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Degree Title	PhD
Title of Thesis	ENHANCING TRANSMISSION CONTROL PROTOCOL PERFORMANCE IN WIRELESS AD-HOC NETWORKS
Published Article Title	A Cross-Layer Solution for Contention Control to Enhance TCP Performance in Wireless Ad-Hoc Networks
Journal Name	IEEE ACCESS
HEC HJRS Journal Category	W

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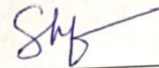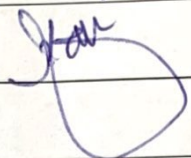Signature of Student

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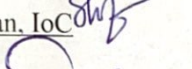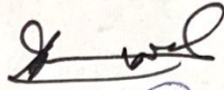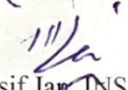
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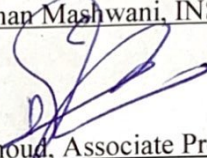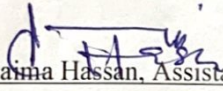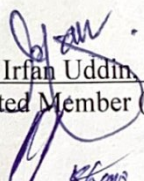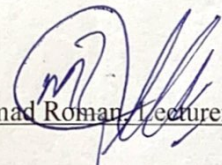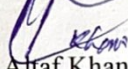
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Thesis Summary

This thesis aims to improve the performance of Transmission Control Protocol (TCP) in Wireless Ad-hoc Networks (WANETs). A background is provided in Chapter 1 on why TCP performs poorly in WANET and how it can be improved.

Chapter 2 of this thesis is reserved for presenting the literature review, an overview of TCP, and the various challenges TCP faces in WANET. Furthermore, to discuss the mechanism the IEEE 802.11 MAC protocol uses to access the medium.

Two mechanisms are presented in this thesis to enhance the performance of TCP in WANETs. **Cross-layer Solution for Contention Control (CSCC)** to Enhance TCP Performance in WANETs is one of these mechanisms presented in Chapter 3.

Using the CSCC mechanism, each node counts the number of attempts to access the medium for transmission at the MAC layer. After that, each node calculates the Weighted Moving Average (WMA) of the number of tries to estimate the Channel Contention (CC) and react accordingly. When the WMA reaches a specific threshold CC_{Thresh} (Channel Contention Threshold), the MAC layer will set the CC status ON. As a result, the node will start marking packets to inform the TCP's source node about contention. On receipt of CC notification, the source node adjusts its transmission rate to control contention.

Multi-hop wireless simulation experiments were conducted to verify the performance of the proposed mechanism against TCP NewReno, using the network simulator NS2.35. String topology was considered during the simulation to determine the effect of the increasing number of hops. Then a grid topology and a more realistic random topology were evaluated with a growing number of flows. Throughput and flow fairness criteria were chosen for the performance study, and simulation tests were conducted with 95% confidence. The quantity of retransmitted packets is also used as a performance indicator. TCP retransmits packets for two reasons: (i) when any packet loss is detected or (ii) when a retransmission timeout occurs. As a result, if an algorithm has a

low number of retransmissions, it also has a low number of retransmission timeouts and dropped packets. **This chapter is published in the IEEE Access, Volume 11 journal, under the title "A Cross-Layer Solution for Contention Control to Enhance TCP Performance in Wireless Ad-Hoc Networks".**

Chapter 4 is reserved to present our second mechanism called **Channel Usage-Based Backoff (CHUBB) Algorithm,** the proposed CHUBB algorithm aims to tune the BEB algorithm of the IEEE 802.11 MAC protocol so that the network attains high throughput and lessens the effect of unfairness. In the proposed algorithm, each node with a data frame to transmit monitors the medium's usage for a specified time interval. After that, it calculates the proportion of the time interval during which the associated node used the medium or in other words, each node computes its transmission ratio. Then the node chooses an adaptive multiplicative factor for the incoming interval based on the computed ratio that will be used to adjust the CW. One of the good aspects of this protocol is that it does not put any extra load on the transmission medium.

Using the network simulator NS2.35 [70], the CHUBB algorithm performance was evaluated against the BEB algorithm of the IEEE 802.11 MAC protocol in WANET. TCP and UDP both were employed at transport layer to transfer data fromsource to destination.

To evaluate the suggested algorithm's effectiveness, simulations were conducted in a static environment considering chain, grid, and random topologies. Furthermore, the throughput and fairness index were utilized as performance metrics. The rate of packet retransmission is also considered an indicator of performance. The best results are achieved when CHUBB algorithm was used.

Finally, Chapter 5 presents the concluding remarks.

Enhancing Transmission Control Protocol Performance in Wireless Ad-hoc Networks

by
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Introduction

Transmission Control Protocol (TCP) [1] is a reliable acknowledgement-based transport layer protocol; designed for wired networks. In its early days, TCP faced congestion collapses; and as a result, congestion control algorithms [2], [3] were integrated for further improvement. Due to its reliability, TCP is heavily used in various Internet applications like file transfer, remote access, email, and the web. Furthermore, it is reported that up to 90% of the internet traffic is transmitted through TCP [4], [5], which makes TCP an essential protocol for transmission and requires significant attention for further improvements.

However, with the evolution of wireless technology, users not only have wireless access to the Internet; this also led to the emergence of Wireless Ad-hoc Networks (WANETs), which are helpful in scenarios where the infrastructure might not exist or might be too expensive to use. WANETs consist of wireless nodes that establish wireless connectivity with each other without the aid of any access point, and each node plays the role of host and router. Such networks can be installed at any time and in any location.

Because of this appealing networking paradigm, one can see WANETs emerging into tactical wireless networking (battlefield), the internet of things (IoT), wireless sensor networks (WSN), vehicular ad-hoc networks (VANET), etc[5], [6]. In WANET, the IEEE 802.11 standard [7] is used as a de-facto standard for medium access [8].

But wireless networks have distinct characteristics (such as dynamic topology, shared medium and error-prone medium) compared to wired networks. Due to this difference, TCP faces challenges (such as route failure, channel contention, and hidden and exposed terminal problems) in wireless networks; as a result, TCP performance is not so good in wireless networks, especially in WANETs [9]. Therefore, TCP must overcome these challenges to benefit from the wireless technology, either connecting to the Internet or establishing a WANET.

The research community is looking from different angles to increase the overall performance of wireless networks; such as routing protocols [10]–[14] were suggested to compute network paths efficiently. However, in the presence of such efficient routing protocols, the TCP's performance is still inadequate in a wireless network. Furthermore, TCP executes congestion control algorithms in the event of losses not caused by network congestion, where congestion is the situation when the load on the network is greater than its capacity. That is, TCP cannot differentiate congestion losses from losses caused by the unique characteristics of WANET [15]–[17].

With TCP, buffer overflow is the most common reason for lost packets; this is true for wired networks. But this belief is incorrect in WANETs because packet loss might be induced by route failure or channel contention [18]. In wireless networking, a race condition occurs when two or more nodes attempt to transmit data simultaneously over a shared channel, known as channel contention. Furthermore, it is reported in [19] that buffer overflow is very rare if nodes in the WANET can buffer more than ten packets. However, channel contention is one of the most prevalent reasons for packets dropping in WANETs [19], [20]. Hence, TCP must be aware of channel contention to react appropriately and show better results in WANETs.

The research community has offered several techniques/mechanisms to handle channel contention. It is stated in [21] that the packets collide and drop due to channel contention, causing TCP performance degradation. Therefore, to enhance the services of TCP, Bhavadharini et al. have proposed a cross-layer mechanism named PPSAB (Prioritized Packet Scheduling with Adaptive Backoff window) [21]. In PPSAB, the packets' retransmission probability (RP) is computed based on packets' expiry time and the number of attempts made for frame transmission at the MAC layer. The frame with a smaller lifetime and the highest number of attempts made for its transmission obtains the highest priority to be transmitted. The value of contention window (CW) is adjusted based on the RP and the number of active nodes in the neighbourhood. Let $\alpha 1$ and $\alpha 2$ represent the weight factors, then CW is adjusted according to equation (1).

$$CW_{par} = (\alpha 1 \times \text{Average\_Active\_Neighbors}) + (\alpha 2 \times \text{RP}).$$

$$CW = CW_{max} \times CW_{par} \ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (1)$$

For handling channel contention, a mechanism named PCWM (Priority Contention Window Mechanism) [22] is proposed by Chou et al. In PCWM, the MAC layer acquires information from the network layer about the total and the remaining number of hops on the path. Then, based on this information, PCWM computes the value of the CW at each node along the route. Equations (2) show how to calculate the value of the CW.

$$CW_{Max} = \frac{1024}{2^y}, y = Max\big(0, (L - D - 5)\big)$$

$$CW_{Min} = \frac{1024}{2^x * 2^{(L-D)}}, \ \text{x} = Max(0, (5 - L))$$

L represents the total number of hops on the routing path, and D represents the remaining number of hops counted in the AODV routing table

$$CW = CWMin * 2^{n-1}, n \ is \ the \ number \ of \ attempts \ for \ data \ \text{transmission} \\ CWMin \leq CW \leq CWMax$$

$$(2)$$

It is reported in [23] that TCP cannot differentiate channel losses from congestion losses; as a result, a congestion control process is initiated, resulting in throughput degradation. In the loss recovery phase, the growth rate of the congestion window (cwnd) is very slow, and more time is required to acquire a steady state. Therefore, to introduce an aggressive cwnd growth pattern, a mechanism named FAIR+ (Feedback Assisted Improved Recovery+) algorithm [23] is proposed by Joseph et al.

During the slow start phase, the suggested FAIR+ algorithm sets the initial SS_{Thresh} (slow-start threshold) as the Max_wnd (maximum window) size. The cwnd growth is divided into low and high utilisation regions based on $growth\ threshold\ level\ \delta$ ($\delta = \frac{\text{Max }\_wnd}{2}$). Then the cwnd is incremented by 1 ($i.e.\ cwnd_{k+1} = cwnd_k + 1, if\ cwnd < \frac{\delta}{8}$) on the arrival of each ACK packet. When cwnd enter high utilisation reign ($i.e.\ cwnd \geq \frac{\delta}{8}$), then increment the cwnd according to equation (3) on the arrival of each ACK packet; and The congestion avoidance phase is initiated when the cwnd size becomes greater than Max_wnd.

$$cwnd_{k+1} = cwnd_k + \left(\left((2 * Max\_wnd) - cwnd_k\right) * \gamma\right), if\ cwnd \geq \frac{\delta}{8}\dots\dots\quad (3)$$

To avoid collision due to channel contention, Shan Wu et al. have proposed a mechanism named MNCA-CMAC (Cooperative MAC protocol with Multi-Node Collision Avoidance)[24]. For channel reservation in the MNCA-CMAC protocol, the sender transmits a CRTS (Cooperative Request-To-Send) packet. As a result, the receiving node replies with a CCTS (Cooperative Clear-To-Send) packet to show that it is ready to receive the packet. The sender waits to receive the HTS (help-to-send) packets from the cooperative nodes after the CCTS packets. HTS packet indicates the residual energy at the cooperative node. The sender waits for a predefined time to receive HTS packets or a predefined number of HTS packets. When any of these two conditions occurs, the sender terminates the cooperative node selection process by transmitting the SEI (selection end indicator) packet.

There are several techniques; whose primary focus is sending a delayed acknowledgement to minimise channel contention. The TCP ACK Delay Window (TCP-ADW) [25] also tries to solve the issue of channel contention. This mechanism looks at the channel situation to determine what number of ACKs should be used to increase or decrease the delay window. TCP-ADW estimates the network condition by observing the inter-arrival times (IAT) of the TCP packets. When the total of received packets hits the delay window, the receiver must generate the ACK and set the count variable to zero. However, it issues an ACK immediately in two cases, i.e. (i) on the arrival of the out-of-order packet or (ii) receiving a missing packet.

Furthermore, the receiver delays ACK by enough time to prevent the sender from experiencing a transmission time-out.

Altman et al. [26] have presented the Dynamic Delayed ACK (DDA) approach, which is based on RFC 1122 [27]. In [27], a standard is established to generate an ACK after **d** number of packets where **d**=2; however, it is also suggested to create an ACK if **d** number of packets is not received in a pre-set period. In DDA, the value of **d** ranges from 1 to 4. Initially, DDA creates an ACK for one packet and then increases this number to four packets (d=4) based on the sequence number. Under this strategy, once **d** achieve the value of four, there is no way to bring it back down. To make this concept even better, a mechanism called TCP-DAA (TCP Dynamic Adaptive Acknowledgement) [28] is suggested. This mechanism looks at channel conditions for generating an ACK. If the channel is good, create an ACK after the arrival of four packets; if the channel is bad, generate an ACK after two packets. However, immediately issue an ACK on the appearance of an out-of-order packet or receiving a missing packet. In standard TCP, for fast retransmission, three duplicate ACKs are required; but this number of duplicate ACKs is reduced from three to two in TCP-DAA to avoid unnecessary retransmission.

J. Chen et al. have proposed a mechanism named TCP-DCA (TCP with Delayed Cumulative ACK) [29]; this mechanism seeks to identify the delay windows based on the hop count and is inspired by the theories that drive TCP-DAA. TCP-DCA could pause the ACK for an entire cwnd (i.e., for a short path where the number of hops is less than or equal to three) to achieve the best performance. The receiver issues an ACK after five packets on pathways with a hop count of more than three but less than or equal to nine. If the hops count is more than nine, an ACK is delivered after the arrival of three packets.

Contention-based Path Selection (COPAS) [30], unlike delayed ACK schemes, does not restrict ACK packets' insertion into the network; however, the COPAS mechanism sends data and ACK packets along various pathways and continuously examines them for contention. When the amount of traffic on a path surpasses a certain level, a less congested route is chosen.

A Link layer RED+AP (LRED+AP) mechanism is suggested by Fu et al. [19] to address the issue of channel contention. In this mechanism, every node computes the average number of tries for packet transmission and sets two thresholds, i.e., the maximum and minimum. Drop the packet when the average number of attempts reaches the maximum threshold on any node. While at the minimum point, LRED+AP forces the nodes to extend the backoff time to alleviate the unfairness issue. The extra time is equal to the transmission time of the previous packet.

5

Having presented a summary of the proposals suggested for congestion and contention control, the following section offers the problem statement and proposed mechanism.

Problem Statement

Channel contention due to a shared medium is one of the most prevalent reasons for packet loss and collision in WANETs. When a packet is lost or collided, resources are wasted, and packets will be retransmitted on a contended path. In addition, channel contention creates the issue of unfairness. Therefore, providing a fair share to each flow is necessary.

The wrong notification of route failure also emerges due to channel contention. When a node exceeds a predefined threshold of attempts for accessing the shared medium, the transmission process is aborted, assuming that the receiver is out of the transmission range. Then the MAC layer notifies the network layer that the path is unavailable towards the destination. The network layer initiates a route recovery process without any need, wasting time and resources.

Objectives

Following are the objectives of this work to achieve for enhancing the performance of Transmission control protocol in wireless ad hoc networks.

- To observe channel contention and react at appropriate time for better utilization of the network resources.
- To provide a fair share to each node, in the contented environment, to access the medium for transmission based on the channel usage.
- To reduce the number of wrong notifications from the MAC layer to the Network layer about the route failure.

Methodology

(a) A Cross-layer Solution for Contention Control (CSCC) to Enhance TCP Performance in Wireless ad hoc Networks

To present a cross-layer mechanism named "A Cross-layer Solution for Contention Control (CSCC) to Enhance TCP performance in WANETs". This mechanism will enable TCP to get feedback from lower layers to learn about the network conditions and respond more effectively.

In this mechanism, each node will observe the channel contention on the MAC layer and mark packets when channel contention reaches a particular threshold. Packet marking is used to inform the sender about channel contention; as a result, the TCP source node will regulate its data transmission rate. Equation (4) will be used to observe and reflect the channel contention status.

$$\text{Å}_{n+1} = (1-\alpha)\text{Å}_n + \alpha R_{att} \ \ and \ \ 0 < \alpha < 1 \ \dots\dots\dots\dots\dots\dots\dots\dots\dots \ (4)$$

Å is the weighted moving average, R_{att} is the number of attempts for packet transmission, and α is the weight factor. A tentative flowchart of the proposed mechanism is shown in Figure 1.
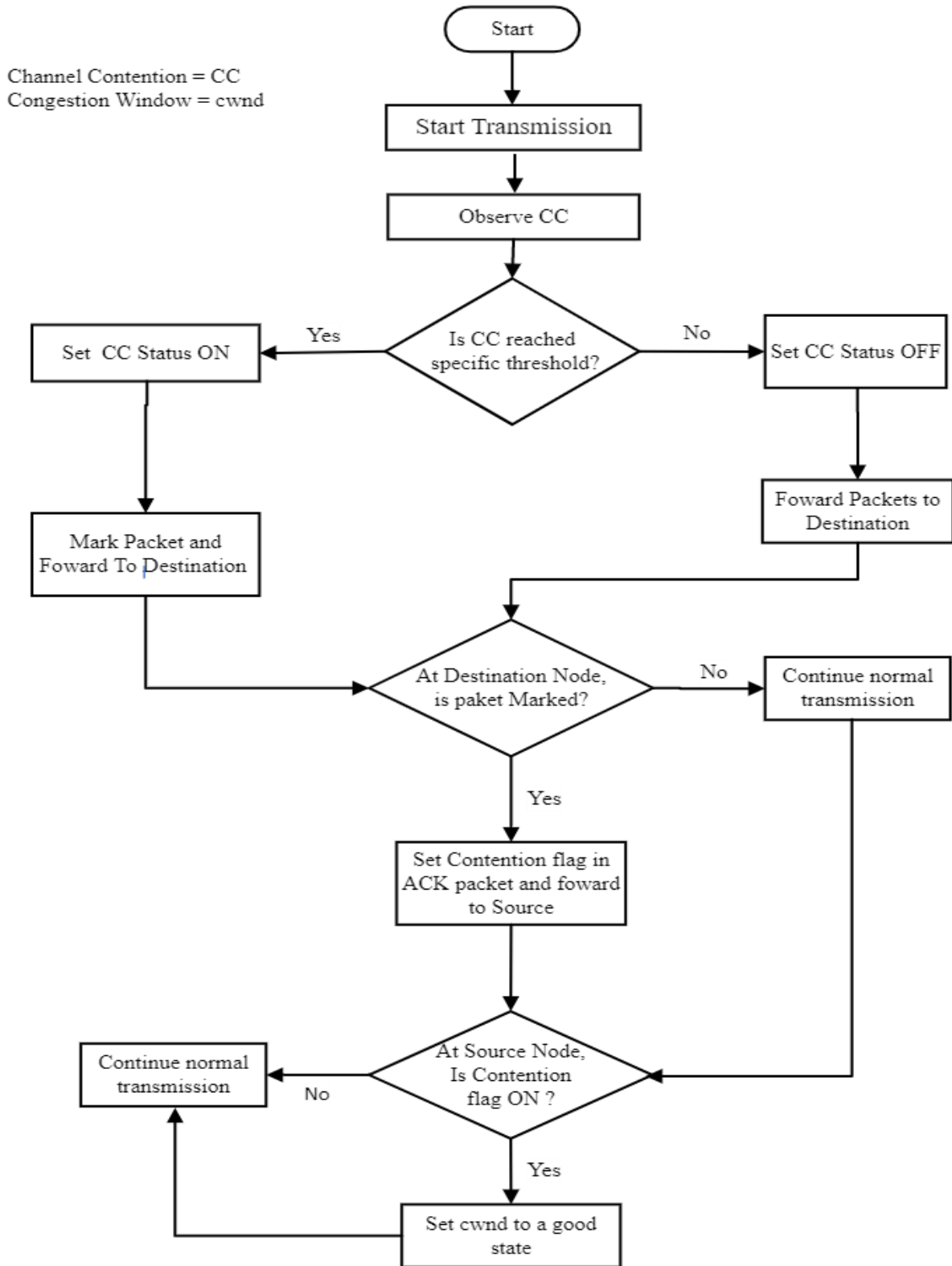

Figure 1: Flowchart of A Cross-layer Solution for Contention Control (CSCC) to Enhance TCP performance in WANETs

(b) Channel Usage-Based Backoff (CHUBB) Algorithm for Contention Control in Wireless Ad-hoc Networks

Our second mechanism is a MAC layer approach named "Channel Usage-Based Backoff (CHUBB) algorithm for contention control in WANETs" to give a fair share to each node for accessing the medium. In this mechanism, each node will measure how long it used the medium in a time interval 'T'. On the expiry of the interval 'T', according to equation (5), the time for which a node uses the medium will compute its usage ratio 'N_{tr}' concerning the total time of the interval.

$$N_{tr} = \frac{N_t}{T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where N_t is a node's time to transmit data over the interval T.

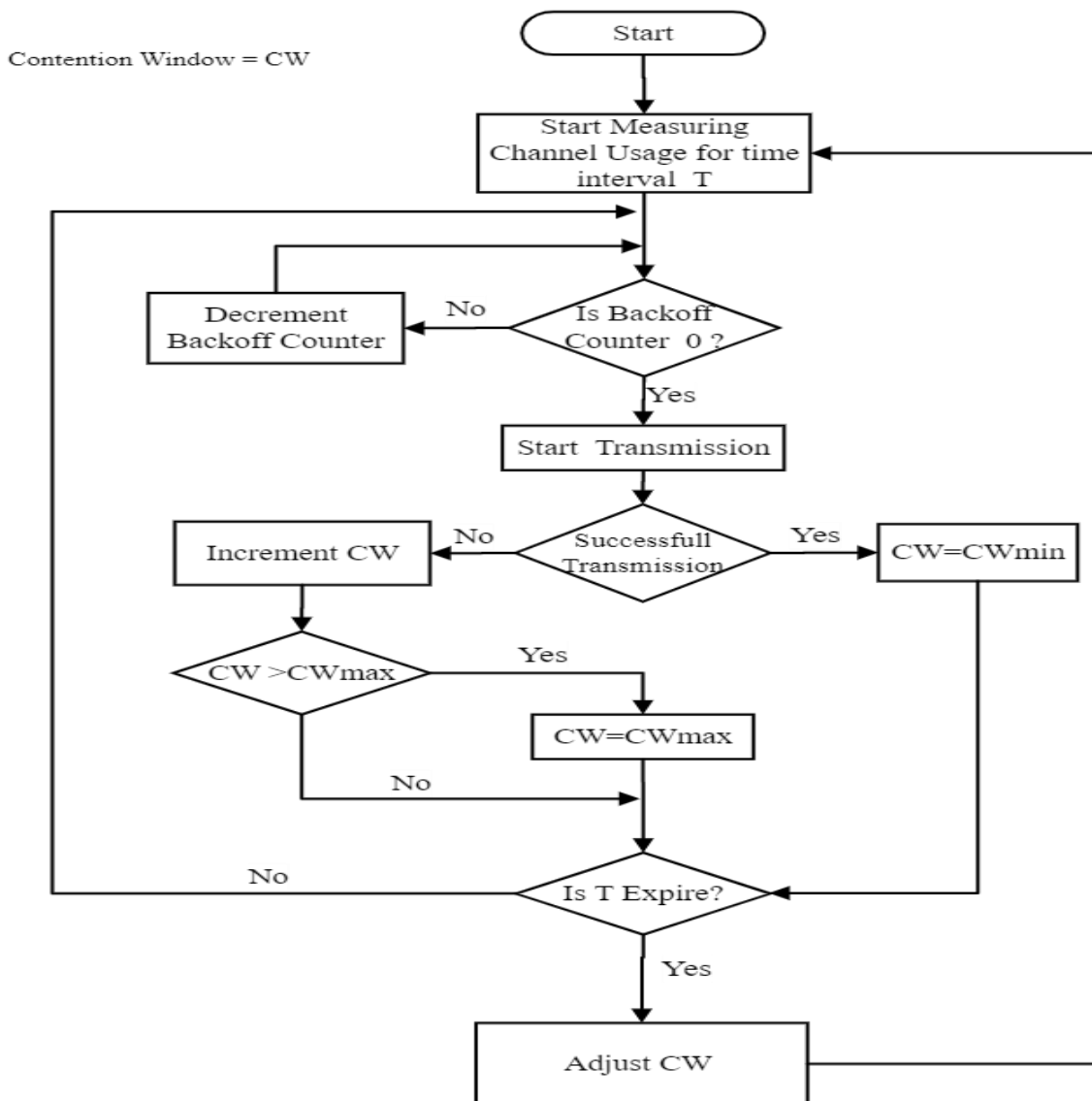A tentative flowchart of this mechanism is shown in *Figure 2*.

Figure 2: Flowchart of the Channel Usage-Based Backoff (CHUBB) Algorithm for Contention Control in WANETs

8

Simulation Environment

The proposed mechanism will be evaluated in different scenarios, such as string and grid topologies, using NS2 (Network Simulator 2) with its default parameters; otherwise, it will be stated. Moreover, cross flows will be considered and to consider the random environment as well.

The DSR (Dynamic Source Routing) and AODV (Ad hoc On-Demand Distance Vector) routing protocol will be used to establish a path between source and destination. DSR is a source routing protocol; path information is maintained in the packet header. On the other hand, AODV supports routing information in a table.

The performance of the proposed algorithms will be tested based on performance metrics or evaluation metrics such as average throughput, dropped or retransmitted packets and Fairness Index. The following equations (6), (7) and (8) show respectively how these metrics will be computed.

$$Average\ Throughput = \frac{Number\ of\ Received\ Packets\ \times\ Packet\ Size}{Total\ Simulation\ Time} \quad (6)$$

$$Average\ Packets\ Dropped\ = \frac{(packets\ sent - Packets\ received)}{Total\ Simulation\ Time} \cdots\cdots\cdots\cdots \quad (7)$$

$$Fairness\ Index = \frac{[\sum_{i=1}^{n} x_i]^2}{n \times \sum_{i=1}^{n} x_i^2} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad (8)$$

Where 'n' represents the number of flows and 'x' is the throughput of flow 'i'.

Time Plan

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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Activity	Literature														
						Problem Design and Solution				`				
									Validation					
												Thesis Writing		

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PROCEEDING OF THE MEETING OF THE ADVANCE STUDIES & RESEARCH BOARD (ASRB), DATED 12.08.2022

A meeting of the Advance Studies & Research Board was held on 12.08.2022 at 09:30 am in the Committee Room of the Vice Chancellor's Secretariat. The following members attended the meeting:

In Chair

Prof. Dr. Sardar Khan
Vice Chancellor, Kohat University of Science & Technology, Kohat

Members

1. **Prof. Dr. Syed Tasleem Hussain**
   Dean, Faculty of Chemical & Pharmaceutical Sciences

2. **Prof. Dr. Shahid Niaz Khan**
   Dean, Faculty of Biological Sciences

3. **Prof. Dr. Muhammad Naseer ud Din**
   Dean, Faculty of Social Sciences

4. **Prof. Dr. Wali Khan**
   Dean, Faculty of Physical & Numerical Sciences

5. **Prof. Dr. Muhammad Jamil**
   Department of Biotechnology & GE

6. **Prof. Dr. Muhammad Iqbal Khan**
   Department of Chemistry

7. **Dr. Saeed Ahmad Khan**
   Associate Professor, Department of Pharmacy

8. **Dr. Sammar Abbas**
   Associate Professor, Institute of Business Studies

9. **Dr. Saad Ullah Khan**
   Associate Professor, Department of Biotechnology & GE

10. **Dr. Muhammad Zeeshan Bangash**
    Director, Quality Enhancement Cell

11. **Dr. Wasiullah Malik**
    Director, ORIC, KUST

12. **Dr. Shamim Saleha**
    Director, Advance Studies and Research

A-Fresh PhD Cases

PhD Synopses in Biotechnology & GE

Agenda Item No.1

Maha Rehman, PhD Scholar of Biotechnology & GE (Reg. # BT420201002)

Research Title: Approved with changes

MOLECULAR IDENTIFICATION, GROWTH KINETICS, AND FOLIC ACID PRODUCTION OF *SPIRULINA SPP.* ISOLATED FROM OLIGOTROPHIC WATER RESERVOIRS OF KOHAT, PAKISTAN

Supervisor-I:
Dr. Rehan Naeem,
Department of Biotechnology & GE, KUST

Supervisor-II:
Dr. Muhammad Jamil,
Department of Biotechnology & GE, KUST

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Corrected/suggested title by the board is "Folic Acid Production of *Spirulina* spp. Isolated from Water Reservoirs of Kohat, (Pakistan) and its Utilization as Food Supplement".

2. Add in introduction a paragraph about the socioeconomic benefits of proposed study.
3. Revise and rephrase objectives according to corrected/suggested title for proposed research
4. What parameters will be used to confirm the oligotrophic status of the reservoirs? Add experimental studies to investigate effects of micro- and macro-nutrients, growth kinetics and photosynthetic elements on growth of *Spirulina* spp. in oligotrophic water reservoirs.
5. Ethical committee approval is required for proposed study.
6. Write "study objectives" as subheading and change numbers with bullets by separating objectives.
7. How you will collect samples from depth instead of bottom of water reservoirs? Add short detail in materials and methods section.
8. Write concentration of HCL that will be used in proposed methodology.
9. Write abbreviation of ultraviolet in parentheses at first use then use this abbreviation in text of materials and methods section.
10. What do the symbols "μ1 and μ2" stand for? Add description in materials and methods section.

Note: Prof. Dr. Sardar Khan, Vice Chancellor, KUST will check the revised synopsis and then issue a certificate of corrections.

PhD Synopses in Microbiology

Agenda Item No.2.1

Maryam Gul, PhD Scholar of Microbiology (Reg. # MB420202004)

Research Title: Approved with changes

GENETIC DIVERSITY AND EVOLUTION OF MYCOBACTERIUM TUBERCULOSIS COMPLEX LINEAGES IN KHYBER PAKHTUNKHWA USING WHOLE GENOME SEQUENCING

Supervisor-I:
Dr. Mubashir Hussain,
Department of Microbiology, KUST

Supervisor-II:
Dr. Taj Ali Khan,
Institute of Basic Medical Sciences, KMU, Peshawar

Supervisor-III:
Dr. Sajid Ali,
Provincial TB Reference Laboratory, Peshawar

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Corrected/suggested title by the board is "Genetic Diversity and Evolution of *Mycobacterium Tuberculosis Complex* Lineages in Khyber Pakhtunkhwa, Pakistan".
2. Add in introduction a paragraph about the socioeconomic benefits of proposed study.
3. Rewrite and rephrase objective # 1 for more clarity and avoid writing again and again Khyber Pakhtunkhwa
4. In objective # 3 write "study area" instead of "Khyber Pakhtunkhwa". Ethical committee approval is required for proposed study.
5. Capitalize the first letter of main words in the name of institute i.e., London School of Hygiene and Tropical Medicine in materials and methods section.

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6. Add a short description of SNPs under subheading "Phylogenetic analysis" in materials and methods section.
7. Correct spelling of Khyber Pakhtunkhwa in text under subheading "study area and sampling" in materials and methods section.
8. Correct in-text citation mistakes and referencing errors in synopsis.

Agenda Item No.2.2

Hakeem Zada, PhD Scholar of Microbiology (Reg. # MB420202003)

Research Title: **Approved with changes**

MOLECULAR ANALYSIS OF VIRULENCE AND ANTIBIOTIC RESISTANCE OF *KLEBSIELLA PNEUMONIAE* ISOLATES OF KHYBER PAKHTUNKHWA

Supervisor-I:
Dr. Muhammad Qasim,
Department of Microbiology, KUST

Supervisor-II:
Dr. Mubashir Hussain,
Department of Microbiology, KUST

RESEARCH PROPOSAL: **Approved with changes**

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Corrected/suggested title by the board is "Virulence and Antibiotic Resistance of *Klebsiella Pneumoniae* Isolates of Khyber Pakhtunkhwa, Pakistan".
2. Write one time "respiratory tract" in first statement of introduction.

3. Add in introduction a paragraph about the socioeconomic benefits of proposed study.
4. In-text citation "Kiaei *et al*., 2017" is missing in reference list.
5. Change numbers with bullets by separating objectives. In addition, correct order of objectives.
6. Write description of inclusion and exclusion criteria in proposed methodology.
7. Write names of antibiotics that will be used in proposed research.
8. Prepare a questionnaire for data collection and present as annexure with revised synopsis.

Note: The revised synopsis will be checked by Department Graduate Committee and then will issue a certificate of corrections.

PhD Synopses in Zoology

Agenda Item No.3

Muhammad Ilyas Khan, PhD Scholar of Zoology (Reg. # ZO420182003)

Research Title: **Approved with changes**

MOLECULAR STATUS OF DRUG RESISTANCE AND THERAPEUTIC POTENTIAL OF PAKISTANI BEE PROPOLIS AGAINST MALARIAL PARASITE

Supervisor-I:
Dr. Syed Ishtiaq Anjum,
Department of Zoology

Supervisor-II:
Dr. Naveeda Akhter Qureshi,
Department of Animal Sciences, QAU, Islamabad

Supervisor-III:
Dr. Huma Fatima,
Department of Zoology, Women University, Mardan

RESEARCH PROPOSAL: **Approved with changes**

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Corrected/suggested title by the board is "Molecular Status of Drug Resistance in Malarial Parasite and Therapeutic Potential of Pakistani Bee Propolis"
2. Revise synopsis for corrections as per University format (correct in-text citations, remove numbering with subheadings as well as with lines, change numbers with bullets by separating objectives and correct referencing errors).
3. Add in introduction a paragraph about the socioeconomic benefits of proposed study.
4. Write aim of study in end of introduction.
5. Write either "by" or "using" at multiple places in synopsis.
6. Do correction for grammatical mistakes in whole synopsis.
7. Specify number of samples.
8. Mention areas of Khyber Pakhtunkhwa and Punjab for samples collection.
9. Write standard conditions and programming for PCR amplifications in methodology.
10. The in vitro approach may be valuable for proposed research. In this regard, the supervisor written consent is required about possibility and inclusion of in vitro approach in proposed study.

PhD Synopses in Physics

Agenda Item No.4

Rifat Sultana, PhD Scholar of Physics (Reg. # PH420202003)

Research Title: **Approved**

ELECTRONIC TRANSPORT CHARACTERISTICS IN BLACK PHOSPHORENE

Supervisor-I:
Dr. Abdullah Yar,
Department of Physics, KUST

RESEARCH PROPOSAL: **Approved with changes**

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Add in introduction a paragraph about the socioeconomic benefits of proposed study.
2. Highlight the novelty of proposed study through the introduction.
3. Change numbers with bullets by separating objectives.
4. Correct referencing errors.

PhD Synopses in Computer Science

Agenda Item No.5

Noor Mast, PhD Scholar of Computer Science (Reg. # CS420201001)

Research Title: **Approved**

ENHANCING TRANSMISSION CONTROL PROTOCOL PERFORMANCE IN WIRELESS AD-HOC NETWORKS

Supervisor-I:
Dr. Shafiullah Khan,
Institute of Computing, KUST

Supervisor-II:
Dr. Muhammad Irfan ud Din,
Institute of Computing, KUST

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RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Rephrase objectives for more clarity and make them precise, comprehensive and confined. In addition, objectives shall reflect the two novelties of the work proposed.
2. Do corrections for grammatical mistakes in whole synopsis.
3. Revise introduction by rephrasing the sentences like "Give Birth to ….".
4. Do corrections of personalized terms such as "we" in text of introduction and use generalized terms.
5. The parameters to be fixed for running the simulation along with simulator detail may be included in the synopsis.

Note: The revised synopsis will be checked by Dr. Muhammad Zeeshan Bangash, Director, Quality Enhancement Cell, KUST and then will issue a certificate of corrections.

B-Referred Back MS/M.Phil. Cases

M.Phil. Synopses in Biotechnology & GE

Agenda Item No.6

Azmat Ullah Khan, M.Phil. Scholar in Biotechnology & GE (Reg. # BT320191007)

Research Title: Approved

MOLECULAR DETECTION OF _ENTAMOEBA HISTOLYTICA_ AND _GIARDIA LAMBLIA_ IN DIFFERENT WATER SOURCES OF DISTRICT KURRAM

Supervisor-I:
Dr. Nawab Ali,
Department of Biotechnology & GE, KUST

Supervisor-II:
Dr. Noor ul Akbar,
Department of Zoology, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form

M.Phil. Synopses in Microbiology

Agenda Item No.7.1

Rabia Hayat, M.Phil Scholar in Microbiology (Reg. # MB320202005)

Research Title: Approved

EVALUATION OF INDEGENOUS BACTERIAL STRAINS FOR DEGRADATION OF PESTICIDES USING MICROCOSMIC ASSAYS.

Supervisor-I:
Dr. Muhammad Anees,
Department of Microbiology, KUST

Supervisor-II:
Dr. Nazish Manzoor,
Department of Microbiology, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form.

Agenda Item No.7.2

Shakeela Naz, M.Phil. Scholar in Microbiology (Reg. # MB320202010)

Research Title: Approved

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STUDY OF BIODEGRADATION OF ROXARSONE USING BACTERIA ISOLATED FROM CHICKEN MANURE

Supervisor-I:
Dr. Waheed Ullah,
Department of Microbiology, KUST

Supervisor-II:
Dr. Nadia Taimur,
Department of Botany, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form.

MS Synopses in English

Agenda Item No.8.1

Maham Khan Khattak, MS Scholar in English (Reg. # EN320192013)

Research Title: Approved

FACTORS AFFECTING L2 MOTIVATIONAL SELF-SYSTEM OF BS ENGLISH STUDENTS AT KHUSHAL KHAN KHATTAK UNIVERSITY KARAK, KHYBER PAKHTUNKHWA, PAKISTAN

Supervisor-I:
Dr. Syed Azaz Ali Shah,
Department of English, KUST

Supervisor-II:
Dr. Mansoor Ali,
Department of English, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form.

Agenda Item No.8.2

Faisal Zeeshan, MS Scholar in English (Reg. # EN320192006)

Research Title: Approved

REASONS AND EFFECTS OF CODE-SWITCHING IN BS CLASSES OF THE DEPARTMENT OF ENGLISH AT KHUSHAL KHAN KHATTAK UNIVERSITY, KARAK, PAKISTAN

Supervisor-I:
Dr. Syed Azaz Ali Shah,
Department of English, KUST

Supervisor-II:
Dr. Syed Shujaat Ali,
Department of English, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form.

Agenda Item No.8.3

Muhammad Hamad Zaman, MS Scholar in English (Reg. # EN320192019)

Research Title: Approved

IMPACT OF USING NON-VERBAL COMMUNICATION ON STUDENTS' ENGLISH LANGUAGE LEARNING AT SECONDARY LEVEL IN FAZAIA SCHOOLS SYSTEM

Supervisor-I:
Dr. Syed Azaz Ali Shah,
Department of English, KUST

Supervisor-II:
Dr. Syed Shujaat Ali,
Department of English, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form.

Agenda Item No.8.4

Abdul Basit, MS Scholar in English (Reg. # EN320192001)

Research Title: Approved

THE LEVEL OF USAGE OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IN ENGLISH LANGUGE LEARNING BY UNDERGRADAUTE STUDENTS IN GOVERNMENT COLLEGES OF DISTRICT KOHAT

Supervisor-I:
Dr. Salma Khatoon,
Department of English, KUST

Supervisor-II:
Dr. Syed Shujaat Ali,
Department of English, KUST

RESEARCH PROPOSAL: Approved

Decision: Synopsis is accepted in its present form.

M.Phil. Synopses in Social Work

Agenda Item No.9.1

Mahin Bangash, M.Phil. Scholar in Social Work (Reg. # SWS320202004)

Research Title: Approved

IMPACTS OF CORPORAL PUNISHMENT ON PERSONALITIES OF GOVERNMENT SECONDARY SCHOOLS MALE STUDENTS IN DISTRICT KOHAT: A SCHOOL SOCIAL WORK PERSPECTIVE

Supervisor-I:
Dr. Mamoon Khan Khattak,
Department of Social

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Write first research questions and then study objectives.
2. Remove space problems between the words from the whole synopsis.

Agenda Item No.9.2

Tayyaba Nayab Nisar, M.Phil. Scholar in Social Work (Reg. # SWS320202006)

Research Title: Approved

IMPACTS OF PARENTAL NEGLECT ON PERSONALITIES OF FEMALE-CHILDREN IN DISTRICT KOHAT: A SOCIAL WORK PERSPECTIVE

Supervisor-I:
Dr. Mamoon Khan Khattak,
Department of Social

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Write first research questions and then study objectives.
2. Delete a statement before objectives. Write "study objectives" as subheading and change numbers with bullets by separating objectives.

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C- MS/M.Phil. Fresh Cases

M.Phil. Synopses in Microbiology

Agenda Item No.10.1

Mehreen Saeed, M. Phil. Scholar in Microbiology (Reg. # MB320211008)

Research Title: **Approved**

MOLECULAR DETECTION OF *MECA* GENE AND ANALYSIS OF RISK FACTORS IN METHICILLIN RESISTANT STAPHYLOCOCCUS AUREUS ASSOCIATED WITH SURGICAL SITE INFECTIONS

Supervisor-I:
Dr. Mubbashir Hussain,
Department of Microbiology, KUST

Supervisor-II:
Prof. Dr. Sohail Aziz Paracha,
KIM-KMU, Kohat

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Rephrase objective # 2 for more clarity. Avoid using terminology "molecularly".
2. Change numbers with bullets by separating objectives.
3. Specify number of samples for proposed research.
4. Write components of PCR reactions' mix., in methodology.
5. Add some description of statistical test in methodology.

Agenda Item No.10.2

Humaira Alam, M.Phil. Scholar in Microbiology (Reg. # MB320211003)

Research Title: **Referred Back**

MICROORGANISMS INVOLVED IN THE DETERIORATION OF *PSIDIUM GUAJAVA* FRUIT SHELF LIFE AND THEIR CONTROL BY LOCAL PRESERVATIVES

Supervisor-I:
Dr. Niaz Muhammad,
Department of Microbiology, KUST

Supervisor-II:
Dr. Muhammad Jamil,
Department of Biotechnology & GE, KUST

RESEARCH PROPOSAL: Referred Back

Decision: Revised proposal should be submitted to the Directorate for resubmission to ASRB after making the following corrections in the proposal:

1. Change numbers with bullets by separating objectives.
2. Make a distinction in identification techniques (culturing, stanning and biochemical tests) used for bacteria and fungi by writing separately in methodology.
3. Revise methodology under subheading "Preservation of Guava through local preservatives" keeping in mind the high cost of mentioned different preservatives for preservation of Guava.
4. Add some description of statistical test in methodology.

The revised synopsis will be checked by Department Graduate Committee and then will issue a certificate of corrections.

Agenda Item No.10.3

Faiqa Rashid, M.Phil. Scholar in Microbiology (Reg. # MB320202001)

Research Title: **Referred Back**

CATALYTIC EFFECT OF ZINC OXIDE NANOPARTICLES USING PEEL EXTRACT OF CITRUS LIMON AGAINST MULTIDRUG RESISTANT BACTERIA

Supervisor-I:
Dr. Niaz Muhammad,
Department of Microbiology, KUST

Supervisor-II:
Dr. Abdul Rehman,
Department of Microbiology, KUST

RESEARCH PROPOSAL: **Referred Back**

Decision: Revised proposal should be submitted to the Directorate for resubmission to ASRB after making the following corrections in the proposal:

1. Rephrase title to summarize the main idea and adequately describe the contents or purpose of proposed study.
2. Highlight the novelty of proposed study through the introduction.
3. Explain to clarify "antibiotic discs coated with ZNO-NPs in text of synopsis.
4. Explain methodology of susceptibility testing for ZNO-NPs coated antibiotics against MDR bacteria.
5. Revise methodology by addition of description about qualitative analysis and catalysis of citrus peel extract and previously identified multi-drug resistant bacterial strains.
6. Add some description of statistical test in methodology.

Note: Dr. Saeed Ahmad Khan, Associate Professor, Department of Pharmacy will check the revised synopsis and then issue a certificate of correction.

M.Phil. Synopses in Zoology

Agenda Item No.11.1

Iram Nowsheen, M.Phil. Scholar in Zoology (Reg. # ZO320211007)

Research Title: **Approved**

IDENTIFICATION AND CHARACTERIZATION OF ANTIBIOTIC RESISTANT BACTERIA FROM THE GUT OF HONEY BEE *APIS MELLIFERA*

Supervisor-I:
Dr. Syed Ishtiaq Anjum,
Department of Zoology, KUST

Supervisor-II:
Dr. Muhammad Anees,
Department of Microbiology, KUST

RESEARCH PROPOSAL: **Approved with changes**

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Revise synopsis for corrections as per University format (remove numbering with lines and change numbers with bullets by separating objectives).
2. Write standard conditions and programming for PCR amplifications in methodology.
3. Write version name of SPSS software in methodology.
4. Correct referencing errors.

Agenda Item No.11.2

Bushra Andaleeb, M.Phil. Scholar in Zoology (Reg. # ZO320211002)

Research Title: **Referred Back**

RESPONSE OF CHRONIC HEPATITIS C PATIENTS TO DIRECT ACTING ANTIVIRALS (DAAS)

Supervisor-I:
Dr. Abdul Majid,
Department of Zoology, KUST

Supervisor-II:
Dr. Malik Nawaz Shuja,
Department of Microbiology, KUST

RESEARCH PROPOSAL: Referred Back

Decision: Revised proposal should be submitted to the Directorate for resubmission to ASRB after making the following corrections in the proposal;

1. Rephrase title to summarize the main idea and adequately describe the contents or purpose of proposed study.
2. There are many language mistakes in synopsis that need to be corrected.
3. Change numbers with bullets by separating objectives.
4. There are space problems between the words particularly between word and unit in methodology. Remove these problems.
5. Choose a realistic number of samples for proposed research.

Note: The Departmental Graduate Committee (DGC) have pointed mistakes on copy of proposal that was submitted to ASRB. However, those mistakes have not been corrected. The DGC will check the revised synopsis and then issue a certificate of correction. In addition, Chairman, Dept. of Zoology will forward the revised proposal after confirmation of changes by DGC.

M. Phil. Synopses in Botany

Agenda Item No.12

Atif Sohail, M.Phil. Scholar in Botany (Reg. # BO320211002)
Research Title: Referred Back

EFFECTS OF SILVER NANOPARTICLES ON PHYSIOLGICAL AND BIOCHEMICAL PARAMETERS OF MAIZE (*ZEA MAYS L.*) UNDER SALT STRESS

Supervisor-I:
Dr. Muhammad Adnan,
Department of Botany, KUST

Supervisor-II:
Dr. Jehanzeb Khan,
Department of Botany, GPGC, Kohat

RESEARCH PROPOSAL: Referred Back

Decision: Revised proposal should be submitted to the Directorate for resubmission to ASRB after making the following corrections in the proposal:

1. Silver nanoparticles are economically expensive, therefore write research rationale.
2. Mention concentration of salt and nanoparticles in methodology
3. Correct in-text citation errors
4. Add description of salt type that will be used in proposed research
5. Add a brief description of silver nanoparticles that will be taken from Dept. of Chemistry for proposed research.
6. Correct "diluted distilled water" in methodology.
7. Select more parameters for study to obtain valuable findings.

The revised synopsis will be checked by Department Graduate Committee and then will issue a certificate of corrections.

M.Phil. Synopses in Chemistry

Agenda Item No.13

Asif Mehmood Khan, M.Phil. Scholar in Chemistry (Reg. # CH320192047)
Research Title: Approved with changes

PREPARATION OF BIMETALLIC NI-AG SUPPORTED TIO2 NANOCOMPOSITES AND ITS USE FOR PHOTOCATALYTIC REDUCTION OF NITROPHENOL

Supervisor-I:
Dr. Muhammad Bilal,
Department of Chemistry, KUST

Supervisor-II:
Dr. Javed Ali,
Department of Chemistry, KUST

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies after incorporating the suggestions/modifications pointed out by the Board as given below:

1. In title write complete words for abbreviations.
2. There are space problems between the words, remove these problems.
3. Replace "experimental work" with "materials and methods"
4. There is no uniformity in the time frame format, revise it correctly as per University format.

M.Phil. Synopses in Physics

Agenda Item No.14.1

Naimat Ullah, M.Phil. Scholar in Physics (Reg. # PH320202010)

Research Title: Approved

A COMPUTATIONAL STUDY OF RADIATION SHIELDING PARAMETERS OF ZINC BISMUTH ALLOYS

Supervisor-I:
Dr. Sajid Khan,
Department of Physics, KUST
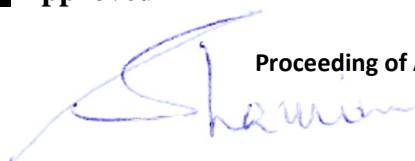
Supervisor-II:
Dr. Rashid Ahmad,
Department of Physics, KUST

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Change numbers with bullets by separating objectives
2. Do corrections of personalized terms such as "we" in text of introduction and use generalized terms.
3. Do corrections for grammatical mistakes in whole synopsis.
4. Correct in-text citation errors.
5. Adopt uniformity in writing symbols.
6. Explain why the SRIM CODE (2003) will be used? Why MATLAB ….or WinXcom, Phy-X/PSD, and Monte Carlo will not be used?
7. Add description of parameters that have been fixed for the simulator.
8. Write about learning outcomes from the simulation
9. Braggs rule has been mentioned but the equation mathematical model not mentioned.
10. What are the physical and optical properties of the mentioned composition for the study?

_____

11. There is no uniformity in the time frame format, revise it correctly as per University format.
12. Include in proposal most relevant and most recent references.

Agenda Item No.14.2

Bibi Saba, M.Phil. Scholar in Physics (Reg. # PH320202012)

Research Title: Approved

EFFECTS OF EXCHANGE-CORRELATION POTENTIAL ON THE PROPAGATION CHARACTERISTICS OF SURFACE PLASMA WAVES IN SPIN-POLARIZED QUANTUM PLASMA

Supervisor-I:
Dr. Muhammad Adnan,
Department of Physics, KUST

Supervisor-II:
Dr. Ikramullah,
Department of Physics, KUST

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Change numbers with bullets by separating objectives.
2. Do corrections for grammatical mistakes in whole synopsis.
3. Add description about appropriate boundary conditions in methodology.
4. There is no uniformity in the time frame format, revise it correctly as per University format.

M.Phil. Synopses in Islamic Studies

Agenda Item No.15.1

Saifullah Khan, M.Phil. Scholar in Islamic Studies (Reg. # IS320201005)

Research Title: Approved
شیخ الحدیث مولانا محمد امین اورکزئیؒ کی دینی و علمی خدمات کا تحقیقی جائزہ

Supervisor-I:
Dr. Qaisar Bilal,
Department of Islamic Studies, KUST

Supervisor-II:
Dr. Mazhar Islam,
Department of Social Work & Sociology, KUST

RESEARCH PROPOSAL: Approved with changes

Decision: Submit a revised synopsis to the Directorate of Advance Studies & Research after incorporating the suggestions/ modifications pointed out by the Board as given below:

1. Revise methodology for more clarity particularly clarify whether the data collection will be through interview or questionnaire.

Agenda Item No.15.2

Rafiq Ahmed, M.Phil. Scholar in Islamic Studies (Reg. # IS320192012)

Research Title: Referred Back

مولانا شاه احمد نورانی کی علمی، سیاسی، معاشرتی اور روحانی خدمات کا تحقیقی جائزہ

Supervisor-I:
Dr. Qaisar Bilal,
Department of Islamic Studies, KUST

Supervisor-II:
Dr. Mazhar Islam,
Department of Social Work & Sociology,
KUST

RESEARCH PROPOSAL: Referred Back

Decision: Revised proposal should be submitted to the Directorate for resubmission to ASRB after making the following corrections in the proposal:

1. Write a paragraph about scholar in introduction.
2. Research questions and objectives don't align.
3. Follow the university format for writing a complete synopsis, as chapters are missing in synopsis.

The revised synopsis will be checked by Department Graduate Committee and then will issue a certificate of corrections.

D-Other cases/general items

Guidelines for Reasonable Conduct of Research in HEIs

Agenda Item No.16

Decision:
The Board adopted the HEC "Guidelines for Reasonable Conduct of Research in HEIs" and further recommended to constitute a Committee for reporting and responding to research misconduct with reference to ethical guidelines.

The meeting was ended with a vote of thanks to the chair.

(Dr. Shamim Saleha)
Director Advanced Studies & Research

Confirmed & Approved by:

(Prof. Dr. Sardar Khan)
Vice Chancellor
Kohat University of Science & Technology,
Kohat

RESEARCH ARTICLE

A Cross-Layer Solution for Contention Control to Enhance TCP Performance in Wireless Ad-Hoc Networks

NOOR MAST [ID] [1], **SHAFIULLAH KHAN** [ID] [1,2], **M. IRFAN UDDIN** [ID] [1], **YAZEED YASIN GHADI** [ID] [3], **HEND KHALID ALKAHTANI** [ID] [4], **AND SAMIH M. MOSTAFA** [ID] [5]

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[2] Faculty of Computer and Software Engineering, Huaiyin Institute of Technology, Huai'an 233003, China
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[4] Department of Information Systems, College of Computer and Information Sciences, Princess Nourah Bint Abdulrahman University, Riyadh 11671, Saudi Arabia
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ABSTRACT With the development of wireless technology, users not only have wireless access to the Internet, but this has also sparked the emergence of Wireless Ad-hoc Networks (WANETs); this promising networking paradigm has the potential to adopt the shape of new emergent networks such as the Internet of Things (IoT), Vehicular Ad-hoc Networks (VANET) and Wireless Sensor Networks (WSN). However, channel contention (CC) is one of the key reasons why the TCP performs poorly in WANETs. This paper presents a mechanism called Cross-layer Solution for Contention Control (CSCC) to enhance TCP performance in WANETs. Each node starts marking packets in the proposed mechanism when its CC level reaches a certain threshold. As a result, the source node adjusts the congestion window (cwnd) size to a good state to control the insertion ratio of packets into the network. To provide a fair share to each flow, the flow having a large cwnd is penalized more. Numerous simulations have been conducted across several topologies to clarify the performance of the suggested mechanism. The simulation findings show that, in the presence of the Ad-hoc On-demand Distance Vector (AODV) routing and Dynamic Source Routing (DSR) protocols, the proposed CSCC mechanism outperformed TCP NewReno in terms of throughput and fairness. In comparison to TCP NewReno, the suggested mechanism has fewer retransmitted packets.

INDEX TERMS TCP, wireless ad-hoc networks (WANETs), channel contention (CC), congestion window (cwnd), CSCC, IEE802.11.

I. INTRODUCTION

Transmission Control Protocol(TCP) [1] is a reliable acknowledgment-based transport layer protocol initially designed for wired networks. When TCP was in its early days, it faced congestion problems, which led to the integration of congestion algorithms [2], [3] for further advancement. Due to its reliability, TCP is widely utilized in numerous Internet applications such as email, remote access, and file transfer. Moreover, according to reports, TCP is used to carry up to

The associate editor coordinating the review of this manuscript and approving it for publication was Jose Saldana [ID].

90% of all internet traffic [4], [5], making it a vital protocol that still needs work to be improved.

However, with the development of wireless technology, users not only have wireless access to the Internet, but this has also led to the emergence of Wireless Ad-hoc Networks (WANETs). These networks are beneficial when the infrastructure may not exist or may be too expensive. WANETs are built up of wireless nodes (as depicted in Fig. 1), where nodes are connected wirelessly to each other without using any access point, and every node performs the roles of both a host and a router. These networks can be quickly deployed anywhere at any time. This alluring networking paradigm has the

potential to adopt the shape of new emerging networks such as the Internet of Things (IoT), Wireless Sensor Networks (WSN), Vehicular Ad-hoc Networks (VANET) and Tactical Wireless Networks [5], [6]. The IEEE 802.11 standard [7] is a de-facto standard for accessing medium in WANET [8].

However, wireless networks have unique properties (such as dynamic topology, a shared medium, and a medium prone to errors) compared to wired networks. Due to this mismatch, TCP experiences difficulties on wireless networks and performs poorly, notably in WANETs [9]. TCP must overcome these difficulties to efficiently use wireless technologies by connecting to the Internet or creating a WANET.
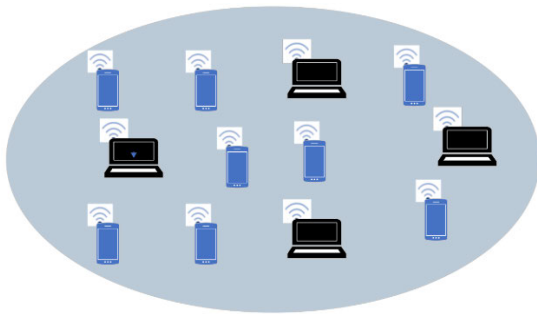
FIGURE 1. A scenario of a wireless Ad hoc network.

The research community works on various aspects to improve wireless networks' overall performance. For example, many routing protocols like [10], [11], [12], [13], [14], and [15] have been proposed to establish network paths effectively. But TCP's performance on wireless networks is still insufficient in the presence of such routing algorithms. Because there have been changes to the wireless technology's lower tiers of the communications stack without considering how those changes would affect the higher layers; therefore, wireless networks have a very different communication environment than cable ones. However, TCP fails to account for this shift and continues to operate as though a wireless network were wired. Furthermore, utilizing congestion algorithms in the event of losses not arising from network congestion is the primary problem for TCP in WANET. That is to say, TCP cannot tell the difference between losses due to congestion and losses due to the unique features of WANET [16], [17], [18].

For wired networks using TCP, buffer overflow is the most common cause of lost packets. But this assumption is false with WANETs because packet loss can be caused by channel contention (CC) or route failure [19]. Furthermore, if the WANET nodes can store more than ten packets in the buffer, then buffer overflow is rare. However, one of the most frequent causes of packet loss in WANETs is CC, resulting from the shared medium [20], [21]. Therefore, TCP must be aware of CC to respond accordingly and operate more effectively in WANETs.

To enhance TCP's functionality in WANETs, this paper presents a mechanism known as Cross-layer Solution for Contention Control (CSCC). In the proposed mechanism, packets are marked at each node once the CC at the MAC layer reaches a certain threshold. As a result, the source node adjusts the congestion window (cwnd) size to a good state to control the insertion ratio of packets into the network. To provide a fair share to each flow, the flow having a large cwnd is penalized more.

Here is how the rest of the paper is structured. Section II describes the Distributed Coordination Function of the IEEE 802.11 MAC protocol. Section III summarises the relevant literature. The proposed mechanism is described in detail, beginning with section IV. Results from simulation experiments of the suggested mechanism's performance are reported in Section V, and section VI offers the conclusion.

II. THE DISTRIBUTED COORDINATION FUNCTION

In the IEEE 802.11 MAC protocol, the Distributed Coordination Function (DCF) provides two mechanisms for accessing the medium. One of these mechanisms is the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) used to share the medium among compatible devices, also known as the basic access mechanism. Before commencing a transmission in CSMA/CA, A node will check by sensing the medium that any other node within the range is sending data. The node transmits a frame if the medium is free for longer than the distributed inter-frame space (DIFS). Otherwise, the node defers transmission using the binary exponential backoff process to reduce the chance of packet collisions with packets sent by other nodes. The receiver sends an acknowledgement (ACK) to the sender when the frame is received. Otherwise, the sender schedules a retransmission of the frame. Additionally, the CSMA/CA algorithm requires that adjacent frame sequences have a minimum specified space between them.

On the other hand, the virtual carrier sensing method is an alternative to the basic access mechanism that calls for exchanging special RTS and CTS (Request to Send and Clear to Send) frames before transmitting actual data frames. With virtual carrier sensing, a sender will first send an RTS frame, and then, after a brief delay called short inter-frame space (SIFS), the receiving node will send a CTS frame in response. If the CTS frame is received after the RTS frame, the sender is free to send the data frame; otherwise, the transmission of the RTS frame is rescheduled.

When the medium is busy, both medium access mechanisms initiate the Binary Exponential Backoff (BEB) algorithm, where CW_{min} (minimum contention window) is the initial size of the contention window (CW) in the BEB algorithm. After that, the size of the CW is incremented exponentially for each unsuccessful transmission. However, the size of the CW cannot exceed the size of the CW_{max} (maximum contention window).

The IEEE 802.11 MAC protocol specifies that if the number of tries for transmitting a frame hits its maximum limit, then drop the frame and set CW to its minimum value. Also, reduce the value of CW to a minimum in the case of

successful transmission. Since the RTS and CTS frames in the virtual carrier sensing mechanism provide information about the time needed to transmit a frame. Any listening node can read this information and utilize it to update its NAV (Network Allocation Vector). Each node uses its NAV to estimate how long the medium will be busy and defers transmission accordingly.

From the above explanation, DCF utilized in non-QoS WLAN defines four components—Physical Carrier Sense, Virtual Carrier Sense, Random Back-off timings, and Inter-frame Spaces (IFS)—to guarantee that devices share the medium fairly.

DCF gives all users the same priority, so it is not considered the best mechanism for transmitting highly sensitive packets such as voice or video. Therefore, a mechanism was required to assign different priorities to different types of packets and allow higher-priority packets more access to the shared medium. It resulted in the development of Enhanced Distribution Coordination Access (EDCA), also called The Enhanced DCF.

EDCA assigns the highest priority to voice, followed by video, while best effort and background are placed in the third and fourth categories. So, for queueing packets, there are four Access Categories (ACs) in EDCA, and each AC has its respective queue and contention requirements.

The packets to be transmitted through EDCA faces two types of contention: internal contention among the ACs and external contention among nodes. While the packets to be transmitted through DCF only faces external contention. However, the proposed mechanism is not only in DCF; it can be adopted with EDCA.

III. RELATED WORK

The researchers have proposed various mechanisms for addressing the CC problem to improve TCP performance. We want to present a brief overview of these techniques here. One of these mechanisms is the Prioritized Packet Scheduling with Adaptive Backoff window (PPSAB) [22]. This mechanism calculates the retransmission probability (RP) based on the packet expiry time and the number of tries made for frame transmission. The frame with the shortest lifespan and the most transmission attempts is given the highest priority. Then each node modifies the CW using the RP and number of neighbor nodes. The weight components $\alpha1$ and $\alpha2$ are used to calculate CW_{par}, and CW is then dynamically adjusted by equation (1).

$$CW_{par} = (\alpha1 \times Average\_Active\_Neighbors) + (\alpha2 \times RP)$$
$$CW = CW_{max} \times CW_{par} \quad (1)$$

A mechanism named Priority Contention Window Approach (PCWM) [23] is proposed by Chou et al. to tackle the CC problem. The MAC layer receives data from the network layer about the total and remaining hops in the PCWM mechanism. Then, using equation (2) provided, the value of

CW is determined at each node along the path.

$$CW_{Max} = 1024/2^y, \quad y = Max\,(0, (L - D - 5))$$
$$CW_{Min} = 1024/(2^x * 2^{(L-D)}), \quad x = Max\,(0, (5 - L))$$

L is the routing path's overall hop count, and D is the remaining hop counts in the Ad-hoc On-demand Distance Vector (AODV) routing table.

$$CW = CW_{Min} * 2^{n-1} \quad (2)$$

In equation (2) n is the number of attempts for data transmission, and $CW_{Min} \le CW \le CW_{Max}$

A mechanism named Cooperative MAC protocol with Multi-Node Collision Avoidance (MNCA-CMAC) [24] is proposed by Shan Wu et al. to avoid collision among frames. This mechanism consists of three phases, i.e., (i) channel reservation phase, (ii) cooperative node selection phase and (iii) data transmission phase. The Cooperative RTS and Cooperative CTS (CCTS) packets are used for channel reservation. After receiving the CCTS packets, the sender awaits to receive the HTS (help-to-send) packets from the cooperating nodes, which identify the residual energy of a cooperative node. The sender waits for a predetermined interval to elapse or to receive a specified number of HTS packets. When either of these two conditions occurs, the sender sends an SEI (Selection End Indicator) packet to terminate the selection phase of the cooperative node. After that, the data packet is transmitted to the most cooperative node.

Some techniques are focused on generating a delayed/proxy ACK to minimize CC. Proxy Acknowledgement (PACK) [25] is one such mechanism; in this mechanism, a proxy node is nominated if the number of hops on the path surpasses a predefined threshold. The proxy node identifies missing packets and informs the source node by sending an ACK packet. As a result, the source node will retransmit the lost packets without waiting for a retransmission time-out. One of the delay ACK mechanisms is the TCP ACK Delay Window (TCP-ADW) [26]; this mechanism looks at the channel situation to determine the number of ACKs for increasing/decreasing the delay window. The receiver must provide an ACK and set the count variable to zero when the sum of all received packets reaches the delay window. If an out-of-order packet arrives, then immediately provide an ACK or if a packet fills a gap in the receiver's buffer.

Altman et al. proposed a mechanism called the Dynamic Delayed ACK (DDA) [27] based on RFC1122 [28] also belongs to the category of delay ACK. After receiving **d** packets (where **d**=2), RFC 1122 specifies a standard for sending an ACK. However, send an ACK if **d** packets are not received within a specific time. The value of **d** in DDA can be between 1 and 4. Initially, DDA creates an ACK on the arrival of each packet and then increases this number to four (**d**=4) based on the sequence number of a segment. Under this strategy, once **d** achieves the value of four, there is no way to bring it back down. To improve this idea, even more, a mechanism called TCP-DAA (TCP Dynamic Adaptive ACK) [29] is suggested.

This mechanism considers the channel situation for sending an ACK; if the channel is good, send an ACK after four packets or two packets. However, immediately send an ACK if an out-of-order packet arrives or a packet fills the gap in the receiver's buffer. In standard TCP, three duplicate ACKs are required for fast retransmission, whereas in TCP-DAA, two are needed.

The author says in [17] that TCP-DCA (TCP with Delayed Cumulative ACK) is a technique that aims to determine the delay windows based on the hop count. The ACK might be suspended for an entire cwnd using TCP-DCA if the number of hops on the path is less or equal to three. On paths with a hop count of more than three but less or equal to nine, the receiver delivers an ACK after five packets. However, send an ACK after three packets in the case of more than nine hops. In contrast, TCP-ADA (TCP with Adaptive Delayed Acknowledgement) [30] is a technique; according to this approach, to avoid contention and collision, the best solution is to generate an ACK for a single cwnd. In the Contention-based Path Selection (COPAS) [31] mechanism, a different approach has been adopted than delay ACK techniques. The COPAS uses different routes for forwarding the data and ACK packets. After that, continuously monitors the paths for contention. A less-contended route is selected as soon as the traffic on a path exceeds a certain level.

The NRED (Neighbourhood Random Early Detection) [32] technique, which is based on [33], is proposed by Xu et al. to alleviate the effect of unfairness in WANETs. In the NRED algorithm, a distributed neighborhood queue strategy is adopted, in which all neighbor nodes' queues are aggregated so that every node holds a piece of the distributed queue. To determine the size of the distributed queue, each node monitors channel utilization; the packet dropping/marking probability is determined based on channel utilisation.

Fu et al. have proposed a mechanism called Link layer RED+AP (LRED+AP) [20]; this mechanism selects two thresholds (i.e., maximum and minimum) to manage CC. The packets are dropped at the maximum threshold and added extra time to back-off time at the minimum threshold level. The additional time is equal to the transmission time of the preceding packet. Thus, the spare time depends on the size of the last transmitted packet.

Cross-layer congestion control (C^3TCP) [34] has been proposed to deal with network congestion to improve TCP performance. This mechanism minimizes the data injected into the network for congestion avoidance. Therefore, the bandwidth and the delay experienced by each link are evaluated at each node. The collected data are inserted into the MAC header's option field. After collecting the bandwidth and link delay information at the first node, the next node compares its bandwidth with the bandwidth of the previous node and chooses the smallest one. However, the delay on the current link will be added to the previous delay. The process mentioned above is repeated on each intermediate node. As a result, when the destination node receives a data packet, it contains the minimum available bandwidth on the path. It will also include the link delay information for the entire route. After that, the bandwidth and link delay information is communicated to the source nod in the ACK packet for transmission rate adjustment.

The Wireless Contention Control Protocol (WCCP) [19] uses channel busyness to identify the network utilization and congestion status. Moreover, it allocates resources to a flow based on available bandwidth. WCCP replaces the TCP's window technique with a rate-based algorithm. As a result, WCCP introduces two modules: one at the transport layer and the second between the network and MAC layer, to check and, if required, alter the value of the feedback field in the TCP's packet. The source node adjusts its transmission rate based on the value of the feedback field.

Hamadani proposed a solution to address the problem of intra-flow instability called TCP ConTention Control (TCTC) [35]. The leading cause of intra-flow instability, according to [35], is transmitting more data to the network. In the proposed solution, the destination node monitors the amount of throughput achieved for a fixed interval of time and the level of contention in this interval. The receiver node decides the appropriate amount of data to be emitted by the sender node based on the information collected within the fixed interval to achieve high throughput and reduce the delay on each connection. After presenting a summary of the proposals suggested by the research community, the following section offers the proposed CSCC mechanism.

TABLE 1. presents a summary of the proposals discussed as related work. Several proposals are based on delayed ACKs, and all these proposals have a limitation in common: excessive ACK delays can upset TCP's round-trip time and packet clocking algorithms. In contrast, mechanisms such as PACK violate the end-to-end connection handling mechanism of TCP. Moreover, failure of the node responsible for proxy ACK may lead to more poor performance if the destination node demands retransmission.

In PPSAB, estimating active nodes is challenging, and the wrong estimation can affect the algorithm decision. While in MNCA-CMAC, after the CCTS packets, the exchange of the HTS packets is also required to determine the cooperative nodes. So, it is an extra burden on the shared medium. On the other hand, in WANET, the probability of route failure increases with high mobility, and the routing's overhead will also increase. Therefore, COPAS, which maintains two routes, is unsuitable in a high-mobility environment.

Moreover, the extra delay at the MAC layer in the case of LRED+AP is also a reason for low throughput and retransmission may occur. None of those mentioned above mechanisms enable TCP to distinguish that the network is congested or has high contention. However, the proposed mechanism sends a contention notification to the sender that the network has contended, and the sender can take appropriate action in the case of contention..

TABLE 1. A summary of the related work.

Mechanism	Layers Involved	Problem to Handle	Routing Protocol used	Brief Description	Simulation Environment
PPSAB	N & MAC	Channel contention	Not mentioned	Adjust the CW based on the number of active nodes and the retransmission probability (RP).	Mobile
PCWM	N & MAC	Channel contention	AODV	To adjust CW of a node based on the total hop count and remaining hop count in the routing.	Mobile
MNCA-CMAC	MAC	Channel contention	Not mentioned	Calculates the contention waiting time based on the network's probability of channel gains.	Static
PACK	T	Channel contention	AODV	A proxy node is nominated if the number of hops on the path surpasses a predefined threshold.	Mobile
DDA	T	Channel contention	AODV	Suggests the DACK for one to four packets based on the sequence number.	Static
TCP-ADW	T	Channel contention	AODV	To estimate the channel situation and set the delay window based on cwnd, packet loss and packets' inter-arrival times.	Mobile
TCP-DAA	T	To minimize retransmission due to contention	Not mentioned	Delay ACK for a maximum of 4 packets, based on the inter-arrival time of packets to estimate channel condition.	Static
TCP-DCA	T	Channel contention	AODV and DSR	To delay ACK based on hop count.	Mobile
TCP-ADA	T	Channel contention	DSR	Suggested one ACK for the whole cwnd.	Mobile
COPAS	N	Channel contention	DSR	Forward Data and ACK packets on different routes based on Backoff time.	Static
NRED	MAC	Unfairness	AODV	Extends the RED concept to the distributed neighborhood queue, and packet dropping probability is based on channel usage.	Static
LRED+AP	MAC	Channel contention	Manual routing	Specifies two thresholds; packets are dropped at the maximum threshold and add a delay at the minimum threshold.	Static
C^{3}TCP)	T & MAC	Congestion	Not mentioned	Adjusting transmission rate based on bandwidth and delay	Static
WCCP	T & MAC	Unfairness due to contention	AODV	Adjust the sending rate based on Channel Usage. It replaces the window algorithm with a rate control algorithm.	Static
TCTC	T & MAC	Congestion	DSR	Adjust the data rate based on the achieved throughput and contention delay experienced by packets in a specific interval.	Static

IV. PROPOSED SOLUTION

In the proposed mechanism, each node counts the number of attempts to access the medium for transmission at the MAC layer. After that, each node calculates the Weighted Moving Average (WMA) of the number of tries (as explained in subsection A of Section IV) to estimate the CC and react accordingly. When the WMA reaches a specific threshold CC$_{Thresh}$ (Channel Contention Threshold), the MAC layer will set the CC status ON. As a result, the node will start marking packets to inform the TCP's source node about

contention (Subsection B of Section IV describes how to notify the source node). On receipt of CC notification, the source node adjusts its transmission rate to control contention.

Marking packets is more effective than dropping packets. Because when the MAC layer fails to transmit a frame, it is dropped and wrongly notifies the network layer that the path is unavailable. The network layer then initiates an unnecessary route recovery process [36]. The proposed mechanism attempts to control packet drop due to CC to save the time
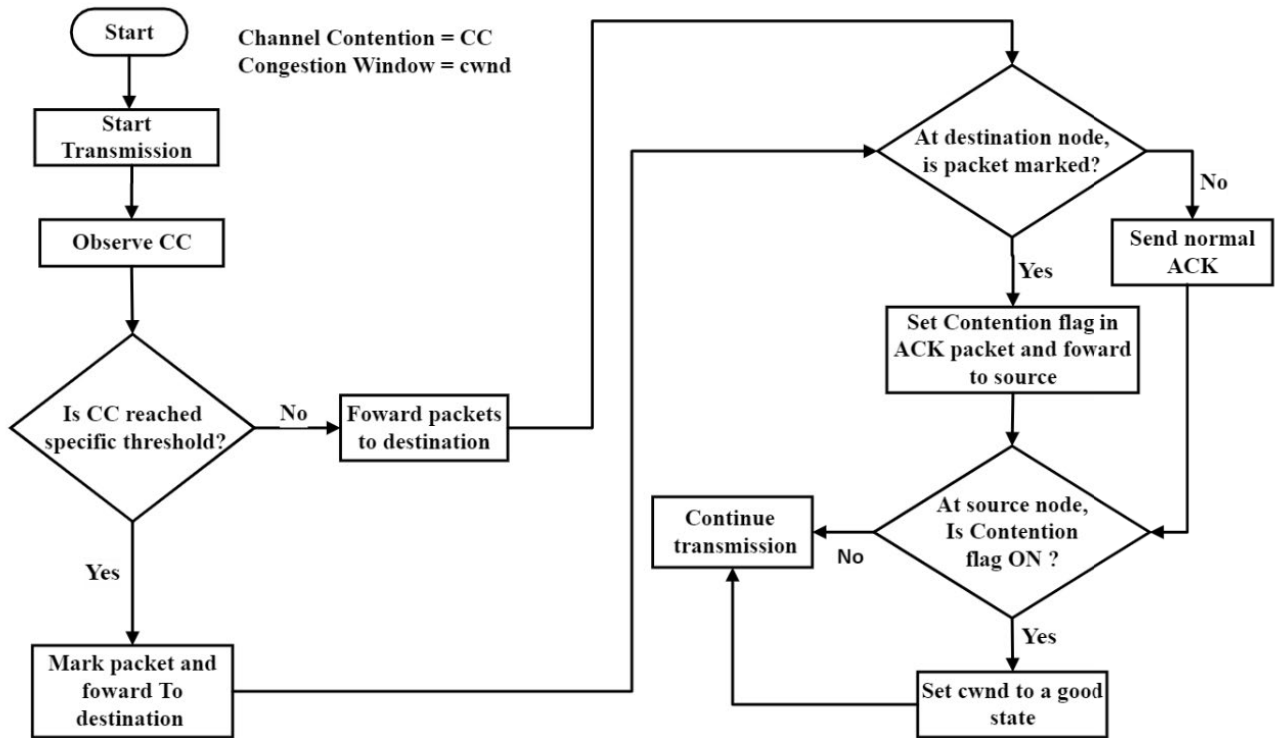
FIGURE 2. Flowchart of a cross-layer solution for contention control (CSCC) to Enhance TCP performance in WANET.

TABLE 2. Computing the weighted moving average (WMA).

Packets Transmission Sequence	Node A		Node B	
	WMA	Transmission Attempts	WMA	Transmission Attempts
	Initially $A_{WMA}=0$		Initially $BWMA=0$	
1	$A_{WMA}= (0.55 \times 1) + (1-0.55) \times 0$ $= 0.55 + 0$ $= \mathbf{0.55}$	1	$B_{WMA}= (0.55 \times 2) + (1-0.55) \times 0$ $=1.1 + 0$ $=\mathbf{1.1}$	2
2	$A_{WMA}= (0.55 \times 2) + (1-0.55) \times 0.55$ $=1.1 + 0.2475$ $=\mathbf{1.3475}$	2	$B_{WMA}= (0.55 \times 3) + (1-0.55) \times 1.1$ $=1.65 + 0.495$ $=\mathbf{2.145}$	3
3	$A_{WMA}= (0.55 \times 1) + (1-0.55) \times 1.3475$ $= 0.55 + 606375$ $=\mathbf{1.156375}$	1	$B_{WMA}= (0.55 \times 3) + (1-0.55) \times 2.145$ $=1.65 + 0.96525$ $=\mathbf{2.61525}$	3
4	**2.1704**	3	**2.2769**	2
5	**2.0767**	2	**2.1246**	2
6	**1.4845**	1	**1.5061**	1

the network layer searches for a new path due to a wrong notification of route failure.

The problem of contention and congestion occurs because of the greedy behaviour of TCP. However, in WANETs, congestion control is often turned on due to MAC layer losses and not buffer overflow. The proposed mechanism enables the TCP to distinguish congestion and contention losses and react

accordingly. The CC leads to the problem of unfairness as well. So, in the case of CC, it makes sense to impose a higher penalty on flows with a larger cwnd. Therefore, the proposed mechanism adjusts the cwnd size to a good state (good state is explained in subsection C of section IV) to make fair and efficient use of channel resources. Fig. 2 shows the flowchart of the suggested mechanism.
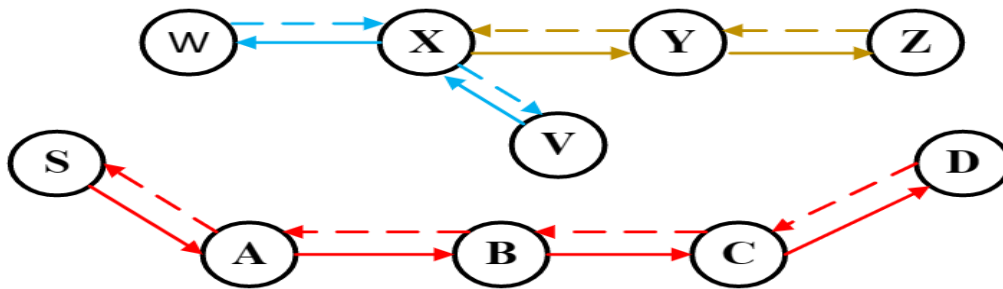
FIGURE 3. A ten nodes scenario of WANET.

FIGURE 4. IP header with suggested modification.

FIGURE 5. A portion of the TCP header with suggested modification.

A. COMPUTING THE WEIGHTED MOVING AVERAGE (WMA)

Whereas accessing the medium for transmission, the increase/decrease in the number of attempts means the node has potentially identified an increase/decrease in the CC. Therefore, to estimate the CC, each node obtains the WMA of the number of tries made to transmit a frame. Suppose the WMA is denoted by Å. Suppose again that R_{Att} is the number of attempts made by a node N transmitting a frame. Then at the end of every successful/unsuccessful transmission, a WMA is computed according to equation (3) [37] to reflect increases/decreases in the contention.

$$\begin{cases} Å_{n+1} = \alpha R_{att} + (1 - \alpha) Å_n, 0 < \alpha < 1 \\ \qquad \textit{if transmission is successful} \\ Å = CC_{Thresh} \; \textit{Otherwise} \end{cases} \quad (3)$$

The value of α is constant and must be chosen very carefully; the value for α must be selected such that it does not reveal contention early. Otherwise, TCP will reduce the cwnd size unnecessarily. On the other hand, conflict reflection would not even need to be long enough to allow cwnd to grow to a larger size. Both cases lead to the poor performance of the network.

When $Å \geq CC_{Thresh}$, the MAC layer sets the contention status ON. After that, the concerned node starts to mark packets to inform the source node about the medium contention. On receiving the contention notification, the source node adjusts its cwnd size to a good state, as explained in Subsection C of Section IV. Whereas algorithm 1 shows how to observe and set the CC status.

To illustrate the WMA computing process with an example, see Fig. 3, where the solid line represents the direction

of data packets, such that source S is sending data packets to destination D. Similarly dotted line represents the direction of ACK packets between the endpoints. So, in Fig. 3, three data flows are employed to transfer data packets; one flow is from S to D, the second is from V to W, and the third is from X to Z.

On the path S-A-B-C-D, the A_{WMA} and B_{WMA} denote the WMAs at nodes A and B, respectively. The initial value of WMA at each node is zero, as shown in TABLE 2, and the weight factor (α) value is 0.55. Suppose, at first-time, Node A after one attempt and Node B after two attempts transmit a frame. Furthermore, how the WMA will be computed at nodes A and B, in this case, is shown in TABLE 2. The computed values for AWMA and BWMA are 0.55 and 1.1, respectively. It is also shown in TABLE 2 how WMA will be calculated at Nodes A and B after transmitting the second and third packets. The computed WMA in the case of the fourth, fifth and sixth packets is also listed. Looking at TABLE 2, after transmitting the third packet, the WMA value at Node B is 2.61525, suppose it is greater than the CCThresh. So, the MAC layer of Node B will notify that the channel has contended. As a result, the network layer of Node B will start packet marking to inform the source node.

Algorithm 1 Observing Channel Contention

Initialization
{
$\qquad$ $\mathring{A} = 0$
$\qquad$ $R_{Att} = 0$
}
Counts Number of R_{Att}
IF (Transmission successful == True)
$\qquad$ $\mathring{A} = (1 - \alpha) \mathring{A}_{Retry} + \alpha R_{Att}$
Else
$\qquad$ $\mathring{A} = CC_{Thresh}$
Endif
IF($\mathring{A} \geq CC_{Thresh}$)
$\qquad$ Contention Status ON
Else
$\qquad$ Contention Status OFF
Endif

B. CHANNEL CONTENTION NOTIFICATION

Changes have been suggested in the IP (Internet Protocol) header for informing the source node about contention on the path. The IP header has a reserved field; the proposed mechanism uses this field to mark packets. Suppose the name of this field is CCE (Channel Contention Experienced), as shown in Fig. 4. When the MAC layer notifies that the contention has occurred, the network layer starts marking packets using the CCE field, as given in algorithm 2.

As clear from the literature, the ECN [38] mechanism has been proposed to inform the source node about the congestion or queue status. The ECN mechanism uses the ECN field in the IP header to mark packets in the case of congestion,

as shown in Fig. 4. So, the proposed mechanism and ECN mechanisms can be implemented together. As a result, the TCP's source will be able to differentiate between congestion and CC losses and react accordingly.

In the TCP header, there are eight control bits. The suggested mechanism introduces two new control bits called CCF (Channel Contention Flag) and CCR (Channel Contention Responded), as shown in Fig. 5. When a packet arrives at the destination node with the CCE field ON. The destination node sets the value of the CCF field to one in the ACK packet to inform the source node about contention. On receiving the ACK packet with the CCF field ON, the response of the source node is explained in subsection C of section IV.

Algorithm 2 Marking Packets to Inform Source Node

//At Intermediate Node
IF (Contention Status ON)
$\qquad$ Set CCE = 1
Endif
//At Destination Node
Sending ACK
IF (CCE == 1)
$\qquad$ IN ACK Header Set CCF=1
Endif

C. RESPONSE OF SOURCE NODE TO MARKED PACKETS

To control contention and provide fairness among data flows, the source node adjusts the size of the cwnd to a good state when receiving an ACK packet where the CCF field has one value. To explain a good state, suppose there is a TCP flow with an initial cwnd size of one. Its size hits 128 after some time without receiving a channel contention notification. Now all sizes of cwnd that falls below 128 are good states. Suppose again, when TCP's cwnd size is 128, the source node receives a channel contention notification. Then cwnd size will adopt a value below 128 (in this case, all values below 128 represent good states) according to algorithm 3. Furthermore, a flow with a cwnd size is less than the slow start threshold (ssthresh) is considered a flow with a small cwnd; otherwise, it is a flow with a large cwnd. Algorithm 3 shows how to adopt a good state and sets the value of the CCR field to one to inform the destination node that the cwnd has been reduced. Moreover, if the TCP source receives a CCF notification in a good state before the expiry of one round trip time, the TCP source should ignore the succeeding CCF.

D. SELECTION OF VALUE FOR ALPHA (α)

The WMA given by equation (3) is a recursive function, and one can write it in terms of older weights, as provided by equation (4). Expanding equation (4) to its older value will continue until it reaches the base term $\mathring{A}_0$. So, the recursive property of WMA implies that it calculates the value of the current state using the prior observation. The only choice a WMA user must make is the parameter alpha (α) selection,
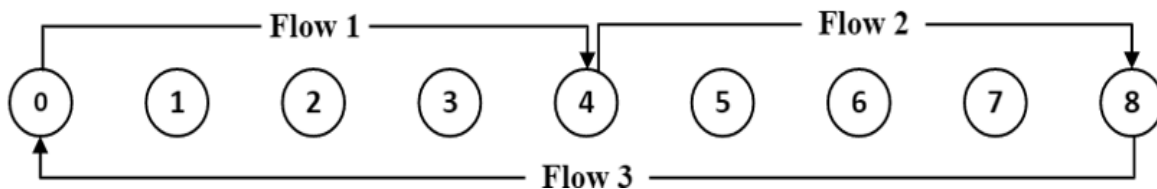
FIGURE 6. String topology of 9 nodes and three flows of TCP.

TABLE 3. Results achieved on a string topology of 9 nodes.

Values assigned to alpha (α).	Throughput (Flow 1)	Throughput (Flow 2)	Throughput (Flow 3)	Total Throughput (Kbps)	Fairness Index
0.40	130.51	159.43	25.17	315.11	0.768
0.45	121.11	168.73	43.15	332.99	0.821
0.50	140.67	176.56	37.31	354.54	0.800
0.55	123.63	169.66	63.70	356.99	0.883
0.60	119.41	160.65	34.27	314.33	0.799
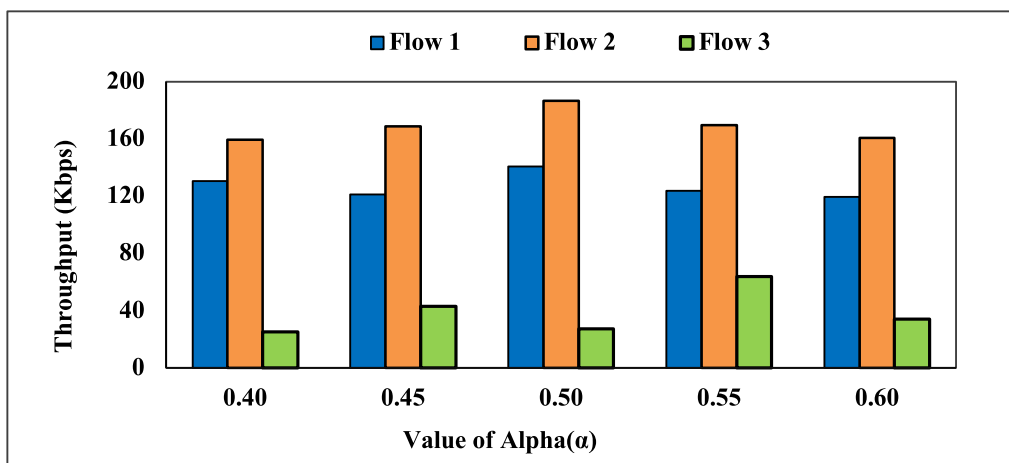
FIGURE 7. The throughput achieved on the nine nodes string.

which determines how significant the recent observation is in the WMA's computation.

Some simulation experiments have been conducted to determine the value of alpha (α) for efficient utilization of the network resources. Therefore, the performance of the proposed mechanism was analyzed in the string topology of 9 nodes depicted in Fig. 6. The values assigned to alpha(α) are 0.40, 0.45, 0.50, 0.55 and 0.60. The number of TCP flows was 3, each with a payload of 1460 bytes.

$$\begin{cases} Å_{n+1} = \alpha R_{att} + (1-\alpha)\,Å_n, \\ \quad 0 < \alpha < 1 \\ if\ transmission\ is\ successful \\ Å_{n+1} = \alpha R_{att} + (1-\alpha) \\ \quad * \begin{pmatrix} \alpha R_{att-1} + \\ (1-\alpha)\,Å_{n-1} \end{pmatrix} \\ Å_{n+1} = \alpha R_{att} + (1-\alpha) \\ \quad *(\alpha R_{att-1} + (1-\alpha) \\ \quad * \left(\alpha R_{att-2} + (1-\alpha)\,Å_{n-2}\right) \end{cases} \quad (4)$$

Conducting the simulation experiments, the throughput achieved by the proposed mechanism is shown in Fig. 7, and

Fig. 8 illustrates the fairness indexes achieved in each case. For further detail, look at TABLE 3.

Looking at the results illustrated in Fig. 7 and Fig. 8 and listed in TABLE 3, high throughput and more fairness have been obtained by assigning a value of 0.55 to alpha(α). The closest results were achieved when a value of 0.50 was assigned to alpha(α); however, the best results were achieved when a weight of 0.55 was used for alpha. Therefore, during further simulation experiments, the value of 0.55 was used.

V. PERFORMANCE EVALUATION

Using the network simulator NS2.35 [39], multi-hop wireless simulation experiments were conducted to verify the proposed mechanism's performance against TCP NewReno. However, implementing the proposed algorithm, the most modified files are tcp.h, tcp.cc and tcp-newreno.cc at the transport layer. While at the MAC layer, the files called mac-802.h and mac-802.cc were modified to measure the channel usage and declare whether the channel has contended. During simulation experiments, in each scenario, each node's transmission range and sensing ranges were 250 and 550 meters,

Algorithm 3 Adjusting the Size of Cwnd to a Good State

// on Receipt of ACK packet
ACK packet received
IF (CCF is ON)
    IF ($cwnd \leq ssThresh$)
        IF ($cwnd \leq \frac{1}{2}ssThresh$)
            $cwnd = cwnd$
        Else
            $cwnd = \frac{3}{4}ssThresh$
        Endif
    Else IF ($cwnd > ssthresh$)
        IF ($\frac{cwnd}{2} \leq ssThresh$)
            $cwnd = cwnd/2$
        Else
            $cwnd = ssThresh$
        Endif
    Endif
    Set CCR = 1
Endif

TABLE 4. Values of parameters used in the simulation.

Parameters	Value
Simulation Time	300 Second
Topologies and number of nodes	A string of 16 nodes
	13x13 Grid
	Random topology in a 1000 x 1000 meters area with 100 nodes
Routing protocols	AODV and DSR
Transmission Range	250m
Data rate	2Mbps
Queue size	20 packets
Packet size	1460 Bytes
Slot time	20 µs
SIFS	10 µs
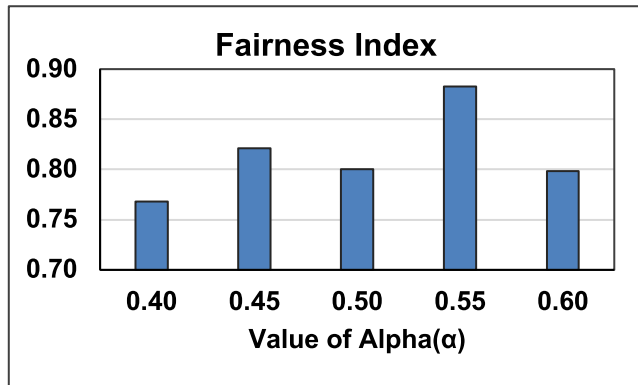
FIGURE 8. The fairness indexes achieved with different values of alpha.

TABLE 5. Confidence intervals computed for throughput on a string topology with AODV.

	TCP NewReno			CSCC		
		95% Confidence Interval			95% Confidence Interval	
Number of Hops	Throughput	Lower Bound	Upper Bound	Throughput	Lower Bound	Upper Bound
3	327.59	325.92	329.26	363.58	361.81	365.35
4	247.01	245.71	248.31	283.60	282.73	284.46
5	205.45	203.93	206.98	241.66	240.87	242.46
6	180.01	178.51	181.51	220.25	219.02	221.47
7	155.45	146.29	164.60	201.60	196.87	206.34
8	139.88	132.22	147.54	188.20	178.29	198.11
9	131.53	126.22	136.84	177.77	164.67	190.87
10	122.33	117.08	127.58	168.01	162.17	173.85
11	116.07	109.23	122.91	160.52	150.65	170.39
12	106.99	99.87	114.11	153.79	148.03	159.56
13	99.53	91.96	107.10	147.80	138.51	157.09
14	93.80	88.20	99.40	142.46	134.55	150.36
15	89.11	82.13	96.09	139.40	133.84	144.96

respectively, and the data transfer rate was assumed to be 2Mbps. TCP packet in each case had a size of 1460 bytes. For each scenario, the simulation lasted 300 seconds. Each scenario's results are based on an average of 15 runs.

String topology was considered during the simulation to determine the effect of the increasing number of hops. Then a grid topology and a more realistic random topology were evaluated with a growing number of flows. Throughput and flow fairness criteria were chosen for the performance study, and simulation tests were conducted with 95% confidence. The quantity of retransmitted packets is also used as a performance indicator. TCP retransmits packets for two reasons: (i) when any packet loss is detected or (ii) when a retransmission timeout occurs. As a result, if an algorithm has a low number of retransmissions, it also has a low number of retransmission timeouts and dropped packets.

The AODV [11] and Dynamic Source Routing (DSR) [10] routing protocols were employed to establish the routes. DSR and AODV are on-demand routing protocols, i.e., a path is kept around for as long as it is essential. The DSR uses source routing in which the sender of a packet determines the complete sequence of the nodes through which the packet must pass. But in AODV, each node has a routing table that it uses to decide where to forward packets. TABLE 5 provides a detailed description of the simulation parameters used for the experiments.

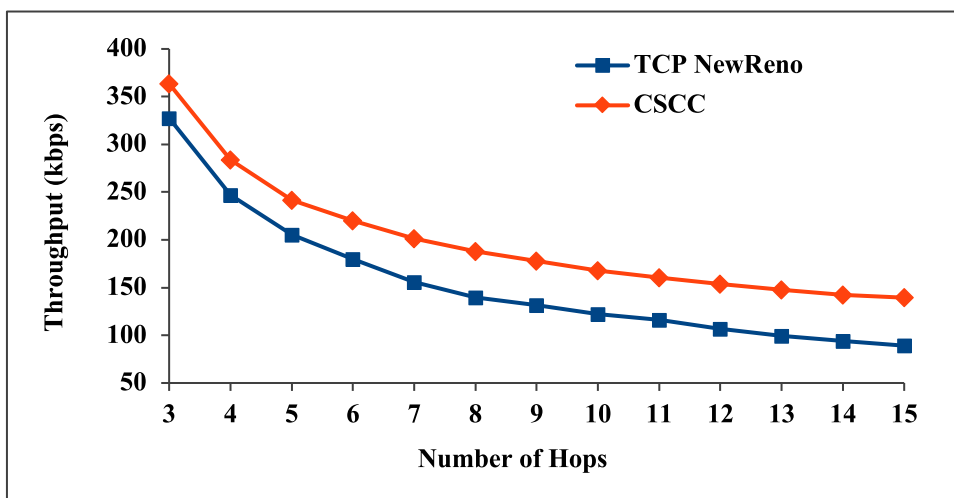FIGURE 9. String topology of 16 nodes.

FIGURE 10. Throughput achieved in the string topology with AODV.

TABLE 6. Confidence intervals computed for throughput on a string topology with DSR.

Number of Hops	TCP NewReno			CSCC		
	Throughput	95% Confidence Interval		Throughput	95% Confidence Interval	
		Lower Bound	Upper Bound		Lower Bound	Upper Bound
3	230.79	227.00	234.58	259.83	256.41	263.25
4	195.33	191.95	198.71	227.97	221.70	234.23
5	166.82	164.54	169.10	201.54	196.51	206.58
6	142.13	138.93	145.32	176.72	172.75	180.68
7	128.48	123.17	133.78	164.84	159.67	170.01
8	119.47	115.85	123.10	161.61	158.07	165.16
9	114.47	111.35	117.59	159.51	153.72	165.31
10	112.26	108.67	115.86	158.86	155.91	161.81
11	107.98	104.91	111.05	155.74	152.29	159.19
12	105.08	100.75	109.40	150.70	147.59	153.80
13	102.61	99.30	105.92	151.84	147.66	156.03
14	98.46	96.35	100.58	145.90	143.19	148.61
15	92.38	89.61	95.15	142.92	138.82	147.03

A. STRING TOPOLOGY

To analyze how an increasing number of hops affects the performance of the proposed mechanism, the multi-hop simulations were performed in a string topology of 16 nodes.

The path length of a minimum of three and a maximum of 15 hops was considered. The distance between the adjacent nodes was set at 200 meters. The graphical representation of this topology is shown in Fig. 9. In the first case considered, a connection has been established between node 0 and node 3 to transfer the data, where node 0 and node 3 act as the source and destination nodes, respectively, which are not in the direct transmission range of each other.

In the second case, node 0 and node 4 are considered to act as the source and destination nodes, respectively, whereas nodes 1, 2 and 3 are intermediate nodes that forward packets between node 0 and node 4. This way, the transmission between node 0 and node 5, then node 6 and 7 up to node 15, was considered.

In each case considered for the string topology, the throughput achieved with TCP NewReno and the CSCC mechanism is depicted in Fig. 10 and Fig. 11; it is clear from these figures that the performance of the CSCC mechanism is more satisfactory than that of TCP NewReno in terms of throughput. The suggested mechanism achieved high throughput over TCP NewReno as the number of hops increased, ranging from 10.99% to 56.43% and a 12.58% to 54.71% in the presence of AODV and DSR, respectively. The 95% confidence intervals computed for the achieved throughput for the string topology cases considered with AODV and DSR are given in Tables 6 and 7, respectively.

It is clear from Fig. 12 and Fig. 13, illustrating the number of retransmitted packets, that the CSCC mechanism is transmitting fewer packets than TCP NewReno and achieving high throughput because there is lower contention on the channel. A reduced number of retransmissions
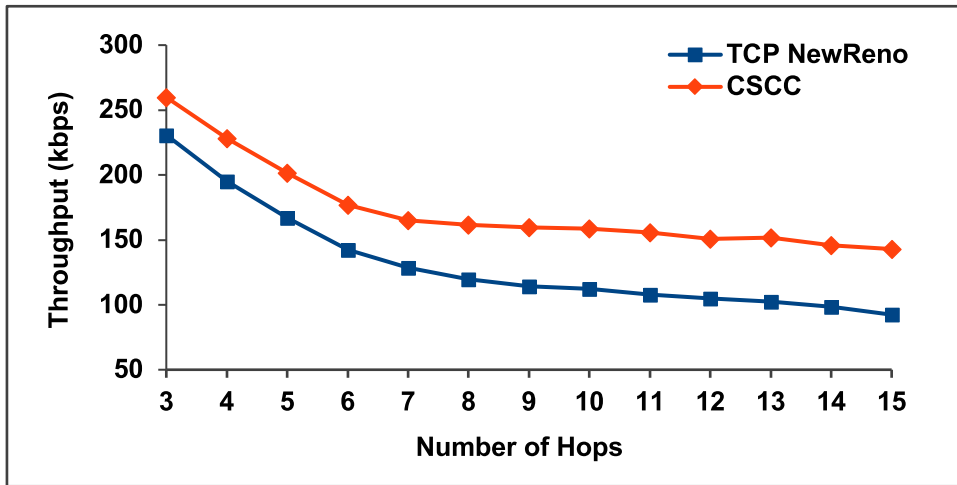
FIGURE 11. Throughput achieved in the string topology with DSR.
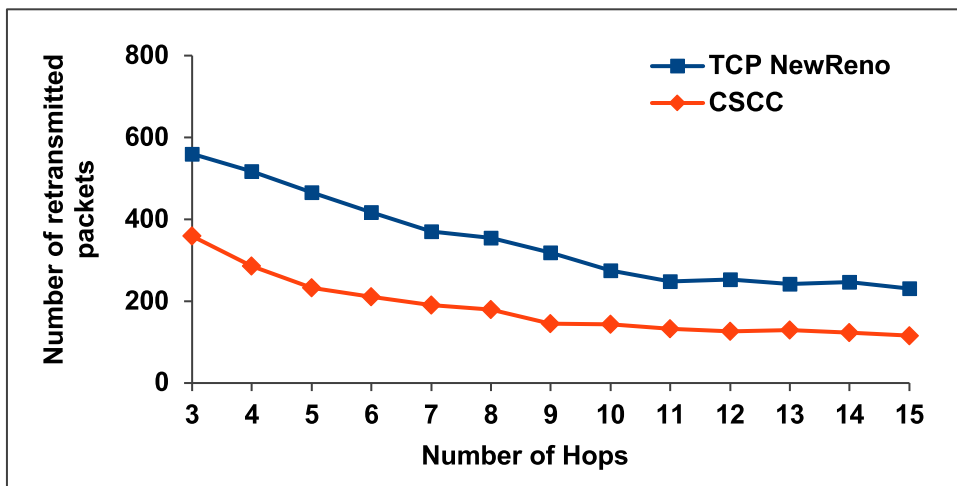

FIGURE 12. The number of retransmitted packets in the string topology with AODV.
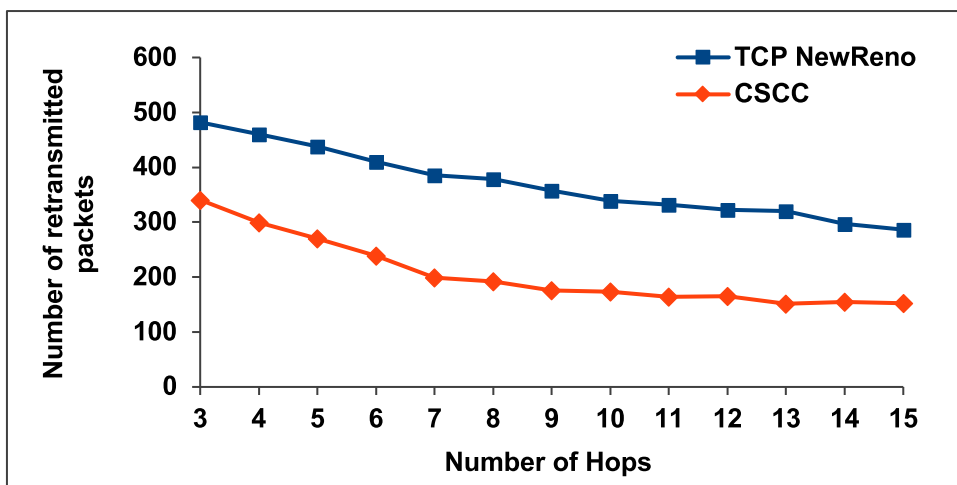

FIGURE 13. The number of retransmitted packets in the string topology with DSR.

means an improved utilization of network resources. Thus, the proposed mechanism handles contention more efficiently.

B. GRID TOPOLOGY

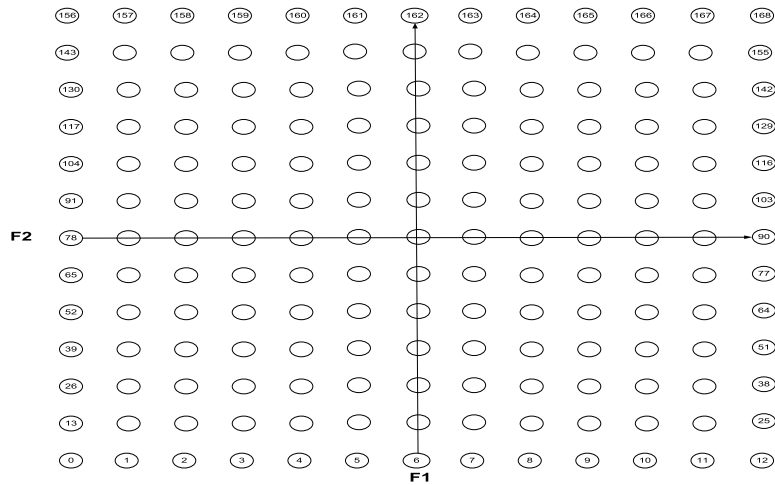This subsection reports the results of the simulation analysis of the CSCC mechanism on a grid topology against TCP

FIGURE 14. 13 × 13 grid with two flows.
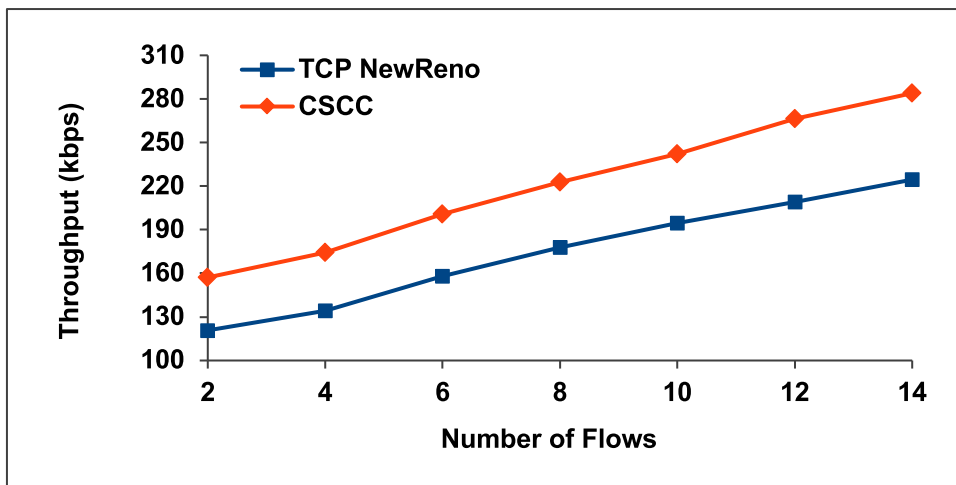
FIGURE 15. Throughput achieved on the 13 × 13 grid topology with AODV.
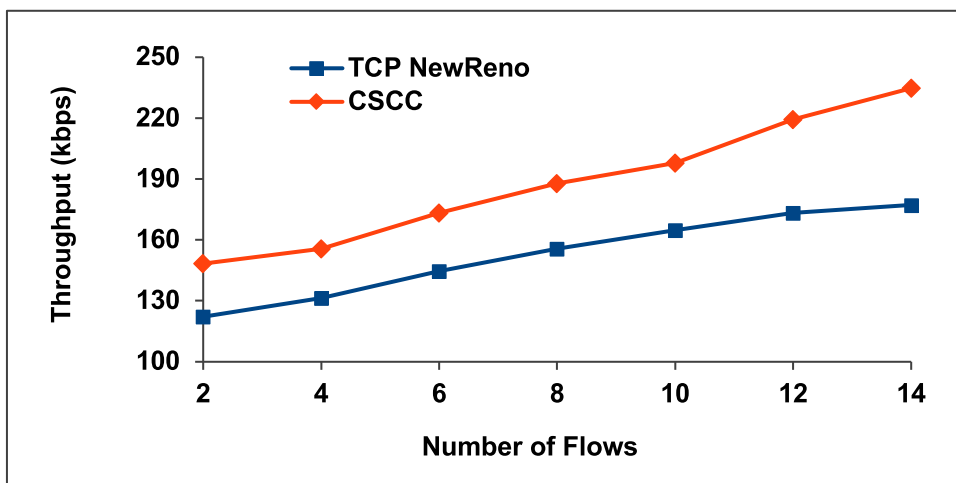
FIGURE 16. Throughput achieved on the 13 × 13 grid topology with DSR.

NewReno. A total of 169 nodes were simulated and placed in a 13 × 13 grid, depicted in Fig. 14. The distance between the

adjacent nodes, as was the case in the previously considered scenarios, was 200 meters. Compared to the string topology

TABLE 7. Confidence intervals and fairness indexes for the 13 × 13 grid topology, where the routing protocol is AODV.

Number of flows	TCP NewReno				CSCC			
	Throughput	95% Confidence Interval		Fairness Index	Throughput	95% Confidence Interval		Fairness Index
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
2	120.75	116.49	125.01	0.990	157.18	152.52	161.84	0.994
4	134.14	129.64	138.63	0.697	174.28	170.81	177.74	0.995
6	158.07	153.38	162.75	0.748	200.83	197.19	204.47	0.990
8	177.76	173.94	181.58	0.670	222.84	218.60	227.08	0.990
10	194.62	190.54	198.70	0.658	241.97	238.46	245.48	0.970
12	209.16	205.92	212.40	0.693	266.55	260.99	272.10	0.897
14	224.47	220.41	228.53	0.661	283.96	277.76	290.15	0.890

TABLE 8. Confidence intervals and fairness indexes for the 13 × 13 grid topology, where the routing protocol is DSR.

| Number of flows	TCP NewReno				CSCC			
	Throughput	95% Confidence Interval		Fairness Index	Throughput	95% Confidence Interval		Fairness Index
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
2	122.19	119.51	124.87	0.830	148.34	145.38	151.31	0.996
4	131.43	129.27	133.59	0.797	155.53	152.65	158.40	0.998
6	144.50	141.73	147.28	0.819	173.29	170.52	176.07	0.991
8	155.52	150.15	160.89	0.835	187.93	182.46	193.40	0.916
10	164.67	159.13	170.20	0.910	197.99	190.99	204.99	0.970
12	173.29	168.36	178.22	0.884	219.50	214.86	224.14	0.929
14	177.27	167.59	186.94	0.935	234.74	226.93	242.55	0.971
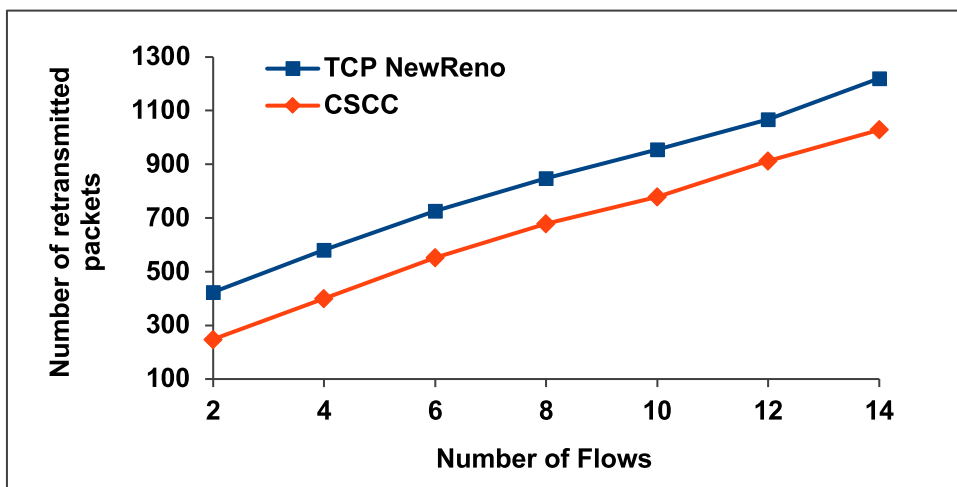
FIGURE 17. The number of retransmitted packets on the 13 × 13 grid topology with AODV.

considered in previous subsections, the grid topology has more nodes, and more data flows are considered to create a highly contended environment. At the start, two flows (F1 and F2) were considered so that the flows cross each other
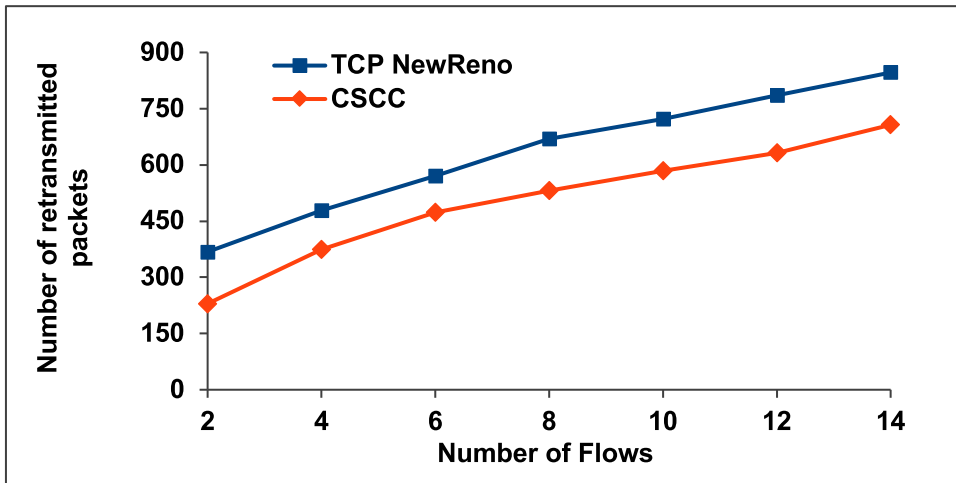
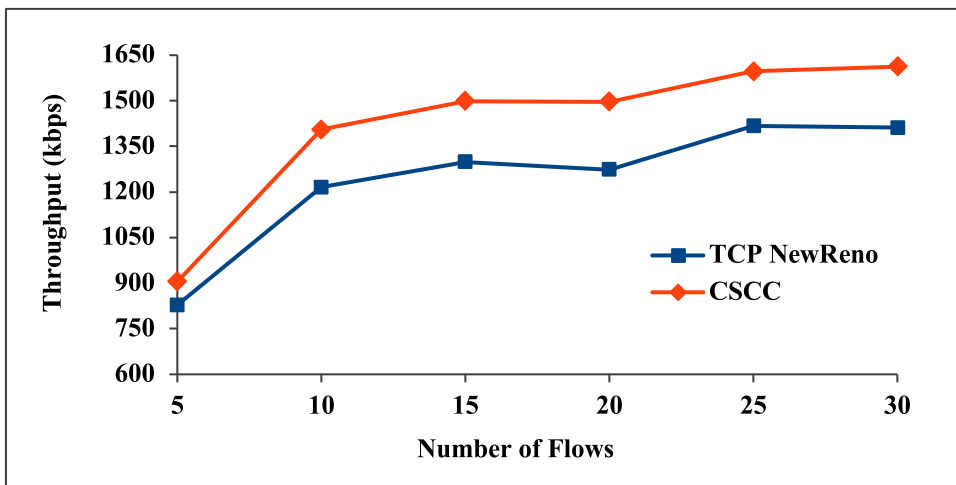**FIGURE 18.** The number of retransmitted packets on the 13 × 13 grid topology with DSR.

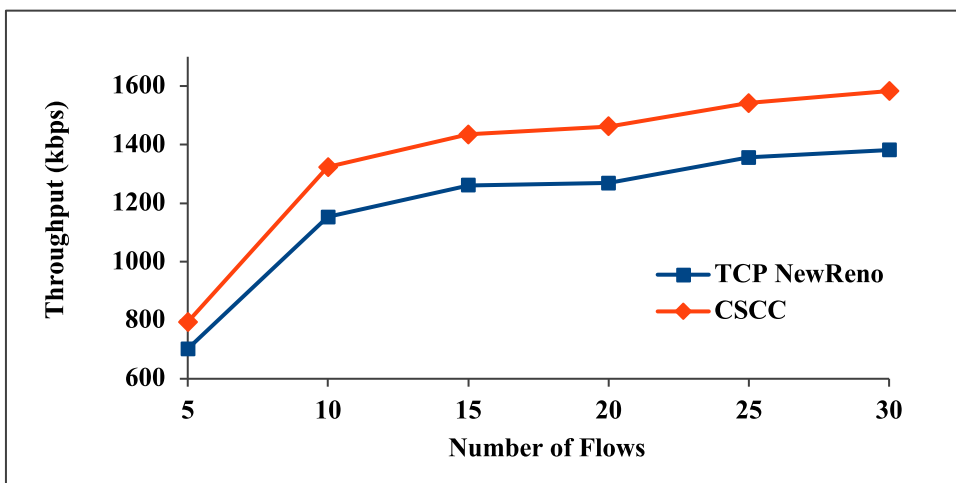**FIGURE 19.** Throughput achieved on the random topology with AODV.

FIGURE 20. Throughput achieved on the random topology with DSR.

and move from one end to the other end of the grid, as shown in Fig. 14. Then two further flows (F3 and F4) were added, one starting on each side and flowing opposite to the first one. The number of flows was increased to 14 by adding two

TABLE 9. Confidence intervals and fairness indexes for the random topology, where the routing protocol is AODV.

Number of flows	TCP NewReno				CSCC			
	Throughput	95% Confidence Interval		Fairness Index	Throughput	95% Confidence Interval		Fairness Index
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
5	828.08	809.67	846.50	0.370	838.15	810.80	865.50	0.450
10	1215.84	1169.04	1262.63	0.290	1405.30	1379.00	1431.60	0.391
15	1299.04	1252.20	1345.89	0.273	1498.57	1453.49	1543.65	0.389
20	1273.79	1219.14	1328.44	0.223	1497.07	1458.40	1535.73	0.360
25	1417.22	1358.29	1476.14	0.192	1596.25	1548.48	1644.02	0.344
30	1411.76	1344.62	1478.91	0.184	1612.11	1569.67	1654.55	0.341

TABLE 10. Confidence intervals and fairness indexes for the random topology, where the routing protocol is DSR.

| Number of flows	TCP NewReno				CSCC			
	Throughput	95% Confidence Interval		Fairness Index	Throughput	95% Confidence Interval		Fairness Index
		Lower Bound	Upper Bound			Lower Bound	Upper Bound	
5	702.23	650.58	753.87	0.37	793.98	736.42	851.54	0.45
10	1152.24	1119.92	1184.56	0.29	1323.29	1288.20	1358.38	0.39
15	1261.29	1232.84	1289.73	0.27	1435.18	1409.65	1460.71	0.39
20	1268.77	1250.31	1287.23	0.22	1461.83	1442.30	1481.37	0.36
25	1356.24	1321.76	1390.72	0.19	1541.81	1515.60	1568.02	0.34
30	1381.37	1325.19	1437.56	0.18	1582.95	1561.30	1604.60	0.34
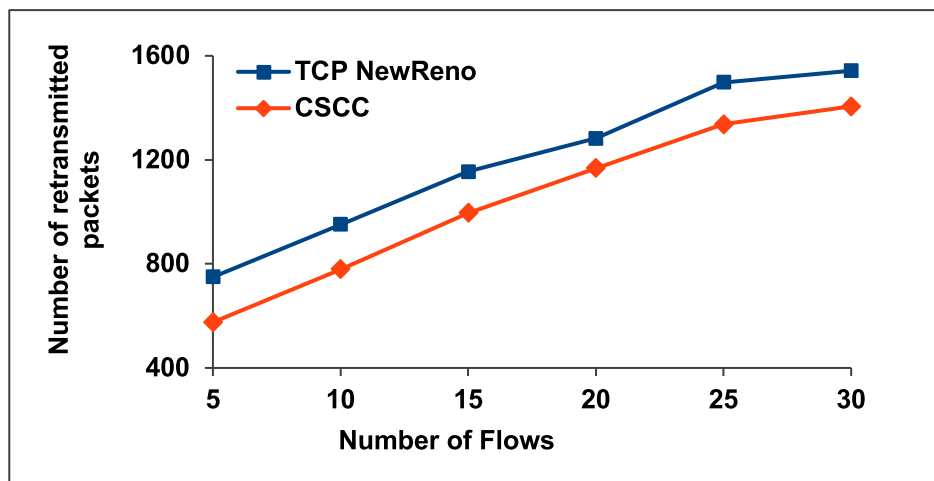
FIGURE 21. Number of retransmitted packets on the random topology with AODV.

successive flows at a time. The throughput recorded using the AODV and DSR routing protocols, respectively, is depicted in Fig. 15 and Fig. 16 for each scenario. The improvement achieved by the CSCC mechanism against TCP NewReno ranges from 24.33 to 30.17% with AODV and from 18.33 to 32.42% with DSR. At the same time, the 95% confidence intervals and fairness indexes computed for the achieved throughput for each scenario are listed in Tables 7 and 8.
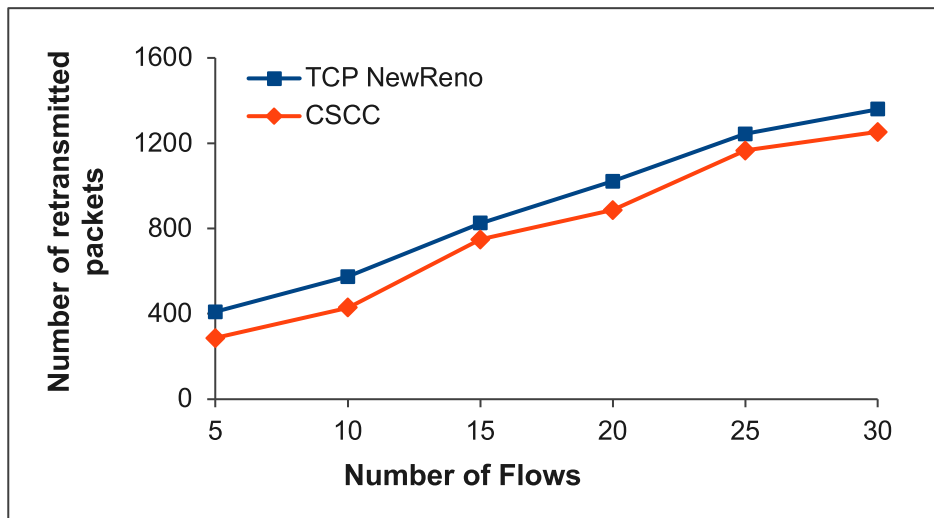
FIGURE 22. Number of retransmitted packets on the random topology with DSR.

Jain's fairness index was calculated according to equation (5).

$$f(x) = \frac{\left[\sum_{i=n}^{n} x_i\right]^2}{n \times \sum_{i=n}^{n} x_i^2} \qquad (5)$$

In equation (5), n counts for the total number of flows, and xi for the ith flow's throughput. Equation (5) will provide a result between 0 and 1. The fairness increases as the calculated result approach one and decreases as it approaches zero (0).

Looking at Fig. 17 and Fig. 18, it is clear that the number of retransmitted packets in the case of the CSCC mechanism is less than in the case of TCP NewReno, in the presence of both the AODV and DSR routing protocols. Thus, the CSCC mechanism handles CC more efficiently in a dense network.

C. RANDOM TOPOLOGY

The suggested CSSS mechanism's ability to handle growing traffic flows—from five to thirty connections—is evaluated using simulation experiments. A random network topology is employed in this simulation, with 100 nodes distributed at random throughout an area measuring 1000 by 1000 meters. Like all previous scenarios, the outcomes are averaged over 15 runs. For conducting traffic flow experiments, the throughput achieved by TCP NewReno and the proposed CSCC mechanism with AODV and DSR is illustrated in Fig. 19 and Fig. 20, respectively. Moreover, Fig. 21 and Fig. 22 show each case's retransmitted packets. Analyzing these graphs, the CSCC mechanism has achieved high throughput than TCP NewReno, and less retransmission is observed in the case of the proposed CSCC mechanism. Furthermore, the 95% confidence interval and Jain's fairness index computed in random topology, in the presence of AODV and DSR, are listed in Tables 9 and 10, respectively. The improvement in throughput achieved by the proposed CSCC mechanism against TCP NewReno ranges from 9.27 to 17.53% and from 13.07 to 15.22% in the presence of AODV and DSR, respectively.

VI. CONCLUSION

Improving the performance of TCP in WANETs is the main objective of the proposed CSCC mechanism. In the proposed mechanism, each node calculates the WMA of the number of tries attempted for a frame transmission at the MAC layer to reflect CC. When the WMA at any node hits a pre-defined threshold, the node begins marking packets to alert the sender about contention. Consequently, the sending node must adjust the injection of packets into the network based on the cwnd size of the data flow.

The performance of the proposed CSCC mechanism has been evaluated against TCP NewReno and observed that the proposed mechanism outperformed TCP NewReno in terms of throughput. The number of retransmitted packets is fewer with the proposed mechanism than TCP NewReno, which is a sign of contention control. Moreover, fewer retransmission means the packet drop rate is low.

For the string topology, the CSCC mechanism achieved 10.99% to 56.43% and 12.58% to 54.71% improvement in throughput against TCP NewReno with the AODV and DSR routing protocols, respectively. When the grid topology was considered, the CSCC mechanism achieved 24.33% to 30.17% and 18.33% to 32.42% improvement in throughput against TCP NewReno with the AODV and DSR routing protocols, respectively. A random topology was also considered to evaluate the ability of the CSCC mechanism to handle an increasing number of flows; the CSCC mechanism achieved 9.27% to 17.53% and 13.07% to 15.22% improvement in throughput against TCP NewReno with the AODV and DSR routing protocols, respectively.

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