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Effective Utilization of Bandwidth for Mobile Ad Hoc Network

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Abstract

Background: A Mobile Ad hoc Network is self-configuring and infrastructure less system or network for mobile devices. Unavailability of infrastructure is common in the situations like Military war fields, disaster relief, sensor networks and Wireless mesh network. The prime objective of this paper is to understand the behavior of different TCP implementations on various mobility models of MANET for selecting the best TCP. **Methods:** Adequate simulations and its analysis are must before practically implementing and commissioning any system. The simulations are carried out using network simulator and Bonn motion as simulation tools, which are very much effective tools in this kind of scenario creation. Different mobility patterns common in MANET were generated using the mentioned tools. Parameters chosen are majorly comparable with real networks of MANET. **Findings:** Each node in a MANET is permitted to move autonomously in any direction sand this way changes its connections to different nodes most of the time. In these kinds of networks, congestion occurs in any intermediate node when data packets travel from source to destination and they incur high packet loss and long delay, which causes the performance degradation of a network. Congestion control is an issue that is taken care at transport layer. So the efforts are made to analyze the performance of most reliable protocol of transport layer: Transmission Control Protocol (TCP). The congestion control algorithm was thoroughly studied for finding the scope of improvement for TCP in MANET. The experimental results show that TCP Westwood NR gives high performance in case of throughput and congestion window utilization with low latency because of its ability to calculate the available bandwidth in most of the scenarios. So it is the most suitable transport layer protocol for effective utilization of channel bandwidth in wireless/MANET scenario. **Application/Improvements:** TCP is inseparable part of File Transfer Protocol, Web browsing, remote login, e-mail and video conferencing. It uses Internet Protocol so it can seamlessly applicable over satellite networks. Westwood NR of TCP can be enhanced with its congestion control and filter implantation to achieve high performance in MANET.

Keywords: Bonn Motion, MANET: Mobile Ad hoc Network, Network Simulator 2, TCP: Transmission Control Protocol, UDP: User Datagram Protocol, Westwood NR

1. Introduction

In today's scenario, various methods and applications have been utilized in general to transmit data through heterogeneous remote systems. Classification of wireless networks broadly falls in two categories, infrastructure network and ad hoc network. MANET (Mobile Ad hoc Network) systems are the autonomous systems that communicate through wireless links for multi hop communication. Ad hoc networks have few advantages like cost effectiveness, moderate network maintenance and very convenient scope of service[1]. Congestion may take place if the traffic is more than the network capacity. This can result increased delay and loss of data, which can result further in reduction of throughput. Throughput is an important parameter to measure rate of successfully delivered data over communication channel. This is measured in bits per second (bps) and it is the most important performance parameter for measurement of efficiency of any network. Degradation in throughput can result in reduction of majority of performance measures for networks which are either wired or wireless. The paper discusses the behavior of different TCP implementations on MANET. This requires setting the simulation parameters for Mobility Model and Traffic Generation as well as the Network Simulator. TCP was

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designed by keeping wired networks in consideration. The modifications were employed, so as to improve the behavior of TCPs. The different versions for TCP are discussed in following section.

2. Transmission Control Protocol

TCP/IP is well known, broadly proven and readily accepted protocol suit. Objective of the transport layer protocols is to incorporate the message from the application layer of the source host to the destination host[2]. To fulfill this objective two very widely used conventional protocols are utilized, which are TCP (Transmission Control Protocol) and UDP (User Datagram Protocol). These protocols are characterized on transport layer for making process to process communication possible. While TCP is the most reliable protocol for making end to end communication between two hosts possible, UDP support non-reliable and connectionless services to transport layer. TCP is the best suitable protocol for applications that prefer accuracy over prompt delivery like, control information related to the flow control, congestion control and error control. Majority of wireless network applications always rely on TCP for communication this is possible with TCP-dominant and wired hosts, it is likely that TCP will remain as the major transport protocol for the clients of 802.11 networks[3].

Heart of TCP is its congestion control algorithm. TCP's congestion control mechanisms have been developed and enhanced over a period of time, from basic TCP Tahoe to the latest generally utilized TCP Reno imolementation[4] like NewReno[5] and SACK[6]. TCP Tahoe has slow start and congestion avoidance algorithm, Reno supports fast retransmission and fast recovery, whereas SACK gives SACK block information for lost data. Number of issues for TCP Reno have been realized, when it has been observed that their throughput corrupts in very high speed networks and wireless channels[7].

Few of the TCP's proactive versions like, TCP Westwood NR[8], TCP Veno[9] and New Jersey[10], are perticularly designed to improve the flow control and so avoid packet losses from certain network parameters estimation.

Performance of three TCPs is evaluated for Mobile Ad-hoc Networks (MANET). The results are focused on the evaluation of performance for TCP Westwood NR (TCPW). TCP Westwood NR is a sender-side modification of the TCP's basic congestion control algorithm which enhances the behavior of TCP Reno in any remote, wired and wireless networks. The performance is proved to be the best in wireless systems and satellite link with the loss prone connections. TCPW is not exceptionally sensitive to random drops while TCP Reno is extremely sensitive to random drops. TCPW is designed to have track of duplicated and delayed acknowledgements. Estimation of bandwidth based on available channel capacity is explained next.

2.1 Bandwidth Estimation for TCP Westwood NR[8,11]

TCP Westwood NR is designed to calculate available bandwidth for a particular connection. It uses this information on two of the cases one that is after loss episode and second is for time out occurrences. TCPW is the modified implementation of TCP Reno. It enhances the congestion window control and back off process. TCPW sender consistently monitors the rate of acknowledgment reception and from that it estimates rate of data currently achieved for a particular connection. Whenever sender perceives the loss either by getting 3 duplicate acknowledgements or time out, the sender applies its calculated estimation for bandwidth. This helps to calculate congestion window (cwnd) and slow start threshold (ssthresh). TCPW avoids conservative reduction of congestion window and utilize the available bandwidth. It preserves the fairness and friendliness properties of TCP. The simulation results presented in section 4 confirm high performance of TCPW compared to other TCP versions. TCPW implements the bandwidth estimation as discussed in next paragraph.

On the occurrence of 3 DUPACKS TCP Westwood NR applies calculated ssthresh based on estimated bandwidth i.e. ssthresh = (BWES*MinRTT) /segment_size and set cwnd=ssthresh, in similar manner after any Timeout occurrence ssthresh and cwnd are made applicable and the algorithm enters in the slow start phase. If ssthresh calculated is less than 2 the algorithm will set ssthresh to 2. It is significant to understand how bandwidth is estimated. Main focus of TCP WestwoodNR was how to derive the estimation of bandwidth i.e. BWES. The bandwidth estimation is performed using a first order low-pass filter[12]. The transfer function of first order low pass filter is $\frac{\overline{\chi(s)}}{\chi(s)} = \frac{1}{1+\tau_f}$

This results in simplification of first order low pass filter implementation which is used for bandwidth estimation.

$$\bar{x}_k = \alpha \bar{x}_k \quad + (1-\alpha)\frac{\qquad}{f \quad s} x_k$$

With τ_f as time constant and *Ts* is the time between each and every measurement possible, it is the sampling interval in other words. This can be mentioned for TCPW's bandwidth estimation as mentioned below.

On (reception of ACK)

smpl_BWES[n] = (data_ack*data_packet_size*8)/(prsnt_time - prv_acktime);

BWES[n] = α_{k*}BWES[n-1]+(1-α_k) *(smpl_BWES[n]+smpl_BWES[n-1]);

Endif

Analysis of Westwood NR showed that average value of α_k is around 0.99. Thus it can be said that value of estimated bandwidth is all dependent around of 99% on the present value of b_{k-1} and only just 1% of the recent value of b_{k-1}. Since the architecture of cellular towers plus wireless access points are not compulsorily highly deployed due to the costs or geographic limits, hence only number of nodes is engaged in communication with each other. Creation of MANET in real scenario is not an easy task. First the structure should be implemented and evaluated on simulator for validation. The selection of different models and protocols should be made possible by using most suitable simulators. So it's important to understand different simulation steps for MANET implementation using simulators.

3. Simulation of MANET

One testing tool is never enough evident for any system to get widely adapted. So the experiments carried out with simulators must be verified with real scenarios also. Simulator is program that makes a computer enabled for executing programs which are written to get executed on different platforms. MANET simulator is a system that is designed to provide the reasonable reproduction of experimental set up and implementations for node being mobile node or any other complex network system used for experimental purposes. Simulation of MANET requires few steps to be performed as shown in Figure 1.

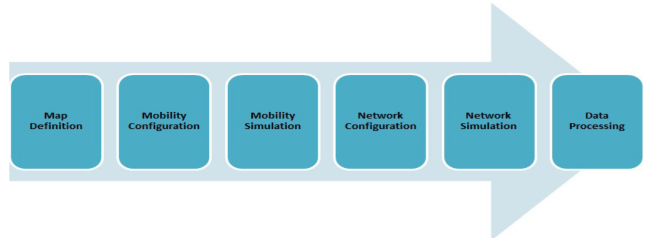

Figure 1. MANET simulation steps.

- It requires map on which simulation will take place.
- Then mobility pattern for the nodes is to be defined.
- Mobility traces creation.
- Once this is done network parameters and mobility simulation are available for network simulator configuration.
- The data processing based on performance aspects is done finally.

There are two major problems in carrying out simulation of MANET, one is its complexity with validation base simulation and existing simulation tools and second is lack of common criteria in defining the simulation tools. The goal of the transport layer is to transfer the message from the application layer of source host to that of the destination host. To target this objective, two conventional protocols, TCP (Transmission Control Protocol) and UDP (User Datagram Protocol) are characterized at this layer. While TCP provides end to end and most reliable services between two hosts, UDP support a non-reliable connectionless transport layer services. TCP is perfect for application that lean toward precision over brief conveyance for the most part, control data identified with the stream control, congestion control and controlled services over the Internet. So the most essential qualities of TCP are evaluated. Simulation set up basically needs three different simulators for MANET implementation 1. Mobility simulators; they focus on generating different mobility traces, 2. Network simulators, which is involved in data exchanges between network nodes and 3. Integration of all features of the first two types. The next section is focused on the mobility and traffic models for MANET. In addition to this brief discussion of their simulators has been done.

3.1 Mobility Model and Traffic Generation

The efforts are initiated to analyze the TCP implementations on MANET. Creation of algorithm that is suitable for MANET largely depends on critical parameters of nodes and the authentic mobility model for keep on forwarding the data packets to next node[13]. It is compulsory to set a realistic model for mobility, the parameters such as map structure, density and speed, urban or geographic conditions including obstacles such as buildings and trees need to be accounted. Basic methodologies applied in the mobility model are mentioned below three of them are chosen in analysis[14].

- The Randolemem Waypoint model ("RandomWaypoint")
- The Manhattan Grid model ("ManhattanGrid")
- Static scenarios ("Static")
- Static scenarios with drift ("StaticDrift")
- Random Street ("RandomStreet")
- Random Direction Model ("RandomDirection")
- Random Walk Model ("RandomWalk")
- Chain model ("ChainScenario")
- The Reference Point Group Mobility model ("RPGM").

Similarly traffic simulators can generate realistic trace of traffic which can be used as an input to network simulator. Traffic simulators generate traces containing node locations and timing details. Examples of widely used open source traffic simulators are SUMO, MOVE, BONN MOTION, STRAW and CityMob. Commercial one is PARAMICS[15]. Network Simulators play the vital role in creation of MANET. For selection of appropriate network simulator very keen literature survey was done. Different network simulators like JiST and OMNeT++ are capable to handle very large-scale network simulations in very efficient way[16]. In contradiction for very small scale implementations the ns-2 is sufficient enough. ns-2 has huge library for utilization and modules can easily be implemented. It is easy and simple to use in comparison to other network simulators[17].

4. Simulation Set Up and Results

Simulations for evaluation of the three widely used TCPs were done in different mobility pattern. The experiments were done for selection of appropriate Routing Protocol and to find best mobility model. Then the experiments were carried out for three of above mentioned mobility models, which are the Randolemem Waypoint model ("RandomWaypoint"), The Manhattan Grid model ("ManhattanGrid") and The Reference Point Group Mobility model ("RPGM")[14,20]. These three models are feasible cases of MANET for implementation. In following section the results for TCP evaluation in different scenario are discussed.

It was primarily required to set the parameters for traffic and networks simulators for smooth simulation according to the most happening cases in MANET.

Table 1. Traffic simulator parameters

Parameters	Value
Number of nodes	10, 40, 70, 100
Scenario duration	300 Sec
Width of simulation area	900 m
Height of simulation area	900 m
Pause time	0.00

Bonn Motion was chosen as traffic simulator. The parameters have been selected based on the traffic scenarios available for MANET. For different number of nodes the simulations were carried out. And three mobility models were evaluated in presence of TCP traffics.

Table 2. Network simulator parameters

Parameter	Value
Number of node	10, 40, 70, 100
Channel type	Wireless
Routing Protocol	AODV, DSDV, DSR
Interface queue type	Priority Queue
Queue length	50 packet
Dimension of the Topology	900 * 900
Time of the simulation end	300 Sec
Traffic type	TCP
Transport Layer Protocol	Reno, SACK, Westwood
Speed	40m/s
MAC Protocol	IEEE 802.11

Similarly Table 2 mentions the network simulation parameters which have been chosen in very widely used network simulator ns-2. Simulation of different routing protocols showed that AODV (Ad hoc On-Demand Distance Vector Routing) gives best performance in most of the conditions as it discovers route on required basis via route discovery process. AODV always adopts different techniques for maintaining routing table entries. So it gives better performance compared to DSR and DSDV[18,19]. The simulations were done for 900 m*900 m area.

4.1 Comparison for Routing Protocols

Routing is needed for selecting the best path even across the network. It is critical to choose best routing protocol for any wired or wireless network. The different routing protocols have been analyzed for selection of best routing protocol. The experiments were done on ns-2 and repeated fifteen times for consistency check.

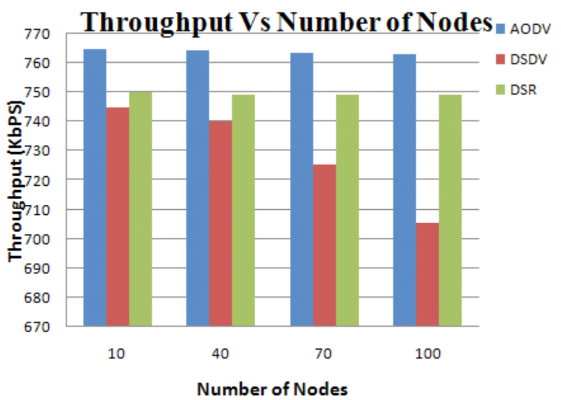

Figure 2. Comparisons of different routing protocols.

The plot in Figure 2 shows that the throughput of AODV routing protocol is better than the other two very popular and widely used routing protocols. AODV continuously discovers the rout based on requirement. It is adoptable to different techniques for route discovery[20]. This makes the protocol most efficient. Throughput is a vital parameter for any network measurement so it is included in the results. On the basis of this evaluation the remaining experiments were done with AODV as routing protocol[21].

In following section the comparison of TCP flavors are discussed in different mobility scenarios for MANET. Throughput is rate of data successfully travel communication channel. This is measured in data per second and is the most important parameter for any network performance. So the results are discussed with its regards. Congestion window, Round Trip Time, packet delivery ratio and number of retransmissions can be the other parameters for accessing the network performance. Out of the methodologies mentioned for creation of mobility in above discussion three have been included here. The analysis was done for 1. Randolemem Waypoint model ("RandomWaypoint") 2. The Manhattan Grid model ("ManhattanGrid") and 3. Reference Point Group Mobility model ("RPGM").

4.2 Performance Evaluation of TCP Implementations for Random Waypoint

In this scenario nodes move randomly either in 1D, 2D, 3D or 4D for their Random Waypoint behavior. Movements can be specified with several attraction points which are concatenated and separated by commas. E.g. to place two attraction points on (100, 100) and (350, 200) with intensities 1 and 1.5, in addition to this the standard deviations 20, 20 and 31, 35 can be implemented with the use of: -a 100, 100, 1, 20, 20, 350, 200, 1.5, 31, 35.

The parameters mentioned for traffic and network simulators are discussed in previous section are chosen for simulation purpose.

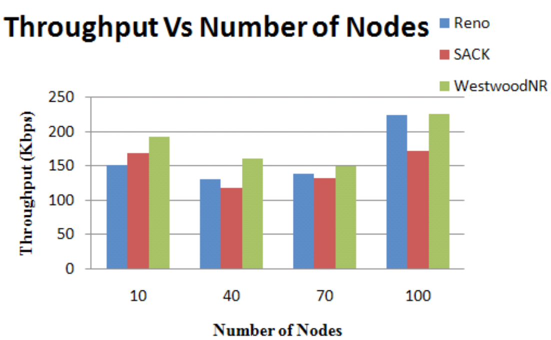

Figure 3. Throughput comparison of TCPs for random waypoint model.

Node movement in random fashion results in to the different throughput for simulations carried out. So simulations were repeated for fifteen times. Performance of TCPs versions were evaluated for different mobility model. Random Way Point was implemented using the traffic and network simulators. Congestion control algorithm for TCP was designed for wired networks and then enhanced for wireless behavior. So its basic versions like Tahoe, Reno, New Reno and SACK does not perform in the way TCP WestwetwoodNR[22] does. The plots shown in Figure 3 shows superior behavior of TCP Westwood NR because of its ability to utilize available bandwidth.

4.3 Performance Evaluation of TCP Implementations for Manhattan Grid Model

In Manhattan Grid model involved nodes move only on predefined paths. The arguments can be set for number of blocks between the paths. In addition to this minimum speed for a mobile node can be introduced. Even pause time can be the important parameter which can be added.

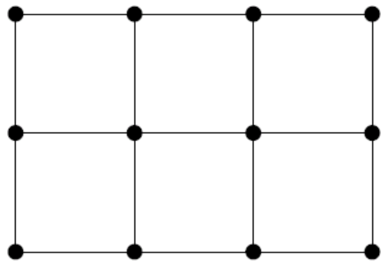

Figure 4. Manhattan grid.

The Figure 4 shows the typical Manhattan Grid, Which has the path on which the mobile nodes can travel. This model is in general used for urban areas.

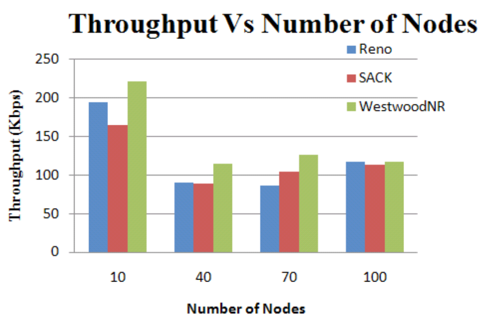

Figure 5. Throughput comparison of TCPS for Manhattan grid model.

In this model for mobility nodes cannot move in random fashion. They have systematic movement of nodes. The traffic was introduced for 10, 40, 70 and 100 nodes. As per increase in number of nodes the behavior difference between the TCP implementation decreases. They all behave in same manner as opportunity to utilize available resources becomes saturated. Still TCP Westwood NR is fair enough for sharing common resources. Increase in nodes can result in to less probability of link failures, because of number of increase in intermediate nodes. This does not allow the nodes to break communication. And the algorithm for TCP Westwood NR does not get chance to play role. Figure 5 indicates the performance of TCPs involved is compatible for all involved TCPs.

4.4 Performance Evaluation of TCP for Reference Point Group Mobility Model (RPGM)

In case of RPGM mobility model nodes are allowed to move in the group. This model has some dynamic groups, whenever node comes in the area of another allocated group it can change its belongingness to this new group with probability that can be set with "-c <probability>". This can be deactivated in future with "-c 0" option. When this feature is activated, "empty" groups may be moving along the simulation area and nodes coming into their areas may change their memberships to other.

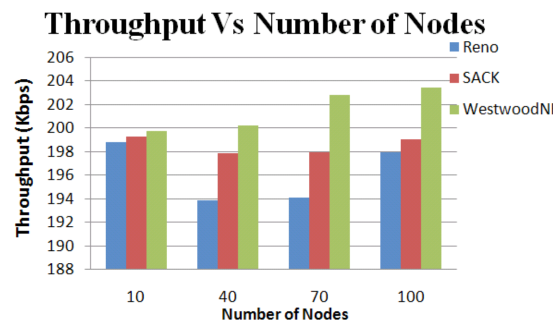

Figure 6. Throughput comparison of TCPs for RPGM model.

The plots of Figure 6 show the behavior of three TCPs for RPGM model. The two nodes assigned the different TCP traffic flows they can be in same or different groups. The TCP Reno and SACK always decrease the congestion window to half of its working congestion window on loss episode. But TCP Westwood NR adjusts its ssthresh and congestion window according to its available bandwidth with fairness and friendliness properties. The effectiveness of TCP Westwood NR with increase in involved nodes has been improved which could never achieved in previously discussed two mobility models. The performance difference between the three implementations is also noticeable.

4.5 Comparison for Mobility Models

In the last set of experiment the three mobility models were evaluated using AODV as routing protocol. RWP, Manhattan Grid and RPGM are the most commonly used mobility models for Ad hoc networks. So these models were implemented. To find out the best behavior in wireless scenario the simulations were executed. The comparison for throughput was done by introducing TCP traffic that is TCP Westwood NR as traffic generation protocol. RWP and Manhattan Grid give considerable performance. But the RPGM model where nodes are distributed in groups the performance of this Mobility model is outstanding.

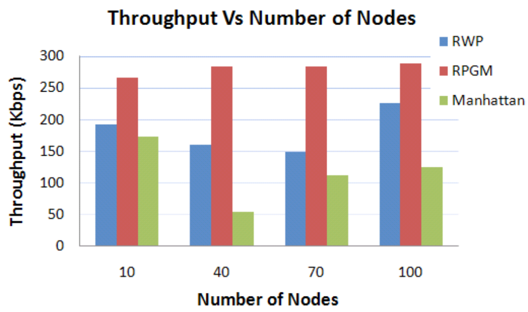

Figure 7. Throughput comparison of mobility models.

RWP gives 56.74% performance difference from Manhattan Grid model, whereas RPGM gives107.31% more throughput from Manhattan Grid. These two mobility models give considerable throughput which further results in decrease in end to end delay, can increase PDR and CWND utilization can be improved. PDR, end to end delay and CWND utilization can be other parameters for performance measurement[23]. The difference in performance is noticeable that is shown in graph of Figure 7. RPGM could be the better option for mobility model generation compared to RWP and Manhattan Grid Model. Similarly the other mobility models available can also be evaluated and analyzed in presence of different traffics.

5. Conclusion and Future Work

TCP Westwood NR has the ability calculate the available bandwidth for a particular connection. It is a sender side modification for TCP. For wireless scenarios loss due to link failure is most common where effective utilization of bandwidth is always an issue for other versions of TCPs. TCP Westwood NR can be modified for calculating the available bandwidth for a particular connection on reception of each acknowledgement for most efficient use of resources. Dependency on currently received data can be increased compared to previously received data. In that way filter performance can be improved.

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7. References

1. SenthilKumaran T, Sankaranarayanan V. Early congestion detection and adaptive routing in MANET. Egyptian Informatics Journal. 2011 Nov; 12(3):165–75.
2. Postel JB. RFC-793: Transmission control protocol. IETF. 1981 Sept.
3. Nahm K, Helmy A, Jay Kuo C-C. TCP over multi-hop 802.11 networks: Issues and performance enhancement. Proceedings of the ACM MobiHoc; Urbana-Champaign, IL, USA. 2005 May. 277-87.
4. Richard Stevens W. TCP slow start, congestion avoidance, fast retransmit and fast recovery algorithms. RFC. 2001.
5. Hoe JC. Improving the start-up behavior of a congestion control scheme for TCP. ACM SIGCOMM, Computer Communication Review. 1996 Aug; 26(3):5–21.
6. Fall K, Floyd S. Comparisons of Tahoe, Reno and SACK TCP. 1995. Available from: ftp://ftp.ee.lbl.gov/papers/sacks.ps Tsiknas K, Stamatelos G. Performance evaluation of TCP in IEEE 802.16 Networks. Proceedings of IEEE WCNC; Shanghai. 2012. p. 2951-5.
7. Casetti C, Gerla M, Mascolo S, Sanadidi MY. Westwood NR: End-to- end congestion control for wired/wireless networks. Wireless Networks Journal. Netherlands: Springer Kluwer Academic Publishers. 2002; 8:467-79.
8. Zhang CL, Fu CP, Yap Ma-Tit, Foh CH, Wong KK, Lau CT, Lai MK. Dynamics comparison of TCP Veno and Reno. Proceedings of IEEE Globecom; Texas USA. 2004. p. 1329-33.
9. Xu K, et al. Improving TCP performance in integrated wireless communications networks. Elsevier Journal of Computer Networks. 2005 Feb; 47(2):219–37.
10. Mascolo S, Casetti C, Gerla M, Lee SS, Sanadidi M. TCP Westwood NR: Congestion control with faster recovery. Conference Paper on Network Research Lab; 2002.
11. First order low pass filter derivation. Available from: https://www.google.co.in/url?sa=tandrct=jandq=andesrc=sandsource=webandcd=1andcad=rjaanduact=8andved=0ahUKEwiOsejv57HMAhVIG44KHVNtAMIQFggbMAAandurl=http%3A%2F%2Ftechteach.no%2Fsimview%2Flowpass_filter%2Fdoc%2Ffilter_algorithm.pdfandusg=AFQjCNEHm_WNlFKkYRifslSld0I817RsRg
12. Stieglitz S, Fuch C. Challenges of MANET for mobile social networks. Proceeded in Computer Science 6th International Symposium on Intelligent Systems Techniques for Ad hoc and Wireless Sensor Networks (IST-AWSN); Ontario Canada. 2011. p. 820-5.
13. BonnMotion Manual. Available from: http://sys.cs.uos.de/bonnmotion/doc/BonnMotion_Docu.pdf
14. Hussain SA, Saeed A. An analysis of simulators for vehicular ad hoc networks. World Applied Sciences Journal. 2013 Jul; 23(8):1044-8.

15. Weingartner E, vom Lehn H, Wehrle K. A performance comparison of recent network simulators. Proceedings of IEEE-ICC; Dresden Germany. 2009 Jun. p. 1-5.
16. ns-2, Network simulator, Ver. 2. LBL. Available from: http://www-mash.cs.berkeley.edu/ns
17. DinhCuong D, Van Tam N, GiaHieu N. Improving Multipath routing protocols performance in mobile ad hoc networks based on QoS cross-layer routing. Indian Journal of Science and Technology. 2016 May; 9(19). Doi no:10.17485/ijst/2016/v9i19/92304
18. Anand V, Sairam N. Methodologies for Addressing the performance issues of routing in mobile ad hoc networks: A review. Indian Journal of Science and Technology. 2015 Jul; 8(15). Doi no: 10.17485/ijst/2015/v8i15/70511
19. Sudhakar T, Hannah Inbarani H. Comparative analysis of Indoor Mobility Scenarios Creation (IMSC) in mobile ad hoc networks. Indian Journal of Science and Technology. 2016 May; 9(19). Doi no:10.17485/ijst/2016/v9i19/93830
20. Ranjan P, Ahirwar KK. Comparative study of VANET and MANET routing protocols. Proceedings of the International Conference on Advanced Computing and Communication Technologies (ACCT); 2011. p. 517-23.
21. TCP Westwood NR modules for ns-2. Available from: http://www1.tcl.polito.it/casetti/tcp-WestwoodNR
22. Senthilkumaran T, Sankaranarayanan V. Dynamic congestion detection and control routing in ad hoc networks. Journal of King Saud University – Computer and Information Sciences. 2013 Jan; 25(1):25–34.