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Article

A NOVEL PERFORMANCE RANKING SCHEME FOR TCP MODELS IN NS3 WITH MANETS

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Abstract: TCP-Transmission Control Protocol is a connection-oriented and reliable transport layer protocol for end-to-end delivery in computer networks. Over the years many TCP variants are proposed for different types of networks to address various challenges. Performance of TCP for wireless networks has remained an active area of research due to its inability to differentiate losses other than of due to network congestion. NS-3, Network Simulator-3 has several implementations of benchmark TCP Models which are also implemented with real world networks. This paper proposes a novel performance ranking scheme to analyze different TCP Models. This scheme evaluates performances of 14 TCP models in NS-3 simulator, for a large number of MANET scenarios. The primary objective of this work is to introduce a novel performance ranking scheme applicable to TCP models developed using diverse design approaches. The proposed framework aims to provide a unified and systematic methodology for evaluating and comparing different TCP variants. By employing a single ranking mechanism, the scheme facilitates the identification of the most suitable and promising TCP model for specific network environments in an objective and consistent manner..

Keywords: TCP, MANETs, Performance Ranking, Throughput, Packet Delivery Ratio

1. INTRODUCTION

TCP-Transmission Control Protocol is one of the most widely deployed transport layer protocols for connection oriented and reliable end-to-end delivery. TCP provides connection oriented communication with three-way handshaking. TCP ensures reliability with congestion control, flow control and error control mechanisms. Congestion control limits the transmission rate according to the traffic in a network. Flow control limits the transmission rate so receiver does not get overwhelmed. Error control manages lost or corrupted packets with selective retransmissions. The conventional TCP variants often consider any packet loss as a cause of network congestion. Subsequently, transmission rate is reduced. This theory suits well with the wired networks where the packets are mainly lost due to congestion. Wireless networks may experience packet losses due to other issues such as transmission impairments, route failures, network partitions etc. When the conventional TCP variants are used for wireless networks, significant amount of performance degradation can be noticed. Ideally, TCP should able to identify the cause of a packet loss to act accordingly. To let TCP take decisions more accurately and effectively, many TCP variants are proposed for different type of networks addressing various issues [1-5].

NS-3 (Network Simulator 3) TCP model has implementations of some of the benchmark TCP variants which are most widely used in real world networks. These TCP variants are TCP Bic, TCP HighSpeed, TCP HTCP, TCP Hybla, TCP Illinois, TCP Ledbat, TCP Lp, TCP NewReno, TCP Scalable, TCP Vegas, TCP Veno, TCP Westwood, TCP WestwoodPlus (TCP Westwood+), and TCP Yeah [6-7]. This paper introduces a performance ranking scheme to evaluate multiple TCP variants in a systematic manner. This scheme is used for above mentioned 14 TCP variants with a large number of random MANETs – Mobile Adhoc Networks. Section-2 discusses existing TCP Models in NS-3. Section-3 discusses proposed performance ranking scheme. Section-4 discusses performance analysis. This

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paper concludes with the details of the performance analysis completed with the proposed scheme. This research work is a part of the doctoral study of the author.

2. TCP MODELs in ns-3

NS-3 (Network Simulator 3) TCP model has implementations of some of the benchmark TCP variants which are most widely used in real world networks This section discusses 14 TCP Variants. These TCP Variants mainly differ in terms of how they set value of Cwnd-Congestion Window or how they detect congestion [6-7]. TCP Tahoe is based on AIMD – Additive Increase Multiplicative Decrease congestion control. Tahoe introduce fast retransmission phase to detect congestion earlier – before RTO-Retransmission Timeout with arrival of three duplicate acknowledgements. Tahoe reduces transmission rate to initial rate in both the cases. TCP Reno considers three duplicate acknowledgements as weaker congestion possibility where as RTO as stronger congestion possibility. Reno halves transmission rate on three duplicate acknowledgements where as reduces transmission rate to initial rate on RTO. TCP NewReno further improves TCP Reno by detecting partial acknowledgements those confirm reception of some of the transmitted bytes. NewReno avoids reduction of transmission rate multiple times for the packet losses belonging to the same transmission window [8-9]. TCP BIC views congestion control as a search problem. The starting point is current value of Cwnd and target point is maximum possible value of Cwnd [10]. TCP High Speed is designed for high-capacity TCP connections with large Cwnd. It grows Cwnd faster during probing phases [11]. TCP Hybla obtains same instantaneous transmission rate for TCP connections for long RTT as well as with lower RTT [12]. TCP Westwood and TCP Westwood+ / TCP WestwoodPlus are based on AIAD – Additive Increase / Adaptive Decrease scheme. These variants estimate network's bandwidth to adjust Cwnd. Westwood performs bandwidth sampling every ACK. Westwood+ performs bandwidth sampling every RTT [13-14]. TCP Vegas is proactive delay-based variant based on congestion avoidance. Vegas continuously samples the RTT to compute the difference between actual throughput and expected throughput to decide amount of extra packets being queued at the bottleneck. Cwnd is increased / decreased linearly [15]. TCP Scalable utilizes available bandwidth in a better way for highspeed wide area network [16]. TCP Veno is a combination of TCP Reno and TCP Vegas. Veno deals with random packet loss by distinguishing congestive and non-congestive states [17]. YeAH-TCP (Yet Another HighSpeed TCP) is a heuristic that has two modes. Fast mode increases Cwnd aggressively when congestion level is low. Slow mode acts as Reno in high congestion [18]. TCP Illinois is a hybrid congestion control algorithm for high-speed networks. Illinois is based on Concave-AIMD (or C-AIMD) algorithm that uses packet loss to determine direction of Cwnd update and queuing delay to determine the amount of change [19]. H-TCP is designed for high BDP – Bandwidth-Delay Product paths. In normal condition, it works like traditional TCP. When it finds no congestion, it increases Cwnd based on a function based on the elapsed time from the last congestion [20]. Low Extra Delay Background Transport (LEDBAT) is experimental delay-based algorithm to utilize available bandwidth on end-to-end path. It uses changes in one-way delay to limit congestion [21]. TCP-LP TCP-Low Priority is also a delay based congestion control algorithm in which the low priority data utilizes only the excess bandwidth available on an end-to-end path [22].

The traditional TCP variants were proposed mainly for the wired networks. Wired networks often experience packet losses mainly due to network congestion. When the same TCP variants were used with wireless networks, performance degradation was found. The reason was the fundamental assumption of any loss as a cause of congestion is not always true for the wireless networks. Wireless networks often experience packet losses due to transmission issues. In recent years, researchers have proposed different TCP variants to manage various losses. These TCP variants can be classified according to their approaches in handling losses: loss differentiation, loss avoidance and loss prediction approaches. A detail discussion and comparison of these TCP variants are given in [23]. FLS-Fuzzy Logic System based TCP variants are also proposed to handle uncertain, inaccurate and partial network state information. FLS based loss handling, FLS based transmission rate and FLS based RED techniques are discussed in [24]. To improve decision making capability of TCP with accuracy and efficiency, researchers have proposed ML-Machine Learning based variants. These variants are discussed in [26].

3. PERFORMANCE RANKING SCHEME

3.1 Experimental Setup

NS-3 (Network Simulator 3) TCP model has implementations of some of the benchmark TCP variants which are most widely used in real world networks. These TCP variants are TCP Bic, TCP HighSpeed, TCP HTCP, TCP Hybla, TCP Illinois, TCP Ledbat, TCP Lp, TCP NewReno, TCP Scalable, TCP Vegas, TCP Veno, TCP Westwood, TCP WestwoodPlus (TCP Westwood+), and TCP Yeah. We have evaluated performances of these 14 existing TCP variants with a large number of randomly generated MANET scenarios. These MANET scenarios are random and different with their number of nodes, mobility patterns, transmission and loss range, number of TCP flows etc. The evaluation is analyzed with our proposed performance ranking scheme. The evaluation is divided into two experimental setups named as phases, P-1 and P-2. The Phase-1 (P-1) selects 05 most promising TCP variants by evaluating 14 existing TCP variants. The Phase-2 (P-2) selects 03 most promising TCP variants by evaluating 05 TCP variants selected from Phase-1.

3.2 Performance Ranking Scheme

The performances of TCP Variants are evaluated with a ranking scheme. As TCP is an end-to-end transport layer protocol, 03 end-to-end metrics are selected with different weights as per their relevance to the data transfer perceptive. Weight 3 is for the most important parameter and Weight 1 is for relatively less important parameter. The detail is shown in Table 1.

Tab. 1. TCP Variants Performance Ranking Scheme - Parameters

Metric No.	Metric	Weight	Rank Order
1	Total Received Data	3	Ascending
2	Throughput	2	Ascending
3	Packet Delivery Ratio	1	Ascending

The value of $\boldsymbol{Rank}(\boldsymbol{TCP_i}, \boldsymbol{M_j})$ is the ascending order rank of $\boldsymbol{TCP_i}$ variant for parameter $\boldsymbol{M_j}$ among all the TCP variants. The weighted sum of all ranks of a TCP Variant $\boldsymbol{TCP_i}$, for all three parameters is its score: $\boldsymbol{Score}(\boldsymbol{TCP_i})$.

$$\boldsymbol{Score}(\boldsymbol{TCP_i}) = \sum_{j=1}^{3} \boldsymbol{Rank}\left(\boldsymbol{TCP_i}, \boldsymbol{M_j}\right) * \boldsymbol{Weight}\left(\boldsymbol{M_j}\right)$$

The final rank of a TCP variant: $\boldsymbol{Final_{Rank}}(\boldsymbol{TCP_i})$ is its ascending order rank among the scores of all TCP variants.

$$\boldsymbol{Final_{Rank}}(\boldsymbol{TCP_i}) = \boldsymbol{Rank}(\boldsymbol{TCP_i}, \boldsymbol{Score}(\boldsymbol{TCP_i}))$$

3.3 Evaluation Phase - 1

The evaluation phase-1 (P-1) evaluates performances of 14 existing TCP variants with a large number of MANET scenarios. These TCP variants are TCP Bic, TCP HighSpeed, TCP HTCP, TCP Hybla, TCP Illinois, TCP Ledbat, TCP Lp, TCP NewReno, TCP Scalable, TCP Vegas, TCP Veno, TCP Westwood, TCP WestwoodPlus (TCP Westwood+), and TCP Yeah.

The MANET scenarios with number of nodes (05 to 50) are categorized according to the level of mobility, congestion and transmission issues. All these 03 parameters are defined as 03 levels: Low, Medium and High. To include all combinations, total 27 main categories are defined. Each of these 27 categories has 50 scenarios which are different in terms of mobility, congestion and transmission issues according to their respective levels. So total distinct network scenarios are 27 * 50 = 1350. Each scenario is evaluated for different TCP variants. Every scenario has a randomly selected number of TCP flows according to the respective level of congestion. The total TCP Flows among all scenarios is 63882. Total 14 TCP variants are evaluated and so total scenarios are 1350 * 14 = 18900. Each scenario was evaluated for 60 Seconds and so total simulation time was 18900 Minutes (315 Hours). A summary is shown in Table 2.

Tab. 2. Evaluation Phase-1

ID	Per TCP Variant				All TCP Variants			
	Total Scenarios	TCP Variants	TCP Flows	Simulation Time (Hours)	Total Scenarios	TCP Variants	TCP Flows	Simulation Time (Hours)
P-1	1350	1	4563	22.5	18900	14	63882	315

3.4 Evaluation Phase - 2

The evaluation phase-2 (P-2) evaluates performances of 05 existing TCP variants (TcpVegas, TCP WestwoodPlus, TcpLp, TcpYeah, and TCP NewReno) selected from evaluation phase-1. This phase has MANET scenarios with randomly selected number of nodes (05 to 100), level of mobility, congestion (number of TCP flows) and transmission issues. This phase has 10000 MANET scenarios with total 126215 TCP Flows. Total 05 TCP variants are evaluated and so total scenarios are 10000 * 05 = 50000. Each scenario was evaluated for 60 Seconds and so total simulation time was 50000 Minutes (833.33 Hours). A summary is shown in Table 3.

Tab. 3. Evaluation Phase-2

ID	Per TCP Variant				All TCP Variants			
	Total Scenarios	TCP Variants	TCP Flows	Simulation Time (Hours)	Total Scenarios	TCP Variants	TCP Flows	Simulation Time (Hours)
P-2	10000	1	126215	166.66	50000	5	631075	833.33

4. PERFORMANCE ANALYSIS

4.1 Evaluation Phase – 1 Analysis

The performance analysis of phase-1 is shown in table 4 and figure 1. As per our TCP variant performance ranking scheme, the most promising five TCP variants (in descending order) are TCP Vegas, TCP Westwoodplus, TCP LP, TCP Yeah, and TCP NewReno.

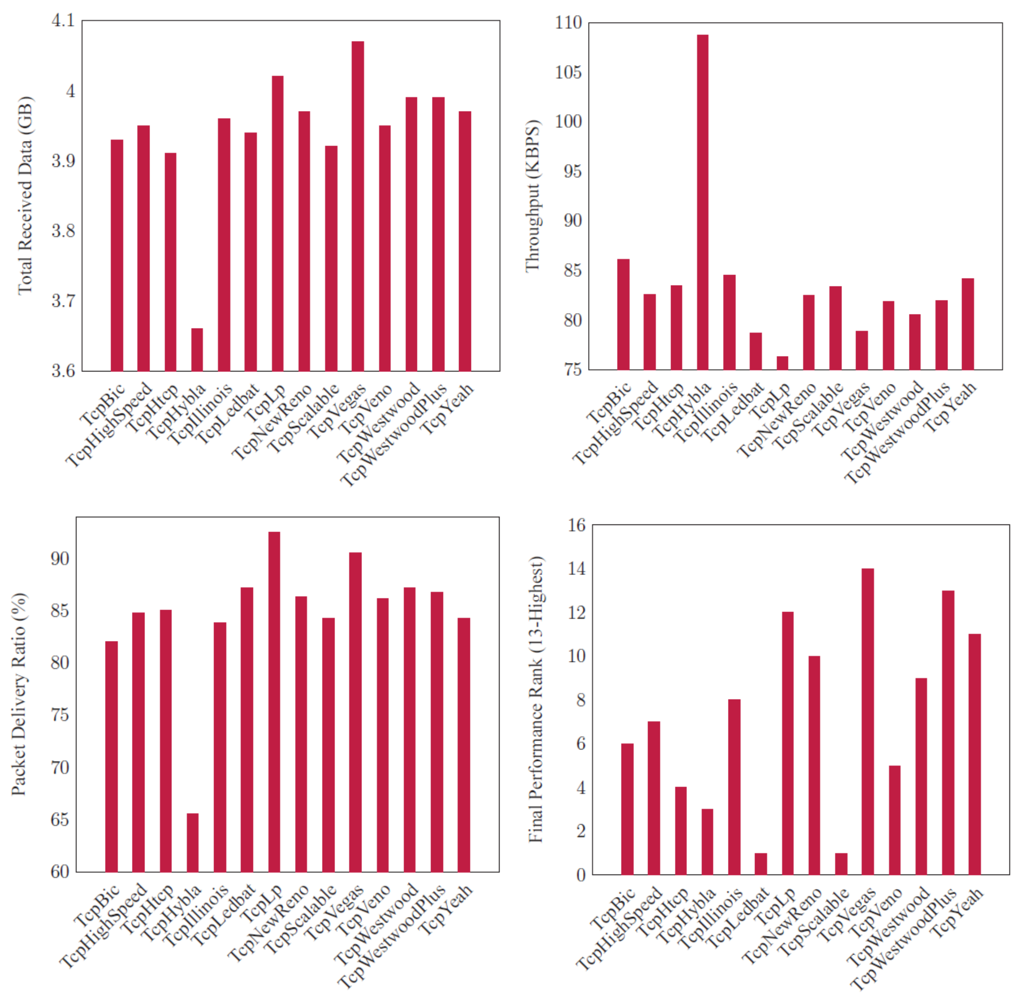
Tab. 4. Performance Analysis Phase-1

Evaluation 1	Total Received Data (GB)		Throughput (KBPS)		Packet Delivery Ratio (%)		Final Rank	
T - TCP Variant	Value(M1)	Rank(T,M1)	Value(M2)	Rank(T,M2)	Value(M3)	Rank(T,M3)	Score(T)	Final_Rank(T)
TcpBic	3.93	4	86.15	13	82.01	2	40	6
TcpHighSpeed	3.95	7	82.57	8	84.75	6	43	7
TcpHtcp	3.91	2	83.44	10	85.01	7	33	4
TcpHybla	3.66	1	108.71	14	65.57	1	32	3
TcpIllinois	3.96	8	84.49	12	83.87	3	51	8
TcpLedbat	3.94	5	78.70	2	87.17	12	31	1
TcpLp	4.02	13	76.31	1	92.54	14	55	12
TcpNewReno	3.97	10	82.46	7	86.29	9	53	10
TcpScalable	3.92	3	83.35	9	84.26	4	31	1
TcpVegas	4.07	14	78.85	3	90.52	13	61	14
TcpVeno	3.95	6	81.87	5	86.13	8	36	5
TcpWestwood	3.99	11	80.56	4	87.14	11	52	9
TcpWestwoodPlus	3.99	12	81.94	6	86.72	10	58	13
TcpYeah	3.97	9	84.2	11	84.27	5	54	11

Tab. 5. Performance Analysis Phase-2

Evaluation 2	Total Received Data (GB)		Throughput (KBPS)		Packet Delivery Ratio (%)		Final Rank	
T - TCP Variant	Value(M1)	Rank(T,M1)	Value(M2)	Rank(T,M2)	Value(M3)	Rank(T,M3)	Score(T)	Final_Rank(T)
TcpLp	217.165	2	34.01	1	80.42	5	13	1
TcpNewReno	219.801	3	37.22	4	73.74	2	19	3
TcpVegas	221.858	5	35.52	2	76.12	4	23	5
TcpWestwoodPlus	220.119	4	36.58	3	74.45	3	21	4
TcpYeah	216.807	1	40.50	5	69.57	1	14	2

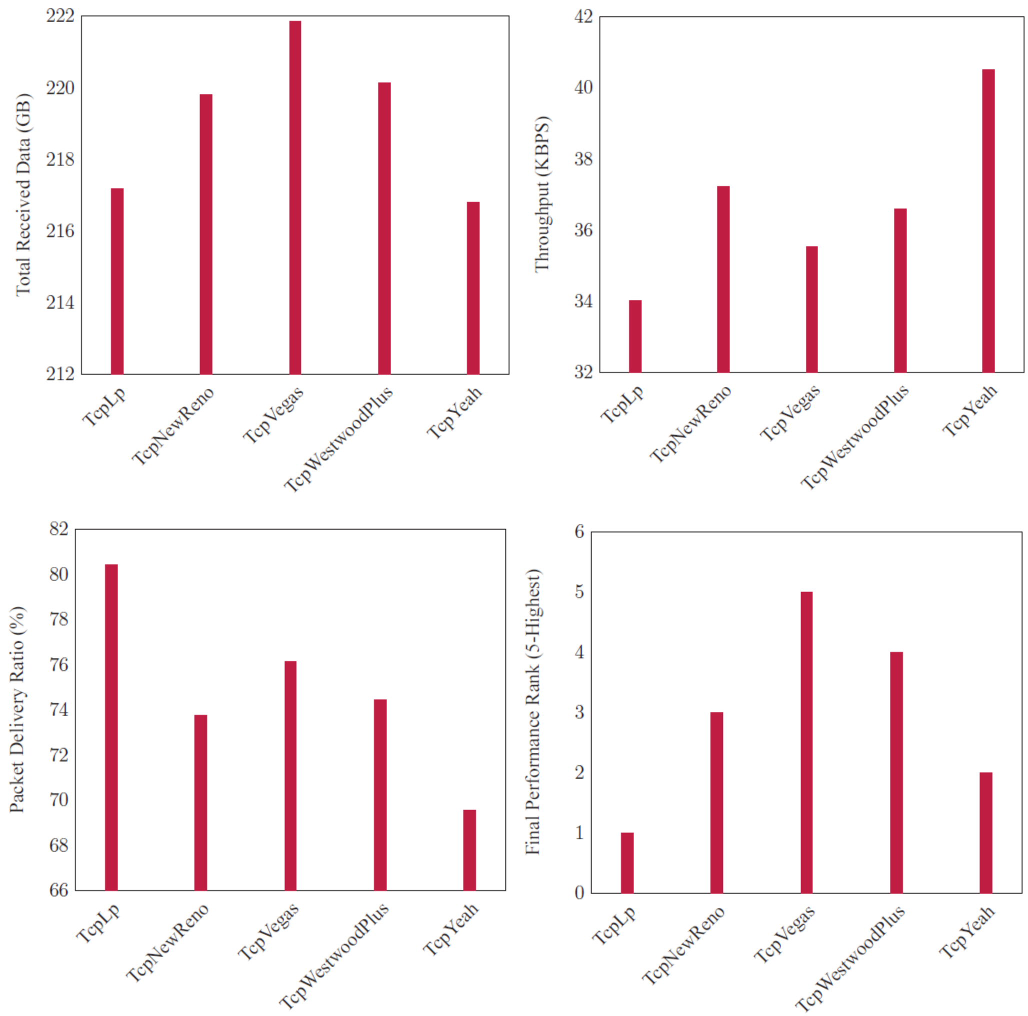
Figure 1. Performance Analysis Phase-1



4.2 Evaluation Phase – 2 Analysis

The performance analysis of phase-2 is shown in Table 5 and Figure 2. As per our TCP variant performance ranking scheme, the most promising three TCP variants (in descending order) are TCP Vegas, TCP WestwoodPlus, and TCP NewReno.

Figure 2. Performance Analysis Phase-2



5. CONCLUSION

The performance analysis of TCP remains an active area of research over the years. Researchers have proposed different TCP variants for different type of networks and to address various issues such as congestion control, loss management etc. It is necessary to evaluate performances of various TCP variants systematically with a large number of network scenarios for accurate analysis. We have proposed a performance ranking scheme to identify most promising TCP variant based on three end-to-end metrics: Total received data, Throughput, and Packet delivery ratio. 14 TCP variants are evaluated on a large number of MANET scenarios with this scheme. We have observed that on average most promising three TCP variants (in descending order) are TCP Vegas, TCP WestwoodPlus, and TCP NewReno. This scheme can be used for other types of networks with more TCP variants easily. It can be further improved with additional metrics easily...

References:

1. W. Richard Stevens. Tcp/ip illustrated, vol. 1: The protocols. Addison-Wesley Professional Computing Series, 2000.
2. James F. Kurose and Keith W. Ross. Computer Networking: A Top-Down Approach. Pearson, 6th edition, 2012.
3. Kamel H. Rahouma, Mona Sayed Abdul-Karim, and Khalid Salih Nasr. Tcp/ip network layers and their protocols (a survey). Internet of Things-Applications and Future, pages 287-323, 2020.
4. Ghassan A. Abed, Mahamod Ismail, and Kasmiran Jumari. Exploration and evaluation of traditional tcp congestion control techniques. Journal of King Saud University - Computer and Information Sciences, 24(2):145-155, July 2012.
5. B. Qureshi, M. Othman, and N. A. W. Hamid. Progress in various tcp variants. 2nd IEEE International Conference on Computer, Control and Communication, pages 1-6, 2009.

6. Maurizio Casoni, Carlo Augusto Grazia, Martin Klapez, and Natale Patriciello. Implementation and validation of tcp options and congestion control algorithms for ns-3. Proceedings of the 2015 Workshop on Ns-3 - ACM, pages 112-119, 2015.
7. Kriti Nagori, Meenakshy Balachandran, Ankit Deepak, Mohit P. Tahiliani, and B. R. Chandavarkar. Common tcp evaluation suite for ns-3: Design, implementation and open issues. Proceedings of the Workshop on Ns-3 - ACM, 2017.
8. W. Stevens. Tcp slow start, congestion avoidance, fast retransmit, and fast recovery algorithms. RFC 2001, 1997.
9. M. Allman, V. Paxson, and W. Stevens. Tcp congestion control. RFC 2581, 1999.
10. Lisong Xu, K. Harfoush, and Injong Rhee. Binary increase congestion control (bic) for fast long-distance networks. 4:2514--2524 vol.4, 2004.
11. Sally Floyd. Highspeed tcp for large congestion windows. RFC 3649, 2003.
12. Carlo Caini and Rosario Firrincieli. Tcp hybla: A tcp enhancement for heterogeneous networks. International Journal of Satellite Communications and Networking, 22(5):547–566, 2004.
13. Douglas Leith and Robert Shorten. H-tcp: Tcp for high-speed and long-distance networks. 2004.
14. Claudio Casetti, Mario Gerla, Saverio Mascolo, M.Y. Sanadidi, and Ren Wang. Tcpwestwood:End-to-end congestion control for wired wireless networks. Springer-Wireless Networks, 8(5):467-479, 2002.
15. Siddharth Gangadhar, Truc Nguyen, Greeshma Umapathi, and James Sterbenz. Tcp westwood(+) protocol implementation in ns-3. Proceedings of the 6th International ICST Conference on Simulation Tools and Techniques, pages 167--175, 03 2013.
16. Lawrence S. Brakmo, Sean W. OMalley, and Larry L. Peterson. Tcp vegas: New techniques for congestion detection and avoidance. SIGCOMM '94 the conference on Communications architectures, protocols and applications, pages 24--35, 1994.
17. Tom Kelly. Scalable tcp: Improving performance in highspeed wide area networks. ACM SIGCOMM Computer Communication Review, 33(2):83–91, 2003.
18. Cheng Peng Fu and S.C. Liew. Tcp veno: Tcp enhancement for transmission over wireless access networks. IEEE Journal on Selected Areas in Communications, 21:216-228, 2003.
19. Andrea Baiocchi, Angelo P. Castellani, and Francesco Vacirca. Yeah-tcp: Yet another highspeed tcp. 2007.
20. Shao Liu, Tamer Başar, and R. Srikant. Tcp-illinois: A loss and delay-based congestion control algorithm for high-speed networks. page 55–es, 2006.
21. Douglas Leith and Robert Shorten. H-tcp: Tcp for high-speed and long-distance networks. 2004.
22. S. Shalunov and G. Hazel. Low extra delay background transport (ledbat). RFC 6817, 2012.
23. Aleksandar Kuzmanovic and Edward W. Knightly. Tcp-lp: Low-priority service via end-point congestion control. IEEE/ACM Transactions on Networking, 14(4):739–752, 2006.
24. Hardik K. Molia and Amit D. Kothari. Tcp variants for mobile adhoc networks: Challenges and solutions. Wireless Personal Communications - Springer, 100:1791-1836, June 2018.
25. Hardik K. Molia and Amit D. Kothari. Fuzzy logic systems for transmission control protocol. Proceedings of the 2nd International Conference on Communication, Devices and Computing, Lecture Notes in Electrical Engineering, 602:553-565, 2020.
26. Hardik K. Molia and Amit D. Kothari. Tcp with machine learning - advances and opportunities. International Journal of Advanced Trends in Computer Science and Engineering, 8:3526--3534, December 2019..