PERFORMANCE ANALYSIS OF ROUTING PROTOCOLS AND TCP VARIANTS UNDER HTTP AND FTP TRAFFIC IN MANETS

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ABSTRACT

MANET stands for mobile ad-hoc network that has multi-hop and dynamic nature, where each station changes its location frequently and automatically configures itself. In this paper, four routing protocols that are OLSR, GRP, DSR, and AODV are discussed along with three TCP variants that are SACK, New Reno and Reno. The main focus of this paper is to study the impact scalability, mobility and traffic loads on routing protocols and TCP variants. The paper results shows that the proactive protocols OLSR and GRP outperform the reactive protocols AODV and DSR with the same nodes size, nodes speed, and traffic load. On the other hand, the TCP variants research reveal the superiority of the TCP SACK variant over the other two variants in case of adapting to varying network size, while the TCP Reno variant acts more robustly in varying mobility speeds and traffic loads.

KEYWORDS

MANET, Routing Protocols, TCP Variants, Mobility.

1. INTRODUCTION

The requirement for exchanging data information over the wireless environments in the recent years is rapidly growing. There is an increasing demand on connections to access the Internet; therefore there is a need for reliable and effective routing protocol and transmission control protocol (TCP) to guarantee a reliable end-to-end data packet transmission of the information across the wireless and MANET networks, here the key problem in MANET is to find and choose reliable, effective and accurate routing protocol that plays optimal role for selecting the best route. In MANET, TCP is still required due to its commonly used for achieving the integration very smoothly through the current global Internet. The traditional TCP does not perform well on MANETs and it raises serious performance issues. Therefore, several TCP variants were designed for MANET applications. The objectives of this paper are to get accurate perception and finding the best behavior of the MANET reactive, and proactive routing protocols under mobility, scalability and heavy, medium and low traffic load with hypertext transfer protocol (HTTP) traffics, and TCP variants under mobility, scalability and heavy, medium and low traffic load with file transfer protocol (FTP) and HTTP traffics. The main contribution of this paper is to find the effect of different scenarios on the routing protocols and the TCP variants. Many research studies have been carried out for the performance evaluation of routing protocols and TCP variants regarding scalability and mobility by the use of network simulators such as NS-2 and OPNET. In [1] performance evaluation of MANET routing protocols have been done

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with packet delivery fraction and end-to-end delay, where AODV has the best all round performance. DSR is suitable for networks with moderate mobility rate. It has low overhead that makes it suitable for low bandwidth and low power network. Mobility kinds have been specified and implemented in [2] where the mobility of node affects total performance of the routing protocols. The research in [3] evaluate the performance of DSR routing protocol under CBR and TCP variants. Research in [4] integrated a discussion on protocols of dynamic source routing (DSR), ad-hoc on-demand distance vector (AODV), TORA and OLSR, regarding scalability and mobility, where OLSR was the most favorite proactive routing protocol, while AODV has been designated as the most effective on-demand protocol for MANET scenarios. The author in[5] also evaluate the performance of different TCP variants such as Tahoe, Reno, New reno and SACK under different node speeds and its effect on Throughput, End to end delay, FTP download response time and FTP upload response time. Also MANET TCP optimization has been investigated in many studies [6, 7]. Due to intolerance mechanisms of TCP in dealing with link failures, this leads to incapability of distinguishing the difference between network congestions and link failures in MANET. Many research addressed the TCP performance problems due to route failures in MANETs [8]. A study conducted in [9] regarding the Westwood, TCP Reno, and BIC-TCP demonstrated the superiority of Reno variant over the others. However it lacked in recognizing different realistic scenarios with one source of TCP traffic was simulated in this research. The research in [10] discussed the performance evaluations of Reno, Tahoe, New Reno and SACK in different MANET realistic scenarios under the conditions of fading, signal attenuation, and multipath. It was shown here that TCP Reno version overcame the other congestion control algorithms regarding throughput, congestion window, and goodput.

This paper analyzes the impact of scalability, mobility and traffic loads on routing protocols and TCP variants. The paper results shows that the proactive protocols OLSR and GRP outperform the reactive protocols AODV and DSR with the same nodes size, nodes speed, and traffic load.
The paper is structured as follows. In the next section routing protocols types is discussed and presented along with the TCP variants. Section 3 discusses the performance parameters and software environment. Section 4 shows the simulation results that illustrates the performance of routing protocols. Finally the last section presents the conclusions.

2. ROUTING PROTOCOLS AND TCP VARIANTS

2.1 Routing Protocols

Routes in ad-hoc networks are enabled using multi-hop between the network nodes in a restricted wireless radio propagation range. When the nodes are busy in traversing packets over MANET, they are not aware of the network topology. Therefore to facilitate the communication and discovering the network topology in the network, many network management routing protocols has been used to determine the best routes from the source to the destination node. Basically, routing protocols in MANET are categorized into three groups, reactive routing protocols, proactive routing protocols and the combination of both protocols known as hybrid protocols [2].

2.1.1Reactive (On-demand) Routing Protocols

On-demand routing protocols are another name for the reactive protocols, where there are no pre-defined routes between the network nodes. When a transmission is required a source node demands for the route discovery mechanism that depends on the flooding procedure to define a fresh route, where the source node transmits to all of its neighbor nodes only its data packet, and intermediate nodes basically forwards the same data packet to their neighbor nodes until it reaches the destination node. Briefly reactive techniques have higher latency but shorter routing.

AODV and DSR routing protocols are discussed in more details as examples of reactive routing protocols [4].

2.1.1.1 Ad-hoc On-demand Distance Vector (AODV)

AODV's reactive approach indicates that it requests and sets up a route to destination only when it requires one to transmit data, and it does not maintain the initiated route after the transmission is finished. AODV protocol starts a broadcast route discovery mechanism to find the recent effective route to destination by using a route request (RREQ) route reply (RREP) query cycle. An AODV sender broadcasts an RREQ packet to all nodes in the network, and after receiving this packet the nodes update their information in the routing table for the sender node and initiate a route back to the sender node through the RREQ path. Then nodes unicast a RREP packet to the sender if the receiver node has an active route to the destination, otherwise, the RREQ packet is forwarded to other nodes. When there is a reply transmitted, all the nodes in that route can record the route to the destination in this packet. Because other paths can be found between the sender and the destination, the sender can receive the RREQ packet multiple times. In case of route failure, due to mobility or link disconnection a route error (RERR) packet is sent to the neighbors to inform about the broken paths, and activate the route discovery mechanism. A destination sequence number is also used for avoiding routing loops, and guaranteeing the recent routes to be selected, where the larger the number is the fresher the route is. AODV protocol is used in relatively static networks, with low byte overhead and loops free routing using the destination sequence numbers [1].

2.1.1.2 Dynamic Source Routing (DSR)

DSR's reactive approach uses source routing mechanism for transmitting data, meaning the sender must know the complete sequence of hops to reach the destination. DSR also sets up a route only when required and does not maintain routes after the transmission is finished. It consists of two parts: route discovery and route maintenance. Every network node preserves a route cache that stores all known routes, and if a desirable route cannot be found in the cache, it starts a route discovery mechanism to lower the RREQ packets broadcasted. As each node receives the RREQ packet and sees the request identifier from the sender it discards it. Otherwise it includes its address to the request list and rebroadcasts it. After RREQ reaching to the destination node, it sends back a RREP packet to the sender, including accumulated list addresses from the request. Finally after receiving the RREP packet, it caches the new route in its route cache. If a link break is detected, the sender starts route maintenance mechanism, where a RERR packet is transmitted back to the sender for maintaining the information of the route. When the sender receives the RERR packet, it starts again a route discovery mechanism. The advantage of DSR is the decrease in the overheads of the control packets of the route discovery with using route cache. On the other hand the disadvantage is that source routing can lead increase in the packet header size with route length [1].

2.1.2 Proactive (Table-Driven) Routing Protocols

Table-driven protocols are another name for proactive protocols. Where the routes between the network nodes are preserved in routing table and the data packets of the source node are transmitted over the chosen route in the routing table. In this phase, the forwarding of the data packets are done quicker, nevertheless the routing overhead is larger. Therefore, all of the routes need to be defined before transmitting the data packets, and maintained at all the times. Therefore proactive protocols have smaller latency. OLSR and GRP protocols are considered and explained [6].

2.1.2.1 Optimized Link State Routing (OLSR)

OLSR's proactive approach updates and stores at all-time its routing table. It always maintains its routing table to provide routes when required. All network nodes broadcast periodically their routing tables to permit all nodes for knowing the topology of the network. As a disadvantage of this, it generates an overhead to the network. To decrease this overhead, it limits the number of the network nodes that can pass the traffic of the network by using multi point relays (MPRs). The responsibilities of MPRs are to pass the routing packets and enhance the control flooding and its operations. MPRs selected nodes can decrease the control packet size and pass the control traffic. All network nodes select MPR group from one away neighbor hop, where each chosen MPR can reach other two hop neighbor by minimum one MPR. Each network node broadcasts periodically its selected MPR list rather than the all neighbors list. In case of broken links due to mobility, topology control packets are broadcasted over the network. All network nodes preserve the routing table that includes routes to all reachable destination network nodes. OLSR protocol does not inform the sender when there is a route failure immediately. Therefore the sender comes to know about the broken links when the intermediate node broadcasts its next packet [3].

2.1.2.2 Geographic Routing Protocol (GRP)

GRP is a position based protocol, where each node in the network knows its geographic location, its immediate nodes and the sender knows the destination position. Each node updates the location of its immediate neighbors periodically by using Hello messages. The destination node geographic location is used for routing the data packets through the network without needing network address. GRP functions without the need for routing tables. Therefore, it can reach the destination node by using the information of the physical position concerning its neighbor's nodes. Each network node defines its position by using Global Positioning System (GPS) or other positioning services, and flooding that information by quadrants nodes. The node can also return the data packet to the last previous node when the route becomes unavailable to the destination node. GRP divides the MANET network into various quadrants for decreasing the route flooding, where every node in the quadrants knows the initial position of every reachable node after the initial flooding is finished in the network [3].

2.2 Transmission Control Protocol (TCP)

Different TCP variants initially designed for the wired networks properties. TCP works with the end systems at a higher level like web servers and web browsers and many application works with TCP. Requests are used by TCP when transmitting the data for the packet loss to minimize the network congestion and rearrange the out of order packets. Although TCP is an efficient packet delivery mechanism, it sometimes leads to long delays by the use of requests for lost packets [11]. The algorithms of the TCP congestion control cannot execute efficiently in diverse networks. The standard TCP always uses more than one of the four congestion control algorithms, namely: slow start, congestion avoidance, fast retransmit and fast recovery [12]. The original design of the TCP was reliable, but unable to provide acceptable performance in a large and congested network. Three standard TCP variants namely Reno, New Reno, and SACK are discussed in this paper.

2.2.1 TCP Reno

The current three TCP variants are constructed upon the TCP Tahoe mechanisms. TCP Reno is the most widely deployed TCP variant that most operating systems used. It is similar to TCP Tahoe, but with more mechanisms for detecting the lost packets earlier. When three duplicate ACKs are obtained by the TCP Reno sender, it retransmits one packet and decreases its Slow

Start Threshold by half. Then it increases it for each received duplicated ACK. After receiving an ACK for a new data by the sender, it exits the fast recovery mechanism. The TCP Reno fast recovery mechanism is enhanced for the losses of one packet from the data window, but it does not execute well in case of multiple packets losses, where in this scenario the retransmission timer expires and causes the congestion avoidance mechanism to start with a lower throughput.

2.2.2 TCP New Reno

TCP New Reno attempts to enhance the problems of Reno. It eliminates TCP Reno's waiting retransmission timer during multiple lost packets by the use of the information included in the partial ACKs differently. Partial ACKs acknowledge several packets in the sender's window but not all the unacknowledged packets. The partial ACK in TCP Reno makes the sender exit the fast recovery mechanism. The received partial ACK through the fast recovery mechanism in TCP New Reno indicates the loss of the packet that follows the partial ACK and needs to be retransmitted. Therefore, in case of multiple packet losses partial ACKs guarantee the retransmission of the lost packets without waiting the retransmit timer to expire. After all transmitted packets are acknowledged during fast recovery phase, TCP New Reno exits the fast recovery mechanism. New Reno needs one round trip time (RTT) to sense the lost packet.

2.2.3 TCP SACK

The TCP SACK was built over TCP New Reno. It contains more functions for quicker data recovery in case of multiple packet losses. When an out of order data block is received by the receiver, it makes a hole in the buffer of the receiver. It leads the receiver to create for the packets received a duplicate ACK before the hole. It also contains the packet's first and last sequence numbers that are delivered out of order. This data information is known as selective acknowledgments (SACKs). Therefore, every ACK has a block that indicates which packets are acknowledged ensuring that the sender knows which packets are still outstanding. This TCP mechanism permits the sender to recover from the losses of multiple packets in the data window during one loss detection RTT. When the TCP sender receives three duplicate ACKs it senses a lost packet. Then it retransmits the single packet, reduces the congestion window by half, and starts the fast recovery mechanism, similar to Reno, and New Reno. A variable known as pipe is used by SACK to estimate the number of outstanding packets in the path. The pipe decreases for received duplicate ACK having a new SACK and increases for each transmission. Depending on the received SACK, the sender has a list for the lost packets, and it retransmits these packets when the pipe is lower than the congestion window. In the end, once receiving partial ACKs, the SACK sender decreases the pipe by half. SACK also runs the fast recovery mechanism once every packet in the window during fast recovery mechanism is ACK. One important disadvantage of SACK is to have no selective acknowledgment option at the receiver.

3. PERFORMANCE PARAMETERS AND SOFTWARE ENVIROMENT

Internet traffic models are required for the purpose of architecture refinement and network dimensioning. Currently, in residential and backbone access networks most of the traffic is World Wide Web (WWW), where mostly HTTP and FTP protocols are used to exchange or transfer hypertext and files together with TCP. In this paper, the discussions about the Internet traffic and TCP study has been performed by using discrete event simulator software called OPNET. With a modeled network with a size of 1,000×1,000 m^2 that includes 100, 80, 60, 40 and 20 nodes and one node specified as a server. The network nodes are sets to move with varying speeds of 10, 10-20, and 30 m/s. all the nodes are connected by using AODV, OLSR, DSR, and GRP routing protocols and traffic type of HTTP for the routing protocols scenarios. And DSR protocol with the traffic type of HTTP and FTP for the TCP variants scenarios. The parameters sets can be shown as in Table 1.

Table 1: Simulation Parameters

Parameter	Routing Protocols	TCP Variants
Simulator	OPNET modeler 17.5	OPNET modeler 17.5
Simulation time	600 seconds	600 seconds
Routing protocols	AODV, DSR, OLSR and GRP	DSR
Topology size	1,000 m × 1,000 m^2	1,000 m × 1,000 m^2
Number of nodes	100, 80, 60, 40, and 20	100, 80, 60, 40, and 20
Start and pause time	0, 50 sec.	0, 50 sec.
Speed	10, 10-20, and 30 m/s	10, 10-20, and 30 m/s
Traffic type	HTTP	HTTP and FTP
Address Mode	IPv4	IPv4
Packet size	512 bytes	512 bytes
Address mode	IPv4	IPv4
MAC type	802.11	802.11
Data rate	5.5 Mbps	5.5 Mbps
Mobility model	Random way point	Random way point
Packet Size	512 Bytes	512 Bytes

Internet traffic transports a widely range of various information resources and data services, such as HTTP, FTP, e-mail, media streams. In this paper, the HTTP and FTP traffics as the most widely traffic types used in the Internet are simulated for MANETs.

HTTP is the foundation of data communication for WWW. It plays a key role of web browsers communication with the web servers. By avoiding counterfeits and eavesdroppers, it certifies and guarantees the security of communication. The standard of HTTP is not only restricted to the exchange of the fixed information, nevertheless it can exchange and store all kinds of information. The performance evaluation of routing protocols and TCP variants in this paper is carried out under different amount of HTTP traffic such as low, medium and high. **Table 2** shows the used parameter for HTTP traffic.

Table 2: Application HTTP Parameters

Attribute	Value
Specification	1.1HTTP
Page inter-arrival time (s)	Exponential (60, 270, 720)
Page properties (bytes)	Constant (500-750-1,000), 5 small and medium image
Server selection	Browse
RSVP parameters	None
Type of service	Best effort (0)

Along with HTTP, FTP is a protocol that transfers files from any node through the Internet and other networks. The performance evaluation of TCP variants in this paper is carried out under different amount of FTP traffic as shown in **Table 3**, such as low, medium and high together with HTTP traffic.

Table 3: Application FTP Parameters

Profile Configuration	Value
Inter request time	360, 720, 3,600
File size	500, 5,000, 50,000
Symbolic server name	FTP

In order to study and analyze the overall network performance, two parameter metrics are presented to measure the effectiveness of MANET routing protocols in finding the best route to the destination, such as the average throughput and the end-to-end delay and two parameters metrics are also presented to measure the effectiveness of TCP variants such as a page response time and retransmission attempts.

3.1 Delay

The end-to-end average packet delay of the data packet is the time (in seconds) required as the source/sender node to generate and transmit a data packet across the network, until it is received by the destination node.

3.2 Throughput

The average network throughput refers to the amount of the data packets in seconds that are transmitted over a communication channel to the final destination node successfully. In this paper throughput is defined as in equation (1):

$$\text{Throughput} = \frac{\text{Number of delivered packet} \times \text{Packet size} \times 8\ \text{bit}}{\text{Total duration of simulation}} \quad (1)$$

In (1) the number of delivered packets does not only include the HTTP or FTP data but also routing protocol’s Hello, control packets and topology information.

3.3 Page Response Time

Page response time can be defined as the time that a web page needs to be displayed completely on the user’s browser. The page response time can be represented as in equation (2) [13]:

$$\text{Page Response Time} = \frac{\text{Page Size}}{\text{Minimum Bandwidth}} + (\text{RTT} \times \text{Turns}) + \text{SPT} + \text{CPT} \quad (2)$$

where page size is the size of the transmitted page measured in Kbytes, minimum bandwidth is the lowest transmission line bandwidth between the web page and the end user, RTT is the latency between sending a page request and receiving the first bytes, turns is the number of TCP connections needed to fully download a page, SPT is the server processing time and CPT is the client processing time needed to assemble and view the required page.

3.4 Retransmission Attempts

Retransmission attempts occur when the transmitted data packets are not successfully delivered to the final destination node, due to dropping or losing the packets in the network. Then the sender retransmits the data packets again. Therefore, the number of times for retransmitting the packets through the network can be defined as the retransmission attempts.

4. SIMULATION RESULTS

This subsection analyzes the performances of both routing protocols and TCP variants scenarios. For achieving the most accurate OPNET results, the simulations are repeated ten times for each scenario in all categories for the routing protocols performance, with different constant seeds of the pseudo random number generator (PRNG) [14].

4.1 Impact of nodes Scalability

As it can be notice from Figure1, the OLSR and GRP have lower end-to-end average delay on average; they set up quick connections between network nodes without creating major delays, because they do not need much time in a route discovery mechanism, where the routes are available in advance resulting lesser delay in transmission. Mainly this advantage in OLSR protocol is due to the utilizing of the MPR nodes, to permit the control messages to be forwarded to other nodes. While the information in GRP is gathered rapidly at a source node without spending a large amount of overheads, the source node still has to wait until a route to the destination node can be discovered, increasing the response time. On the other hand, both AODV and DSR protocols cannot set up the node connection quickly and create larger delays in the network. Due to the reactive approach nature of the DSR protocol, it is highly possible that the data packets wait in the buffers, till it discovers a route on its way to the destination node. In time a RREQ packet is transmitted and replied back from the receiver. Therefore, DSR protocol needs large time to determine the lowest congested route. The DSR also follows a source routing mechanism where the information of the complete route is included in the header of the data packet, causing an increase in the length of the data packet, and resulting also an increase in the delay experienced by the network data packets.

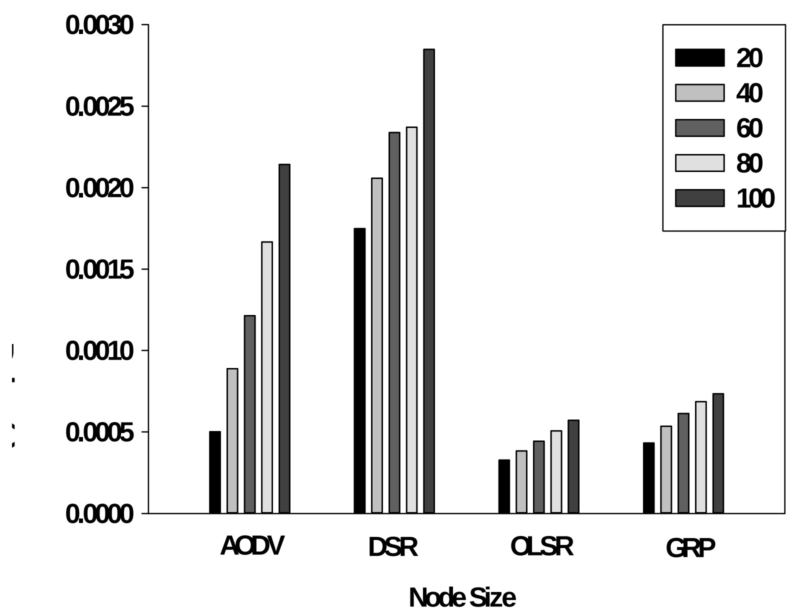

Figure 1: Routing Protocols Performance in terms of End-to-End Delay with Varying Node Size.

Figure2 shows the OLSR protocol performs better in receiving the highest throughput. Considering the AODV and the DSR as reactive protocols, the data packets received for AODV is found to be higher than DSR. The performance of DSR tends to fall after some seconds, whereas AODV is found to be more stable at the same time. As the size of the network is increased, the overall throughput increases since more nodes are available to route the data packets to the destination nodes. It is obvious that the OLSR protocol keeps overtaking other three routing protocols by achieving the highest throughput. In a large network (80 – 100 nodes), OLSR protocol continues to be dominating over AODV, DSR and GRP due to the proactive characteristics approached by this protocol. The OLSR protocol constantly sets up, maintains and updates the routing information with the assist of MPR in the network, which leads to the reduction of routing overhead in the network [15]. Likewise, GRP and AODV protocols are also desirable when the network aims for achieving higher throughputs, despite of the scalability of the network. The GRP source node predefines better routes depending on the gathered data. Therefore it always sends the data packets even if the current routes are disjointed. AODV protocol also follows a routing mechanism known as hop by hop and removes the overhead of the source routing within the network [16]. Related to above, the availability of multiple route information in the AODV assists in producing the higher amount of throughput in the network. For the DSR protocol, it receives a minimum amount of throughput even with the performance tends to be improved in case of denser network. Since the DSR protocol follows a source routing mechanism, the byte overhead in each packet extremely affects the total byte overhead when the network size increases. Therefore, the DSR protocol tends to achieve lower amount of data packets in more stressful network.

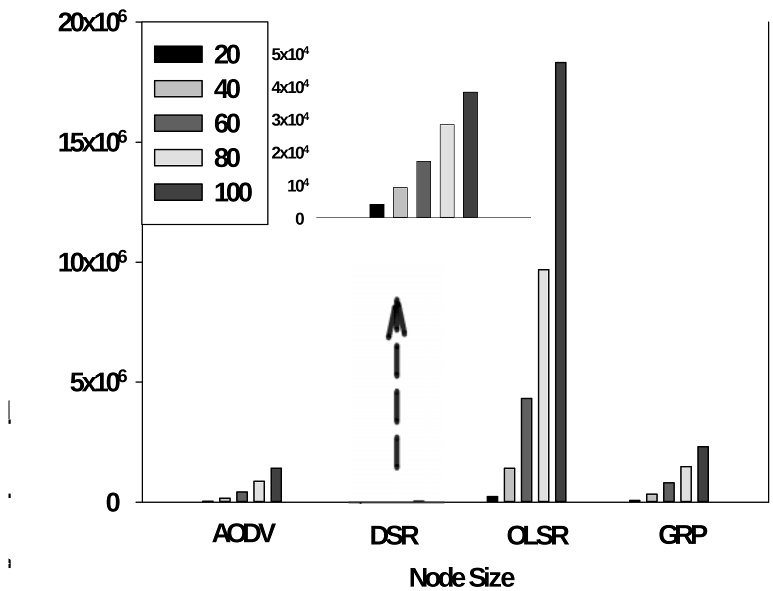

Figure 2: Performance of Routing Protocols in term of Throughput with Varying Node Size.

In Figure 3, the page response time is demonstrated for the TCP variants. The page response time increases as extra nodes are added in the network. In a small and medium network all TCP variants has almost the same page response time. On the other hand, SACK and Reno overtakes the New Reno in a large network, where more links are established, the network becomes more disposed as a result to multipath fading and signal attenuation. This situation forces the TCP to unnecessarily invoke the counterproductive and consume the time of congestion control mechanisms. This leads to performance instabilities and degradations for TCP variants. Thus extra time is needed to finish the data recovery activities, meaning more time is spent to load a web page in the existence of high number of nodes in a network. The results show that both TCP Reno and SACK achieve a shorter page response time compared to TCP New Reno especially at 100 nodes. When congestion and signal attenuation happen in the network due to the heavy load, both TCP Reno and SACK preserve a larger congestion window size and the larger the congestion window size is the shorter the web page response time is for a TCP [12].

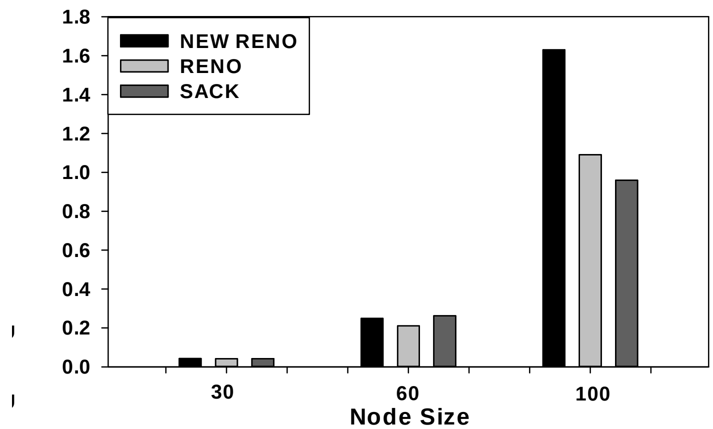

Figure 3: Average Page Response Time of TCP Variants with Varying Node Size

In Figure 4, the highest packet drops are noticed for the large network size (100 nodes) where TCP New Reno makes the highest retransmission tries, followed by TCP Reno and SACK. When the network size decreases to small size (30 nodes) and medium size (60 nodes), TCP Reno has slightly lower retransmission attempts compared to the other two TCP variants.

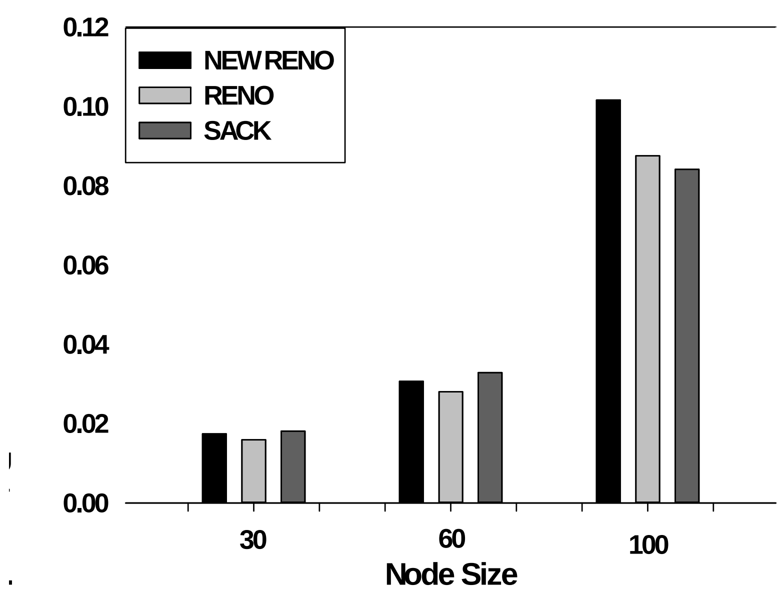

Figure 4: Retransmission Attempts of TCP Variants with Varying Node Size

In case of wired connection, the TCP retransmissions are triggered frequently because of the network congestions. As compared to the wired medium, the wireless medium provides much extra noisy physical links for the transmissions of the data. Signals spread through wireless links can experience from interference, degradation, and noise [15]. Hence more data packet is lost that leads to more retransmissions. When the number of nodes is increased, the number of retransmission attempts is also increased for the three windows based congestion control protocols. This is because of disconnection of the physical layer when the receive signals are not connected or linked to a transmitting network signal source, also the increase in the packet error rates in big size network, and the increase of the channel contention as more routing loads are experienced. In larger networks, the window mechanisms aggressive employment is counted as one of the primary factors responsible for more retransmission in TCP New Reno. Through the slow start phase, the aggressive and unsuitable window growth of TCP New Reno causes the network to be overloaded, which encourages repeated packet losses on the link layer and extra frequent timeouts in the transport layer. Therefore, repeated link contentions and many link failures happen in the MAC layers and cause an excessive number of retransmission in the network [17].

4.2 Impact of nodes Mobility

Figure 5 presents the routing protocols mobility impact as a summary. AODV protocol does not maintain the unused routes Due to its reactive approach. As an alternative, the AODV starts to search for new routes when they become needed. The purpose for this strategy is usually to generate less control traffic. Therefore it raises the networks total end-to-end delay, as the ready to send packets kept in buffers waiting until they are transmitted. Also it preserves only one route to the destination in its routing table. Consequently, anytime a route break-down occurs between the nodes in the network (due to high mobility); an additional route discovery mechanism is required each time to establish the new route [16]. Similar to the AODV protocol, the DSR protocol does not activate the route discovery mechanism frequently, because of the existence of the abundant route caches in each node. Therefore, a route discovery mechanism is not started unless all cached routes are fragmented. Nevertheless, for these caches it has a high probability to become tale in high mobility network scenario.

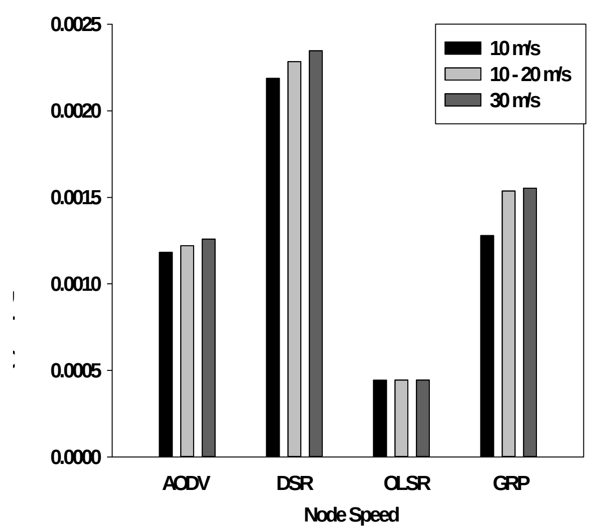

Figure 5: Performance of Routing Protocols in terms of End-to-End Average Delay with Varying Node Speed

The interference to the data traffic is also increased in the DSR network as a result to the generation of a high MAC overhead, which happens during the route discovery mechanism [18].Contrast to the AODV and DSR, the OLSR protocol does not obviously show its reaction to link breakage or failure, since it is subset of one of the link state protocols and the associated MPR nodes periodically transmit the information of the topology to different nodes within the network. Therefore, it displays the lowest end-to-end average delay comparing to the other three routing protocols. GRP protocol also shows small reaction to the link breakage or failure, because it depends on the node position information for deciding the best route. When the nodes speed increases in the network, it broadcasts its new location to the source node. Hence, by increasing the nodes speed, the local topology information gets old. Therefore GRP intelligently generates necessary control messages for tracking the nodes position, causing a higher delay than OLSR protocol.

The Figure 6 presents a comparative analysis on the throughput. When the node speed increases and moves over a specified point, it transmits a flooding packet with its new position, and it forces the GRP nodes to send the flooding packets more frequently. OLSR protocol is the highest for all mobility speeds compared to other protocols, where it successfully maintains a consistent throughput, even with higher mobility rates in the network, and it keeps its performance at a steady level. In case of increased mobility rates, many frequent changes of the node positions and their neighbor positions occur successively leading frequent changes in the link state, and as well packet losses. With low mobility rate, however, the performance of the AODV protocol is found to be slightly enhanced as the topology of the network remains almost constant for a low speed network.

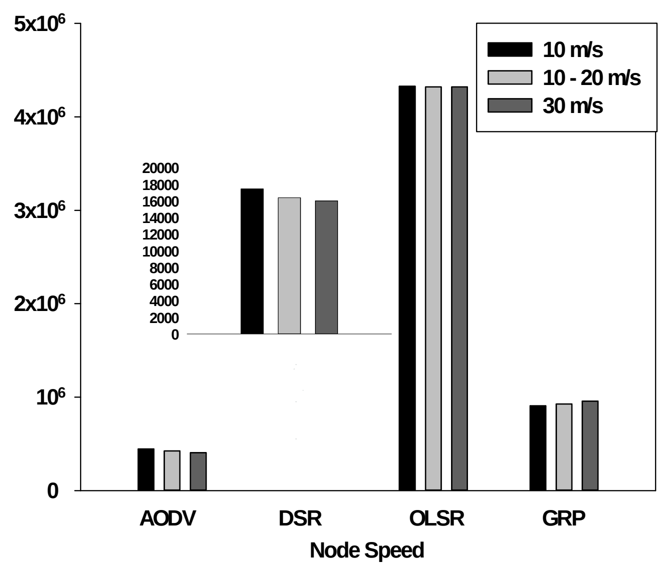

Figure 6: Performance of Routing Protocols in terms of Throughput with Varying Node Speed for (a) AODV, (b) DSR (c) OLSR and (d) GRP

Throughput of AODV protocol is lower than the throughputs of OLSR and GRP protocols at all node speeds since the routing tables are more regularly updated in response to the changes of the topology in the network, causing a fewer packet drops and less performance degradation. Likewise, the DSR protocol stored route cache can effectively be used with a lower node speed in the network. Nevertheless, in a high mobility rate presence, the DSR protocol performs the worse because of its dependency on the cache routes, which are more likely to become stale at higher node speeds. The OLSR protocol outperforms the other three routing protocols due to its ability to preserve the constant information of the network topology. It can be shown that even with a high mobility scenario, the throughput of OLSR protocol does not decrease significantly. The superiority of the OLSR protocol comes from its ability of instantly detecting the route failure and executing continuous searches for all the routes to all potential destinations. Thus the routing information is updated very quickly. In this case, the number of dropped packets is likely very low, resulting in more data packets are successfully received in the network.

The Figure 7 demonstrates the page response time of the TCP variants, the lowest average page response time is observed for TCP Reno and New Reno. For the node speed of 10-20 m/s, TCP Reno remains in accounting for the lowest page response time on average, while TCP New Reno and SACK versions need higher page response time respectively. In the higher mobility rate such as 30 m/s, the average page response time of SACK and New Reno is slightly less than that in a 10-20 m/s speed network. It can be also observed that TCP Reno always achieves lowest page response time in all mobility rates compared to others. It can be concluded that, when the node speed is increased, TCP performance does not always decrease in a wireless environment. When the node speed is set to 30 m/s, it can lead to frequent changes in the topology of the network and frequent link breakages. Nevertheless, it is also possible that it enhances the possibility for the ad-hoc routing protocol to re-establish the breakage link faster [19]. This causes the page response time for high node speed such as 30 m/s to decrease.

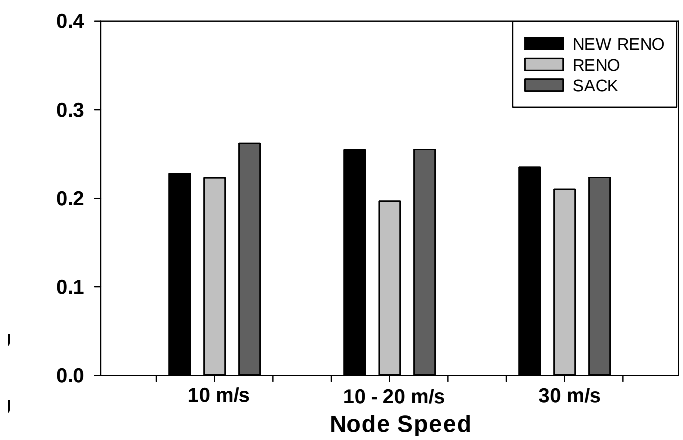

Figure 7: Page Response Time of TCP Variants with Varying Node Speed

Figure 8 show the three TCP variants in terms of retransmission attempt. It can be observed from the result of Reno that when the speed of the nodes increases to 10-20 m/s, it can lead to a decrease in retransmission attempts, while when the speed of the nodes is increased to 30 m/s; it leads to an increase in retransmission attempts. It can be conclude from the figure that the TCP Reno variant achieves the lowest average retransmission attempts rate for the low and medium node speeds such as 10 m/s and 10-20 m/s. However, TCP SACK performs the best with high node speed such as 30 m/s.

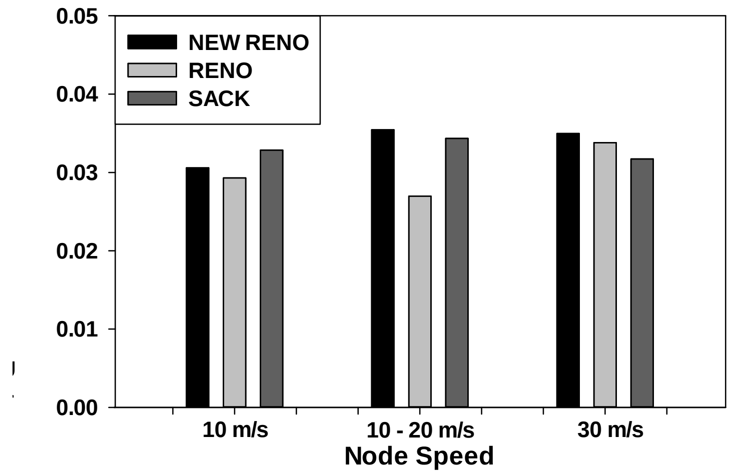

Figure 8: Average Retransmission Attempts of TCP Variants with Varying Node Speed

Wireless links suffers from wireless link failure and channel error within the wireless network. Therefore the link failures in MANET can lead to a major amount of packet losses. As a reaction to a packet loss, TCP retransmits the lost packet again. Still, in a MANET associated with a high error rate, TCP possibly will have to take multiple retransmissions to deliver a packet to its destination successfully. Also, when the mobility nodes speed is 10 m/s, the communication route can be considered quite stable, and therefore the dropped packets is few. Oppositely, in a high mobility rate such as 30 m/s, all the three TCP variants retransmit higher amount of data packets. This can be described to the fact that all of the three versions of the TCP variants are not capable of adjusting the size of the congestion window dynamically. And when link failure takes place, due to the mobility changes, all of three TCP versions mostly distinguish the packet loss through observing the TCP retransmission time-out timer. But none of them are designed to handle with such situations (link losses). Therefore they all respond similarly. But, the TCP SACK is found to be fairly more robust to the dynamics of the wireless channels. Since SACK version allows a receiver to only indicate the segments that has been received, the sender commonly retransmits only the lost segments, leading to lower number of retransmission attempts as compared to the other two versions.

4.3 Impact of Network Load

In heavy, medium and low HTTP traffic load as shown in Figure 9, the DSR illustrates higher end-to-end average delay. In the beginning of the simulation, the initial DSR delay for heavy, medium and low traffic load is pretty high. Similar to DSR, the AODV also shows higher delay than OLSR and GRP, the reason for the high delay is because of the needs of the reactive approach to discover, transmit and receive the appropriate data packets. On the other hand, OLSR presents low difference in the end-to-end average delay. The reason for the low delay of the OLSR protocol is due to is proactive nature. It does not need much time in a route discovery mechanism, as mentioned before, due to the availability of the routes in advance, and also due to the utilizing of the MPR nodes. Meanwhile, the GRP protocol collects the network information and decides the best routes at the source node. Therefore, it does not expose on delay performance for the three traffic types.

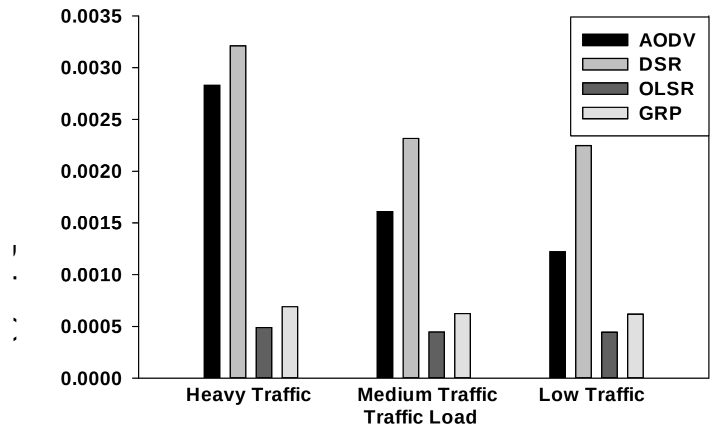

Figure 9: Performance of Routing Protocols in terms of End-to-End Average Delay with Varying Traffic Load

The results in Figure 10 show that the DSR protocol has the lowest throughput, compared to the other three protocols under heavy, medium and low load traffic. The OLSR high performance can be resulted as mentioned to the proactive approached. The results also show that when the number of packets increases for the high traffic, the AODV demonstrates better performance than GRP, because AODV protocol choses lesser number of hops per route, resulting lower dropped data packets. However, GRP maintains its throughput in the three traffic types, due to its proactive approach.

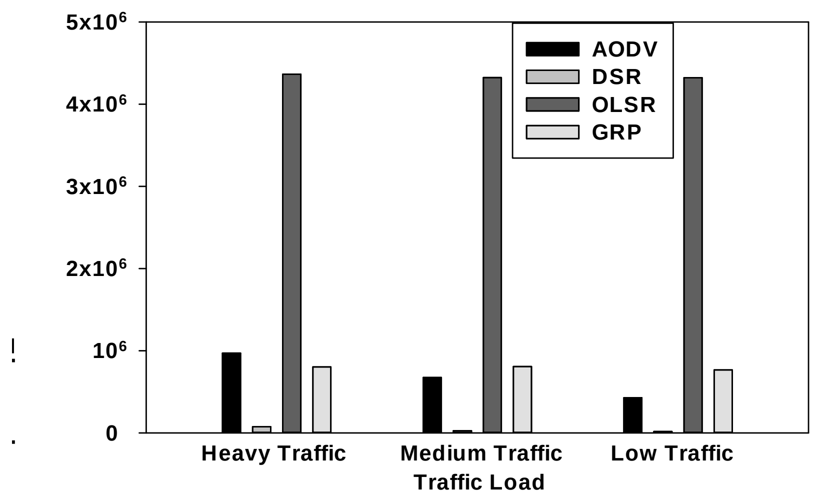

Figure 10: Performance of Routing Protocols in terms of Throughput with Varying Traffic Load

The Figure 11 illustrates that the page response time for the TCP variants when exposed to low traffic is lower than medium and heavy traffic and all the three variants have almost the same response time at the low and medium traffic. When the network traffic increases due to congestion, the page response time also increases for the medium traffic. In case of heavy traffic, all the three TCP variants show very high response time with TCP SACK as the highest one.

When there is large traffic in the network, the TCP Reno, New Reno, and SACK handles many packets dropped due to congestion. Therefore TCP forces to invoke the congestion control mechanisms, leading to performance instabilities and degradations among the three different TCP variants. Thus an extra time is needed to finish the data recovery activities, meaning more time is to be spent to load a web page in the existence of high number of nodes in a network.

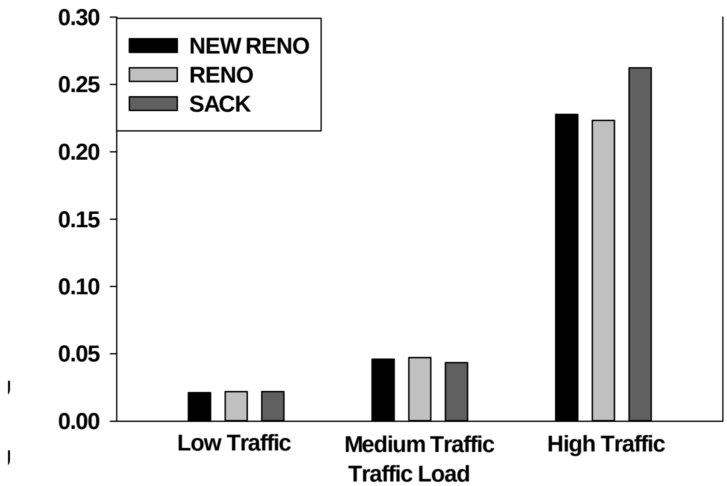

Figure 11: Page Response Time of TCP Variants with Varying Traffic Load

The performance of the three TCP variants in terms of retransmission attempt is also examined in Figure 12 illustrates that all the three variants have similar page response time in the three traffic loads. The similar retransmission attempts of all TCP variants are due to having the same packet size for all nodes, and also queuing the packets at the intermediate nodes, and transmitting to the destination without needing any retransmission by the DSR protocol at the congested networks because of large number of packets (like heavy nodes case). The purpose of that is to decrease the congestion further with the retransmissions. On the other side, when congestion is less as the low load case, the retransmission attempts are carried out to make the delivery of the packets to the destination as demonstrate in [2].

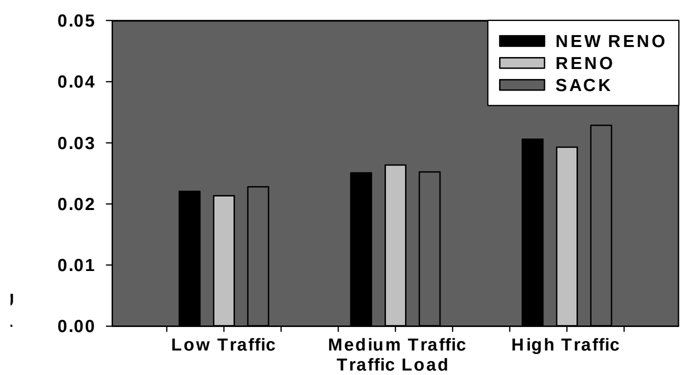

Figure 12: Average Retransmission Attempts of TCP Variants with Varying Traffic Load

5. CONCLUSIONS

This paper presents and discusses four MANET routing protocols, namely AODV, DSR, OLSR, and GRP, and the basic concepts of three commonly used standard TCP variants, namely, TCP Reno, New Reno and SACK regarding how they respond to scalability, mobility, and different traffic load. These results assist in specifying the best appropriate TCP variants and routing protocol which achieve more robust and efficient MANET under different conditions. The highest average throughput and the lowest end-to-end average packet delay performances are achieved by the use of OLSR protocol under all the scalability, mobility and traffic load conditions. The performance of GRP is acceptable when the nodes size, speed and traffic load is increased. It is observed from the results of the simulations that performance of AODV protocol decreases as the number and speed of nodes and traffic load increase. On the other hand, the DSR protocol shows an extremely low average throughput as a means of dropping more data packets, and high end-to-end average packet delay as the number of nodes, speed and traffic load increase. It can be concluded that the DSR protocol is limited for small networks with low mobility. In summary, the proactive protocols OLSR and GRP are verified to be very efficient and effective routing protocols for MANETs under heavy network size, load, and mobility conditions.

The research also analyzes the performances of the TCP variants. It is noticed from the simulation results that performances of the TCP variants decrease as the number of nodes, and traffic load increase. On the other hand, it can be observed that when the speed of nodes increases the TCP sometimes shows better performance such as in the page response time for all the TCP variants. The TCP SACK outperforms other two TCP variants in terms of page response time and retransmission attempts in a MANET with high number of nodes. The performance of TCP Reno is also remarkable for a medium or small sized network. When the effect of the mobility is observed over the TCP variants, TCP Reno usually presents better performance than others. Simulation results also show that the performance of TCP SACK is also remarkable for high mobility, especially in terms of retransmission attempts. Instead, New Reno TCP is less appropriate for high network and mobility conditions.

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