Channel Occupancy Ratio Based TCP Congestion Control in Adhoc Networks

R. Jayaraj, T.Suresh

Abstract: ***Wireless Network is been used widely in the recent years due to its low-cost nature. More number of real time applications have been used by varied segments of users across the world. The advancements in the mobile technology have made ad hoc networks as important and active field of communication and networks. Most of the time the network cannot handle the traffic in the network which ultimately affects the Quality of Service (QoS). The conventional Transmission Control Protocol (TCP) cannot handle this huge volume of traffic and control the congestion in the network. This issue in the wireless network is been addressed by various researchers in the world but still the scope and need for improvements are more. This paper analyzes many TCP congestion control mechanisms and proposes an efficient approach for congestion control by estimating Channel Occupancy Ratio (COR). The COR is estimated based on machine learning algorithm which is trained using the historical data extracted from MAC layer. This cross layer based approach is found to be more efficient when compared to other methods proposed in the literature.***

Keywords: Quality of service, transmission control protocol, channel occupancy ratio, machine learning.

I. INTRODUCTION

TCP supports majorly multi network applications and it is connection oriented end to end reliable protocol [1]. TCP has the ability to adjust its transmission rate corresponding to the estimated congestion in the network. Congestion in a network marks a state where the number of data packet being sent from source nodes is higher than the capacity of the network. The network congestion degrades its Quality of Service and it increases the delay in the network and reduces the overall throughput. During connection establishment the receiver sender is informed about the buffer size by the receiving node. The sender transmits only a portion of the data packets depending on the size of the window size. When the receiver is not able to receive the data in the rate sent by the source then it requests for reduction in the window size. This approach synchronizes the transmitter and receiver and in case of a packet loss the receiver will send duplicate acknowledgement for the packet received before the loss.

Revised Manuscript Received on August 05, 2019

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The schematic view above mentioned approach is presented in the Fig. 1. More number of duplicate acknowledgements may symbolize packet loss due to congestion.

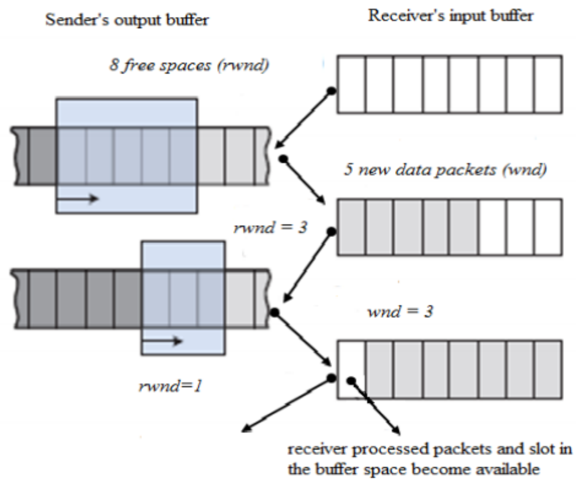

Fig. 1 Sliding Window approach in TCP

Congestion Control (CC) is counter mechanism to prevent or avoid congestion in the network. The aim of CC is to reduce the delay in the network and increase the overall performance of the network. The traditional congestion control mechanisms used in the TCP protocol and its variants are more suitable for wired networks than wireless networks [10]. Congestion in the network results in more packet loss and many of the congestion control mechanisms depends on the packet loss in detecting congestion. But in case of wireless networks the packet losses can be due to various other factors such as mobility of the node, and high BER (Bit Error Rate) [2]. In TCP congestion control mechanisms once a packet loss is detected the protocol initiates the control mechanism. The source node has to stop or reduce its transmission rate.

This approach reduces the quality of service at times when the cause of packet loss may be due to buffer overflow and random errors in the intermediate nodes. A long RTT during high delay in the network is considered as congestion and the senders reduce their transmission rate as per the congestion control mechanism. Even during low traffic conditions sometimes there will be a delay in the network due to scheduling bandwidth on the wireless links. Thus, under these scenarios the probability of performance degradation in the network is higher.

More in wired networks CC mechanisms are implemented at the transport layer and it is separated from the functionalities of the other layers in the network.

In case of wireless network, the availability of limited bandwidth, power, and buffer size are the some of the challenges to be faced while designing a CC mechanism. The mobility of the nodes is also a reason for frequent route failures and consequently there will be increase in the packet delay. This research aims at designing a CC mechanism to detect the cause of the packet losses by estimating the channel occupancy status from the information extracted from the MAC layer and react accordingly. This work helps to distribute the traffic in the network evenly by finding a non-congested path [12].

The rest of this paper is organized as follows. In Section 2 the various literatures related to TCP congestion control techniques are reviewed and analyzed. In Section 3 the dataset used to train the channel occupancy ratio estimation algorithm is described and in Section 4. The proposed methodology is explained in section 5 and section 6 finally concludes the paper with scope for further research.

II. RELATED WORKS

This work reviews various factors affecting the performance of the network especially the TCP layer and variety of improvements proposed in the literatures including their merits and demerits. Channel interferences cause multi-path fading and due to high BER cause high packet loss and reduce the efficiency of the network. Due to mobility of the nodes there is frequent route failure and subsequent packet losses are common in ad hoc networks. The random temporal variation in the ad hoc network decides the SINR (signal to interference plus noise ratio) of the received signal. When the channel is faded heavily the SINR of the received packets are low and the destination node cannot decode the signal properly. In this case the node has to drop the packets even if there is no congestion in the network.

Congestion is considered to be one of the factors affecting QoS in ad hoc networks. When the number of packets transmitted in the network reaches maximum capacity then it is considered to be congested. Either by adopting a congestion avoidance or congestion control mechanism it can be dealt. At this stage there will be too many packets drops in the network and the objective of these two mechanisms is to limit or distribute the packet flow in the network. Usually the lost packets are re-transmitted which consumes more energy bandwidth. CC mechanism in TCP aims at finding out optimal size of TCP congestion window. The congestion window size decides the number of packets a sender can transmit without receiving acknowledgement [3]. If the window size is small the available bandwidth will not be utilized fully and if the window size is larger than the packets will queue up at router and causes packet loss. In past several methods have been proposed in various literatures [4] and in recent past researchers have started applying machine intelligence in mitigating the congestion problem. The work in [5] suggested a congestion control mechanism capable of discriminating the congestion losses from error losses. The work assumes that if SNR is greater than 5dB then the packet loss is caused due to congestion and the congestion window is adjusted to control the packet loss. In [6] the authors have proposed a modified TCP based on the multiplicative decrease algorithm of TCP NewReno. Statistical counters and occurrence frequencies of timeouts and three duplicate acknowledgements are considered to differentiate congestion and non-congestion incidents.

The protocol proposed in [7] presents a fair bandwidth allocation method based on the congestion feedback computed based on the congestion information. The protocol stabilizes the network at a smaller but more optional sending window size rather than the window size used in conventional TCP with low buffer occupation delay.

A TCP CC mechanism implemented at the receiver side is proposed in [8] in which the TCP receiver window is adjusted proactively even before packet loss is sensed in the network. The cross layer based congestion control of TCP and MAC provides the avoidance of system control congestion. A hop by hop congestion control mechanism instead of end to end mechanism is proposed to decouple congestion control from TCP [9]. The congestion window is not used to regulate the transmission rate. A systematic review of TCP congestion control and their implementation based on dynamic window sizing, fast retransmit and fast recovery were analyzed [11].

The approach used in this work is to train machine learning algorithm that learns to make decisions to change the size of the window dynamically for controlling congestion in the network. A simple solution to improve the throughput of the network at times when packet losses are increasing due to link error is to implement an algorithm either in the sender or receiver node to classify the cause of the packet loss with information available at the respective node.

III. PROPOSED MACHINE LEARNING BASED CONGESTION CONTROL

A straightforward solution to increase the throughput of TCP over wireless links is to prevent it from reducing its packet delivery rate when it faces a loss due to a link error as it does when it faces congestion. Section 2 has reviewed several approaches proposed in the networking literature that assumes the support of the network. The approach adopted in this research is to endow one of the end systems (i.e the sender or the receiver) with an algorithm able to determine the cause of a packet loss only from information available at this end system. The sender receives one or two duplicate ACK once a segment is lost or to be reordered and if the sender receives three or more number of duplicate ACKs then it is considered to be lost packets. TCP layer in the sending node decides to retransmit the lost packets without waiting for re-transmission time to complete. In this scenario after receiving a triple duplicate the ML model deployed in the source node identifies the cause of the packet loss. If there is congestion in the network the sender alters it congestion window else the congestion window is fixed constant. This method is simple to implement as it does not require any support from the network as only end-to-end nodes are concerned with the classification tasks. In various literatures rule-based classifiers are used employed to perform classification tasks. But these rule-based classifiers are not well suited for such task and hence an ensemble learning decision tree-based algorithm is used in this work to predict the channel occupancy ratio and hence determine the cause of the loss. This model is trained using historical data in a supervised mode and in real time the statistics from either sender/ receiver node is given as input to classify the cause of the loss in the network.

In order to maintain the quality of data transmission the end-to-end traffic control becomes essential. The channel occupancy ratio is estimated based on the information extracted from the MAC layer. The information about the MAC layer is stored in the Physical layer and then it is passed to a channel occupancy detection module. Initially a threshold range is selected to decide the channel occupancy and the threshold values are represented as $\alpha$and β. Estimated channel occupancy value is threshold to know whether the channel is busy, normal or less occupied.

If estimated COR is less than alpha then the wireless channel is free, if COR value lies between$\alpha$and βthen it is considered to be normal and if the COR value is above theβ then it is congested heavily. The congestion control module then varies the *cwnd* and *awnd* based on the thresholding results and the TCP traffic generation is modified according to the channel occupancy. This procedure is repeated iteratively after a fixed interval of time.

As similar to conventional TCP protocol the congestion window (*cwnd*) and receiver window (rwnd) is used to control and avoid the congestion in the network. The congestion and receiver windows are managed by the source and the destination node respectively. The congestion window size decides the amount of data packets that can be transmitted through a TCP connection. The destination node fixes the rwnd size and it denotes the amount of data that the destination can receive. This inturn helps the source to decide on the size of the *cwnd* which indicates the number of data packets that can be transmitted without receiving the acknowledgement. The evolution of the congestion window with respect the increase in the congestion is presented in the Fig. 2. The *cwnd* is increased gradually upto the *rwnd* value or until the network is congested. May be the size of *cwnd* is fixed small when compared to the *rwnd* value.

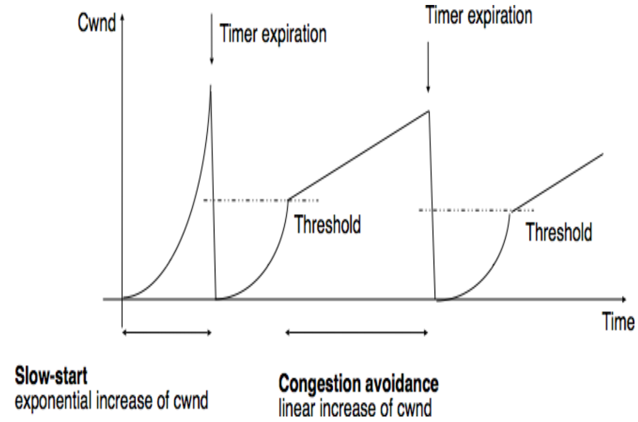

Fig. 2 Evolution of Congestion window with respect to congestion

Once a source receives more than three duplicate acknowledgments then it calls the congestion detection module which encompasses the machine learning model to predict channel occupancy. Congestion detection in the network is initiated based on the number of duplicate acknowledgements. Once congestion is detected by the sender then the congestion window is reduced by a factor decided by the congestion control mechanism. The maximum amount of unacknowledged data that the source can send is the lower of the two windows.

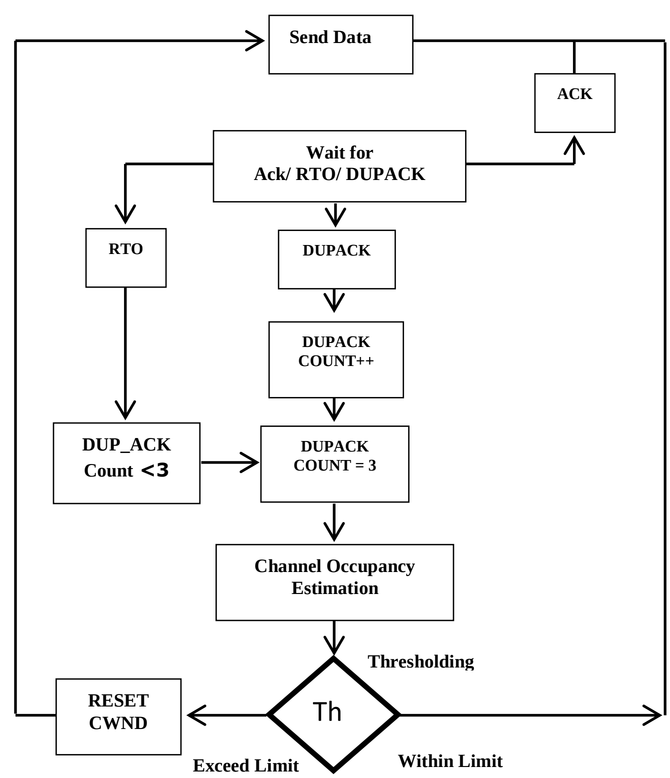

Fig. 3 Process Flow in Proposed approach

IV. DATASET

The dataset consists of the the 802.15.4 MAC layer performance attributes such as: 'Num Of Received', 'PRR', 'packet Loss', 'PLR', 'throughput', 'IPI', 'Density', and 'COR'.

i. Num_of _received – it gives the number of data frames received within an interval of time period.
ii. Packet Reception Ratio – the ratio between the received number of data frames to the number of frames sent from the source to that respective destination.
iii. Packet_Loss – It is the number of frames that have not reached the destination.
iv. Packet_Loss_Rate – It is the percentage of frames lost with in an observed time period.
v. Throughput – It is an aggregated measure of throughput of all source nodes in the network.
vi. IPI – Inter Packet Interval of the source node expressed as X/128 (seconds).
vii. Density – Number of nodes transmitting actively in the network within the observation time.
viii. COR – It can be defined as the time occupancy ratio.

V. EXPERIMENT & RESULTS

The efficiency of the proposed approach depends on the accurate estimation of Channel Occupancy Ratio (COR) by the Random Forest (RF) Regression algorithm. Initially the RF algorithm is trained with the historical MAC layer information stored by the physical layer using supervised learning method. The attributes used in estimation of COR is described in section IV. The performance of the RF algorithm is compared with the prediction results of other regression algorithms such as gradient boost, polynomial, and support vector regression techniques.

The dataset used for training and testing the regression model was captured from real time environment with the configuration given in Table 1. From the simulation various MAC layer parameter such as Throughput, packet loss count, packet loss rate, were estimated. To measure the spectrum/ channel occupancy directly using functions there are no supported Wireless LAN chipset available at present. To measure channel occupancy generally separate measurement hardware kit is used and they consume more power. The proposed approach was a cheap and easy to implement solution. Using a spectrum analyzer the channel occupancy is measured. The transceiver IC present in spectrum analyzer can be programmed sweep in between the frequency range 2399 MHz to 2485 MHz with a step size of 500 kHz. Each step is considered as a sub channel and in total 173 sub channels analyzed for a dwel time of ~1.56ms/sub-channel. From the sub-channel measurements an average value is calculated for every fixed time window to yield channel occupancy. The measured values are used to train the random forest regression model. The accuracy COR estimation mainly depends on the choice of thresholds. The thresholds are adjusted dynamically to suit different signal source and clear channel assessment. The thresholds are to be fixed in such a way that the error should be minimum in estimating the COR.

Table. 1 Network Configuration

Parameter	Specification
Number of Nodes	40
Number of Sink Node	01
Mobility Model	Random Waypoint
Physical Layer	IEEE 802.11
Routing protocol	AODV
Radio Frequency	2.4GHz
Traffic Source	CBR
Queue Model	DropTail
Buffer size	50

The performance of the random forest regression technique is compared with the other regression algorithms and it is presented in Fig. 4. The accuracy of the RF algorithm in predicting the COR is found to be satisfactory when compared to other regression algorithms.

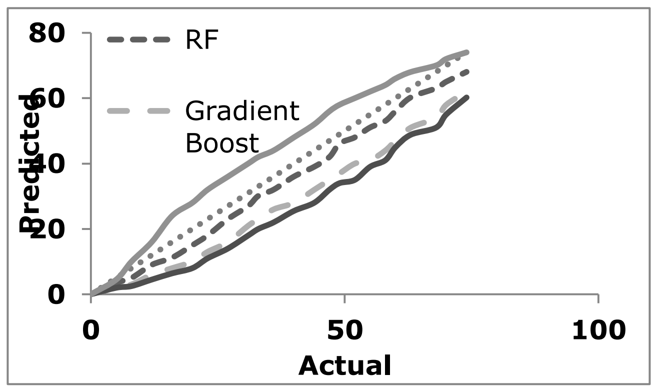

Fig. 4 Actual vs Predicted COR

The error measure for assessing the performance of the time series forecasting is the root mean squared error and it is presented in Fig 5.

$$RMSE = \sqrt{\frac{\sum_{k=1}^{n}(y^k - t^k)^2}{n}} \quad \text{-------(1)}$$

Where y – actual and t – predicted COR

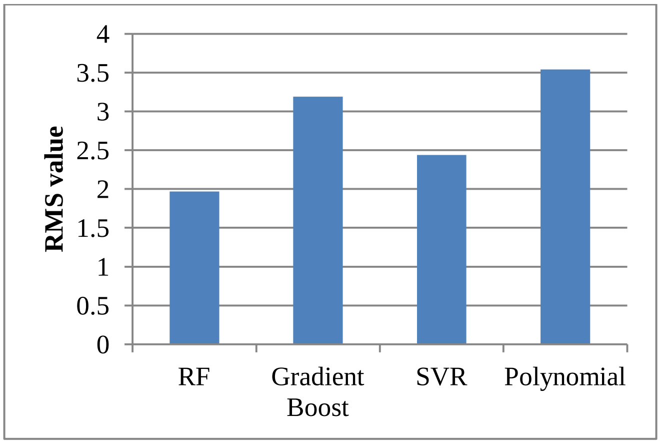

Fig. 5 Error measurement in COR prediction

After constructing the COR estimation model the standard TCP protocol given in Network simulator NS2 is modified and the trained model is embedded within C++ code. The model is invoked upon receiving the three consecutive duplicate acknowledgements and it determines the status of the channel in real time simulation. When congestion is sensed in the network the window is reset, otherwise the transfer of next data packet is continued. This approach refrain the network from becoming more congested when more number of packets is lost due to increased transmission rate from all CBR source nodes. It prevents further packet losses. The model is implemented in the source node which holds all end to end information. The simulation is run on both standard TCP and the modified TCP. The improved performance (increased throughput and reduced packet loss) of the proposed approach is shown in Fig.6 and in Fig 7. the packet loss sensed during the simulations are shown.

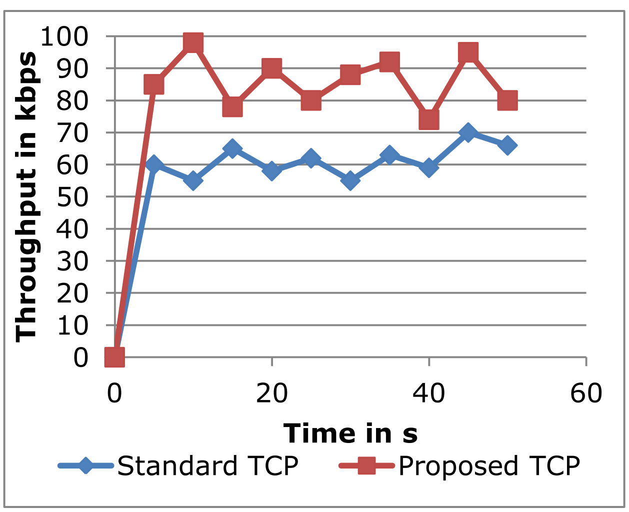

Fig. 6Throughput comparison between TCP and proposed

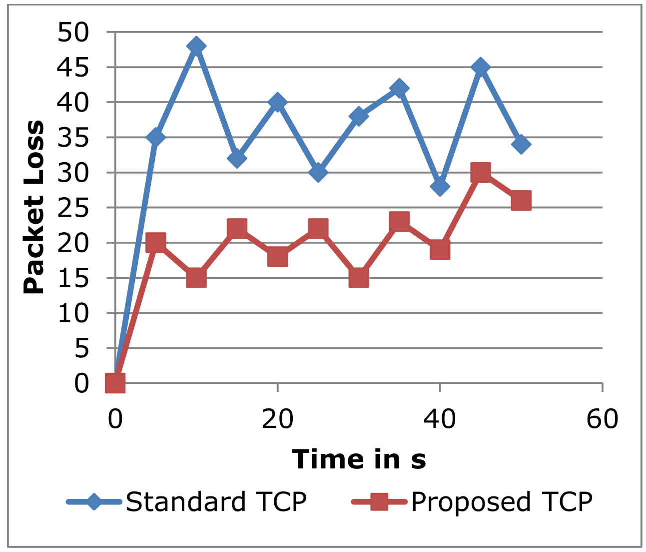

Fig. 7 Packet Loss comparison between TCP and proposed

VI. CONCLUSION

The objective of this research is to propose a simple and effective solution for TCP congestion control. This work introduces a COR estimation method which suppress the effects of false alarm generated by standard COR estimation methods. A detailed systematic review was performed and the experimental results confirm that the proposed congestion control method was effective in under various traffic scenarios during simulation. In the future work, methods with knowledge of the SNR will be considered for obtaining a higher performance but requiring more information. We will also consider other noise uncertainty models. In future work further the accuracy of the COR estimation under various interference situations (low, high and average) must be analyzed. In the current work state, the random forest model can already be used for coarse-grained estimations and is implementable on WLAN adapters. The proposed approach need to be evaluated on a multi-channel network.

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