TCP over MANET Routing Protocols: Comparative Study and a possible Improved Variant

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Abstract*—The collective term of MANET or mobile ad-hoc network refers to network nodes that are mobile and wireless in nature. Wireless communication between said nodes can be observed in a decentralized autonomous system. The protocols to be used in MANET depends on Packet Drop Rate, Capabilities of devices and other factors Reliable data transfer(Rdt) is provided by TCP making it a suitable candidate for MANETs. TCP is undesirable for ad-hoc networks and despite this revisions in TCP can take place so as to observe an improvement in performance. *This paper involves an attempt to determine which among the TCP variants perform best over MANET and a conceivable way to improvise it.
Keywords— MANET, TCP, ad-hoc

I. INTRODUCTION

It is known that TCP works better in wired networks and not much preferred in ad-hoc networks. However, for application in ad-hoc networks, TCP can be altered to enhance its execution.

The protocols to be used in MANET may vary contingent on the competence of the devices, packet drop rate and other components. Numerous existing researches have been carried out and extemporized variants of TCP by only one or two measures have been proposed. There is reason to doubt the efficacy of the techniques proposed to facilitate satisfactory analysis of improvised varieties of TCP.

In MANET when a new node enters into ad-hoc network it must state it's arrival and residence and also be attentive to the other nodes state. MANET consist of three types. They are namely, Proactive or sometimes referred to as Table-driven routing, Reactive or On-demand routing and Hybrid.

Proactive protocol consist of a segregated table for every node which has the information about all possible routes to mobile nodes in that network. Proactive consists of two main variants, the Global State Routing Protocol (GSR) and the Destination Sequenced Distance Vector Routing Protocols (DSDV). Reactive Protocol uncovers routes only when required. Two phases in reactive protocol are route maintenance and route discovery which can be further divided into the Dynamic Source Routing Protocol (DSR) and the Ad-hoc On Demand Vector Routing Protocol (AODV). Hybrid MANET protocol is adaptable in nature combining both the previous types. This identifies routes on the basis of zonal positioning and the location of various nodes.

As a result, our intention here is the evaluation of the performance of different variants of TCP and their results are obtained whilst utilizing different (DSDV, AODV, OLSR) routing protocols, and proposal of the ideal through this paper.

The focus of rest of the paper would be on the mentioned strategies, where Section 2 focuses on Literature survey, where all the related work are explained and analyzed. The next section focuses on tools used, where all the tools used for implementation are briefed upon. The next sections explain the methods and materials for our approach and the results and analysis part lead us to proposing an idea whose intentions are explained in the subsequent sections, following which conclusions are drawn.

II. LITERATURE SURVEY

In [10], the author demonstrates the basic congestion control strategy. This paper involves a comparative study of five TCP variants which include TCP Tahoe, TCP Reno,TCP New Reno, TCP Vegas and TCP Dynamic Vegas. TCP variant can be abstractly investigated and analysed extensively due to the presence of the algorithms such as Slow Start, Congestion Avoidance and Congestion Detection.

In [1,24]. Performance observations of MANET routing protocols with TCP congestion control algorithms are well depicted. The research carried out here, shows that performance of the routing protocols used proves the Quality of Service (QoS). Detailed analysis is given about QoS among all reactive protocols.There is no mention about the traffic sources, though the author concludes that optimal application of congestion control algorithms is necessary to make the network reliable along with the routing protocols, and that AODV performs well in most of the cases for ad hoc networking scenarios.

In [3], The author discusses the traditional TCP variants and various losses in MANETs and also focuses on exploring the challenges while using TCP with MANETs. Characteristics and restrictions of Cross Layered based TCP variants for route failure losses were listed by the author in a tabulated format. The author clearly states that no TCP variant provides a complete solution to all the problems in all scenarios.

The UDP traffic environment table is not clearly mentioned, in spite of an effective explanation of drawbacks related to MANETs. The paper refrains from discussion about CBR environment and hybrid protocol, which might seem to be the research gap in the particular version including analysis for networks with static nodes without any issues of link breakages caused by node mobility.

In [25], the author compares the Variants on a Qualnet simulator based on different parameters and simulation results are tabulated well. The paper analyses why transmission flow in TCP Tahoe decreases, that is when the packet loss is detected, only after the whole timeout interval. The paper tries to convey that few protocols show better response and some of them show poor responsiveness to changing network conditions and network utilization. Author in [4] concludes from simulations that performance of DSR protocol is best suited while compared with AODV for applications with large node networks were analyzed using only a few of the parameters for MANETs.

In the citations provided, delay in routing because of the route discovery process is discussed as the disadvantage of AODV. Also a bidirectional connection is needed in order to detect a single link, which is eventually neglected.

In [14], The proposed model of the author utilizes wireless resources efficiently and provides better QoS support for delay-sensitive communications as supported by the simulation results that shows it reduces the PDR and E2E delay without much impact on control overhead. In [8], the author presents a novel transport solution designed to provide 100percent reliability without completely neglecting the other factors. The obtained results from simulation seem to confirm the scalability and efficiency of CARTEE and shows that it outperforms the recent proposed transport protocols in terms of congestion avoidance, reliability, latency and data cache occupancy.

In [26], the objective of the proposed method according to the author is to achieve congestion controlled data transmission on a cross layer based MANET network. The author here has faced a challenge to distinguish a real loss of packets from an out of order delivery packet. The simulation results give an efficient result towards congestion control and helps us infer that the flow rate is also maintained by this algorithm and hence the PDR is improved.

In [4], the author analyses the existing work in the field of TCP variants Using Routing Protocols. The results indicate better performance of FullTCP when compared to Newreno and Vegas in terms of the packet delivery ratio as well as packet loss without consideration to which routing protocol was used. The shortcoming of this analysis is that, only two of the existing protocols have been analysed with just 25 nodes and hence the results may be misleading on consideration of a larger number of nodes.

We infer from [27] that quite a number of solutions have been proposed that schedule effectively and stabilize the load over the available qualified paths, still, many mentioned solutions were not able to specifically handle the needless cwnd growth adaptations. In [12], the author has put forward a new reactive routing protocol, an extension of AODV, named Mobility Aware and Dual Phase AODV with Adaptive Hello Messages - MA-DP-AODV-AHM. Building a hop between any given source - destination pair without considering the network's mobility status is the main aim of this protocol. The simulation results exemplify the superior performance of the proposed protocol over the existing AODV protocol.
A working model of AODV as a routing protocol and analyzing its performance along with enhancing the number of mobile nodes is proposed, but the proposed model is only for reactive protocols, and only AODV has been considered, which was optimized with load balancing. In a few of papers cited in the reference section, Hybrid protocols are totally ignored, and performance metrics are not included and cited as required, since we cannot conclude on the basis of one performance metric alone.

III. Methods and Materials

A wireless network is simulated, where the nodes keep moving randomly with TCP flows on the simulation topology. The analysis of TCP flows' fairness is a laborious ordeal when TCP varieties used in conjunction with different routing protocols are done solely with theoretical and mathematical formulae. Thus, the simulation of the MANET gives a progressing viewpoint helping us to infer parameters' sway on the MANET's behaviour, consequently suggesting a better theoretical solution to deal with TCP congestion control and packet losses.

Throughout the simulation, every node starts from a random source and moves to a random chosen destination. Once the destination is reached, the node takes a rest of your time in seconds and another random destination is chosen subsequently pause time. This repeats throughout inflicting continuous changes within the topology of the underlying network, totally different network state of affairs for varieties of nodes and pause times square measure generated.

Nam (Network Animator) is a tool that is used to graphically represent packet traces and the network. A network topology must be created first, in order to run a scenario. In ns2, collection of nodes and links constitute a topology. The simulator allows creation of the nodes and define the links between them using the available member functions. Basic functions are defined in the simulator class.The command ns is used to access simulator class functions. If the node does not fall in the category of a router traffic agent such as TCP, UDP etc. and traffic sources which include FTP, CBR etc. must be set up. It allows an FTP traffic source to be formed by the use of TCP in the capacity of a transport protocol or CBR traffic source utilizing UDP in the form of a transport protocol. These are done using the NSG2.1 (Network Scenario Generator) Jar file. Once the Network has been generated using NSG2.1, we can view the TCL script in the GUI available over there. Queue/DropTail/PriQueue that is the model for DSDV, is not supported by DSR, hence it is preferred to go for CMUPriQueue. DSR obeys the queue model called CMUPriQueue that is not the one specified for AODV. TCL code reflects the same.

Simulation Parameters

Parameters	Values
Number of nodes	17 and 50
Speed of nodes	5 mps
MAC Protocol	IEEE 802.11
MANET Routing Protocols	AODV,DSDV,DSR
TCP Variants	Vegas,Reno,New Reno, SACK1,FACK,Linux
Antenna Type	Omni-antenna
Signal Propagation Model	Two-ray ground
Traffic Type	FTP,CBR

A network is created with a varying number of mobile nodes and the nodes are moving with an interference of certain meters and transmission range is defined, and other parameters are defined in the interface itself. Initially (for 25 nodes), OLSR is proactive in nature and creates routes in advance thereby outperforming AODV, whereas AODV wastes time in creating routes. The overhead of OLSR does degrade its performance to a certain extent, hence creating an interference in the network and also causes loss of packets. The overhead of OLSR is small for smaller topologies

The popular Two-Ray Ground radio propagation model is used to model wireless communication. An Omni directional antenna is an antenna that allows for transmission and receiving of signals at the same capacity in every direction. In other words, an Omnidirectional antenna transmits signals in 360 degree angle. Addressing of nodes is done using IP addressing. Each nodes has its routing table that is responsible for storing details of neighbouring nodes. AODV supports unicasting and multicasting within a uniform framework. Every route has a lifetime associated with it that causes its expiry after a set period of disuse.

Mobility models are used to represent patterns in which the mobile nodes conduct their movement. As location, velocity and acceleration change with time coupled with the variations in movement of each node. The integral role played by said mobility patterns in ascertaining the performance of a protocol, as a result, it is essential for said mobility models to accurately simulate the movement patterns of the selected networks. Incremental updates are sent to avoid excess traffic. Networks that change quickly often show full dumps due to the capability of incremental packets to grow large in size.

A source with no conceivable route to the destination was considered. When said node comes into possession of data packets that it requires to send to the destination, a RouteRequest packet is initiated. This is flooded throughout the network. Whenever a node receives a RouteRequest packet, it rebroadcasts that packet to the neighbouring node in case it has not been re-transmitted already. This takes place in the sole scenario that the node in consideration differs from destination node and the Time To Live(TTL) counter of the packet has not been exceeded.

TCP Variants are simulated over AODV, DSDV and DSR routing protocols and the topology and the results are to be seen here. The tabulation results for the same can be found here. Performance of TCP is influenced to a great extent by the intrinsic routing protocol. From the situation fabricated, it is apparent that as TCP variants do not possess an inherent mechanism in which it can be made aware of the route re-establishment period, degradation in throughput due to a large delay in packet transmission can occur.

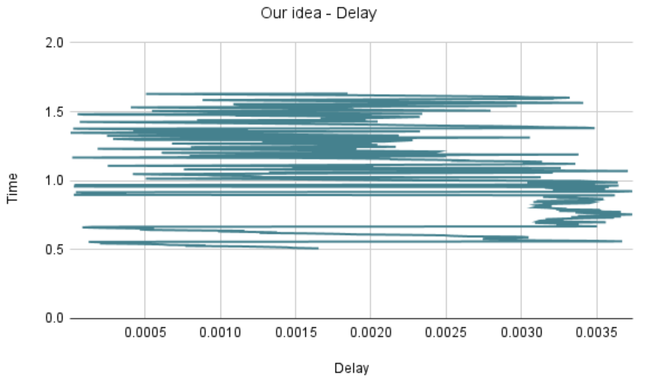
A. *Proposed Idea*

In our comparison model, we simulated the wireless network topology for 50nodes and we have analyzed the results carefully which indicate DSDV achieves least End to End Delay while used with any TCP variant, and that AODV with Vegas, DSDV with Reno perform well on respective parameters.

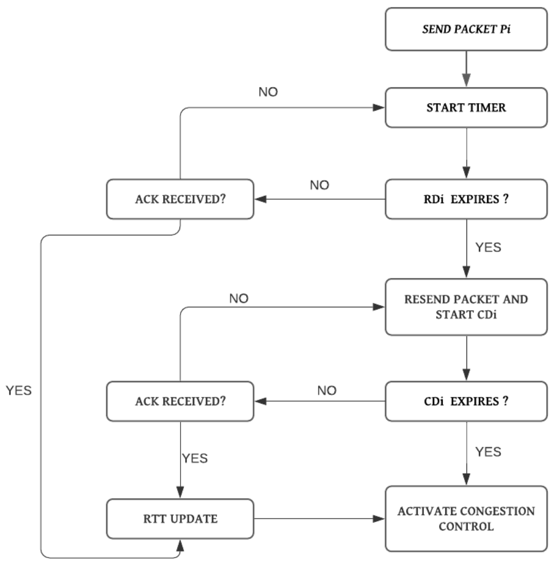
The proposed model which we have named Hybrid Reno aims to serve the primary purpose of the achievement of data transmission appropriately implementing congestion control paired with the medium of a MANET of the cross-layer type. From the analysis and results, it is inferred that in data link layer, there would be packet traffic since a shared channel is used. The portion of Medium Access Control of the data-link layer computes the intensity of traffic congestion. Since contention is also controlled by RTT, it will also lead to packet loss. A certain set of values may be assigned to each packet, for guaranteeing delivery of packets and also for recovering of these packets. The proposed model communicates with the link layer so as to infer a suitable transmission rate in order to appropriately favor congestion avoidance. So as to successfully calculate the net delay of the link layer, it is imperative that every node along the path plays a part in the computation of the available bandwidth. To measure the total delay from link layer, every intermediate node participates in calculation of available bandwidth. It must be implemented for every intermediate node, hence would be severely difficult in case of high mobility networks. In order to implement this, IEEE 802.11 MAC protocol must see its header's option field reach an appropriate modification thus enabling the propagation of the estimated bandwidth and information regarding delays from sender to receiver. This might also reduce the self-interference between packets and IEEE MAC 802.11 Control Packets. Minimum of all the estimated bandwidth, evaluated after configuring each of the intermediate nodes is sent to to TCP sender as part of MAC header of the ACK. Thus,Hybrid Reno can be capable of more accurately calculating the transmission rate . The cross-layered varieties of TCP though possibly the more accurate option tend to be rather complex and are far from easy to implement.

The Hybrid Reno attempts to make appropriate changes to the congestion control mechanism used as a result of its ability to enable packet reordering and issues regarding loss of a channel as well. In the model, a clear separation is shown between the ideas of the mechanisms handling retransmission of packets from the mechanisms handling congestion control. Two separate timers are established namely, the Retransmission Decision

Timer and the Congestion Response Decision timer.



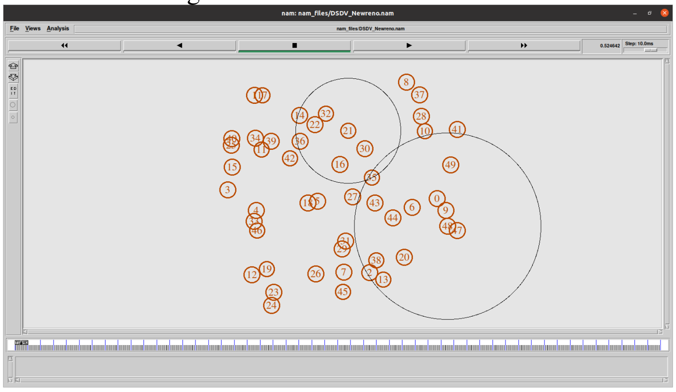
They respectively trigger the retranmission and congestion control mechanism. The model proposed works on the following algorithm.Initially, a packet labelled Pi is sent which starts off the RDi timer. If an ACK is received for the packet labelled Pi, the RDi timer has its count reset. Once that iteration of the Rdi timer expires, the packet labelled Pi is retransmitted and the CDi timer has its count begun. Once an ACK is received for the packet labelled Pi, the CDi timer may be reset and thus consequently it triggers congestion control. Since the algorithm works on the values of RD and CD, the role of these are very critical. Based on the RTT values, the values of RD and CD keep changing dynamically.



IV. Implementation and Results

A. Tools Used

1) NS-2: NS2 is a networking simulator used in research events which aims to provide help in protocols simulation consisting of wired and wireless networks. The simulator is based on UNIX and utilizes TCL as a scripting language.Being an open source simulator has its own pros as it can be freely and extensively used for investigation in network transmission of nodes.



2) NS-3: The primary purpose of ns-3 is to provide an protractible network simulation application. It visualises and simulates working of packet data. Performing impractical and burdensome system computations while scrutinizing them in a rigid environment is the primary application of ns-3.

3) NAM: Network animator is animation tool utilizing Tcl/Tk for providing simulation of network traces dealing with actuality. Various inspection tools for data, animation at packet level and different architectures are in built in it. Network animator is a convenient tool due to its association with Network simulators. It is also able to provide details about the protocols when a simulation is done albeit data from actual network traces can directly be visualised with its help.

4) GNUPLOT: For the plotting of functions ,GNUPLOT is useful tool as it also provides interface which is driven by user command. GNUPLOT allows construction of 2- and 3-dimensional plots of inputs such as functions and data points.

B. Analysis and Results

After a thorough simulation, we plotted graphs for all the parameters in consideration, mentioned in table. Throughout the simulation, every node makes its way to a random spot, subsequently to an arbitrary destination.

Packet Delivery Rate Comparison of TCP

TCP Variant	Best Performance	Worst Performance
FACK	DSDV	DSR
Linux	DSDV	AODV
Reno	DSDV	-
New Reno	DSDV	DSR
SACK1	DSDV	DSR
Vegas	DSDV	AODV

After reaching the destination the node chooses another random destination to travel to. This repeats causing variable changes within the topology of the network. The general circumstances and scenarios for varieties of nodes and pause times square measure is also generated.We infer, after analysing the graph generated for DSDV-TCP Reno with the parameters time and delay, that delay varies between 0 and 1 for time 20-30seconds for a fixed number of nodes.

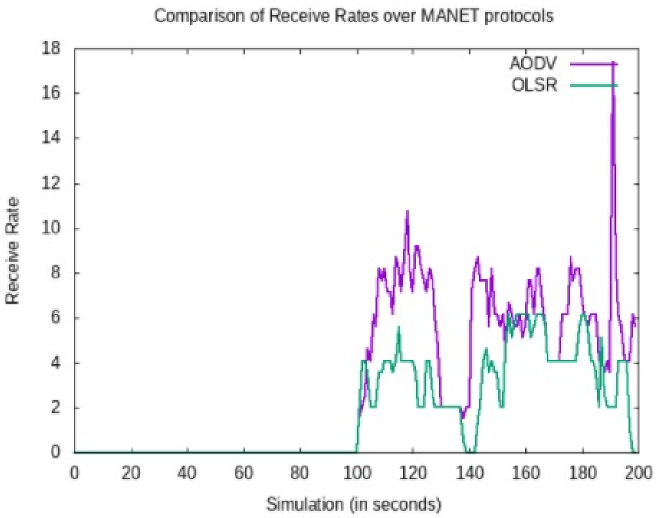
Packet Delivery Rate Comparison of MANET

Routing Protocol	Best Performance	Worst Performance
AODV	Vegas	SACK1
DSR	-	SACK1
DSDV	Linux	Vegas

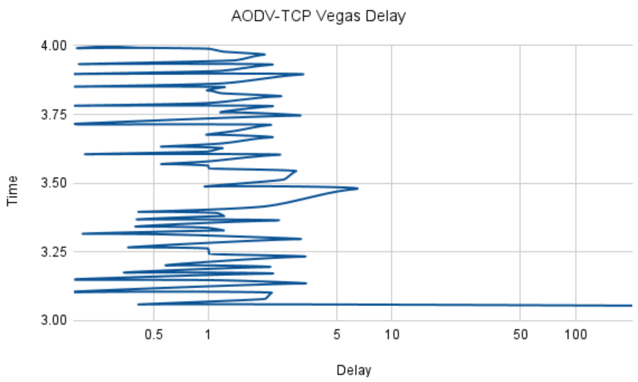
End to End Delay Comparison of MANET

Routing Protocol	Best Performance	Worst Performance
AODV	Vegas	SACK1
DSR	Linux	SACK1
DSDV	Reno	SACK1

Based on our simulations results , we have tabulated the conclusion on comparison of MANET based on packet delivery ratio and end to end delay. It is observed that TCP Vegas has best performance under AODV in terms of both packet delivery ratio and end to end delay. It is also observed that TCP SACK1 has the least performance under all routing protocol with respect to both metrics.



The statistics for packet receive rates were analysed using the graph plotted, which lead us to a conclusion that when nodes propagation delay increases, DSDV is less superior than DSR.

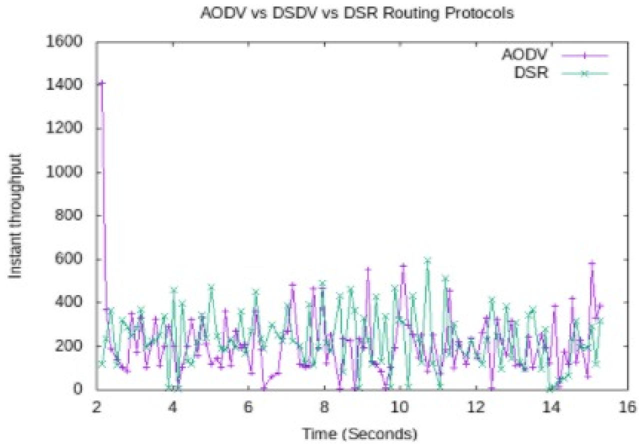


We infer, after analysing the graph generated for AODV-Vegas with the parameters time and delay, that delay varies between 0 and 10 for a specified time for a fixed number of nodes.

Packet Receiving Rate of MANET

Variant	Standard Deviation	Mean
AODV	2.442978728	13.8752
DSDV	3.45439366	9.626
DSR	4.723490988	11.264

The graphs plotted using the gnuplot based on the results retrieved from trace files by writing an AWK script, helps us in a thorough understanding of the performance of various TCP variants over the considered MANET routing protocols. From our simulations and results, DSDV-Reno combination tends to have a higher average throughput when compared to any other MANET-TCP protocol combination. Thorough analysis of the three protocols based on the instant throughput helps us infer AODV is better than the other 2 protocols being compared here, since DSR and DSDV have slightly lower throughput. While analysing the residual energy for the mentioned protocols, AODV is observed to have the highest residual energy.



AODV has high average end to end delay followed by DSR and then DSDV which has the least. A decline in the performance of AODV is apparent observably as a result of an increase in the count of nodes resulting in an increase in the load of routing table exchange as well as an increase in the frequency of exchange brought upon by node mobility. Average End-to-End Delay as observed seems to be the least for DSDV and does not change even if the number of nodes are increased.

The end to end delay and performance have an inverse relationship. The end to end delay comparison has been tabulated below, where we observe that DSDV has the best performance with every TCP variant considered, and AODV predominantly performs the worst, as analyzed from the results tabulated.

End to End Delay Comparison of TCP

TCP Variant	Best Performance	Worst Performance
FACK	DSDV	AODV
Linux	DSDV	AODV
Reno	DSDV	DSR
New Reno	DSDV	DSR
SACK1	DSDV	AODV
Vegas	DSDV	AODV

V. Conclusion

Following a thorough analysis of the performance of the established variants of TCP, TCP Vegas was found to outperform its peers especially in the metrics of average throughput as well as average delay instant throughput. Considering this TCP based traffic , following the analysis of the performance of the various established MANET routing protocols of the present day while ensuring the consideration of uniform sets of scenarios for mobility for each version which comprised of speed of the node and variability in the overall count of the nodes whilst carrying out variation in the routing protocol, AODV was found to perform better than the other routing protocols , owing to its maintenance of connection as a result of periodic information exchange. DSDV is observed to be best suited for networks with high density and low latency, due to its low average end-to-end delay.

Fairness of the established varieties of TCP with special reference to wireless and mobile networks was computed in the scope of our simulation, by utilizing six variants of TCP used over four routing protocols which also included the randomized sharing of FTP connections by every node. From the experimental simulations we have concluded that TCP Reno outperforms other variants under DSDV routing protocol based on the end-to-end delay comparison, TCP Vegas was found to outperform the other variants when used in conjunction with the AODV routing protocol when packet delivery rate was considered as the main metric.

Recent times have seen the proposal of several rather advanced versions of TCP that mainly focused on efficient control and handling of loss. Despite the large number of proposed variants of TCP for MANETs, it appears that a complete solution that addressing every problem in every scenario remains deficit. Each proposed variant appears to be limited to a specific problem set or superior performance localized to very specific scenarios. As a result, a silver bullet TCP solution is still missing. The requirement of a complete and general solution supports future research opportunities especially with regards to efficient handling of loss.

As no one TCP Variant has proven itself as a silver bullet encompassing and rectifying every shortcoming in every scenario of MANETs, a combined solution of multiple proposals could prove itself to be an appropriate TCP variant in a generic use case.Thus, we attempted the fabrication of a TCP variant created following the modification of a set of palpable properties over the implementation of a decision making technique utilizing RTT. The question remained whether TCP should initiate transmission which consequently influences the network layer to begin route discovery or whether TCP must await the network's taking of necessary action. Our modification involved the retransmission of lost packets. In the case that a packet was lost as a result of issues faced by wireless transmission consequentially a requirement does not exist to see a reduction in transmission rate. In the case that a packet was lost as a result of contention issues, reduction in transmission rate was warranted for a period of time in order to influence a reduction in channel contention. However, we have achieved an approximate 15 percent improvement in performance with respect to end to end delay.

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