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Adaptive Rate Control Mechanism For Improving Node Fairness In Ieee 802.11 Wlan Access Network

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***ABSTRACT*- In IEEE 802.11 Wireless Local Area Network (WLAN) flow of packets originating from source node are relayed to the Access Point (AP), which has the responsibility to convey packets for their destination node. Each station should yield the channel access opportunity among all competing stations, so that each station can effectively use channel for equal duration and improves the transmission efficiency of network, which is achieved using Channel Occupancy Time based Rate Control for TCP (COTRC–TCP). This mechanism achieves a higher end-to-end throughput but increases the delay to a higher level and also resource will be wasted. So, a newly proposed algorithm Adaptive Rate Control scheme is implemented to utilize the total bandwidth and also reduce overheads, which eventually increases overall network throughput. Implementation of the algorithm is developed in Linux based NS-2 simulator.**

Key words: IEEE 802.11 Wireless LAN, Fairness, DCF

I. INTRODUCTION

Wireless local area networks (WLANs) based on IEEE 802.11 has become important network infrastructure and is available at various places. WLAN consist of wired/wireless node which serves as upload and download stations for flow of packets across the network. Packets originating from upload stations transmit only its own packets and are relayed to the AP, AP has the responsibility to forwards the packets for all download stations. The main task is to maintain the Fairness in terms of resource allocation and throughput of the network.

In order to improve the aggregate throughput and to achieve the fairness in IEEE 802.11 WLAN, COTRC-TCP [1] is used which divides the overall available channel occupancy time among all stations in the network. The physical layer supports multiple data rates. The associated rate adaptation algorithm at the MAC layer selects one of the data transmission rate according to the varying channel conditions. The IEEE 802.11 Medium Access Control (MAC) layer defines the distributed coordination function which is based on the carrier sense multiple access with collision avoidance (CSMA/CA) protocol. A station wanting to transmit senses the medium, if the medium is busy then it defers, the source node freezes its timer until it becomes free again.

The main drawback of this mechanism is that it wastes available bandwidth by equally dividing among all stations and delay is also higher. To achieve the objective and to overcome the drawback, the Adaptive Rate Control algorithm called ARC [2] is combined with the COTRC_TCP mechanism. Various parameters are used to tune the rate of the buffer for IN and OUT flows.

This approach is based upon utilizing a rate-limiter, which is implemented using a Token Bucket Filter (TBF). It is characterized by two parameters:
1) the rate of generating tokens into the bucket (R), and 2) the capacity of the bucket (bucket depth B). The rate-limiter operates on the overall aggregate of uplink packets. The TBF generates tokens at rate R and puts them in the bucket. The rate limiter forwards arriving uplink packets only if there are tokens available in the bucket, otherwise uplink packets are dropped. Each arriving packet consumes a token. The parameter R can be configured dynamically and adaptively varied as a function of an estimation of the attainable downstream throughput.

The rest of the paper is organized as follows. In Section II, provides a summary about problem statement. In section III gives the work related to the channel access and unfairness in WLANs. Section IV introduces TCP window control mechanism for the 802.11 DCF. Performance evaluation of the proposed scheme in a multirate WLAN is given in section V. Finally, Section VI concludes this paper by summarizing the achievements of the proposed algorithm.

II. PROBLEM STATEMENT

The each stations in the WLAN periodically estimates how long it can use the medium among active stations. This estimation is based on the channel-occupancy time that each station used, which is monitored at the MAC layer, with the assistance of information that is broadcast from the AP. With this estimation, each station calculates the maximum throughput at the TCP layer. Finally, the TCP sender calculates the appropriate window size

The node with the largest channel access may utilize the wireless medium and eventually causes the decrease in the end-to-end throughput of the multirate WLAN. Thus, the algorithm needs to differentiate the channel access probability of each node by adjusting the rate of the transmitting packet depending on the CW size, which results in a significant increase in the end-to-end throughput and achieves fairness in terms of channel occupancy time.

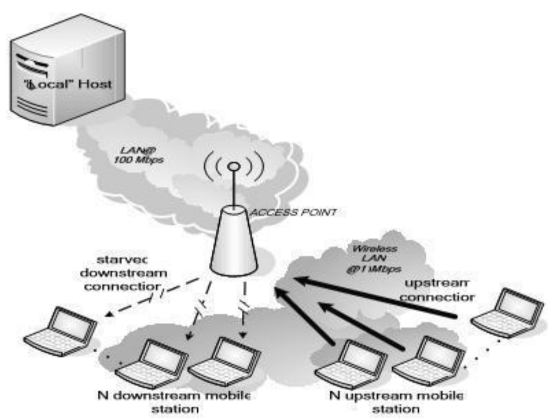

Figure 1. Downstream TCP connection penalized with respect to upstream ones

COTRC-TCP increases the end-to-end throughput and improves fairness but the available resource bandwidth can be wasted in the network. And the downstream TCP connections suffer because of the arising congestion and corresponding packet losses happening in the download buffer at the Access Point. So, downstream packets can be delayed because of congestion.

Thus, for improving resource utilization and reducing end to end delay, the tuning of rate R is configured. Instead of dividing available resource to all nodes, rate of each packet can be varied to varying channel conditions to achieve fairness in the network.

III. RELATED WORK

The related work analyzes following categories:
Resolving unfairness problems:

The IEEE 802.11 DCF results in unfairness among users due to the following two main reasons: To analyze the impact of the back-off parameters on network performance, Kashibuchi, [2] developed the time based rate control for wireless network. Using this, it was shown that the number of stations and the channel occupancy time and contention window size have significant impacts on the overall performance of WLAN. The approaches presented in [3], [5] adjust the frame length or the maximum transmission unit (MTU) to equalize the channel-occupancy time of each station. By doing this lower rate stations are required to transmit frames with short length and thus decrease the throughput. Kim and Yun have derived the solution for performance anomaly issue through differentiation. This is the first work that shows that performance anomaly can be resolved through differentiation [4]. Abeysekera [7] states the problem of unfairness issue between uplink and downlink flows in WLAN. This unfairness is solved by Dynamic contention window scheme, which dynamically controls the minimum contention window size at APs and provides an ample opportunity for them to acquire the transmission. The problem of WLAN fairness at MAC level has been analyzed in several papers. However, MAC level fairness is not enough. Unfairness among TCP connections within a single WLAN was analyzed in [4]; in which the authors propose an elegant solution that addresses not only the so-called critical unfairness, but also a finer “per connection” fairness. Unfairness among TCP and UDP flows in more complex topologies has been preliminary discussed in [5]. In this the solutions aiming at avoiding critical unfairness (i.e., starvation) and at enforcing a fair sharing of radio bandwidth between

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the Access Point and the mobile stations. Our solution works on the aggregate TCP flows crossing the Access Point.

IV. RATE CONTROL SCHME FOR IEEE 802.11DCF

In wireless networks, the achievable throughput is limited by performance anomaly and uplink/downlink unfairness problems. Specifically, flow of packets that are originated with different data rates compete for the channel bandwidth, resulting in unfairness issues. the other hand, unfairness results from the stations with different transmission rate are spread over the wireless network. As each station is exposed to a different level of data rate, it has a different value of throughput in the basic service set.

A. COTRC TCP algorithm:

In the COTRC-TCP mechanism, the fairness index is defined as the ratio of the channel occupancy time to the overall simulation time which given by

where N is the number of stations in BSS, and is the channel-occupancy time used by the *i*th station. If the index is close to one, then more fairness system exhibits in terms of channel occupancy.

Algorithm:

TCP Rate Control scheme COTRC-TCP based on maximum contention window control algorithm requires the following parameters to be calculated.

1: Needs number of active station across the network

2: The channel occupancy time that each station uses for transmitting or receiving the packet

3: Throughput estimation at the TCP layer based on above parameters.

4: Maximum window size calculation using RTT and throughput.

5: Finally adjustment of TCP sending rate

Figure 2. Steps in COTRC-TCP

(= / |S|), where |S| denotes the number of active stations. On the other hand, BSS may have an unoccupied duration. This unused duration is given by (= −). The proposed algorithm evenly allocates this remaining duration among the unsatisfied stations. Here, an unsatisfied station is the station that meets the following criterion:

$$\geq r \cdot (0 < r < 1)$$

where r is a threshold that defines the satisfaction level of a station. The AP finds a set of unsatisfied stations as based on equation (2).

{ x | x/∈ }

+ {x|x ∈ }

Equation (3) denotes the proportion of available duration for stations. Maximum value of the available window size is calculated as

$$= \cdot \qquad (5)$$

Round Trip Time (RTT) denotes the average length of the interval from the time a TCP data packet is generated until the corresponding TCP ACK packet arrives. Finally, TCP sender calculates and adjusts its sending rate by bounding the estimated maximum TCP window size to improve the channel access probability of the stations in the wireless network.

B. ARC Algorithm:

ARC is a dynamic rate control scheme used to vary the rate of token bucket buffer R which is given in Fig 3. C is the WLAN capacity. If the downstream connections are limited to Rdown < C-R, then it causes a waste of capacity in the order of C-R-Rdown. The idea of the adaptive rate control is to increase the rate of the token bucket filter in these conditions up to R'=C-Rdown so that no capacity is wasted. When the downstream connections become again greedy, the rate of the token bucket filter is suitably reduced. The proposed mechanism adapts the rate R via discrete steps of amount Rstep (Mb/s). This adjustment is performed periodically, with an interval of Tp (ms). The choice whether to increase or decrease the token bucket rate is based on a control rule, which in general considers information

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such as the state of the downlink queue, and the estimated uplink and downstream throughputs.

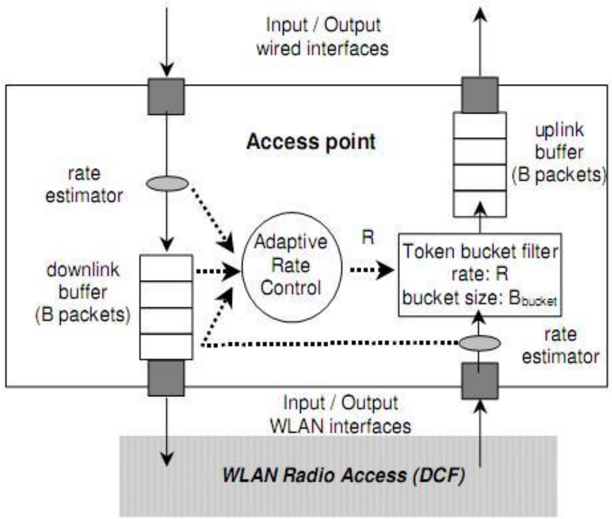

Figure 3. Adaptive Rate Control

Adaptive Rate Control mechanism works as follows:

1: Estimates the "instantaneous" throughput crossing the AP in uplink (Rup) and in downlink (Rdown)

2: Estimation uses an Exponentially Weighted Moving Average (EWMA) algorithm

Let Rup the estimated throughput coming to the AP from the WLAN interface at time k·Tp;

let Rdown the estimated throughput coming to the AP from the wired interface at time k·Tp;
at time k·Tp the TBF rate R is changed according to:

if (Rup+Rdown) > Rmax

then R = max (Rmin, R-Rstep);

else R = min (Rmax, R+Rstep);

Figure 4. Steps involved in ARC

If Rup + Rdown< Rmax, then the token bucket rate can be increased to avoid wasting of resources. The parameters Rmin and Rmax have to be chosen so as to avoid starvation and wasting of resources. Rmax is set to 4.5 Mbps and Rmin is set to 2.3 Mb/s. The difference between the overall capacity and Rmin may be seen as the minimum downlink guaranteed bandwidth. This means that uplink/downlink bandwidth asymmetries can be tuned by suitably regulating the parameter Rmin. The parameter Rstep controls the maximum speed of rate increase and decrease. Too small values of Rstep may make difficult the startup of new and may reduce the efficiency. Too large values of Rstep may give rise to significant throughput oscillations due to interactions with the underlying TCP congestion control mechanisms.

V. SIMULATION RESULTS

Simulation of ARC with COTRC-TCP is done in Network Simulator-2 (NS-2). Comparison is done between normal Standard TCP and ARC with COTRC-TCP algorithms. A network model of 54 nodes that forms a wireless network model with access point as a router. The distance from the AP to each station is fixed to 10 m, where they can transmit/receive frames at a data rate of 54 Mb/s. Simulation configuration parameters are given in the Table I.

Table I

SIMULATION CONFIGURATION PARAMETERS

Configuration Parameters	Value
No of Mobile Nodes	54
Routing Protocol	AODV
Simulation Time	100ms
Packet size	512 bytes
Transmission Range	250m
Area	1500x1500

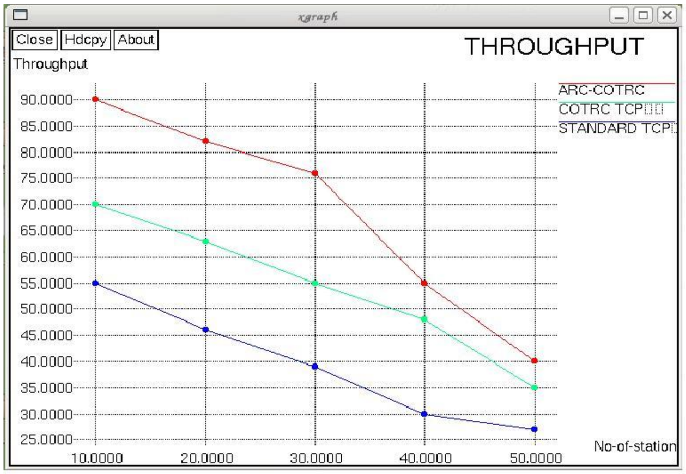

Fig. 5. Throughput Comparison

Aggregate throughput comparison in BSS is done between COTRC and ARC. In fig. 5, the throughput achieved by ARC is higher compared to the COTRC. This is because COTRC mechanism equally divides the channel occupancy time among all nodes some node has insufficient time to transmit and some nodes has large time to send small amount of data.

Fig. 6. Delay comparison

In the figure 6, delay obtained using ARC scheme is lower than that is obtained from normal COTRC-TCP. The reason is that ARC dynamically varies the rate of the IN and OUT flows of packets when it reaches the AP buffer so, by tuning rates of data delay is reduced in ARC mechanism.

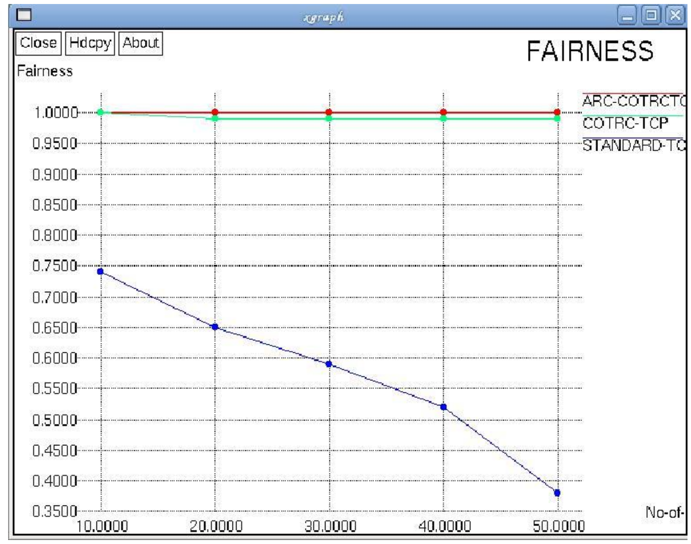

Fig. 7. Channel occupancy ratio

In Figure.7 Fairness index denotes the equal share of resource bandwidth among all stations in the network. It Figure 7 it shows that both schemes achieves perfect fairness but throughput fairness is more in ARC when compare to COTRC.

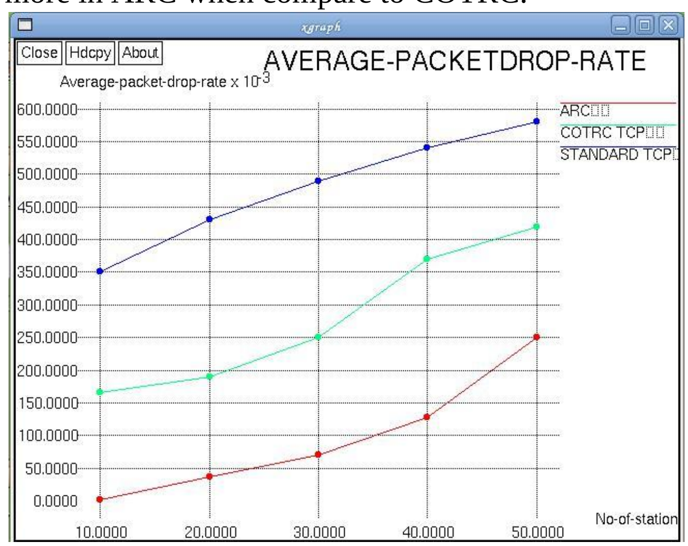

Fig. 8. Average packet drop ratio

In Figure 8 represent the average packet drop rate per station. Packet drop rate is calculated as the percent ratio of dropped TCP data segments to transmitted TCP data segments. The proposed scheme achieves low packet drop rates.

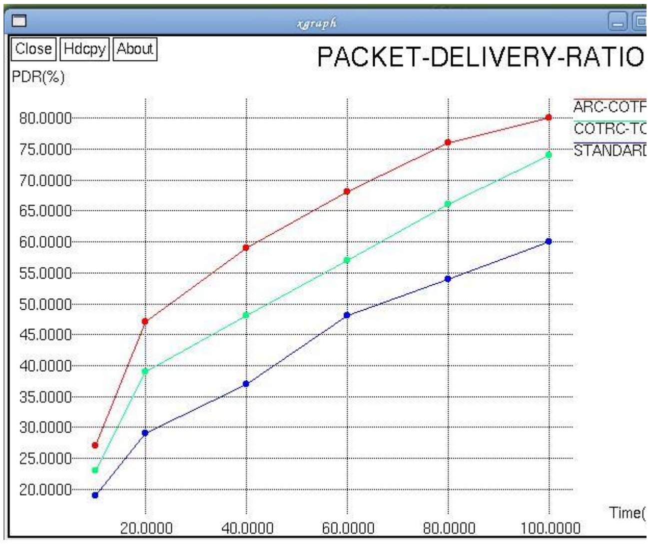

Fig. 9. Average packet delivery ratio

In Figure 8 represent the average packet drop rate per station. Packet drop rate is calculated as the percent ratio of dropped TCP data segments to transmitted TCP data segments. The proposed scheme achieves low packet drop rates.

VI. CONCLUSION

The Adaptive Rate Control algorithm increases the overall network performance. ARC algorithm uses the information that are capacity of the network and instantaneous throughput crossing the AP to vary the value of R rate of the buffer to solve unfairness issues in TCP connections. COTRC-TCP mechanism is applied to each of the nodes in the network. COTRC-TCP algorithm improves the fairness and end to end throughput of the network at the same time delay is higher and resources can be wasted when it equally divided among nodes. But Adaptive Rate Control algorithm reduces the end to end delay by tuning the rate R and also resource will be utilized effectively. As a result, the overall network aggregate throughput and fairness is achieved using ARC algorithm.

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