hop wireless mesh network. For this AIMD based rate control is designed called Wireless Control Protocol (WCP) which recognizes that wireless congestion is neighborhood phenomenon, not a node local one [6]. After this a distributed rate controller is used that estimates the available capacity within each neighborhood, and divides this capacity to contended flow, this is called Wireless Control Protocol with Capacity Estimation. This design works with MAC 802.11 and is extremely easy to implement. But this study has a shortcoming that it cannot account for the loss of capacity caused by interference and how to deal with short-lived flows. This all needs modification in MAC 802.11 to improve the performance.

Multi-hop relay has many challenges such as limited wireless bandwidth, low device power, dynamically changing network topology and high vulnerability to failure. One of the problems in routing is congestion which decreases the performance of network. S.A. Jain, Abhishek Bande proposed best routing algorithm which will improve congestion control mechanism among all the multipath routing protocols

Advantages of multipath routing:-

- Long delay reduction.
- High overload reduction.
- Packet loss reduction.

FZR:-A multipath routing protocol supports congestion control. It classifies the intermediate nodes according to their capacity and efficiency in forwarding packets. FZR protocol is a combination of proactive and reactive routing protocols. FZR lighten congestion and provide better throughput.

In FZR each node maintains a table of fields like destination address, seq no. and hop distance. The nodes broadcast the hello message, and then upon receiving hello message, a node updates its own table. When a distance table propagated throughout the network, each node updates its distance table and first order path are discovered. FZR discovers alternate second order path with on demand approach. Source initiates the route discovery process, when it receives message it sends a reply message to the originating node by up streaming neighbors. The upstream nodes then record the forward path in table and forward the reply message to the originator. Upon receiving a reply message the originator records the path in the forward path table and this procedure repeats it until message packet received at destination [7].

Swastik Brahma *et al.* [8] proposed a distributed congestion control algorithm for tree based communication in wireless sensor network that assigns a fair and efficient transmission rate to each node. They proposed a distributed and adaptive mechanism for controlling congestion in sensor network which seeks to find an optimal transmission rate for the nodes that is both fair and maximally efficient. Here it uses two modules, the utility and fairness among flows. Each node monitors its aggregate output rate and aggregate input rate.

Advantages of this algorithm

1. It adjusts the aggressiveness according to the available bandwidth. This all reduces oscillation, provide stability, and ensure efficient utilization network resources.

2. Decoupling the utility and fairness controlling module.
3. It supports multiple concurrent applications and is also highly robust to change.
4. It improves the channel quality by inducing a phase shifting effect among neighboring nodes.

The fairness module decides on how exactly to apportion the total change in traffic rate required among the flows [8].

Yong Min Liu *et al*. describes the characteristics and content of congestion control in wireless network [10, 11]. An implementation on congestion control algorithm is given which involves technical difficulties aroused and deficiencies made in this paper. Here wireless network merges with modem network to form wireless sensor network.

Congestion control and best effort service model are closely linked with each other.

Characteristics of WSN:-

- Centralized data collection
- Multi-hop data transmission
- many to one traffic pattern

  Here nodes near to base station needs to send more data and has more traffic burden. It leads packet collection and congestion happens so packets get lost

Two criteria of performance measurements

1. The life expectancy
2. Average flow of biggest load node is the energy consumed by the first node, when it is from the sensor network. Longer the life expectancy of network higher the performance.
3. Higher the load on node, lower the performance, means congestion occurs.

LOAD BALANCING:-It balances the node energy consumption and prolongs the lifetime of sensor network.

III. Proposed Algorithm

TFRC Algorithm

The primary goal of equation-based congestion control is not to aggressively find and use available bandwidth, but to maintain a relatively steady sending rate while still being responsive to congestion [19] and the protocol that implements the TCP-equation based approach, TFRC (TCP Friendly Rate Control). TFRC is a protocol that implements equation-based congestion control. In TFRC, The sender directly adjusts its sending rate as a function of the packet loss rate. The scheme relies on a “TCP throughput equation” which captures the TCP throughput over a network path with certain loss rate and round-trip time. In TFRC, the receiver measures the loss event rate (i.e., loss rate) and feeds this information to the sender. The sender uses the feedback messages to measure the RTT, and then inputs the loss rate and RTT to a TCP throughput equation to compute its acceptable transmission rate. TFRC is able to maintain smooth rate change; its throughput is often “beaten” down by competing TCP flows to a certain degree, especially under heavy background traffic and dynamic topology conditions. We also discover certain fundamental difficulties of equation-based flow control in MANET, such as loss rate estimation of the network. Therefore, although equation based flow control is a successful proposal for the Internet; it has serious limitations when applying to the MANET domain.

- TFRC may experience higher loss rate than TCP
- TFRC’s loss rate estimator is highly inaccurate

GAIMD Congestion Control Algorithm

TCP uses an additive increase multiplicative decrease (AIMD) algorithm; the TCP sending rate is controlled by a congestion window which is halved for every window of data containing a packet drop, and increased by one packet per window of data acknowledged. In this the sender’s window size is increased by **a** if there is no packet loss in a round-trip time, and the window size is decreased to **β** of current value if there is a triple-duplicate loss indication, where a and β are parameters. According to Chieu and Jain study **a** and **β** must satisfy the following relations

$$o < a$$

$$0 < \beta < 1$$

then GAIMD congestion control is “stable” and “fair.”

We define a congestion epoch as a period beginning with a congestion window of (1-b)w packet. The congestion window is increased additively by a packets per roundtrip time up to a congestion window of w, when a packet is dropped. Then the congestion window decreased multiplicatively back to (1-b)w.

Each congestion epoch consists of

$$\frac{b}{a}W + 1$$

round-trip times. We let S denote the sending rate in packets per RTT, the average sending rate over one congestion epoch is

$$S = \frac{2-\mathrm{b}}{2}\mathrm{W}$$

this gives a total of

$$\left(\frac{\mathrm{b}}{\mathrm{a}}\mathrm{W}+\right)\mathrm{S} = \left(\frac{\mathrm{b}}{\mathrm{a}}\mathrm{W}+1\right)\frac{2-\mathrm{b}}{2}\mathrm{W}$$

Packets in one congestion epoch. Using an approximation, the total packets transmitted in one congestion epoch is about

$$\frac{\mathrm{b}(2-\mathrm{b})}{2\mathrm{a}}\mathrm{W}^2$$

With one packet dropped at the end of the congestion epoch. The drop rate p is

$$\mathrm{p} \approx \frac{2\mathrm{a}}{(2-\mathrm{b})\mathrm{b}\mathrm{W}^2}$$

We get

$$W \approx \sqrt{\frac{2a}{(2-b)bp}}$$

Submitting it into equation , we get the following

$$S = \frac{\sqrt{2-b}\sqrt{a}}{\sqrt{2b}\sqrt{p}}$$

Currently, TCP uses GAIMD(1,1/2), applying equation, we get the well-known TCP response function

$$S_{1,1/2} = \frac{\sqrt{1.5}}{\sqrt{p}}$$

In order for GAIMD (a, b) to have the same long-term sending rate, we would like to have the same response function:

$$\frac{\sqrt{2-b}\sqrt{a}}{\sqrt{2b}\sqrt{p}} = \frac{\sqrt{1.5}}{\sqrt{p}}$$

This is equivalent to

$$a = \frac{3b}{2-b}$$

To make the sending rate smoother, the most obvious choice would be use a decrease parameter b less than 1/2. The most obvious advantage of GAIMD (a, b) is that GAIMD (a, b) congestion control is familiar and reasonably-well understood, in terms of fairness, stability, oscillations, and other properties.

IV. Results

A topology is required to show the related work and its parameters. Let us have a wireless network where random nodes are movable (free to move anywhere) and all nodes are in the range of each other. Consider an area of 500m*500m. All nodes are involved in two CBR conversations: source and destination.

Simulation parameters are :-

Table 1: Simulation Setup

Parameter	Value
Channel	Wireless
Propagation	Two Ray Ground
Network Interface	Phy/Wireless
Queue	Droptail
LL	Link Layer
Antena	Omniantina
Ifq	50
No. of Mobile node	2
Routing Protocol	DSDV

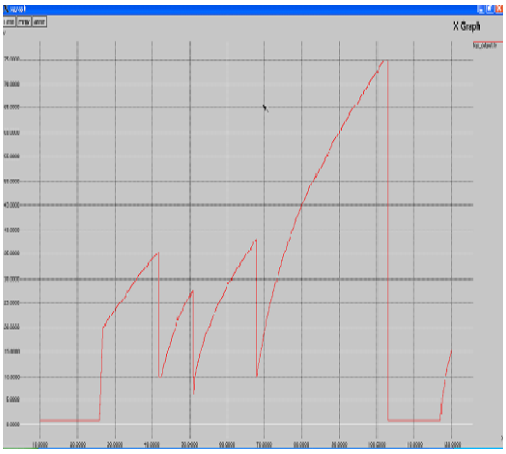

Fig. 2 X Graph in a nine nodes scenario with TCP congestion control protocol

In above graph, the x-axis and y-axis represent the time and packet bursting. At starting time 0.0 data is not transferred and at time 27.0 data is transferred from one node to another as rising curve shown in graph. After some time congestion occurs and network performance leads to be degraded. In this case more congestion occurs due to maximum number of nodes and mobility of nodes. This shows the more throughputs and less smoothness of TCP as compared to TFRC and GAIMD mechanism. TCP throughput is more variable than TFRC as well as GAIMD and having less smoothness, packets are lost due to congestion and mobility of nodes in MANET.

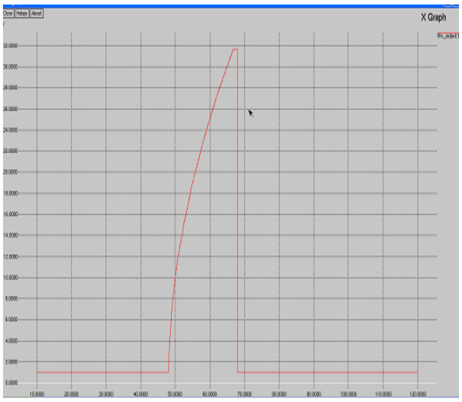

Fig. 3 X Graph in a nine nodes scenario with TFRC congestion control protocol

At starting time 0.0 data is not transferred and at time 48.0 data is transferred from one node to another node as rising curve shown in graph. As congestion becomes in the network it is resolved by TFRC with the help of sending rate. That's why in case of TFRC, the above graph shows the smoother throughput. TFRC throughput is less variable than both of GAIMD and TCP and here the packets are lost due to congestion. TFRC having less throughput and more smoothness than GAIMD and TCP.

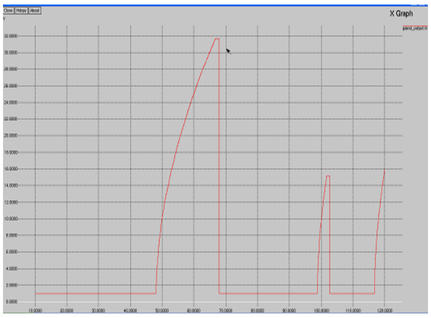

Fig. 4 X Graph in a nine nodes scenario with GAIMD congestion control protocol

At starting time 0.0 data is not transferred and at time 48.0 data is transferred from one node to another node as rising curve shown in graph. As congestion becomes in the network it resolved by GAIMD with the help of decreasing the window size. Again in case of GAIMD the above graph shows the smoother throughput than TCP. GAIMD throughput is more variable than TFRC and having less smoothness, packets are lost due to congestion.

IV. Conclusion

It has been found that TCP VEGAS is better than other TCP variants for sending data and information due to better delivery fraction and average end to end delay. But it has a consistent window size for packet transmission. AIMD is better but it needs significant power and memory corresponding to network bandwidth. WCP needs few modifications in MAC 802.11 and doesn't work well for short lived network. GAIMD is better than TFRC in terms of throughput and TFRC is better than GAIMD in terms of smoothness. In further study some extension in earlier algorithm that can limit the delay and buffer overflow caused by network congestion and provide tradeoff between efficient and fair resource allocation can be done.

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