Smart Acknowledgement Distributed Channel Access Scheme for TCP in MANETs

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Summary
TCP upon wireless network is most challenging issue because of random losses and ACK interference. Also, TCP suffers from performance declination in terms of creating delay and overhead in network because of poor characteristics of wireless channel. In order to overcome these issues, we proposed a smart acknowledgment distribute channel access (SADCA) scheme for TCP in MANET. In the proposed scheme, first a separate access category for data less TCP acknowledgment packets is used and then it is assigned with highest priority. In this way, delay during transmission of packet can be reduced and also packet can be acknowledged immediately. Also, to increase the performance, delay window size can be adjusted by considering the parameters such as transmission rate, number of hops, and channel occupied ratio (COR). Hence the proposed scheme helps to avoid any kind of delay and overhead for sending TCP acknowledgment.

Keywords:
Distributed Channel Access; Access Category; TCP smart acknowledgement; MANETs

1. Introduction

1.1 MANET

A MANET is an autonomous infrastructure-less system with wireless links connecting mobile nodes each operating as an end system as well as a router to forward packets and are free to move and form a network without any base stations. As mobile nodes communication is faster, it has a wide application in military applications, emergent operations, personal electronic device networking, and civilian applications like an ad-hoc meeting or an ad-hoc classroom. MANET's special characteristics like dynamic topologies, bandwidth constrained, variable capacity links, energy constrained operation, limited physical security make it susceptible to various attacks via compromised node. In addition, jamming occurs in unreliable wireless links and eavesdropping due to their inherent broadcast nature. Mobile devices' bandwidth, computing power, as well as battery power constraints causes application-specific trade-offs between devices' security and resource consumption. Behavior anomalies like advertising bogus routes are difficult to detect due to mobility[1].

1.2 TCP and Congestion control in MANET

The Transmission Control Protocol (TCP), the most commonly used reliable transport protocol in the internet, provide end-to-end reliable transmission as well as fair congestion control so as to share network resources efficiently [2]. Congestion control is a necessity for MANET since it operates in bandwidth constrained conditions.

TCP, in today's internet has poor performance and in Mobile Ad Hoc Networks (MANETs) is worsen by contention with increasing UDP-based high priority multimedia traffic and the class differentiation introduced in current QoS protocols, which results into TCP starvation and increased spurious timeouts [3]. The TCP usage over wireless networks rise to problems due to the different characteristics of wireless links with respect to wired ones, in terms of less reliability and time-variant behavior, fading / shadowing problems, node mobility, hand-offs, limited available bandwidth and large RTTs[5]. TCP performs reliably in traditional wired and stationary networks, but network congestion induces losses. Moreover, if the router waiting queues are full or nearly full, the packets received are dropped to cope with losses thereby wired network losses are viewed as an indication of congestion. But the losses occur frequently in wireless networks for various causes such as interference, nodes mobility or poor link quality.

In MANET, data transmission failures due to the environment like mobility, collisions, etc lead often to the congestion control activation by TCP protocol unnecessarily which degrades the performance of TCP in MANETs [2, 4,6].

1.3 Smart Acknowledgment Scheme

The TCP reliability guarantees, TCP sender will forward each packet issued by it to the addressee node by a system of acknowledgments [4]. In TCP protocol, cumulative s (ACKs) were sent by the TCP receiver for successfully received segments so as to let the TCP sender to find out the segments which have successfully received. The loss of packet is determined by TCP sender either by several

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duplicated cumulative ACKs arrival, triggering a fast retransmission, or by the absence of an ACK for a timeout interval equal the sum of the smoothed round-trip delay and four times its mean deviation. TCP retransmits the lost packets, and simultaneously invokes congestion control by reducing its congestion window size and backing off its retransmission time thereby compensating packet losses. These reduce the level of congestion on the intermediate links [7].

The TCP Acknowledgments may return collided with their corresponding data packets in particular if the number of network nodes becomes vital. Such a large number of TCP ACK packets come into contention with TCP packets leads to intra-flow contention [4].

1.4 Problem and Proposed Solution

In our previous work [18], a cross-layer based approach for improving TCP performance in Multihop Mobile Adhoc Networks (MANETs) is proposed. The proposed mechanism triggers congestion whenever the channel occupied ratio (COR) reaches a maximum threshold value and the received signal strength is less than a minimum threshold value. Following it, congestion control scheme controls the data sending rate of the sender by determining available bandwidth, delay of its link and COR. Further, a fair resource allocation scheme is put forwarded.

As an extension to this work, we propose to design a smart acknowledgment scheme for TCP in order to reduce the delay and overhead of sending TCP acknowledgments.

2. LITERATURE REVIEW

Chien-Chia Chen et al [2] presented Combo Coding, a novel coding scheme combining intra- and inter-flow coding and a novel loss adaptation algorithm was featured. Combo Coding decreases the data and ACKs' interference within a TCP session taking advantage of the benefits of both types of codes, and also robustness to high link losses is exhibited. 2 Mbps good put is achieved by Combo Coding successfully with 30% per link packet loss rate; whereas TCP-New Reno with no coding delivers only 200 Kbps. Combo Coding over 2 paths provides a lower good put than that over a single path due to a higher overhead due to extra contentions as in the 20s–50s interval.

Sofiane Hamrioui et al [4] suggested an improvement of the Transmission Control Protocol (TCP), called Improvement of the Acknowledgment mechanism of TCP (IA-TCP), for MANET's better performance. Based on number of nodes, mobility and the communication distance between these nodes, IA-TCP delays TCP's acknowledgments packets. However, only throughput and end-to-end delay parameters are concerned. However, there is degradation of the TCP parameters performance.

Mohammad Amin Kheirandish Fard et al [10] proposed an end-to-end sender-side approach classifying congestion loss, wireless channel loss and link failure loss by queue usage estimation. Queue usage is calculated using relative One-way Trip Time. Congestion loss is estimated using packet losses with queue usage rate greater than predefined threshold whereas non-congestion loss is when queue usage is less than threshold. Non congestion loss recognized by three duplicate ack labels loss caused by wireless channel error as it indicate the route existence between communicating end point that duplicate ACKs moved along.

Deguang Le et al [11] proposed a new cross-layer approach introducing a mobility detection element in the network layer to communicate with the transport layer for optimizing TCP operations. This approach preserves the end to end TCP semantics since end point changes are only made. Unlike other networks utilizing either transport or network layer alone without much cross-layer cooperation, this approach enable mobility information in TCP. However, RTO is reduced significantly compared to the standard TCP/MIPv6 as soon as the handover termination.

Consolee Mbarushimana et al [12] proposed a novel TCP-friendly scheme, IEDCA, for enhancing IEEE 802.11e EDCA mechanism by assigning the highest priority to TCP acknowledgment packets. The proposed scheme improves TCP performance significantly while having very negligible effects on voice traffic. However, the voice traffic dropped by buffer overflow or when the retry threshold is exceeded is higher in EDCA.

Toktam Mahmoodi et al [13] presented and assessed a cross-layer solution for a node for faster adaption of lower-layer characteristics like the coding rate and local ARQ retransmissions threshold according to the detected TCP flavor, so as to optimize the end-to-end performance of the download for that utilized flavor. The proposed scheme has considerable potential to improve the overall download throughput, without burdening the server and requiring no changes to existing TCP implementations. However, end-to-end throughput decreases with increasing propagation distance.

Myungjin Lee et al [14] proposed a path recovery notification (TCP–PRN) mechanism for avoiding performance degradation while handoff. Despite of being attained performance improvement while handoff, Freeze-TCP deployment in real environment is difficult due to obstacles in detecting accurate handoff time and the vulnerability of high variation in the round trip time (RTT). The proposed protocol restore congestion window avoiding it to reduce or immediately initiate slow start algorithm to recover lost packets. However, the handoff prediction is difficult and the variation of RTT is higher.

Ammar Mohammed AI-Jubari and Mohamed Othman [15] proposed a new delay-ACK algorithm for TCP performance enhancement over multi-hop wireless networks. According to factors like TCP startup phase, transmission rate, packet loss event, and number of hops, the optimal delayed ACK window is achieved dynamically as like before. The dynamic adaptive strategy's objective is enabling TCP receiver to adjust itself in terms of the data to ACK ratio. The scheme enhances TCP performance, attaining up to 233 % performance gain, over multi-hop wireless networks, compared to the regular TCP. However, the burst transmission occurs at the sender triggered by delayed ACK. The burstiness increases the packet loss and potentially affects TCP performance.

3. PROPOSED SOLUTION

3.1 Overview

The delay in transmitting packet leads to loss of packet as well as throughput degradation. Hence we use a separate access category for data less TCP acknowledgment packets and assumed higher priority to them [12]. Hence delay in transmitting packet can be reduced and packets are acknowledged instantaneously. Here higher congestion window value is attained than by TCP over Enhanced Distributed Channel Access(EDCA). Further improvements can be made by adjusting the delay window size by considering channel conditions like transmission rate, slow start phase, number of hops and packet lost event [15]. Here the number of acknowledgment packets can be reduced by generating the acknowledgment packets after attaining optimal dynamic delay window. Therefore receiver can adapt according to various delays.

3.2Estimation of Metrics

3.2.1Probability of Successful Transmission

Most of the previous studies propose the probability of successful transmission based on analytical skills to compute delay and throughput that can be attained by different traffic categories in IEEE 802.11e for which they mainly considered Markov model. In this type of model successful transmission is given as below:

$$\gamma = \frac{2}{1+V+pV\sum_{i=0}^{n-1}(2p)^i} \qquad \textbf{(1)}$$

V represents initial contention window during backoff stage, p represents the conditional collision probability, and n represents maximum backoff stage. Also the transmission probability γ_k of a station of Access Category (AC) k can be given as below:

$$\gamma_k = \frac{2}{1+V_k+p_kV_k\sum_{i=0}^{n_k-1}(2p_k)^i} \qquad \textbf{(2)}$$

Based on above equation, similar expression can be obtained for throughput T_k which is attainable by an access category k as below

$$T_k = \frac{n_k\gamma_k(l-p_k)l}{p(t)H_{(t)}+p(c)H_{(s)}+p(e)\,\phi} \qquad \textbf{(3)}$$

Where l represents average transmission time of payload for access category 'k'. p(t), p(c) and p(e) are the probabilities of a slot time contains successful transmission, collision, and channel being idle respectively. H(s), H(t) and ϕ represents average slot length of successful transmission, collision and channel being inactive respectively. From the above expressions, it can be observed that probability of successful transmission for any AC is inversely proportional to contention window V. Hence station with traffic in high priority AC will have low values of V which in turn will have higher chance of transmitting their data than stations with best effort and will have better throughput. But this case is not applicable for TCP traffic. For TCP traffic, a packet is considered to be successfully transmitted in case TCP ACK is received by the sender before the retransmission time is over. Based on the probability idea of successful transmission given by equation (2), successful transmission probability in case of TCP traffic is a combination of probability of successfully transmitted data packet as well as probability of successfully received ACK packet. Hence, for TCP traffic belonging to AC1, probability of successful transmission can be given as below:

$$\boldsymbol{\gamma}_{TCP} = \frac{4}{\left\{1+V_1+p_1V_1\sum_{i=0}^{n_1-1}(2p_i)^i\right\}^2} \qquad (4)$$

Here assume that data and ACK have the same transmission probability, since they belong in the same access category and moreover delayed ACK option is not used. Hence TCP th roughput is different from any other best attempt throughput which is accessible by equation (3), as it depends on the value γTCP which is given in the equation (4)

3.2.2Channel Occupied Ratio (COR)

COR is defined as the ratio of total lengths of busy periods to the total transmission.. Consider T_T denotes the total transmission time and T_b represents total length of busy periods. Hence COR can be given as below:

$$COR = \frac{T_b}{T_T} \qquad (5)$$

By considering channel utilization factor, a threshold value Th_{COR}. It can be given as below:

$$COR \approx C_U(COR \leq Th_{COR}) \qquad (6)$$

Where, C_U denotes channel utilization factor and it is the measure of ratio of channel busyness time for successful transmissions to the total time T_T.

3.3 Smart ACK Distributed Channel Access

This section describes the proposed Smart ACK Distributed channel Access (SADCA). The main aim of the proposed technique is to maximize the throughput without creating any delay in the network.

In this type of technique, an additional fifth access category saved for data less TCP ACK is defined. This new AC is assigned with highest priority. By placing data less TCP ACKs in top priority access category, probability of transmitting them on time is also maximized. Since the TCP ACK transmission probability tends to 1, transmission probability of TCP traffic can be expressed by equation (2). In similar way, the possible TCP throughput can be obtained by equation (3) with the exception that H_s increases by the value equal to time required to transfer both TCP ACK as well as MAC control packets that go along with it. By utilizing this method, the probability that all the TCP packets transmitted get acknowledged are increased. The underlying principle of this method make use of transport layer to control the volume of TCP ACKs on the channel. The volume of TCP ACKs permitted on the channel matches the volume of TCP data which is successfully transmitted and it is independent of the type of other traffic struggling for the same medium. To avoid any kind of congestion due to retransmission COR is validated inside the network using equation (5) and (6), if in case the delay due to congestion is found.

The implementation of the SADCA can be explained in steps as below:

Step1: In the first step, type of service (ToS) is usually applied at the application layer, however TCP ACKs originate from the transport layer, hence transport layer is responsible for assigning a proper ToS to them.

Step2: Since transport layer automatically assign the best effort ToS to TCP ACKs, a different ToS need to be assigned to them to distinguish them from best effort traffic also based on the COR of the network.

Step3: To make the process simple, ToS value (224) is assigned to the data less TCP ACK at the transport layer when they are about to be sent to the lower layer.

Step4: The MAC layer describes 8 user priority levels which are used to arrange the different data packets in to different ACs.

Step5: By considering 224 as their transport layer ToS, TCP ACK will be allocated to the user 7.

Step6: Also a fifth AC is defined corresponding to MAC user priority value of 7 and hence collect the TCP ACKs.

The mapping of client priority (CP) to AC in SADCA is shown in Table 1. Hence an additional traffic queue is obtained in SADCA as shown in Fig. 1. The proposed aim is to allow TCP ACKs priority to the medium. After that priority is assigned to the new AC having smaller values of AIFS, CWmin and CWmax compared to the existing higher priority voice traffic as shown in Table 2.

Table 1: Client Priority for Mapping in SADCA

Client Priority	*Access Category*	*Designation*
1	0	Background
2	0	Background
0	1	Best Effort
3	1	Best Effort
4	2	Video
5	2	Video
6	3	Voice
7	4	TCP ACK
8	1	COR

Table 2:Medium Access Parameters for Different ACs in SADCA

AC	*CW_{min}*	*CW_{max}*	*AIFSN*	*$TXOP_{limit}$*
Voice	7	15	2	3264
Video	15	31	2	6016
Best Effort	31	1023	3	0
Background	31	1023	7	3264
TCP ACK	3	7	1	3264

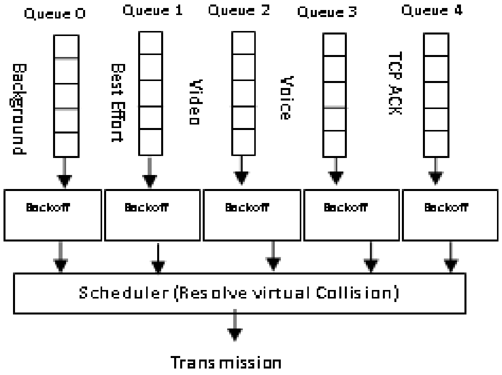

Fig. 1: Node within Transmission Range with Multiple Priority queues in SADCA

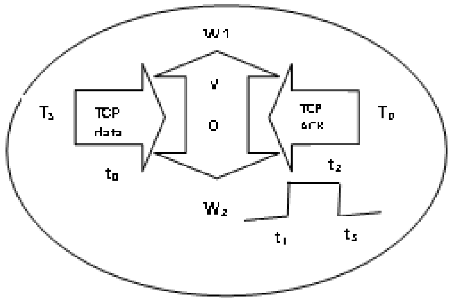

Fig. 2: Illustration of SADCA Technique

The improvement in the proposed technique can be shown with the following example:

In case TCP ACK is produced at the same time as the voice traffic, then station TS gains the medium contention because these TCP ACKs are in an AC with higher priority than voice. Hence it can be said that TS have more chance to transmit the TCP ACK before timeout and hence avoid the retransmission at the source. If the TCP ACK is generated before timeout, and then it avoids any kind of retransmission at the source. Also if TCP ACK is generated after the VoIP conversation started, then it will have a good opportunity to compete for the medium at the end of the next TXOP of the VoIP stations. Hence it can be said that, there is a high chance that ACK will be received within the RTO limit. Also retransmission can be avoided.

The illustration of the proposed technique is shown in Fig. 2. The proposed network consists of four nodes which are within the transmission range. In this example, at time t0, a TCP packet is successfully sent from TCP source TS to destination TD before the time out as the TCP ACKs are with higher priority AC.

4. Simulation Results

4.1 Simulation Setup

NS-2 is used to simulate the Cross Layer based Smart acknowledgment scheme for TCP (CLSA-TCP) protocol. In our simulation, the channel capacity of all mobile hosts is set to 2 Mbps. Distributed coordination function (DCF) of IEEE 802.11 for wireless LANs is used as the MAC layer protocol. It has the functionality to notify the network layer about link breakage. The following metrics are used to compare CLSA-TCP with standard simple TCP protocol.

Packet delivery ratio: It is defined as the ratio of the total number of packets received at the destination over the total number of packets transmitted.

Average end-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Throughput: It is the total bandwidth received at the destination measured in Mb/sec.

4.2 Static Line Topology

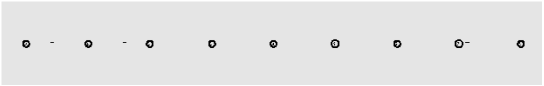

Fig. 3: Static Line Topology

In the static line topology, 9 static nodes are arranged as a line topology in a 1700 meter x 300 meter region as shown in Fig. 3. All nodes have the same transmission range of 250 meters. All the data flows are set as long follows.

The simulation settings and parameters are summarized in Table 3

Table 3: Simulation settings for Static Topology

No. of Nodes	9
Area Size	1700 X 300
Mac	8021.11
Radio Range	250m
Simulation Time	300 sec
Traffic Source	FTP
Packet Size	1000 bytes
No. of Flows	1 to 8
Routing Protocol	AODV

The simulation results are given in the next section.

4.2.1 Results

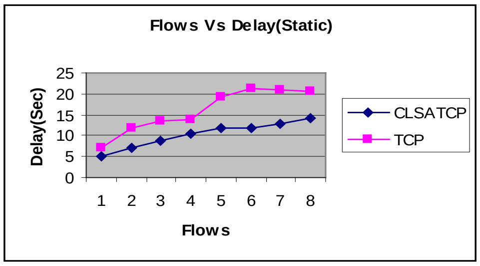

Fig. 4. Flows Vs Delay

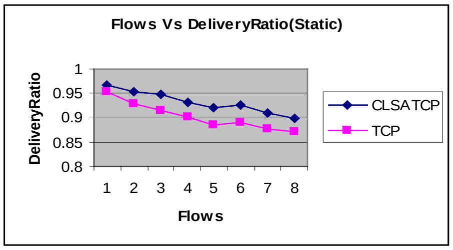

Fig. 5. Flows Vs Delivery Ratio

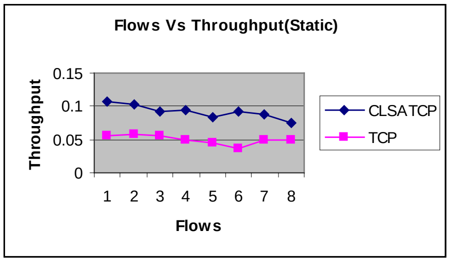

Fig. 6. Flows Vs Throughput

Fig. 4 shows the delay of CLSA-TCP and TCP techniques for different number of flows scenario. We can conclude that the delay of CLSA-TCP has 35% of less than TCP.

Fig. 5 shows the delivery ratio of CLSA-TCP and TCP techniques for different number of flows scenario. We can conclude that the delivery ratio of CLSA-TCP has 3% of higher than TCP.

Fig. 6 shows the throughput of CLSA-TCP and TCP techniques for different number of flows scenario. We can conclude that the throughput of CLSA-TCP has 45% of higher than TCP.

4.3 Dynamic Random Topology

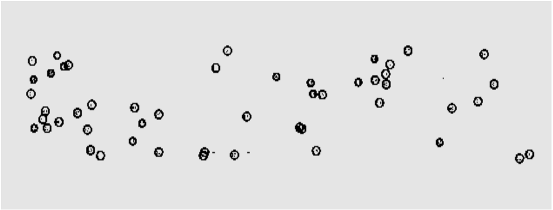

Fig. 7. Dynamic Random Topology

In the dynamic random topology, 50 mobile nodes are deployed randomly in a 1500 meter x 300 meter region as shown in Fig. 7. All nodes have the same transmission range of 250 meters. The random way point model of ns-2 is used as the mobility model in which the pause time of the node is 5 seconds and speed is 10 m/s. There are 10 traffic flows between different set of source and destination pairs.

The simulation settings and parameters are summarized in Table 4.

Table 4: Simulation settings for Dynamic Topology

No. of Nodes	50
Area Size	1500 X 300
Mac	8021.11
Radio Range	250m
Simulation Time	300 sec
Pause time	5 seconds
Speed	10 m/s
Traffic Source	FTP
Packet Size	512 bytes
No. of Flows	1 to 10
Routing Protocol	AODV

4.3.1 Results

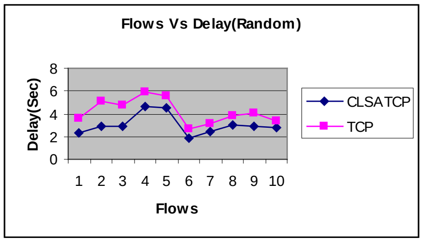

Fig. 8. Flows Vs Delay

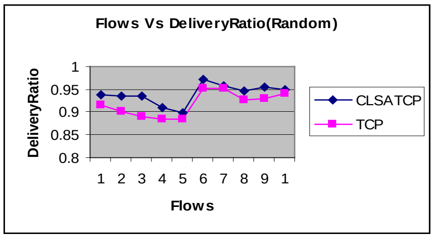

Fig. 9. Flows Vs Delivery Ratio

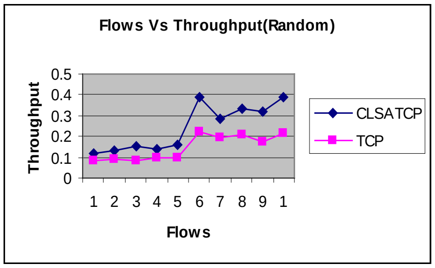

Fig. 10. Flows Vs Throughput

Fig. 8 shows the delay of CLSA-TCP and TCP techniques for different number of flows scenario. We can conclude that the delay of CLSA-TCP has 28% of less than TCP.

Fig. 9 shows the delivery ratio of CLSA-TCP and TCP techniques for different number of flows scenario. We can conclude that the delivery ratio of CLSA-TCP has 2% of higher than TCP.

Fig. 10 shows the throughput of CLSA-TCP and TCP techniques for different number of flows scenario. We can conclude that the throughput of CLSA-TCP has 37% of higher than TCP.

5. Conclusion

In this paper we have proposed a Smart ACK Distributed channel Access (SADCA) for TCP in MANET. In the proposed scheme, first a separate access category for data less TCP acknowledgment packets is used and also it is assigned with highest priority. As the TCP ACK is assigned with new AC with highest priority, so it has maximum probability of successful transmission by making efficient utilization of contention window during backoff stage. In this way, delay during transmission of packet can be reduced and also packet can be acknowledged immediately. Also, to increase the performance, delay window size can be adjusted for optimization purpose by considering the parameters such as transmission rate, number of hops, and congestion occupied ratio (COR). Hence the proposed scheme helps to avoid any kind of delay and overhead for sending TCP acknowledgment

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