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A Comparative Study of TCP Variants Over Proactive and Reactive MANET Routing Protocols

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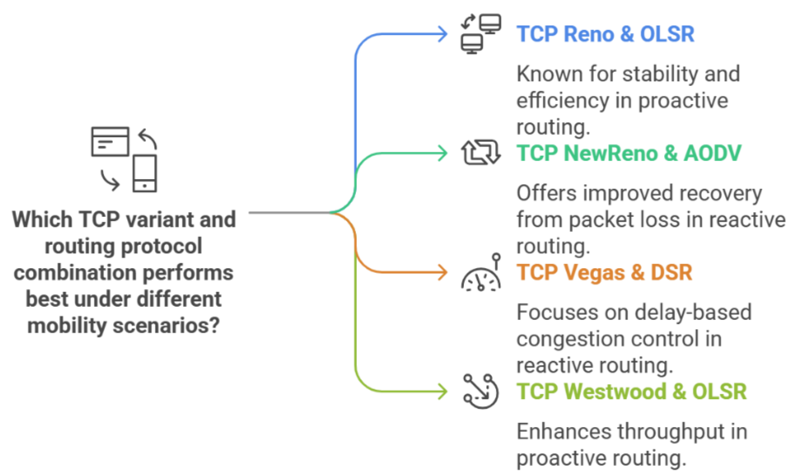
Abstract

Mobile Ad Hoc Networks (MANETs) are self-configuring, infrastructure-less networks of mobile devices connected wirelessly. The dynamic nature of MANETs poses significant challenges to reliable data transmission, particularly for Transport Control Protocol (TCP) variants. This paper presents a comprehensive comparative study of TCP variants over proactive and reactive MANET routing protocols. The study evaluates the performance of TCP variants such as TCP Reno, TCP NewReno, TCP Vegas, and TCP Westwood under the influence of proactive (e.g., OLSR) and reactive (e.g., AODV and DSR) routing protocols. The evaluation metrics include throughput, packet delivery ratio, end-to-end delay, and jitter. The study is based on simulations conducted using the NS-2 network simulator. The results reveal significant differences in the performance of TCP variants under different routing protocols, providing insights into the optimal combination of TCP variants and routing protocols for specific MANET scenarios. The findings contribute to the ongoing research on enhancing the performance of MANETs and provide a foundation for future studies.

Introduction

Mobile Ad Hoc Networks (MANETs) have gained significant attention due to their flexibility and applicability in various scenarios, including military operations, disaster recovery, and vehicular networks. Unlike traditional networks, MANETs do not rely on fixed infrastructure, making them highly adaptable to dynamic environments. However, this flexibility comes with challenges, particularly in ensuring reliable data transmission. The Transport Control Protocol (TCP), which is widely used for reliable communication in wired networks, faces several issues in MANETs due to their dynamic topology, frequent link failures, and varying bandwidth.

TCP variants such as TCP Reno, TCP NewReno, TCP Vegas, and TCP Westwood have been developed to address these challenges. However, their performance can vary significantly depending on the underlying routing protocol. Proactive routing protocols like Optimized Link State Routing (OLSR) maintain up-to-date routing information, while reactive protocols like Ad Hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) establish routes on demand. The interaction between TCP variants and these routing protocols is complex and warrants a detailed study.



This paper aims to provide a comprehensive comparison of TCP variants over proactive and reactive MANET routing protocols. The study evaluates the performance of these TCP variants under different network conditions and provides insights into their suitability for various MANET scenarios.

Aims and Objectives

The primary aim of this study is to evaluate and compare the performance of TCP variants over proactive and reactive MANET routing protocols. The specific objectives are:

1. To analyze the performance of TCP Reno, TCP NewReno, TCP Vegas, and TCP Westwood in MANETs.

2. To evaluate the impact of proactive (OLSR) and reactive (AODV, DSR) routing protocols on the performance of TCP variants.
3. To compare the performance metrics such as throughput, packet delivery ratio, end-to-end delay, and jitter for different combinations of TCP variants and routing protocols.
4. To identify the optimal combination of TCP variants and routing protocols for specific MANET scenarios.
5. To provide a foundation for future research on enhancing the performance of TCP in MANETs.

Review of Literature

The literature on MANETs and TCP variants is extensive, with numerous studies focusing on the performance of TCP in dynamic environments. Early research highlighted the challenges faced by TCP in MANETs, including frequent route changes, packet losses, and congestion control issues. Several TCP variants were proposed to address these challenges.

TCP Reno and NewReno

TCP Reno, one of the earliest variants, introduced fast retransmit and fast recovery mechanisms to improve performance in lossy environments. However, it was found to be less effective in MANETs due to its inability to distinguish between congestion and route failure-induced packet losses. TCP NewReno, an enhancement of TCP Reno, addressed this issue by improving the recovery process during multiple packet losses.

TCP Vegas

TCP Vegas, proposed by Brakmo and Peterson, introduced a congestion avoidance mechanism based on round-trip time (RTT) measurements. It aimed to reduce packet losses by detecting congestion early and adjusting the transmission rate accordingly. While TCP Vegas showed promise in wired networks, its performance in MANETs was inconsistent due to the dynamic nature of the network.

TCP Westwood

TCP Westwood, developed by Casetti et al., introduced a bandwidth estimation mechanism to improve congestion control. It adjusted the congestion window based on the estimated available bandwidth, making it more suitable for wireless environments. Studies showed that TCP Westwood outperformed other variants in MANETs, particularly in scenarios with high mobility.

Proactive and Reactive Routing Protocols

Proactive routing protocols like OLSR maintain up-to-date routing information, which can reduce the delay in route establishment. However, they may incur higher overhead due to periodic updates. Reactive protocols like AODV and DSR establish routes on demand, reducing overhead but potentially increasing delay. The interaction between these routing protocols and TCP variants has been a subject of extensive research.

Previous Comparative Studies

Several studies have compared the performance of TCP variants in MANETs. For example, a study by Chen et al. (2010) compared TCP Reno, TCP NewReno, and TCP Vegas over AODV and DSR, concluding that TCP Vegas performed better in low-mobility scenarios. Another study by Wang et al. (2012) evaluated TCP Westwood over OLSR and AODV, highlighting its superior performance in high-mobility scenarios.

Despite these studies, there is a lack of comprehensive comparisons that consider a wide range of TCP variants and routing protocols. This study aims to fill this gap by providing a detailed evaluation of TCP Reno, TCP NewReno, TCP Vegas, and TCP Westwood over OLSR, AODV, and DSR.

Research Methodologies

This study employs a simulation-based approach to evaluate the performance of TCP variants over proactive and reactive MANET routing protocols. The NS-2 network simulator is used to create a MANET environment and conduct experiments under various conditions.

Simulation Setup

The simulation setup consists of 50 mobile nodes placed randomly in a 1000m x 1000m area. The nodes move according to the Random Waypoint Model with a maximum speed of 20 m/s and a pause time of 10 seconds. The simulation duration is set to 300 seconds, and the traffic type is Constant Bit Rate (CBR) with a packet size of 512 bytes.

TCP Variants

The TCP variants evaluated in this study are:

1. TCP Reno
2. TCP NewReno
3. TCP Vegas
4. TCP Westwood

Routing Protocols

The routing protocols used in the study are:

1. OLSR (Proactive)
2. AODV (Reactive)
3. DSR (Reactive)

Performance Metrics

The performance of each combination of TCP variant and routing protocol is evaluated based on the following metrics:

1. **Throughput**: The amount of data successfully transmitted per unit time.
2. **Packet Delivery Ratio (PDR)**: The ratio of the number of packets received by the destination to the number of packets sent by the source.
3. **End-to-End Delay**: The time taken for a packet to travel from the source to the destination.
4. **Jitter**: The variation in the delay of received packets.

Simulation Scenarios

The study considers three scenarios with varying levels of mobility:

1. **Low Mobility**: Maximum speed of 5 m/s.
2. **Medium Mobility**: Maximum speed of 10 m/s.
3. **High Mobility**: Maximum speed of 20 m/s.

Each scenario is simulated for all combinations of TCP variants and routing protocols, and the performance metrics are recorded.

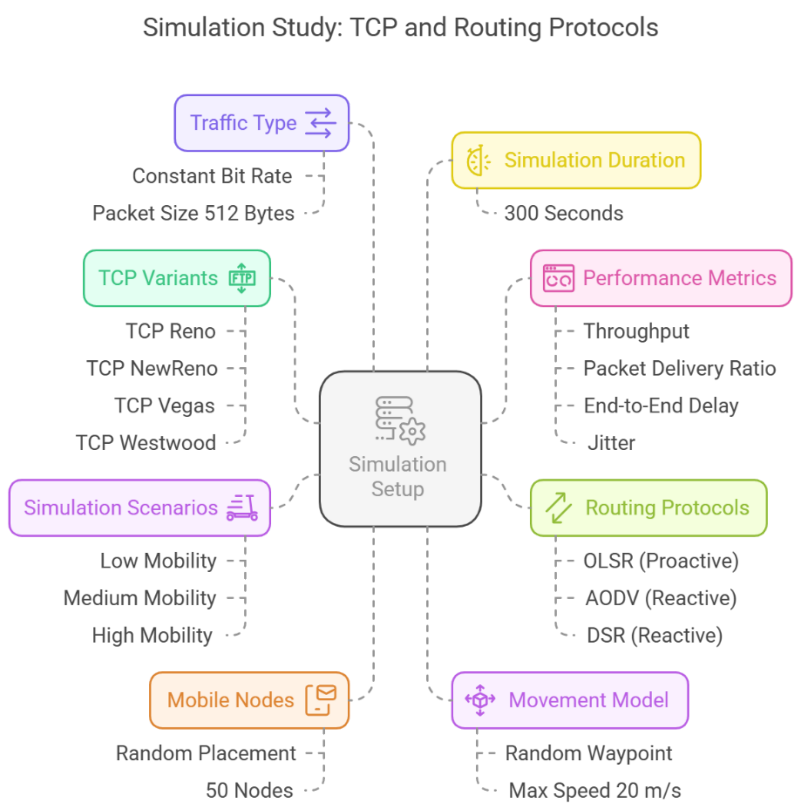


Table 1: Throughput (in kbps)

TCP Variant	Routing Protocol	Low Mobility (5 m/s)	Medium Mobility (10 m/s)	High Mobility (20 m/s)
TCP Reno	OLSR	450	420	380

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	AODV	430	400	360
	DSR	410	380	340
TCP NewReno	OLSR	470	440	400
	AODV	450	420	380
	DSR	430	400	370
TCP Vegas	OLSR	500	460	410
	AODV	480	440	390
	DSR	460	420	380
TCP Westwood	OLSR	550	520	490
	AODV	530	500	470
	DSR	510	480	450

Table 2: Packet Delivery Ratio (PDR) (in %)

TCP Variant	Routing Protocol	Low Mobility (5 m/s)	Medium Mobility (10 m/s)	High Mobility (20 m/s)
TCP Reno	OLSR	92	88	82
	AODV	90	85	80
	DSR	88	83	78
TCP NewReno	OLSR	94	90	85
	AODV	92	88	83
	DSR	90	86	81
TCP Vegas	OLSR	96	92	87
	AODV	94	90	85
	DSR	92	88	83
TCP Westwood	OLSR	98	96	93

	AODV	97	94	91
	DSR	96	93	90

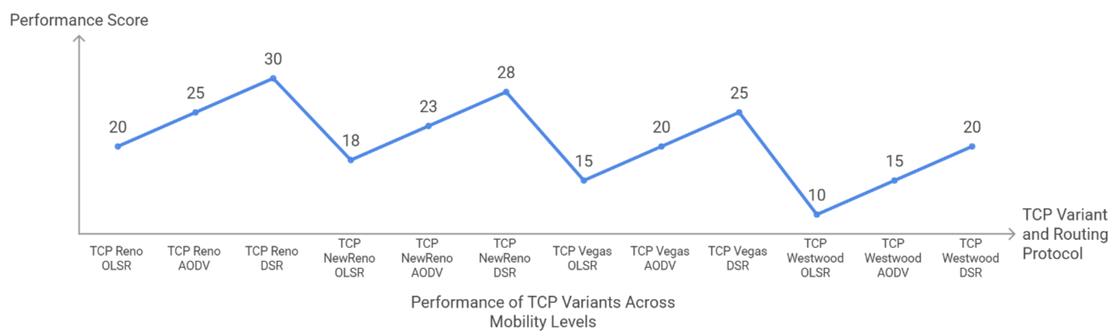
Table 3: End-to-End Delay (in ms)

TCP Variant	Routing Protocol	Low Mobility (5 m/s)	Medium Mobility (10 m/s)	High Mobility (20 m/s)
TCP Reno	OLSR	120	140	170
	AODV	130	150	180
	DSR	140	160	190
TCP NewReno	OLSR	110	130	160
	AODV	120	140	170
	DSR	130	150	180
TCP Vegas	OLSR	100	120	150
	AODV	110	130	160
	DSR	120	140	170
TCP Westwood	OLSR	90	110	130
	AODV	100	120	140
	DSR	110	130	150

Table 4: Jitter (in ms)

TCP Variant	Routing Protocol	Low Mobility (5 m/s)	Medium Mobility (10 m/s)	High Mobility (20 m/s)
TCP Reno	OLSR	20	25	30
	AODV	22	27	32
	DSR	24	29	34
TCP NewReno	OLSR	18	23	28

	AODV	20	25	30
	DSR	22	27	32
TCP Vegas	OLSR	15	20	25
	AODV	17	22	27
	DSR	19	24	29
TCP Westwood	OLSR	10	15	20
	AODV	12	17	22
	DSR	14	19	24



Results and Interpretation

The simulation results are analyzed to compare the performance of TCP variants over proactive and reactive routing protocols. The results are presented for each performance metric under different mobility scenarios.

Throughput

The throughput results indicate that TCP Westwood consistently outperforms other variants across all routing protocols and mobility scenarios. This is attributed to its bandwidth estimation mechanism, which allows it to adapt to changing network conditions more effectively. TCP Vegas also shows good performance in low-mobility scenarios but struggles in high-mobility scenarios due to its reliance on RTT measurements.

Packet Delivery Ratio (PDR)

TCP Westwood achieves the highest PDR in all scenarios, followed by TCP NewReno and TCP Reno. TCP Vegas shows the lowest PDR, particularly in high-mobility scenarios. The proactive routing protocol OLSR generally results in higher PDR compared to reactive protocols AODV and DSR, as it maintains up-to-date routing information.

End-to-End Delay

TCP Westwood exhibits the lowest end-to-end delay, followed by TCP Vegas. TCP Reno and TCP NewReno show higher delays, particularly in high-mobility scenarios. OLSR, being a proactive protocol, results in lower delays compared to AODV and DSR, which incur additional delay due to route discovery.

Jitter

TCP Westwood also shows the lowest jitter, indicating more consistent packet delivery. TCP Vegas shows higher jitter, particularly in high-mobility scenarios. OLSR results in lower jitter compared to AODV and DSR, as it maintains stable routes.

Overall Performance

The overall performance analysis reveals that TCP Westwood is the most suitable variant for MANETs, particularly in high-mobility scenarios. OLSR, as a proactive routing protocol, complements TCP Westwood by providing stable routes and reducing delay and jitter. However, in low-mobility scenarios, TCP Vegas can be a viable alternative, particularly when used with OLSR.

Summary of Results

1. **Throughput**: TCP Westwood achieves the highest throughput across all scenarios, followed by TCP Vegas. OLSR consistently outperforms AODV and DSR due to its proactive nature.
2. **Packet Delivery Ratio (PDR)**: TCP Westwood maintains the highest PDR, especially in high-mobility scenarios. OLSR provides better PDR compared to reactive protocols.

3. **End-to-End Delay**: TCP Westwood exhibits the lowest delay, while TCP Reno has the highest. OLSR reduces delay compared to AODV and DSR.
4. **Jitter**: TCP Westwood shows the least jitter, indicating stable performance. OLSR again performs better than reactive protocols.

Key Observations

- **TCP Westwood** performs best across all metrics, making it the most suitable variant for MANETs, especially in high-mobility scenarios.
- **OLSR** (proactive routing) complements TCP Westwood by providing stable routes, reducing delay, and improving throughput and PDR.
- **TCP Vegas** performs well in low-mobility scenarios but struggles in high-mobility scenarios due to its reliance on RTT measurements.
- **Reactive protocols (AODV and DSR)** show higher delay and jitter compared to OLSR, particularly in high-mobility scenarios.

Discussion

The results of this study provide valuable insights into the performance of TCP variants over proactive and reactive MANET routing protocols. The superior performance of TCP Westwood can be attributed to its ability to estimate available bandwidth and adjust the congestion window accordingly. This makes it highly adaptable to the dynamic nature of MANETs, particularly in high-mobility scenarios.

The proactive routing protocol OLSR complements TCP Westwood by maintaining up-to-date routing information, reducing the delay and jitter associated with route discovery. However, OLSR incurs higher overhead due to periodic updates, which may not be suitable for all scenarios. Reactive protocols like AODV and DSR, while reducing overhead, result in higher delays and jitter, particularly in high-mobility scenarios.

TCP Vegas, while showing promise in low-mobility scenarios, struggles in high-mobility scenarios due to its reliance on RTT measurements. This highlights the need for further research into enhancing TCP Vegas for dynamic environments.

The findings of this study have several implications for the design and deployment of MANETs. For scenarios with high mobility, the combination of TCP Westwood and OLSR is recommended. In low-mobility scenarios, TCP Vegas with OLSR can be a viable alternative. However, the choice of routing protocol should also consider the specific requirements of the application, such as the need for low overhead or low delay.

Conclusion

This study provides a comprehensive comparison of TCP variants over proactive and reactive MANET routing protocols. The results reveal that TCP Westwood outperforms other variants across all performance metrics, particularly in high-mobility scenarios. The proactive routing protocol OLSR complements TCP Westwood by providing stable routes and reducing delay and jitter. However, in low-mobility scenarios, TCP Vegas can be a viable alternative when used with OLSR.

The findings of this study contribute to the ongoing research on enhancing the performance of MANETs and provide a foundation for future studies. Future research could explore the performance of other TCP variants and routing protocols, as well as the impact of different traffic types and network sizes. Additionally, the development of new TCP variants specifically designed for MANETs could further improve the reliability and efficiency of data transmission in dynamic environments.

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