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Performance Improvement in Multihop Wireless Mobile Adhoc Networks

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ABSTRACT

In this paper, a cross layer scheme is proposed to accomplish the flow contention of TCP in multi-hop adhoc networks. The proposed scheme collects the useful information from physical and MAC layer for approximation of channel utilization per station. The *contention window (CW)* has been adjusted to control the competition between stations. The proposed method also achieved the fair channel access by each station to achieve to equivalent throughput. The value of bandwidth allocation to each flow is calculated and sent to the next layer for getting the fair bandwidth allocation to each flow. Then, control the sending rate of TCP flow to resolve the problem of contention between flows. Each flow got almost equal throughput and fairness has been improved. The performance of our proposed method is examined using by *network simulator [NS-2]* on various topologies of multi-hop adhoc network.

KEYWORDS: per-flow and per-station fairness, flow/station contention, throughput, multi-hop adhoc networks

1. INTRODUCTION

Adhoc is basically a Latin means word which means "for this purpose only". Ad hoc Networks are infrastructure less having no central base station or router. Wireless Networks has been used widespread since few years. This type of networks usually decentralized and mostly used in emergency causes like natural disaster or military/rescue operations [1]. In infrastructure mode, a central base station is designed for channel allocation to each node. Whereas the distributed channel allocation method used by ad hoc networks. A Media Access Control (MAC) Protocol specifies in the wireless networks [2]. It provides a number of functions to execute the operations of wireless local area networks. CSMA protocol [3] uses at MAC layer, which leads to hidden terminal problem in wireless ad hoc networks. This problem causes the packet collision and degrades the network performance [4]. In IEEE 802.11 the RTS/CTS mechanism has introduced [5]. The key purpose of RTS/CTS handshake is to avoid the congestion and resulting less packet collision but it suffers the network throughput and fairness as per node [6]. When a node receives an RTS/CTS packet it defer its transmission for a time called NAV and blocks itself. Blocking problem affects the transmission of many nodes and sometimes it leads to a deadlock [7]. BEB mechanism introduced in 802.11 seems to provide the same opportunity to the node for accessing a shared medium [8]. However, due to false blocking problem [9] when a source sends an RTS packet to an already blocked node, that node will not respond and source suspects that the packet may collide; this node will started its back off time. After the back off timer ends its sends again the RTS packet and unfortunately it gets no response, its start its back off timer again. Each time after found the channel is busy the back off timer will be doubled from the previous one. During the back off timer of this node the channel may become idle and accessed by another node. So, the BEB mechanism [10] suffers to unfairness problem and low throughput. The BEB mechanism depends on CW size which corresponds to congestion [11]. It doesn't care about the actual conditions of the neighboring stations for example the number of nodes in a system and number of channel flows. So, from the above discussion we know that CW size is not optimal for fairness after some congestion [12]. TCP specifies a window based congestion control mechanism called AIMD (Additive Increase Multiplicative Decrease) for the adjustment of transmission rate [13]. Thus, in multi hop ad hoc network TCP performance critically depends upon the size of the Contention Window [14] . If the CW is too large, then too many packets will compete for the same channel that results the network congestion due to buffer overflow. It determines unfairness performance and throughput degradation.

The rest of the paper is organized as, section 2 has the related study of TCP performance problems and enhancements. Section 3, describes our proposed scheme. Section 4, in result and discussion portion our proposed scheme is compared with CATRA and original TCP and section 5 concludes the paper.

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2. RELATED WORK

TCP challenges in 802.11 [15] are reported in the adhoc networks. Many factors may affect the performance in multi-hop networks. It effects on the different layers such as, at the Physical layer, fading and interference problem may cause the packet loss and bit errors. At MAC layer, the protocol can't successfully avoid the packet collision which may induce delay, causes the packets lose. A retransmission mechanism used to solve the problem, this mechanism also determines delay and jitter problem. End-to-End transmission will be challenging task as route failure or changing paths between sources to destination. A period without connectivity of network will took place in detecting change in topology. To improve the performance of network different solutions are proposed on different layers independently as layered design method and some of them improve the performance using co-operation between layers by exchanging information as a cross-layer design. Some studies focused on the IEEE 802.11 MAC layer. In channel allocation a source EFIS (Extended Inter-frame Spacing) problem occurs i.e. due to the given value of EFIS the unfairness in bandwidth allocation occurs. They [16] introduce an EIFS value depends on the length of the sensing range (SR) frame. Due to the spatial use of bandwidth the length of SR frame can't be recognized. The physical layer capture mechanism also affects the proportion of sending to receiving bandwidth B1 to B2. When two stations M1 and M2 send packets at same time, the packet of M2 is ignored by M1 because M1 has low power than M2. B2 apply the limitations on the throughput of forwarding flows. So, it causes unfairness between direct/forwarding flows. The three pair problem also affects the performance of network [17]. The analysis of three pair problem solved by Markov chain technique and gives the correct results. IEEE 802.11 Distributed Co-ordination Function (DCF) used in medium access control and physical layer in ad hoc networks. DCF employs binary slotted BEB in addition with CSMA/CA. Due to hidden/exposed node problem DCF degrades performance in term of throughput and fairness. BEB technique modifies in some studies, for achieving the performance improvement in 802.11. In BEB unfairness problems are given in [18] Channel utilization of each station estimates itself and of neighboring stations, after that it's adjust the back off algorithm to give fair channel allocation to each station that is called statistical fair access. The value of statistical fair access based on the topology and generally its value is predefined. To determining per flow fairness some studied had been done in respect of single hope network. TCP employs wrong behavior in multi-hop adhoc networks. A scheme known as NRED (neighborhood RED) proposed [19] to improve the TCP fairness on network layer. Also detect the neighborhood congestion and drop packets by intermediate nodes through NRED scheme considered per flow channel usage. Adjustment of contention window size will be done, to achieve the optimal value for maximizing the throughput. Some techniques used in [20,21] for the fairness and performance improvement in wireless adhoc and sensor networks.

Recently some studies used the cross layer method [22] to enhance the TCP performance according to fairness and throughput. The authors [23] proposed the enhanced form of TCP-CC to improve the performance. The author denotes the congestion and transmission errors and gives an authenticated solution for these problems. Another scheme TCP-CL [24] modifies the TCP protocol and IEEE 802.11 MAC. A parameter retry limit (REIL) defined to reliable operations on communicating channels at MAC layer link failure depended on RETL value and detailed to the TCP layer. High contention in a link mistakenly indicates to link failure by MAC layer. A technique TCP fractional window increment scheme has been proposed [25] to prevent from unwanted network contention by applying the limitation on TCP CW growth. An optimal value of the contention window depending upon the MAC channel efficiency, adjusts the TCP transmission rate. However, MAC layer contention will not be considered. A cross layer design used the information on MAC layer for controlling the transmission rate of TCP.

In this paper, we proposed an algorithm for medium access by a station to enhance the per flow fairness because 802.11 doesn't complete the goal of fair channel access per flow. The unfairness problem at MAC layer has been controlled by giving a suitable CW size. Then control the TCP rate per flow for equal throughput achievement by each flow.

3. The Proposed Method

Unfairness problem in ad hoc networks occurs due the given two reasons, false behavior of channel accessing by DCF and traffic rate control by TCP. In this paper, we will propose a scheme in which CW size has been adjusted, using information got from physical and MAC layer. The false behavior of DCF in channel accessing will be improved and each station will get the equal opportunity of channel usage, if a flexible CW size used in back off state. The unfair bandwidth allocation to different flows by TCP will also improve by adjusting the TCP rate dynamically and provide fair bandwidth allocation to each flow.

3.1 Channel Accessing Control by DCF

In multi-hop adhoc networks [26-42] BEB mechanism indicates the problem of per-station fairness. Per-station fairness is not definitely suitable for per-flow fairness. The equal bandwidth allocation to each station is known as per-station fairness. The equal bandwidth allocation of each flow which is transmitted from a station is known as per-flow fairness. A formula used for per-station fairness is called FBR(fair bandwidth ratio), which is defined as, $\boldsymbol{FBR_S} = \boldsymbol{n_{SEND}} / \boldsymbol{n_{total}}$. Here, n_{SEND} includes two kinds of flows, direct flow and forwarding flows. Direct flows are generated by the station itself and forwarding flows are the flows which are forwarded by the examined station for its neighboring station. In CATRA, n_{total} have two kinds of flows n_{TX} and n_{CS} whereas, in our proposed method n_{total} depends on two type of flows $n^2{}_{SEND}$ $and\ n_{Rec}$. All the flows generated by the station itself and those, who are in the transmission, range of examined station, is said to be $n_{Rec}\ or\ n_{TX}$ flows. All the flows generated by the stations those, who are in sensing range of examined station, is called n_{CS} flows which is used in CATRA [25]. We obtain the value of n_{total} in CATRA by the given formula, $\boldsymbol{n_{total} = n_{TX} + n_{CS}}$. CS flows sense by a station through its own physical power; otherwise a station can't examine the CS flows by local information. If the CS flows exits around the examined station we take the CS value as 1, otherwise we consider the value as 0. We can get fairness when each flow has the same throughput. ACK frame of TCP is ignored. It is not taken as the challenging flow. We can get n_{SEND} and n_{total} from MAC layer. In more complex networks hidden terminal problem cause the exact n_{total} value difficult. By adding the n_{CS} = 1 to n_{TX}, it can assume that their can be some hidden nodes which is identified by CATRA. In our method, we don't use the CS flows. In proposed method the value of $\boldsymbol{n^*{}_{total}}$ is defined as,

$$\boldsymbol{n^*{}_{total} = n^2{}_{SEND} + n_{Rec}} \quad \textbf{(1)}$$

So, according to the 2 we can calculate the FBR per station as follows.

$$\boldsymbol{FBR^*{}_S} = \frac{n_{SEND}}{n^*{}_{total}} = \frac{n_{SEND}}{n^2{}_{SEND} + n_{Rec}} \quad \textbf{(2)}$$

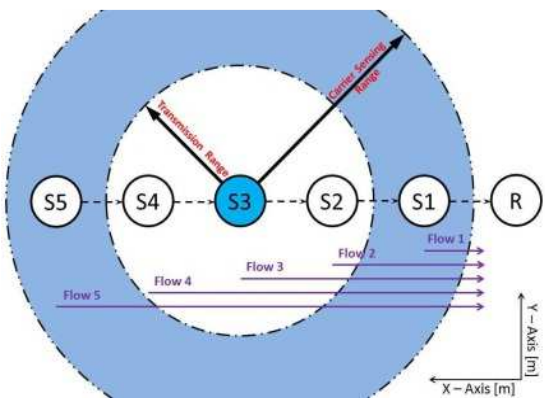

Figure 1: A basic Multihop adhoc network

Table 1: FBR Ratio of S3, S4 and S5 according to the Formula 2

	n_{SEND}	n_{Rec}	n_{CS}	$n^*{}_{total}$	FBR
S3, CATRA	3	6	1	10	3/10
S3, Proposed	3	6	-	15	3/15
S4, CATRA	2	4	1	7	2/7
S4, Proposed	2	4	-	8	2/8
S5, CATRA	1	2	1	4	1/4
S5, Proposed	1	2	-	3	1/3

An example of calculating FBR_S is shown in the given table 1, which is followed by figure 1. The given topology depended on the five sending stations S1,S2,S3,S4,S5 and one receiving stations R whereas, the transmission and sensing range of these stations are shown in the figure 1. The Real bandwidth ratio RBR can also find, in a pre-defined estimation period by measuring the $\bar{T}_{Active}$ of a station. In the Estimation period, the $\bar{T}_{Active}$ is the average time of packet transmitting from a station. $\bar{T}_{Active}$ in TCP flow is calculated by using the sum of TCP-ACK and DATA packets.

$$\boldsymbol{RBR_S = \bar{T}_{Active}/EP} \quad \textbf{(3)}$$

We proposed a better contention window size by collecting the above useful information. Proposed CW size is given as,

$$\boldsymbol{\acute{CW} = min\left(\frac{RBR_S}{FBR_S}\, CW, CW_{max}\right)} \quad \textbf{(4)}$$

Algorithm 1: Active Time Estimation
Initialization:
$\overline{T}_{Active}$=0
t=0
Begin
For each packet p do
if p→ destID==localID **then**
if (p→MacHeader→Type==ACK) **and**
(p→TcpHeader→Type==TCP_{DATA}) **then**
{The transmitting time of TCP-DATA packet}
$t=t+0.5*CW*ST+T_{RTS}+SIFS+T_{CTS}+SIFS+T_{TCP_{DATA}}+SIFS+T_{ACK}+DIFS$
else if (p→MacHeader→Type==DATA) **and**
(p→TcpHeader→Type==TCP_{ACK}) **then**
{The transmitting time of TCP-ACK packet}
$t=t+0.5*CW*ST+T_{RTS}+SIFS+T_{CTS}+SIFS+T_{TCP_{ACK}}+SIFS+T_{ACK}+DIFS$
end if
end if
end for
For each interval time EP **do**
$\overline{T}_{Active}=0.8*\overline{T}_{Active}+0.2*t$
T=0
end for
end

There will be fairer channel access between stations. The disadvantage stations can get a chance of channel accessing. The original CW size will be directly proportional to RBR and inversely proportional to FBR. If FBR is larger than RBR then the original CW will be larger than the proposed CW then, bandwidth allocation to a station will be increased and the station has more chance to access the channel. On the other hand, If the RBR is larger than FBR then the proposed CW will be larger than original CW then the channel has less chance of channel accessing and other disadvantage stations got more chance of channel accessing. So, the fair bandwidth allocation will be improved. In this proposed method, some stations has been accessed the channel easily if small load offered by a station and the bandwidth will share with the other stations. Thus, the throughput degradation is not enforced.

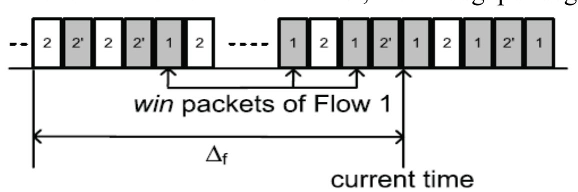

Figure 2: TCP rate adaptation for Flow 1.

3.2 Traffic Rate Control by TCP

As we show, fairness between stations in respect of fair channel access control by each station. Fair bandwidth ratio doesn't mean per flow fairness. Another algorithm defined for per flow fairness in the given section. As we know, in adhoc networks too many stations compete for the same channel in result congestion window grows too large. So, the throughput and performance degraded badly. TCP rate adjustment is necessary for fair share bandwidth allocation. To achieve more throughput a user generates too many flows at the same time. So, we consider all the flows generated by one station as a single flow from one source to destination. Then we allocate the same bandwidth to each flow. Let us assume the TCP rate and rate of flows by examined station, this information is collected from MAC and physical layer. So, for TCP flow we define the FBR per flow as, $\boldsymbol{FBR_f = 1 / n_{total}}$, and the RBR per flow defined as, $\boldsymbol{RBR_f = \overline{T}_f^{Active} / EP}$.
Here $\overline{T}_f^{Active}$ means that in the estimated period the average time of the examined station used for transmitting packets of TCP flow. If the TCP flow has more bandwidth than FBR_f, so, by giving some delay in each packet generating for reduce the bandwidth. In TCP mechanism the collected packet which is ready to send in a TCP flow is, ***win=cwnd+ highest_ack–cur_seqno.*** Here, cwnd is the congestion window size of TCP, highest_ack is the highest sequence no of the ACK packet and

Algorithm 2: Proposed Algorithm

Begin

for each received ACK packet **do**

If $\frac{RBR_f}{FBR_f} > high_{th}$ **then**

$\Delta_f = \frac{RBR_f}{FBR_f} T_f$ {Give the delay of Δ_f before generating the next packet after the completion of win packets transmission}

$cwnd^* = max(cwnd - 2,1)$

else if $low_{th} < \frac{RBR_f}{FBR_f} < high_{th}$ **then**

$\Delta_f = \frac{RBR_f}{FBR_f} T_f$

$cwnd^* = max(cwnd - 1,1)$

else if $\frac{RBR_f}{FBR_f} < low_{th}$ **then**

TCP slow-start algorithm

end if

end for

end

The highest sequence number of data packet is defined as cur_seqno. The T_f for win packet is calculated TCP flow to achieve fair bandwidth ratio as,

$$\boldsymbol{T_f} = \frac{win * \bar{S}_f}{FBR_f * B.} = \frac{1}{FBR_f} * \frac{win * \bar{S}_f}{B}$$

$$= \frac{n^*_{total} * win * \bar{S}_f}{B.}$$

$$= n^*_{total} * win * \bar{T}^{tr}_f$$

The channel capacity and average packet size is defined respectively as B and $\bar{S}_f$ in above formula. $\bar{T}_f^{tr}$ is calculated as, $\bar{T}^{tr}_f = \bar{T}^{Active}_f / N_f$, which is average time for transmitting one packet by one link. Here N_f is the number of packets transmitted in EP by a TCP flow. Then if the TCP rate is more than FBR we give a delay to the packet generated by TCP flow defined as,

$$\Delta_f = \frac{RBR_f}{FBR_f} \boldsymbol{T_f} \quad \textbf{(6)}$$

Table 2: Parameters used in simulation.

Channel data rate	11[Mbps]
Antenna type	Omni direction
Ratio Propagation	Two-ray ground
Transmission range	200[m]
Carrier sensing range	500[m]
MAC protocol	IEEE 802.11b
Contention Window	CW_{min} =32, CW_{max}=1024
Contention type	TCP/FTP (TCP Tahoe)
Buffer size	100[Packets]
Packet size	1[KB]
Simulation time	300[s]

An example shows in the figure 2 where 1 denotes first flow packet sending by S1 and 2 and 2́ are second flow packets sent by S1 to S2, respectively. Δ_f shows a little delay between packets. It can give more chances to neighboring stations to generate flow and achieve throughput. The proposed scheme shows the fairness and keeping the total throughput as original scheme. Modification in TCP shows in Algorithm 2. If the $\frac{RBR_f}{FBR_f} > \boldsymbol{high_{th}}$

with $\boldsymbol{high_{th}} \geq 1$ than a delay between packets should occur which decreased the TCP rate and congestion window size will be reduced slightly to $\boldsymbol{cnwd}^* = \boldsymbol{max}(\boldsymbol{cnwd} - \mathbf{2}, \mathbf{1})$.

If $\frac{RBR_f}{FBR_f} > \boldsymbol{high_{th}}$ **then** $\Delta_f = \frac{RBR_f}{FBR_f} T_f$ **So,** $\boldsymbol{cwnd}^* = \boldsymbol{max}(\boldsymbol{cwnd} - \mathbf{2}, \mathbf{1})$ **(7)**

If $\boldsymbol{low_{th}} < \frac{RBR_f}{FBR_f} < \boldsymbol{high_{th}}$ than a delay between packets should occur which decreased the TCP rate and congestion window size will be reduced to $\boldsymbol{cwnd}^* = \boldsymbol{max}(\boldsymbol{cwnd} - \mathbf{1}, \mathbf{1})$.

If $\boldsymbol{low_{th}} < \frac{RBR_f}{FBR_f} < \boldsymbol{high_{th}}$ **then** $\Delta_f = \frac{RBR_f}{FBR_f} T_f$ **So,** $\boldsymbol{cwnd}^* = \boldsymbol{max}(\boldsymbol{cwnd} - \mathbf{1}, \mathbf{1})$ **(8)**

When $\frac{RBR_f}{FBR_f} < \boldsymbol{low_{th}}$ with $\boldsymbol{low_{th}} \leq 1$ then TCP rate will be increased by generated TCP packet without delay of Δ_f and congestion window size grows too large and the TCP slow-start algorithm begins. Thus per flow fairness will be achieved. This mechanism will also work in case of multiple flows.

4. RESULTS AND DISCUSSION

The performance evaluation of this scheme is compared with the original TCP Tahoe version by using NS-2 network simulator. The parameters taken for this simulation shows in the given table 2. In this proposed scheme we set the threshold as $\boldsymbol{high_{th}}$ *=1.05* and $\boldsymbol{low_{th}}$ *=0.7* and estimated time period ***EP=2*** for all simulations. These given parameters are best values which are used for all simulations. The given parameters are best values which are used for all simulations.

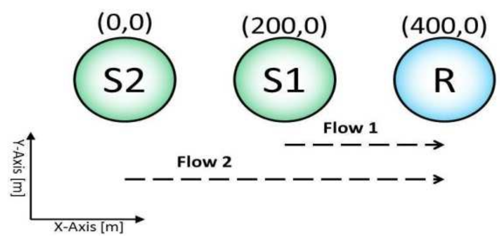

Figure 3: Topology for scenario 1

Scenario 1: Chain topology having two senders

The topology includes having 200m distance a station chain indicated in fig 3. In this figure S1 and S2 sends traffic to the receiver station R. Figure 4 shows the simulation in respect of throughput. The station S1, S2 and R includes in it. Original show TCP and proposed shows our scheme. Flow 1 and 2 shows the throughput of Flow 1 and flow 2 respectively and total shows the average throughput by all stations. Total measures the channel utilization.

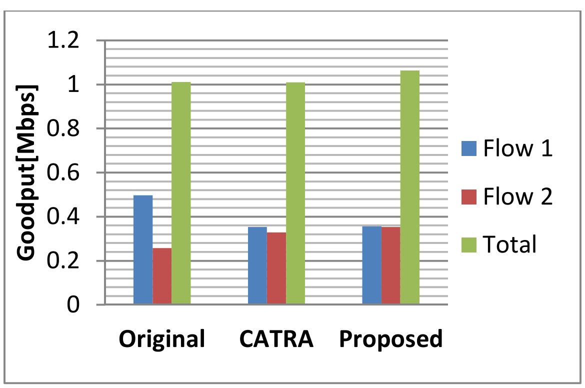

Figure 4: Comparative Goodput in scenario 1.

We can easily see the throughput and fairness per station in this scenario. In case of proposed scheme per station fairness occurred and each station have equal channel utilization and throughput either it is short or long hop. Throughput of flow 1 is more than flow 2 in original TCP and in CATRA the throughput of flow 1 has been decreased but the throughput of flow 2 has been increased as compared to TCP. Hence the fairness index has been improved. As compared to CATRA, our proposed method has well per channel throughput and fairness index has been also improved and we achieve good total throughput. So, proposed scheme have better fairness and good channel utilization.

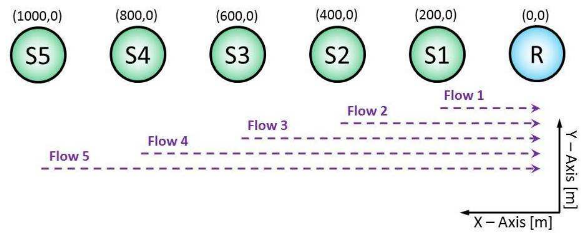

Figure 5: Scenario 2 Long vs Short Hop topology

Scenario 2: Long vs Short Hop Topology

The topology includes having 200m distance a station chain indicated in fig 3. In this figure s1, s2, S3, S4 and S5 sends traffic to the receiver station R. Long hop flow travels through many intermediate nodes and it must contend with short hop flow, so it is difficult for flow 3, flow 4 and flow 5 to reach the destination as compared to flow 2 and flow 1. Figure 4 shows the simulation in respect of throughput and fairness index. TCP shows original and proposed shows our scheme. Flow 1 up to 5 shows the throughput of Flow 1 up to flow 2 respectively and total shows the average throughput by all stations. Total measures the channel utilization. We can easily see the throughput and fairness per station in this scenario.

In TCP scheme short hop flow where stations chain n=3 and n=4, TCP flow 2 still achieve good throughput. However, at longer stations where n=4 and n=5 Flow 1 and 2 achieves the high throughput and flow 3 got small throughput and flow 4 and 5 got 0 throughput.

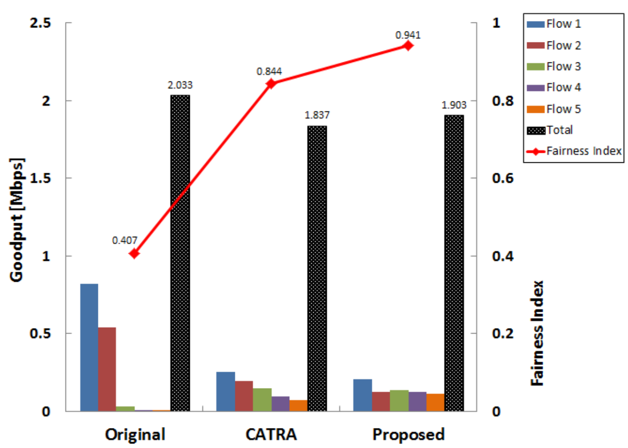

Figure 6: Fairness Index and Throughput of Scenario 2

Thus, the total throughput has been high because flow 1 utilizes more but fairness of stations has been decreased. In CATRA, the fairness index is better than TCP but throughput has been decreased. In case of proposed scheme per station fairness occurred and each station have equal channel utilization and throughput either it is short or long hop. Either per channel throughput has been decreased but still we have good total throughput. As compared to TCP the total throughput is decreased but comparatively we achieve better throughput than CATRA.

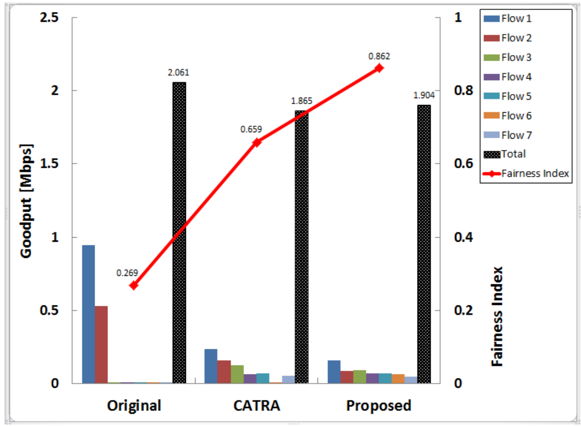

Figure 7: Seven Sender Long vs Short hop topology.

Comparatively, fairness per station of the proposed scheme is better than other both. So, proposed scheme have better fairness and good channel utilization. Same scenarios having seven hops show the following result in figure 7. In seven hops the original scheme flow 1 and flow 2 achieve the whole bandwidth and other flows contain almost zero bandwidth. In CATRA the fairness index is better but the throughput is less than TCP because fairness is inversely proportional to each other. In our proposed scheme the fairness index is better than original TCP and CATRA and also the throughput is improved comparatively.
In nine sender chain topology the original scheme shows inconsistency in allotting bandwidth to each flow as given in figure 8. CATRA has been improved the original scheme in respect of fairness and achieved more throughput than original. Our proposed scheme shows better fairness and high throughput comparatively the other both.

Scenario 3: the cross chain topology

The cross chain topology shows in figure 9. In this topology, contention between station leads to unfairness problem. The problem with this topology is, if one flow win the channel utilization the whole bandwidth allocated to that station for long time. So, the unfairness occurs between stations. We start the Flow 1 a bit earlier than flow 2 because Flow 1 is more advantageous. Thus, result show in figure 10. The throughput of flow 1 up to flow 8 are not that much stable even flow 8 achieve the bandwidth always zero while in proposed scheme the fairness between flows is better than CATRA and original scheme.

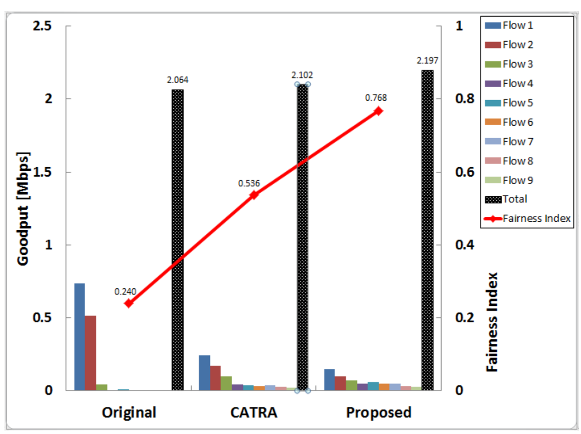

Figure 8: Nine sender Long vs Short hop topology.

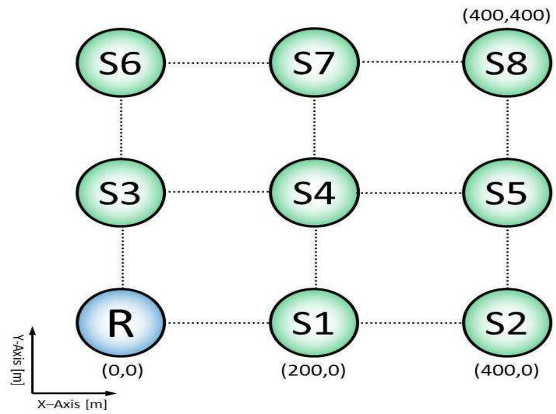

Figure 9: Scenario 3 the cross topology.

5. Conclusion

We proposed a scheme for enhancement of TCP performance in multi hop mobile adhoc networks. In this paper, the contention window size is changed for per-station fairness. We calculate the Fair Bandwidth Ratio and channel utilization. This information sends to the transport layer for per-flow fairness by adjusting TCP rate. Simulations proved the effectiveness for proposed scheme. With achievement of better fairness this scheme also achieves the good total throughput.

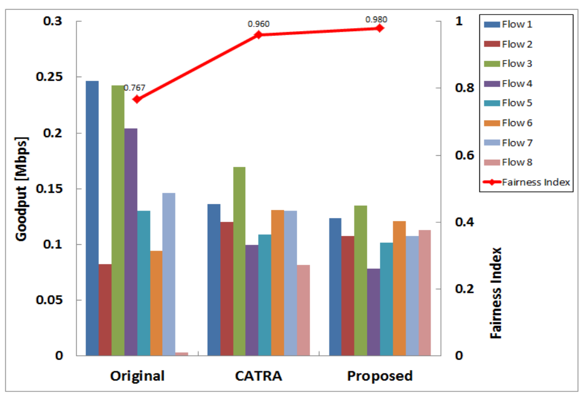

Figure 10: Fairness Index and Throughput of Scenario 3.

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