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# Comparative Analysis of TCP Westwood and Conventional TCP in Wireless Network

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***Abstract:*** *In Mobile Ad hoc Networks (MANETs), congestion mainly arises due to node mobility, which leads to frequent packet loss and repeated retransmissions. To enhance the performance of conventional TCP, several variants such as TCP Tahoe, TCP Reno, TCP New Reno, TCP SACK, and TCP Westwood have been developed. TCP Westwood employs a modified congestion control mechanism that reduces delay-based congestion and achieves improved performance. Key performance metrics such as throughput, packet delivery rate, and end-to-end delay show noticeable improvement with the Westwood approach. However, further enhancements are necessary to optimize other parameters, including jitter delay and bandwidth fairness. This paper examines various enhanced versions of TCP Westwood, such as Westwood-A, Adaptive Westwood, and ARTA Westwood. Among these, ARTA Westwood demonstrates superior performance in improving bandwidth fairness compared to the standard Westwood algorithm.*

***Key Words:*** *Fairness of Bandwidth, Mobile Ad-hoc Network, TCP, TCP Westwood.*

## 1. INTRODUCTION:

Transmission Control Protocol (TCP) is a connection-oriented protocol of the transport layer that provides essential features such as flow control, reliability, congestion control, and overall network management. Although TCP was originally designed for wired networks, it can also operate over wireless networks. However, wireless networks frequently experience sudden changes in topology, which significantly affect TCP performance. In ad hoc networks, TCP encounters packet losses caused by link failures as well as congestion. During timeout events, TCP increases its retransmission timeout through a back-off mechanism, which ultimately degrades the overall network throughput. TCP treats packet losses resulting from node mobility and high bit error rates in wireless links in the same manner as congestion-related losses in wired networks, leading to inefficient performance. Congestion, in simple terms, refers to network overcrowding, where increased traffic results in slower response times and reduced throughput. The primary causes of congestion include limited bandwidth and data traffic exceeding the network's capacity. Reference [1] presents an analysis of various TCP congestion avoidance techniques. To control congestion, TCP employs several mechanisms such as slow start, additive increase and multiplicative decrease (AIMD), fast retransmission, and fast recovery. When the congestion window size reaches the value advertised by the receiver, further growth of the window is restricted.

When packet loss is detected, TCP stores half of the current congestion window (cwnd) value as the slow start threshold and then restarts the slow start phase from its initial point. Upon detecting missing segments, TCP retransmits the lost packets immediately without waiting for the retransmission timer to expire. In the fast recovery mechanism, the slow start phase is avoided and only fast retransmission is carried out. Fast recovery is triggered after the reception of three consecutive duplicate acknowledgements. However, this behavior leads to reduced utilization of available link bandwidth, resulting in degraded performance and lower overall throughput. Several TCP variants have been developed to enhance performance, including TCP Tahoe, TCP Reno, TCP New Reno, TCP SACK, and TCP Westwood. As discussed in [2], TCP Tahoe mandates that whenever a TCP connection begins or restarts after a packet loss, it must enter the slow start phase. Tahoe does not estimate available bandwidth, whereas TCP Westwood continuously and accurately measures bandwidth, allowing more efficient utilization of network resources. TCP Reno improves upon Tahoe by enabling the detection and retransmission of a single lost packet before a timeout occurs. However, Reno reduces the congestion window without considering actual bandwidth conditions, unlike Westwood. While TCP Reno achieves better bandwidth utilization than Tahoe, its performance still falls short of that provided by

TCP Westwood. TCP New Reno eliminates the requirement to wait for three duplicate acknowledgements before retransmitting a lost packet. In TCP SACK, packet loss is used as an indication of congestion. TCP Westwood regulates its transmission rate by operating at an optimal bandwidth utilization level, thereby ensuring greater stability. Consequently, TCP Westwood demonstrates superior performance compared to the other TCP variants discussed. The remainder of this paper is organized as follows: Section I presents the introduction. Section II explains the fundamental algorithm of TCP Westwood. Section III provides a review of existing literature related to Westwood. Finally, Section IV concludes the paper.

## 1.1 TCP WESTWOOD:

All modifications are limited to the sender side, and Westwood is an atypical implementation that works with any other legitimate TCP implementation. The primary algorithms that Westwood revealed in [1] are:

**Westwood – New Retransmission Mechanism:** In TCP Westwood, the round-trip time (RTT) is calculated by recording the time at which a packet is transmitted and the moment its corresponding acknowledgement (ACK) is received. Based on this RTT estimation, retransmission decisions are made more accurately, as described below:

- When a duplicate acknowledgement is received and the newly estimated RTT exceeds the retransmission timeout (RTO), TCP Westwood initiates retransmission immediately without waiting for the arrival of a third duplicate ACK.
- Upon receiving a non-duplicate acknowledgement, TCP Westwood interprets specific ACKs as indicators to determine whether a timeout condition should be triggered.

**Westwood – New Congestion Avoidance Mechanism:** A key feature of TCP Westwood is the use of packet delay as an indicator of congestion rather than packet loss, which is commonly employed in loss-based congestion control algorithms. In TCP Westwood, the congestion window is adjusted according to a predefined set of rules that respond to variations in packet delay.

**Westwood – Modified Slow Start Mechanism:** During the slow start phase, TCP Westwood permits exponential growth of the congestion window only on alternate round-trip times (RTTs) to help detect and prevent congestion at an early stage. In the intervening RTTs, the congestion window remains unchanged, allowing a reliable comparison between expected and actual transmission rates. When the actual rate drops below the expected rate by a predefined γ threshold, TCP Westwood transitions from slow start to a linear increase or decrease mode.

## 2. LITERATURE REVIEW:

This section discusses the research contributions of various authors who have utilized TCP Westwood and its variants to address performance issues such as unfairness, excessive bandwidth consumption, and prolonged delays, all of which negatively impact network efficiency.

In [3], the authors proposed an end-host adaptation to the congestion avoidance mechanism of the original TCP Westwood. The resulting protocol, known as TCP ARTA Westwood, demonstrates improved performance compared to TCP Westwood in both simultaneous and non-simultaneous traffic scenarios. The study also examines fairness issues associated with TCP Westwood. Simulation results reveal that TCP ARTA Westwood competes more effectively with TCP Reno while not only retaining the throughput advantages of TCP Westwood but also further enhancing them.

As presented in [4], Adaptive Westwood was introduced to improve the compatibility and fairness of TCP Westwood through the use of adaptive parameters. Experimental results show that Adaptive Westwood achieves better fairness when coexisting with TCP Reno in real network environments. Compared to the original Westwood, Adaptive Westwood offers improved compatibility while preserving Westwood’s key advantages in terms of packet loss rate, end-to-end delay, and delay jitter.

In [5], the authors examined the challenges encountered when TCP Westwood is deployed in mobile ad hoc networks (MANETs) and proposed a new algorithm called TCP Westwood-HA. This approach incorporates a modified congestion control mechanism based on TCP Westwood and is shown to significantly enhance network throughput. However, empirical parameters may vary across different network conditions, indicating the need to measure and tune these values for each specific network before deploying TCP Westwood-HA. The algorithm would be more effective if supported by an automatic testing mechanism. Additionally, a new method for estimating the base RTT using empirical values was evaluated. Simulation results demonstrate that the proposed algorithm adapts well to variations in route buffers and hop counts, effectively improving TCP Westwood throughput in MANET environments.

` In [6], to address the need for accurate base RTT estimation in MANETs, the authors introduced TCP Westwood-ad hoc. This scheme enables the TCP sender to obtain an updated base RTT without relying on additional explicit control messages when a route change (RC) occurs. When an intermediate node detects a route change, this information is piggybacked in the IP header of an in-transit packet destined for the TCP receiver. The receiver then notifies the sender through TCP acknowledgements, allowing the sender to update the base RTT. Simulation results using ns-2 show that TCP Westwood-ad hoc outperforms standard TCP Westwood, particularly under high node mobility, with performance improvements of up to 20%. The evaluation was conducted using both OLSR and AODV as the underlying proactive and reactive routing protocols.

In [7], the authors presented simulation results from an evaluation of TCP Westwood over large bandwidth-delay network models using various parameter settings. Several studies indicate that TCP Westwood does not always achieve higher efficiency than other TCP variants, despite generating fewer packet retransmissions and offering limited fairness toward connections with longer RTTs. The authors demonstrated that default parameter values in the congestion window algorithm of TCP Westwood fail to deliver competitive performance, especially in high-bandwidth, long-delay networks. However, adjusting key parameters such as alpha and beta leads to improved performance, albeit with increased sensitivity and vulnerability.

## 3. RESEARCH METHOD:

This proposed approach identifies the cause of packet loss by utilizing the Explicit Congestion Notification (ECN) flag in the TCP header. A single ECN bit is employed as a strong indicator of network congestion. The method distinguishes packet losses by analyzing the ratio between timeout events and the occurrence of three duplicate acknowledgements (3 DUPACKs). Based on this ratio, the sender determines the underlying reason for packet loss. Timeouts are considered to result from congestion at the router, whereas the reception of three duplicate acknowledgements at the receiver is attributed to bit errors on the wireless link. The sender calculates the ratio of the number of timeouts to the number of 3 DUPACKs. If this ratio exceeds a predefined threshold, the sender infers that packet loss is caused by congestion, reduces the congestion window size by half, and enters the slow start phase. Conversely, if the ratio is below the threshold, the sender assumes that packet loss is due to bit errors and therefore does not reduce the congestion window, instead transitioning into the congestion avoidance phase. This strategy enhances the overall throughput of TCP Westwood, with the ratio computation performed entirely at the sender side. To further reduce congestion, the approach incorporates Random Early Detection (RED), a modified queue management technique widely used in real-time network scenarios. RED employs ECN to signal impending congestion before packet loss occurs. In the proposed adaptive RED scheme, the average queue length is continuously monitored, and when it exceeds a predefined average threshold, an ECN notification is sent to the sender. This early warning allows the source node to proactively reduce its congestion window, thereby preventing packet drops and improving network performance.

## 4. CONCLUSION:

A survey of different modification techniques for better outcomes than an original Westwood is included in this research. Based on a review of the research, we may determine that various changes can improve Westwood's overall performance. The Westwood algorithm has been found to have several problems, such as fairness. While maintaining the benefits of Westwood in terms of packet loss rate, delay, and delay jitter, Adaptive Westwood exhibits greater compatibility with Reno.

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