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Performance Analysis of RENUM and ENUM in Lossy and Lossless Mobile Ad-hoc Networks

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Abstract* — In lossy Mobile Ad-hoc Networks (MANETs) the data rate of a given flow becomes lower and lower along its routing path. One of the main challenges in lossy Mobile Ad-hoc Networks is how to achieve the conflicting goal of increased network utility and reduced power consumption, while without following the instantaneous state of a fading channel. To address this problem, two effective techniques are taken by literature survey namely Effective Network Utility Maximization (ENUM) and a cross-layer Rate-Effective Network Utility Maximization (RENUM). In this paper the performance analysis of ENUM and RENUM are analyzed based on four parameters namely Average Delay, Average Throughput, Energy Spent and Packet Delivery Ratio (PDR) with different data rates (0.3, 0.4 and 0.5). Simulations are performed by Network Simulator (NS-2); results are analyzed for both ENUM and RENUM in lossy and lossless Mobile Ad-hoc networks. Results demonstrate that in both the cases (Lossy and Lossless) RENUM produces better results compared to ENUM in terms of Average Throughput, PDR, Average Delay, and Energy Spent.

Keywords*— Mobile Ad-hoc Networks, Effective Network Utility Maximization, Rate-Effective Network Utility Maximization, Average Delay, Average Throughput, Energy Spent and Packet Delivery Ratio (PDR)

I. INTRODUCTION

MANET is the new emerging technology which enables users to communicate without any physical infrastructure regardless of their geographical location, that's why it is sometimes referred to as an infrastructure less network. Ad-hoc networks form spontaneously without a need of an infrastructure or centralized controller. This type of peer-to-peer system infers that each node, or user, in the network can act as a data endpoint or intermediate repeater. Thus, all users work together to improve the reliability of network communications. These types of networks are also popularly known to as "mesh networks" because the topology of network communications resembles a mesh. The redundant communication paths provided by ad hoc mesh networks drastically improve fault tolerance for the network. Additionally, the ability for data packets to "hop" from one user to another effectively extends the network coverage area and provides a solution to overcome non-line of sight (LOS) issues.

Mobile applications present additional challenges for mesh networks as changes to the network topology are swift and widespread. Such scenarios require the use of Mobile Ad hoc Networking (MANET) technology to ensure communication routes are updated quickly and accurately. MANETs are self-forming, self-maintained, and self-healing, allowing for extreme network flexibility. While MANETs can be completely self contained, they can also be tied to an IP-based global or local network (e.g. Internet or private networks). These are referred to as Hybrid MANETs.

A. History of MANET's

The earliest MANETs were called "packet radio" networks, and were sponsored by DARPA in the early 1970s. BBN Technologies and SRI International designed, built, and experimented with these earliest systems. Experimenters included Jerry Burchfiel, Robert Kahn, and Ray Tomlinson of later TENEX, Internet and email fame. It is interesting to note that these early packet radio systems predated the Internet, and indeed were part of the motivation of the original Internet Protocol suite. Later DARPA experiments included the Survivable Radio Network (SURAN) project, which took place in the 1980s. Another third wave of academic activity started in the mid 1990s with the advent of inexpensive 802.11 radio cards for personal computer. Current MANETs are designed primary for military utility; examples include JTRS and NTDR.

The popular IEEE 802.11 ("Wi-Fi") wireless protocol incorporates an ad-hoc networking system when no wireless access points are present, although it would be considered a very low grade ad-hoc protocol by specialists in the field. The IEEE 802.11 system only handles traffic within a local "cloud" of wireless devices. Each node transmits and receives data, but does not route anything between the network's systems. However, higher-level protocols can be used to aggregate various IEEE ad-hoc networks into MANETs.

The reminder of this paper is organized as follows. In Section 2 Related Work for ENUM and RENUM are discussed, in section 3 comparison between ENUM and RENUM with different parameters are discussed, in section 4 results and analysis and in section 5 conclusion will be given.

II. RELATED WORK

MOBILE by battery with energy constrained [1], [2], [3]. Hence, nodes in ad hoc networks are usually powered wise allocation of power is critical in wireless mobile ad hoc networks (MANETs) for both prolonging battery life of the mobile devices and increasing utilization of the scarce wireless spectrum. The aim of power control is to intelligently adjust the transmission power to the least that is required to send the data packet to meet the required signal-to-interference-plus-noise ratio (SINR) threshold and achieve the quality of service (QoS) goals in wireless channels. Existing power-control schemes, either centralized, such as [4], [5], [6], or distributed, such as [7], [8], [9], [10]), always assume quasi-stationary of the fading wireless channels and are based on the observed SINR at the receiver or the knowledge of the gains of all the links. Thus, the implicit assumption made is that the power-control updates are made every time the fading state of the channel changes.

However, in wireless communication channels, which exhibit fast fading where the fades can change within milliseconds, this might not always be practical. Very frequent power-control updates can also consume a lot of energy. Therefore, it is desirable that the power-control does not need to be updated when the channel meanders from a fading state to another. Another fundamental task performed frequently by ad hoc networks is to regulate the allowed source rates to maximize the total utility of the users subject to resource constraints. One common approach to achieving this objective is network utility maximization (NUM) through the cross-layer design of joint power and rate control. The cross-layer design takes users' service requirements and interference-limited channel into account to jointly optimize network performance. In fact, the link capacities determined by the power allocation at the physical layer affect the arrival rates at the transport layer, and vice versa. With this coupling, resource optimization within layers is not competent. Therefore, motivated by the benefits, a cross-lay design of NUM has extensively been studied [11], [12], [13], [14], [15], [16].

In [11], Chiang analysed such a joint congestion and power control problem by using Lagrangian primaldual approach. In [12], the authors considered joint routing and rate allocation that maximizes the lifetime of an ad hoc network supporting variable-rate transmissions (link adaptation). In [13], a joint opportunistic power scheduling and end-to-end rate control (JOPRC) scheme was presented for wireless ad hoc networks by modelling the time-varying wireless channel as a stochastic process. In [16], the authors modelled an efficient spatial-TDMA based adaptive power and rate cross-layer scheduling problem as a mixed integer linear program (MILP).

A cross-layer design of power- and rate-allocation was studied in [17] for MANETs with lossy links. All of these works similarly assume the channel to be quasi-stationary and track the instantaneous channel state; meanwhile, the data rate of a given flow is treated unchanged from hop to hop along its route. In wireless networks, however, wireless links are typically lossy and the packet loss rate is often high due to channel impairment such as fading and interference. As a result, the data rate of a flow decreases along its route because of the lossy nature of wireless links. Clearly, these previous studies that follow fast fades directly are not feasible or desirable in this situation due to mobility of the nodes and/or environment. More recently, there have been many studies on the problem of power control with constraints on outage probability in wireless networks with lossy links, in which outage probability is referred to as the probability that the smallest maximum achievable rate among all of users is smaller than a specified transmission rate. In [18], Kandukuri and Boyd proposed a new method of optimal power control in interference-limited fading wireless channels with outage-probability specifications, where interior point methods are employed to find the solution.

In [19], the authors addressed a joint power control and multiuser detection problem with outage-probability constraints in a Rayleigh fast-fading environment. Furthermore, in [20], they proposed a generalized framework for solving the problem under modest assumption on the underlying channel fading. Unlike previous work, which dealt with Rayleigh fast-fading model, each user is allowed to have a different fading distribution. In [21], the outage probability of multiple antenna multicast channels was investigated and its upper and lower-bounds were derived by using extreme value theory. A link outage probability based resource allocation scheme for multi radio multi-channel wireless mesh networks was proposed in [22]. An emerging challenging issue to be addressed for dynamic power and rate allocation in next generation MANETs is how to meet with user's heterogeneous transmission QoS requirements. Among others, the demand for wireless high-speed connectivity for both delay-tolerant "packet" data and delay-sensitive "circuit" data is expected to rise significantly in the next decade. Accordingly, how to optimally allocate both power and rate to support delay constrained data traffic while sufficiently considering the lossy nature of links becomes an

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important research issue.

In RENUM framework which takes account of the lossy nature of links in the objective function and the constraints of rate outage and average delay. In particular, the minimization of the overall power and delay of all links is used as the optimization objective as well, which is the distinct difference between effective network utility maximization (ENUM) with outage constraints in [23]. In RENUM framework, the transmission rate at the source node of each flow is called the injection rate, and the data rate correctly received at the destination node is called the effective rate. Since the effective rate is typically lower than the injection rate, it is natural to examine the utility corresponding to the effective rate. Then the original non-convex RENUM is converted into a convex one by employing some logarithmic transformation.

The convex RENUM problem is further decomposed into three separate maximization sub-problems of rate control, power and delay allocation. Three corresponding distributed sub algorithms are developed, in which some forms of broadcast message passing is required for power-allocation. In practice, it may be desirable to avoid such overhead and thus we include a near-optimal scheme that makes use of autonomous SINR measurements at each link for power allocation. The contributions and findings of the paper can be briefly summarized below. The problem of the frequent rate and power updates induced by fast-fading is addressed, which is imperative especially in a MANET with limited energy, by taking account of the average SINR and rate-outage probability, where flow rate changes per hop. A rate-effective network utility maximization framework is proposed by considering the lossy nature of wireless links and the rate outage constraints with a small tolerable value, which is necessary because the loss of wireless links and packets occurs frequently due to channel impairment and mobility of nodes in MANETs. The minimization of the overall power and average delay of all links is used as the optimization objective while the effect of the loss and the rate outage on optimal joint power, rate and delay control is studied to support delay-constrained data traffic.

III. COMPARISON BETWEEN ENUM AND RENUM

In this section comparison between ENUM and RENUM are given for various parameters like Average Delay, Average Throughput, Packet Delivery Ratio and Energy Spent with different data rates (0.3, 0.4 and 0.5).

The main difference between RENUM and ENUM are

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A. Performance Evolution Metrics

1) Throughput: Throughput is the ratio of packets received by the destination to the packets sent by the source. It is defined as the total number of packets delivered over the total simulation time. Throughput is directly proportional to Packet Delivery Ratio (PDR) and inversely proportional to Packet Loss, End-to-End delay and Energy Consumption (or)

Throughput metric represents the total number of bits forwarded to higher layers per second. It is measured in Kbps. It can also be defined as the total amount of data a receiver actually receives from sender divided by the time taken by the receiver to obtain the last packet. It is the average rate of successful message delivery over a communication channel.

$$\text{Throughput} \propto \frac{1}{\text{Packet Loss}} \quad \ldots\ldots (1)$$

$$\text{Throughput} \propto \frac{1}{\text{End-to-End delay}} \quad \ldots\ldots (2)$$

$$\text{Throughput} \propto \frac{1}{\text{Energy Consumption}} \quad \ldots\ldots (3)$$

$$\text{Throughput} \propto \text{Packet Delivery Ratio (PDR)} \quad \ldots\ldots (4)$$

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2*) Average Delay:* The average time it takes a data packet to reach the destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue. Average delay is represented in milliseconds (or seconds) and throughput is represented in bits per seconds (bps). The lower value of end to end delay means the better performance of the protocol.

Average Delay= sum of the time spent to deliver packets for each destination / number of packets received by the all destination nodes.

$$\text{Average Delay} \propto \frac{1}{\text{Average Throughput}} \;\ldots.. (4)$$

$$\text{Average Delay} \propto \frac{1}{\text{PDR}} \;\ldots.. (5)$$

$$\text{Average Delay} \propto \frac{1}{\text{Energy Spent}} \;\ldots.. (6)$$

B. Packet Delivery Ratio (PDR): Packet delivery ratio is defined as the ratio of data packets received by the destinations to those generated by the sources. For example if a traffic generator sends 10 packets and another application sends packets. If in both scenarios received 100% of the packets is observed, then the PDR is 1 for both of them however the throughput will never be the same. The greater value of packet delivery ratio means the better performance of the protocol. On X-axis, Packet size and on Y-axis PDR in Packets is taken.

Packet Delivery Ratio (PDR) = sum of data packets received by the each destination ÷ sum of data packets generated by the each source

$$\text{PDR} \propto \frac{1}{\text{Average Delay}} \;\ldots.. (7)$$

$$\text{PDR} \propto \text{Average Throughput} \ldots.. (8)$$

1) *Energy Consumption:* It is defined as the amount of energy consumed by the network during the packet transmission from primary users to secondary users. It is measured in terms of Joules. Energy consumption and Power requirements are directly related to each other. Higher is the End-to-End delay, higher will be the Energy consumption.

$$\text{Enegry Spent} \propto \frac{1}{\text{Average Throughput}} \;\ldots.. (9)$$

$$\text{Energy Spent} \propto \text{Averge Delay} \ldots.. (10)$$

IV. NETWORK SIMULATOR (NS-2)

NS-2 or Network Simulator [24] is a discrete-event simulator whose implementation was started by 1989 with the development of the Real Network Simulator. Earlier simulation of wired technology was done by NS-2, and then the Monarch group from the Department of Computer Science at the University of Rice developed the software for wireless mobile nodes. This contribution from the University of Rice is widely accepted all over the world. The main objective of NS-2 is to model the network protocols which includes wired network, wireless network, satellite, TCP, UDP, web, telnet, FTP, multicast, unicast, ad hoc routing and sensor networks. In NS-2 physical activities are translated to events.

NS-2 [25] uses two languages C++ and Object Tool Command Language (OTCL) .C++ is fast to run but slower to change, making it suitable for detailed protocol implementation. OTCL runs much slower as compared to c++ but modification can be done very quickly (and interactively), making it ideal for simulation configuration. In NS-2, the front end of the program is written in TCL (Tool Command Language) and the backend of NS-2 simulator is written in C++ language. When the TCL program is compiled, two files that is trace file and NAM file are created that defines the movement pattern of the nodes and also keeps track of the number of data packets sent by the source node, number of minimum hops between 2 mobile nodes, connection type at each instance of time etc. Moreover, a scenario file is created which defines the destination of mobile nodes along with their speeds and a connection pattern file (CBR file) or (TCP file) defining the pattern of communication, node topology and also the data packet type are also used to create the two files that is trace files and NAM files which are then used by the simulator to simulate the network. NAM, the Network Animator is a Graphical User Interface and is used to visualize ns output and the trace file is used for post processing work. By using these trace files AWK scripts can be written and using these AWK scripts various performance metrics like Average Throughput, End to End Delay, Packet Loss, Packet Delivery Fraction, Packet Delivery Ratio, Normalized Overhead Routing etc can be calculated. Graphs are plotted using GNUPLOT in NS-2 which is a free, command-driven, interactive, function

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and data plotting program. In NS-2, C++ is used for detailed protocol implementation and in general for such cases where every packet of a flow has to be processed. For instance, it is a must to implement a new queuing discipline, and then C++ is the language of choice. OTcl, on the other hand, is suitable for configuration and setup. OTcl runs quite slowly, but it can be changed very quickly making the construction of simulations easier. In ns2, the compiled C++ objects can be made available to the OTcl interpreter. In this way, the ready-made C++ objects can be controlled from the OTcl level.

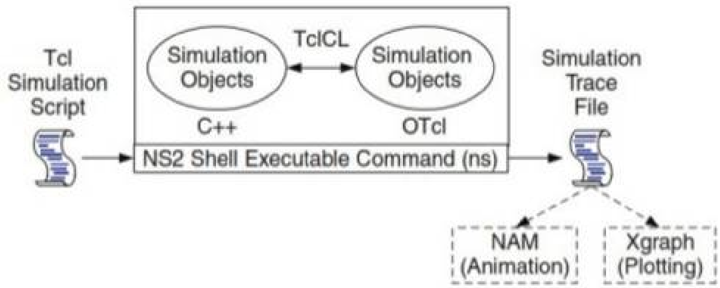


Fig 1 Network Simulator (NS-2) Architecture

V. RESULTS AND ANALYSIS

Simulation results are performed using Network Simulator (NS-2). First generate a wireless network with different number of mobile nodes using NS-2 after that choose source node and destination node among the all nodes. After choosing source node and destination node transfer the data between sources to destination by using shortest path routing algorithms. In this paper simulation produces based on the comparison between EUNM and RENUM Frameworks with different data rates.

Here four performance metrics are considered to evaluate the performance of the ENUM and RENUM frameworks that are Average Delay, Average Throughput, Packet Delivery Ratio and Energy Spent. The four parameters are performed both in ENUM and RENUM with different data rates that are 0.3, 0.4 and 0.5 for both lossy and lossless Mobile Ad-hoc Networks Table 1 shows the general parameters of simulation with ENUM/RENUM as protocols. Results are performed for both the cases lossy Mobile Ad-hoc Networks and Lossless Mobile Ad-hoc Networks.

TABLE I
GENERAL PARAMETERS USED IN SIMULATION

Channel Type	Wireless Channel
Radio-Propagation	Two Ray Ground
Antenna Type	Omni Antenna
Link Layer Type	LL
Interface Queue Type	Drop Tail /Pri-Queue
Max Packet	200
Network Interface Type	Wireless Physical
Mac Type	Mac/802_11
Number of Mobile Nodes	50
Routing Protocol	ENUM/RENUM

Fig 2 (a), (b) and (c) show the simulation results for Average Delay in both ENUM and RENUM Frame Works in Lossy Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Delay are taken. From the simulation results it can be analysed that the Average Delay is more in ENUM compared to RENUM framework. For example at 0.3 data rate the Average Delay in ENUM at 10 sec in X-axis is 114.31sec but the Average Delay is very less in RENUM Frame Work i.e., 13.26 sec only , at data arte 0.4 the Average Delay in ENUM at 10 sec in X-axis is 704.64sec but the Average Delay is very less in RENUM Frame Work i.e., 12.05 sec only and at data rate 0.5 the Average Delay in ENUM at 10 sec in X-axis is 134.56 sec but the Average Delay is very less in RENUM Frame Work i.e., 13.15sec only. From the comparison of all RENUM frame work with the data rate of 0.4 gives better Average Delay.

Fig 3 (a), (b) and (c) show the simulation result for Average Throughput in both ENUM and RENUM Frame Works in Lossy Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Throughput are taken. From the simulation results it can be analysed that the Average Throughput is more in RENUM compared to ENUM framework. For example Average Throughput in RENUM at 10 sec in X-axis is 134.76 Kbps but the Average Throughput is very less in ENUM Frame Work i.e., 32.37Kbps only, at data arte 0.4 the Average Throughput in RENUM at 10 sec in X-axis is 139.16 Kbps but the Average Throughput is very less in ENUM Frame Work i.e., 27.03 Kbps only and at data arte 0.5 the Average Throughput in RENUM at 10 sec in X-axis is 130.24 Kbps but the Average Throughput is very less in ENUM Frame Work i.e., 25.96 Kbps only. From the comparison of all RENUM frame work with the data rate of 0.4 gives better Average Throughput.

Fig 4 (a), (b) and (c) show the simulation results for Energy Spent in both ENUM and RENUM Frame Works in Lossy Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Energy are taken. From the simulation results it can be analysed that the Energy Spent is more in ENUM compared to RENUM framework. For example at 0.3 data rate the Energy Spent in ENUM at 10 sec in X-axis is 17.10 Jowls but the Energy Spent is very less in RENUM Frame Work i.e., 13.29 Jowls only , at data arte 0.4 the Energy Spent in ENUM at 10 sec in X-axis is 16.92 Jowls but the Energy Spent is very less in RENUM Frame Work i.e., 13.21 Jowls only and at data rate 0.5 the Energy Spent in ENUM at 10 sec in X-axis is 16.90 Jowls but the Energy Spent is very less in RENUM Frame Work i.e., 13.26 Jowls only. From the comparison of all RENUM frame work with the data rate of 0.4 consumes less energy.

Fig 5 (a), (b) and (c) show the simulation results for Packet Delivery Ratio (PDR) in both ENUM and RENUM Frame Works in Lossy Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Delivery Ratio are taken. From the simulation results it can be analysed that the Packet Delivery Ratio is more in RENUM compared to ENUM framework. For example at 0.3 data rate the Packet Delivery Ratio in RENUM at 10 sec in X-axis is 0.7598 but the Packet Delivery Ratio is very less in ENUM Frame Work i.e., 0.6700 only, at data arte 0.4 the Packet Delivery Ratio in RENUM at 10 sec in X-axis is 0.9028 but the Packet Delivery Ratio is very less in ENUM Frame Work i.e., 0.6340 only and at data arte 0.5 the Packet Delivery Ratio in RENUM at 10 sec in X-axis is 0.9048but the Packet Delivery Ratio is very less in ENUM Frame Work i.e., 0.6841only. From the comparison of all RENUM frame work with the data rate of 0.4 gives better Packet Delivery Ratio.

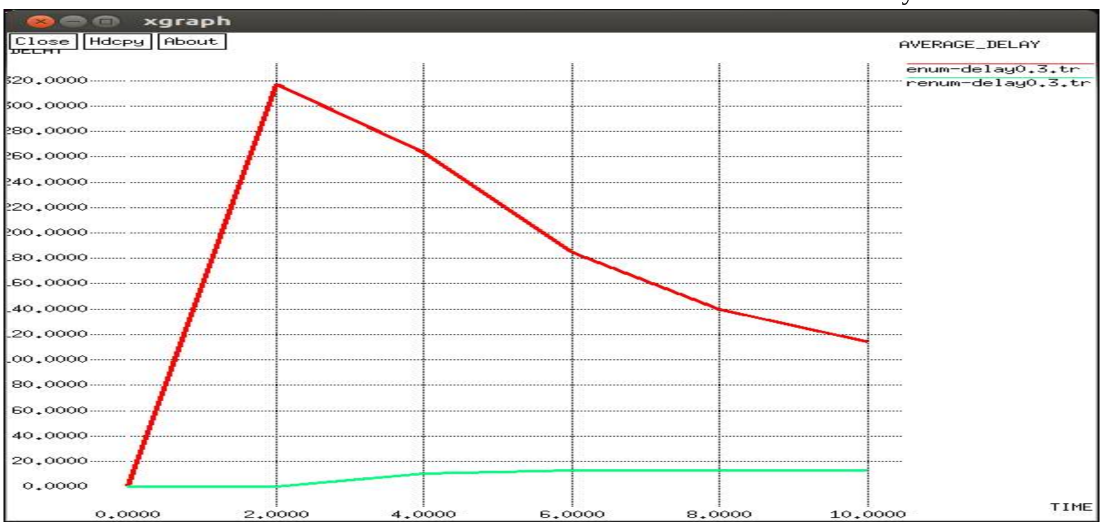
Fig 6 (a), (b) and (c) show the simulation results for Average Delay in both ENUM and RENUM Frame Works in Lossless Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Delay are taken. From the simulation results it can be analyzed that the Average Delay is more in ENUM compared to RENUM framework. For example at 0.3 data rate the Average Delay in ENUM at 10 sec in X-axis is 112.29 sec but the Average Delay is very less in RENUM Frame Work i.e., 6.36 sec only , at data arte 0.4 the Average Delay in ENUM at 10 sec in X-axis is 132.36 sec but the Average Delay is very less in RENUM Frame Work i.e., 6.34 sec only and at data rate 0.5 the Average Delay in ENUM at 10 sec in X-axis is 131.75 sec but the Average Delay is very less in RENUM Frame Work i.e., 6.36 sec only. From the comparison of all RENUM frame work with the data rate of 0.4 gives better Average Delay.

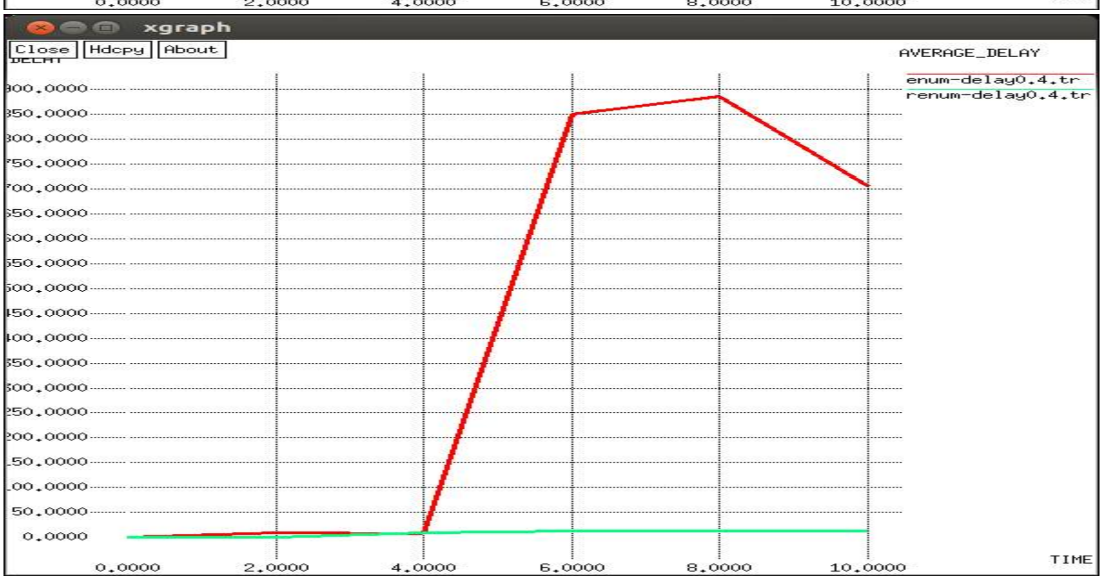
Fig 7 (a), (b) and (c) show the simulation result for Average Throughput in both ENUM and RENUM Frame Works in Lossless Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Throughput are taken. From the simulation results it can be analysed that the Average Throughput is more in RENUM compared to ENUM framework. For example Average Throughput in RENUM at 10 sec in X-axis is 139.67 Kbps but the Average Throughput is very less in ENUM Frame Work i.e., 33.38 Kbps only, at data arte 0.4 the Average Throughput in RENUM at 10 sec in X-axis is 141.81 Kbps but the Average Throughput is very less in ENUM Frame Work i.e., 27.81 Kbps only and at data arte 0.5 the Average Throughput in RENUM at 10 sec in X-axis is 140.61 Kbps but the Average Throughput is very less in ENUM Frame Work i.e., 24.36 Kbps only. From the comparison of all RENUM frame work with the data rate of 0.4 gives better Average Throughput.

Fig 8 (a), (b) and (c) show the simulation results for Energy Spent in both ENUM and RENUM Frame Works in Lossless Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Energy are taken. From the simulation results it can be analysed that the Energy Spent is more in ENUM compared to RENUM framework. For example at 0.3 data rate the Energy Spent in ENUM at 10 sec in X-axis is 16.34 Jowls but the Energy Spent is very less in RENUM Frame Work i.e., 11.54 Jowls only , at data arte 0.4 the Energy Spent in ENUM at 10 sec in X-axis is 16.23 Jowls but the Energy Spent is very less in RENUM Frame Work i.e., 11.39 Jowls only and at data rate 0.5 the Energy Spent in ENUM at 10 sec in X-axis is 16.14 Jowls but the Energy Spent is very less in RENUM Frame Work i.e., 11.47 Jowls only. From the comparison of all RENUM frame work with the data rate of 0.4 consumes less energy.

Fig 9 (a), (b) and (c) show the simulation results for Packet Delivery Ratio (PDR) in both ENUM and RENUM Frame Works in Lossless Mobile Ad-hoc Networks with the data rate of 0.3, 0.4 and 0.5. In X- axis Time in sec and in Y-axis Delivery Ratio are taken. From the simulation results it can be analysed that the Packet Delivery Ratio is more in RENUM compared to ENUM framework. For example at 0.3 data rate the Packet Delivery Ratio in RENUM at 10 sec in X-axis is 0.8979 but the Packet Delivery Ratio is very less in ENUM Frame Work i.e., 0. 7000 only, at data arte 0.4 the Packet Delivery Ratio in RENUM at 10 sec in X-axis is 0.9167 but the Packet Delivery Ratio is very less in ENUM Frame Work i.e., 0. 7000 only and at data arte 0.5 the Packet Delivery Ratio in RENUM at 10 sec in X-axis is 0.9008 but the Packet Delivery Ratio is very less in ENUM Frame Work i.e., 0.7000 only. From the comparison of all RENUM frame work with the data rate of 0.4 gives better Packet Delivery Ratio.

Table 2 gives the comparison between ENUM and RENUM in Lossy Mobile Ad-hoc Networks with Different Data rates, table 3 gives the comparison between ENUM and RENUM in Lossless Mobile Ad-hoc Networks with Different Data rates, table 4 gives the comparison of ENUM in Lossy and Lossless Mobile Ad-hoc Networks with Different Data rates and table 5 gives the comparison of RENUM in Lossy and Lossless Mobile Ad-hoc Networks with Different Data rates. From the analysis of all the results in both the lossy and lossless Mobile Ad-hoc it can understand that data rate 0.4 is gives better performance in all the accepts like Average Delay, Average Throughput, Energy Spent and Packet Delivery Ratio (PDR) , and another important observation is Lossless RENUM gives better performance in all the accepts compared to Lossy RENUM for example the Average Delay in Lossy Mobile Ad-hoc networks is 13.26 sec but in Lossless Mobile Ad-hoc networks it can be 6.36 sec only.





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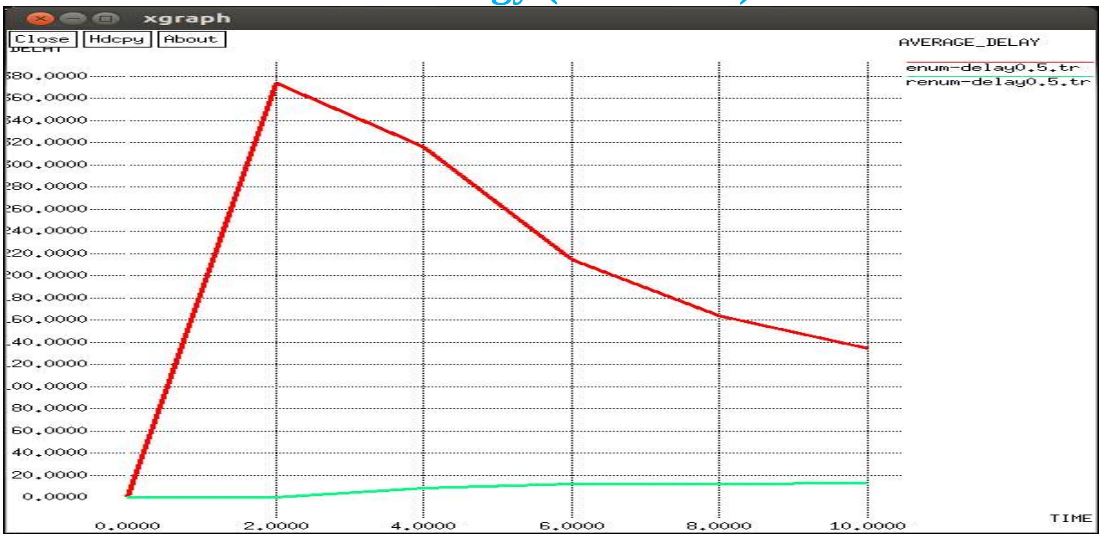
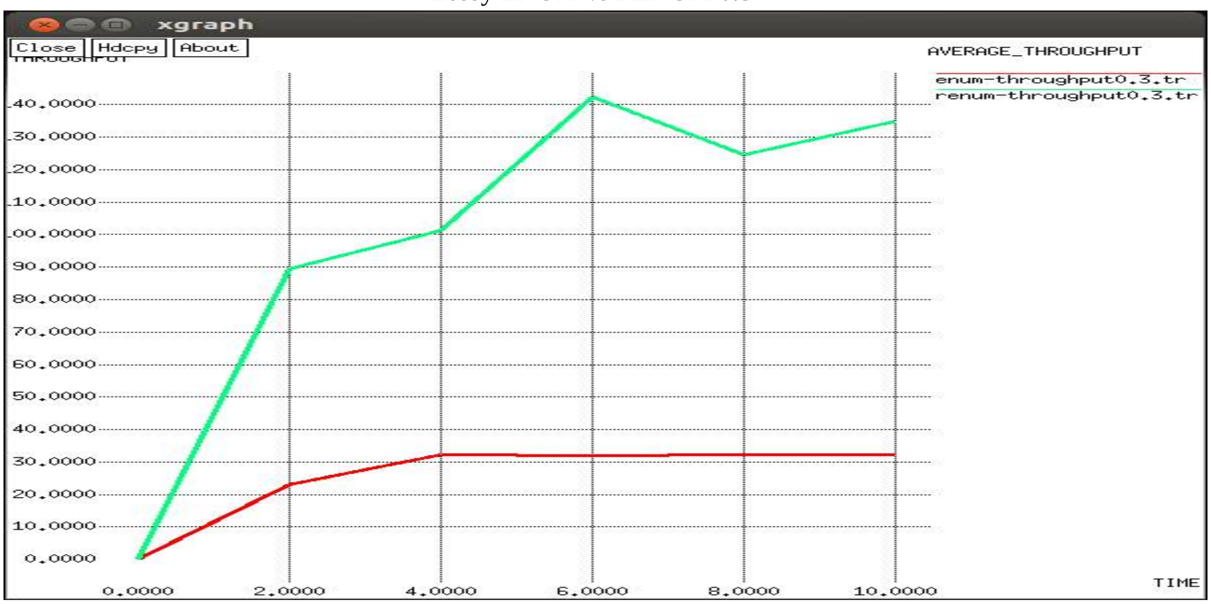
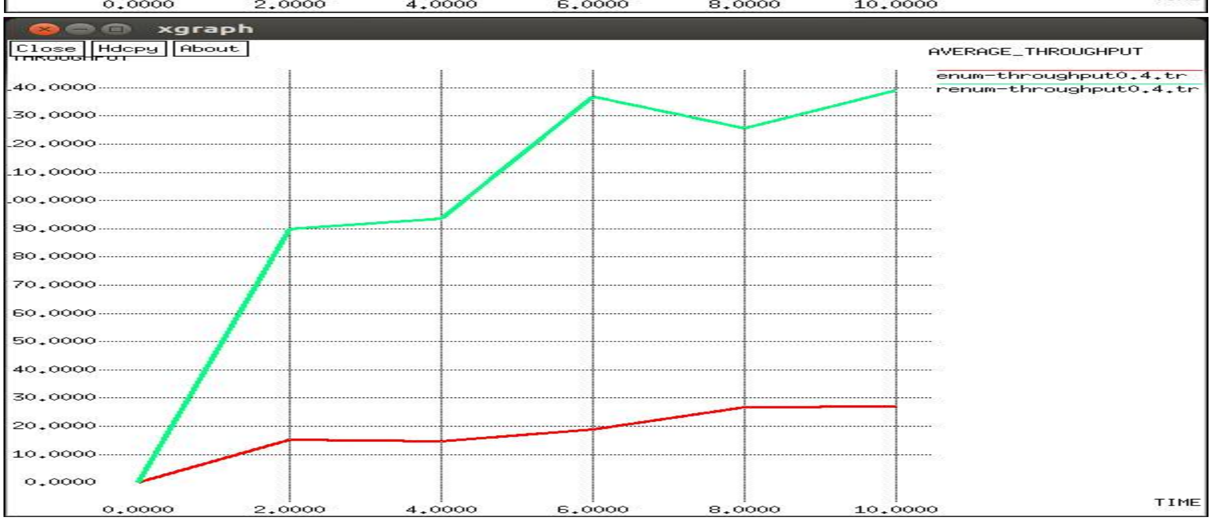


Fig 2 (a) Average Delay Lossy ENUM vs RENUM 0.3; (b) Average Delay Lossy ENUM vs RENUM 0.4; (c) Average Delay Lossy ENUM vs RENUM 0.5





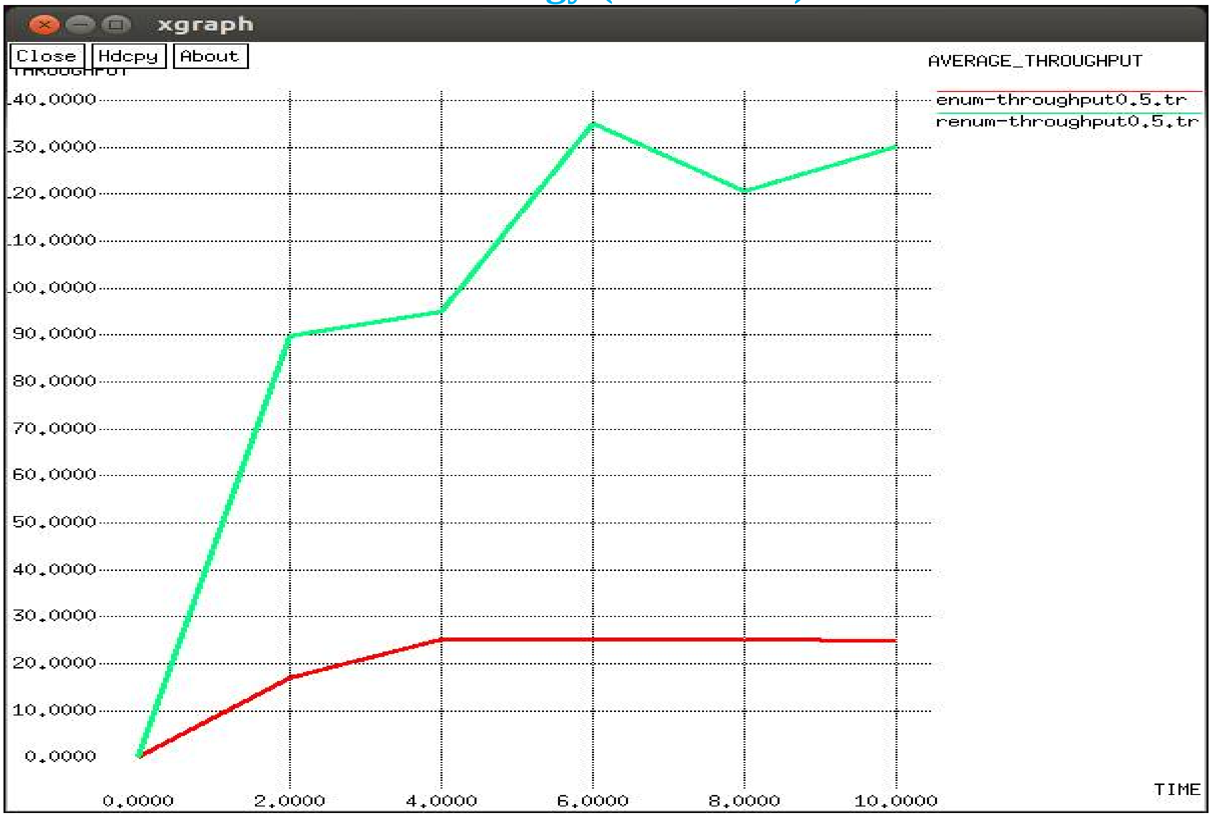


Fig 3(a) Average Throughput Lossy ENUM vs RENUM 0.3; (b) Average Throughput Lossy ENUM vs RENUM 0.4; (c) Average Throughput

Lossy ENUM vs RENUM 0.5

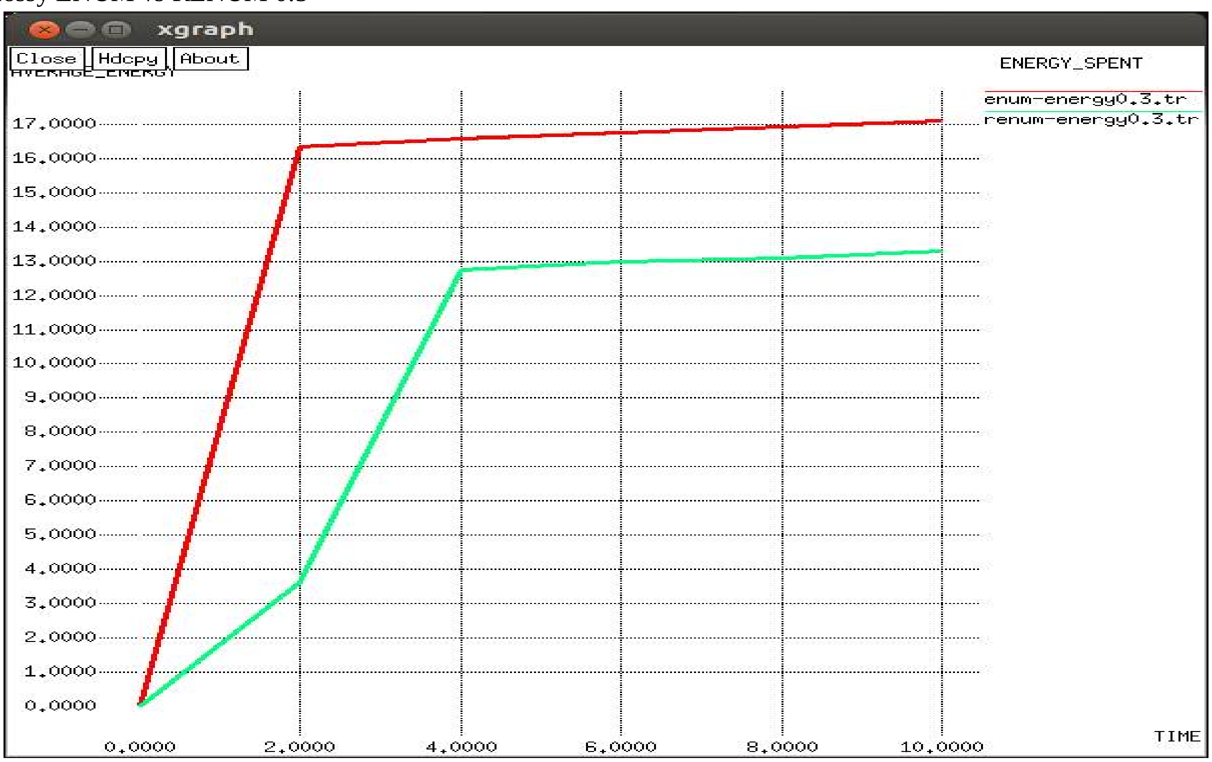


Fig 4 (a) Energy Spent Lossy ENUM vs RENUM 0.3; (b) Energy Spent Lossy ENUM vs RENUM 0.4; (c) Energy Spent Lossy ENUM vs RENUM 0.5

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Fig 5: (a) PDR Lossy ENUM vs RENUM 0.3; (b) PDR Lossy ENUM vs RENUM 0.4; (c) PDR Lossy ENUM vs RENUM 0.5

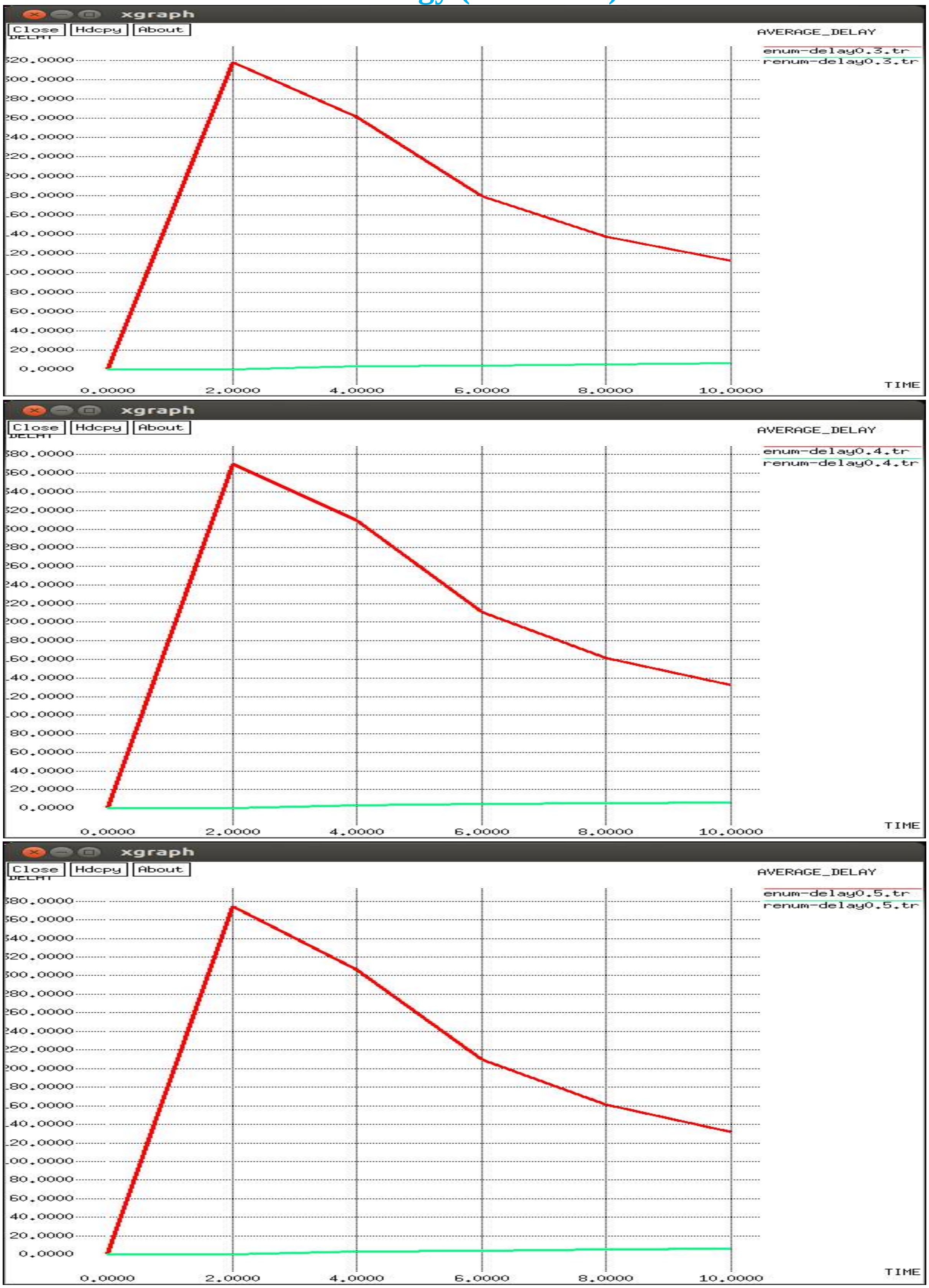

Fig 6 (a) Average Delay Lossless ENUM vs RENUM 0.3; (b) Average Delay Lossless ENUM vs RENUM 0.4; (c)

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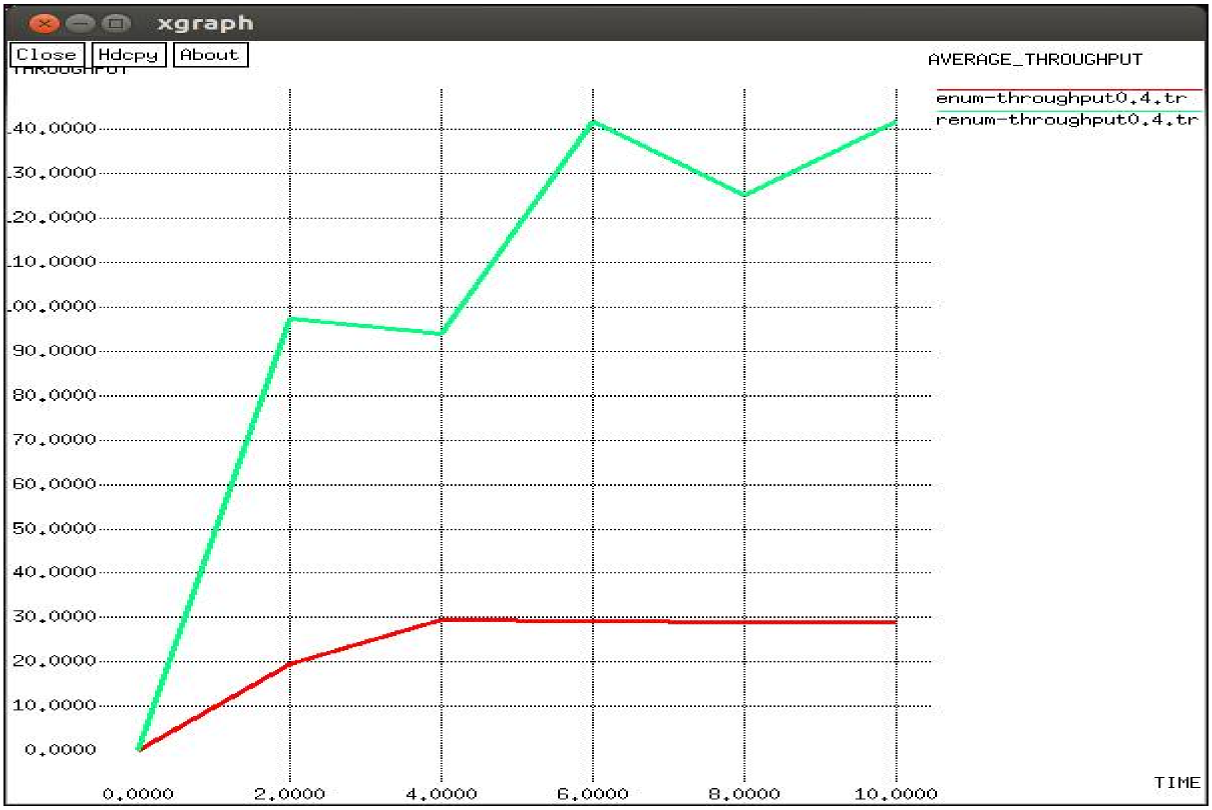
Average Delay Lossless

ENUM vs RENUM 0.5



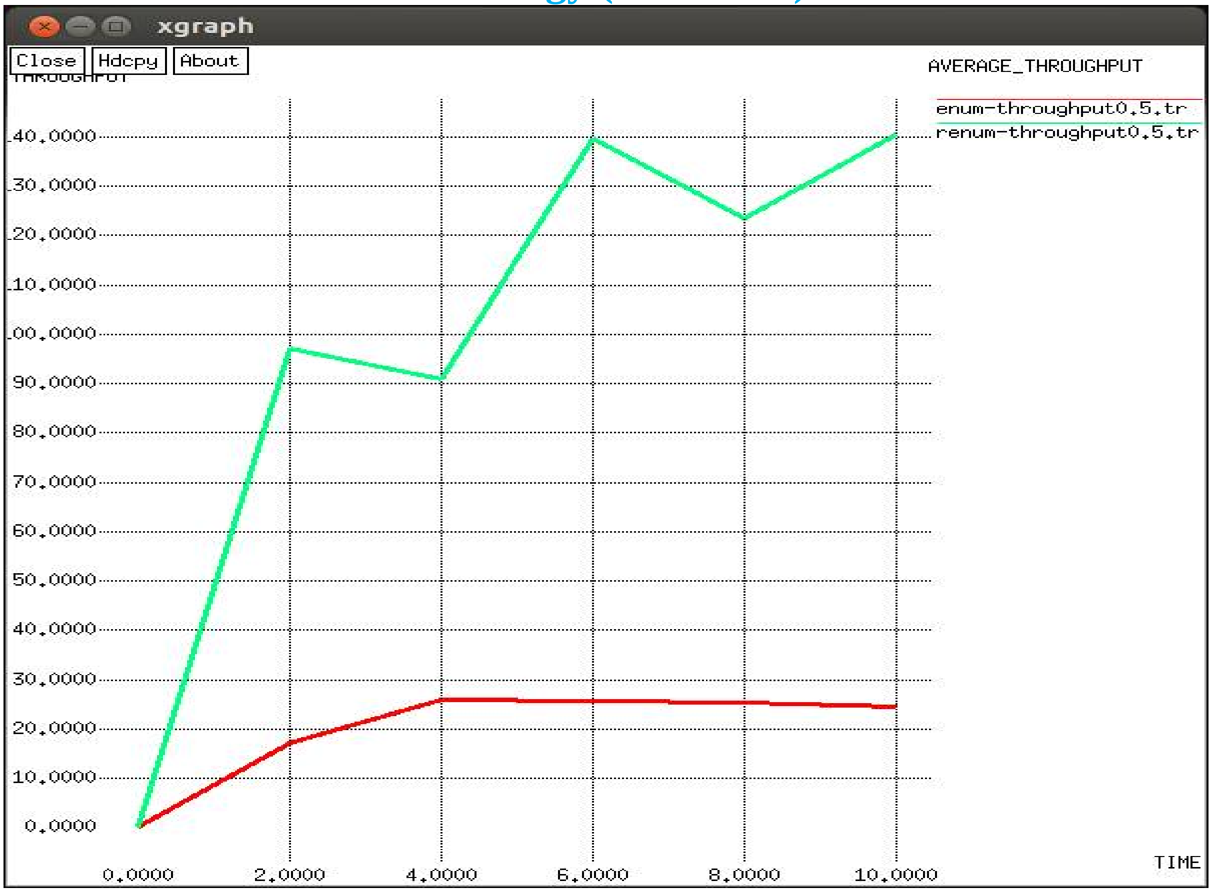
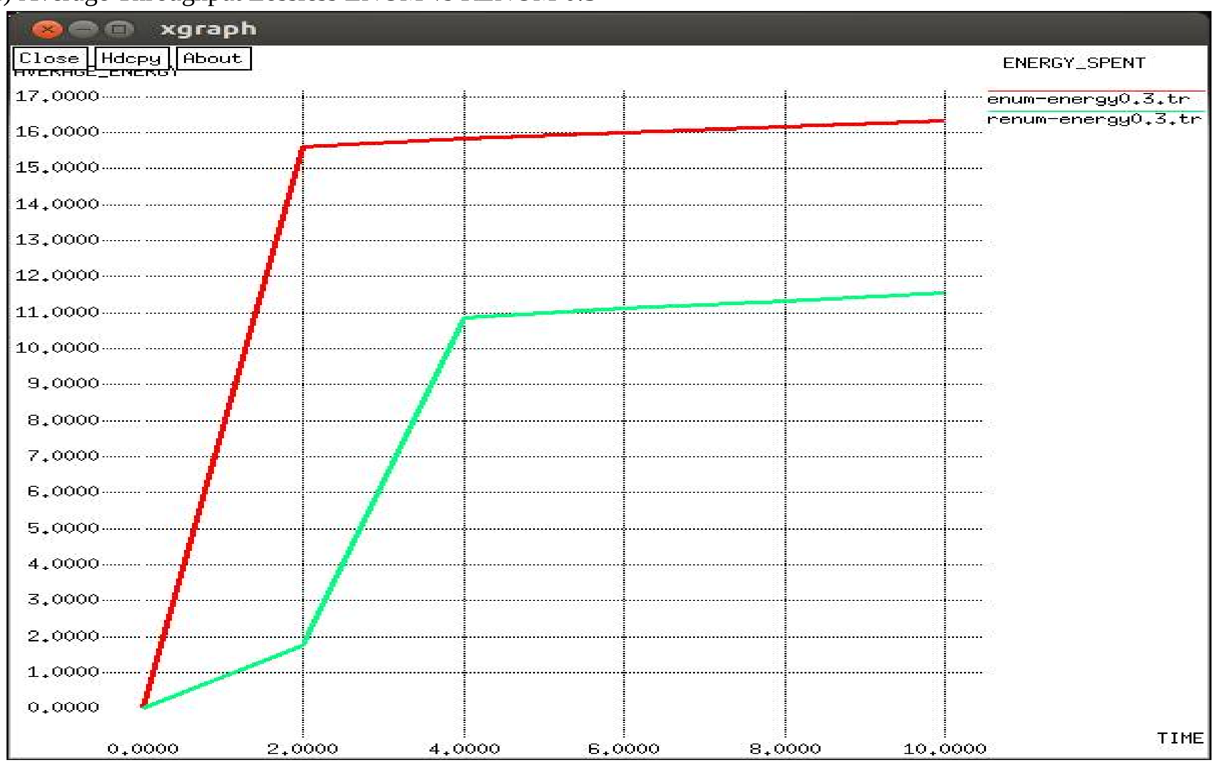


Fig 7 (a) Average Throughput Lossless ENUM vs RENUM 0.3; (b) Average Throughput Lossless ENUM vs RENUM 0.4; (c) Average Throughput Lossless ENUM vs RENUM 0.5



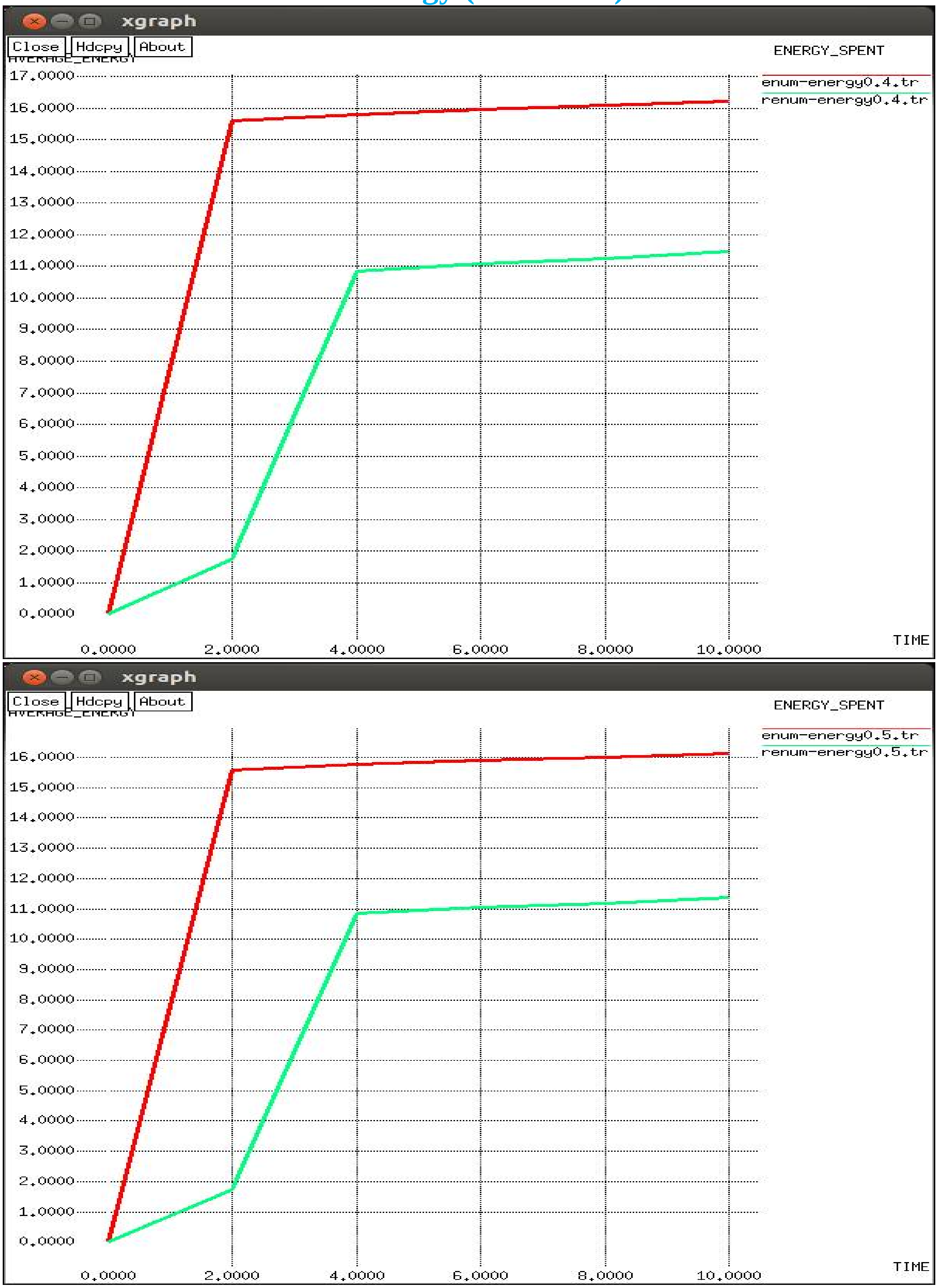


Fig 8 (a) Energy Spent Lossless ENUM vs RENUM 0.3; (b) Energy Spent Lossless ENUM vs RENUM 0.4; (c) Energy Spent Lossless ENUM vs RENUM 0.5

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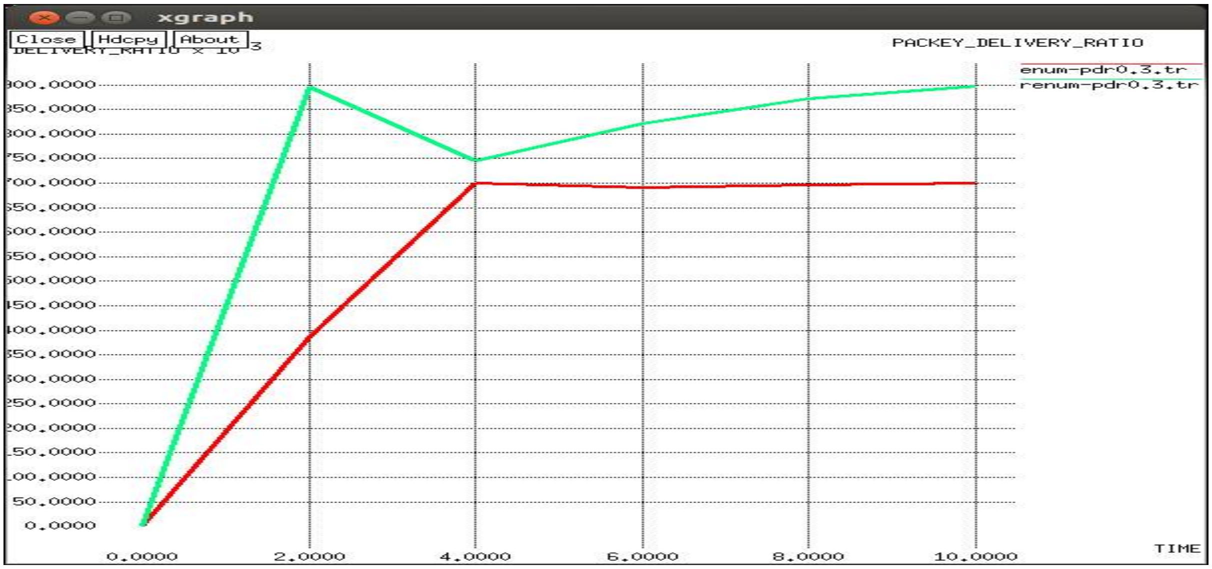

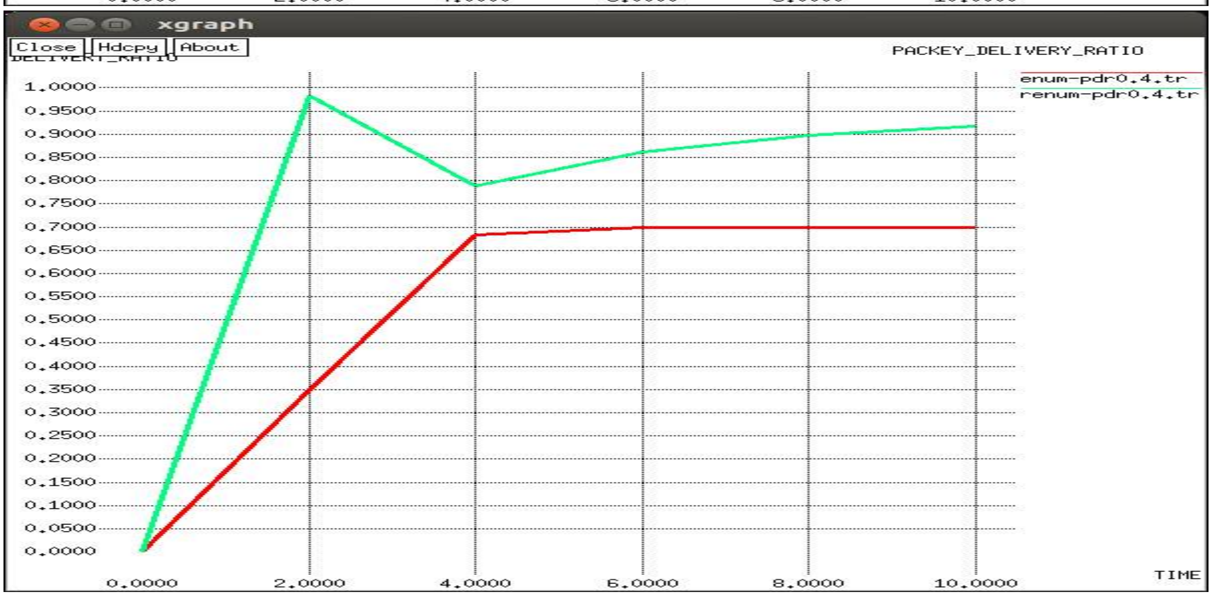

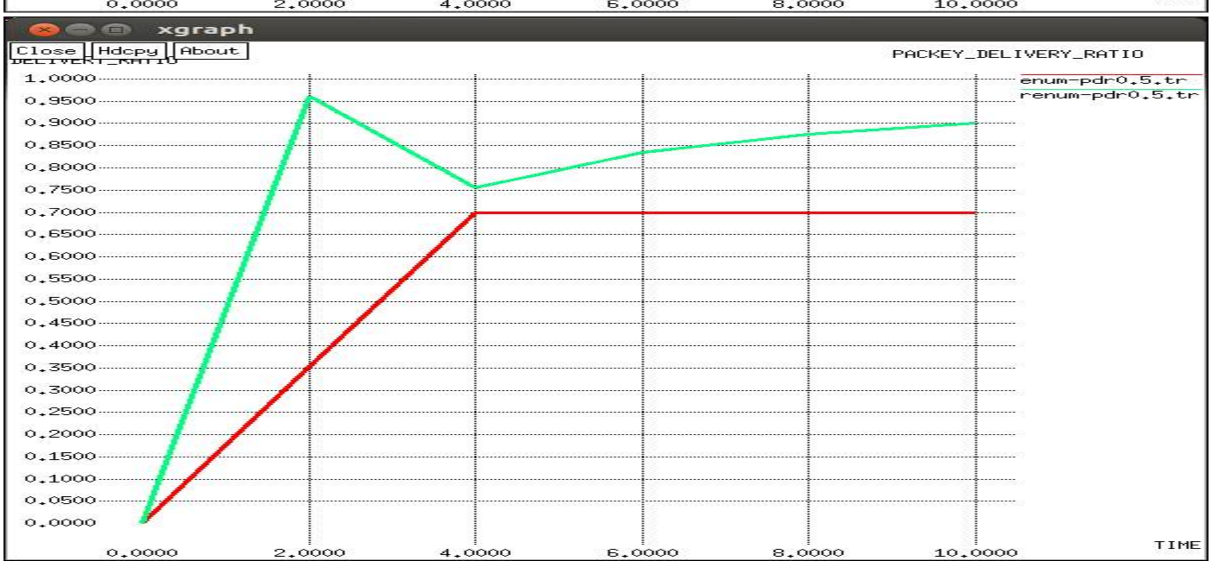

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Fig 9 (a) PDR Lossless ENUM vs RENUM 0.3; (b) PDR Lossless ENUM vs RENUM 0.4; (c) PDR Lossless ENUM vs RENUM 0.5

TABLE 2

COMPARISON OF ENUM AND RENUM IN LOSSY MOBILE AD-HOC NETWORKS WITH DIFFERENT DATA RATES

Parameters	Time (Sec)	ENUM			RENUM		
		0.3	0.4	0.5	0.3	0.4	0.5
Average Delay (in Sec)	0	0	0	0	0	0	0
	2	317.39	8.49	373.8	0	0	0
	4	263.24	7.12	316.61	10.56	9.34	8.60
	6	184.79	850.32	214.81	12.93	13.30	12.52
	8	139.54	886.42	164.08	12.67	12.26	12.58
	10	114.31	704.64	134.56	13.26	12.05	13.15
Energy Spent (in Joules)	0	0	0	0	0	0	0
	2	16.32	16.27	16.30	3.62	3.62	3.62
	4	16.56	16.32	16.51	12.76	12.74	12.72
	6	16.75	16.49	16.64	12.99	12.95	12.91
	8	16.92	16.78	17.77	13.10	13.08	13.01
	10	17.10	16.92	16.90	13.29	13.21	13.26
Packet Delivery Ratio (PDR)	0	0	0	0	0	0	0
	2	0.3866	0.2000	0.3538	0	0	0
	4	0.6624	0.2000	0.6706	0.4887	0.4407	0.3824
	6	0.6453	0.3552	0.6803	0.8159	0.7931	0.7763
	8	0.6663	0.6181	0.6851	0.7416	0.8491	0.7475
	10	0.6700	0.6340	0.6841	0.7598	0.9028	0.9048
Average Throughput (Kbps)	0	0	0	0	0	0	0
	2	23.11	15.26	17.08	89.39	89.89	89.89
	4	32.27	14.77	25.14	101.14	93.56	95.10
	6	31.89	19.01	25.09	142.44	136.90	135.18
	8	32.26	26.63	25.07	124.49	125.63	120.60
	10	32.37	27.03	25.96	134.76	139.16	130.24

TABLE 3

COMPARISON OF ENUM AND RENUM IN LOSSLESS MOBILE AD-HOC NETWORKS WITH DIFFERENT DATA RATES

Parameters	Time (Sec)	ENUM			RENUM		
		0.3	0.4	0.5	0.3	0.4	0.5
	0	0	0	0	0	0	0
	2	317.98	370.05	374.63	0	0	0
	4	261.42	309.21	306.12	3.16	3.13	3.10

Average Delay (in Sec)	6	178.99	210.47	209.74	4.30	4.39	4.30
	8	137.26	161.14	161.12	5.36	5.34	5.35
	10	112.29	132.36	131.75	6.36	6.34	6.36
Energy Spent (in Joules)	0	0	0	0	0	0	0
	2	15.62	15.60	15.59	1.75	1.75	1.75
	4	15.85	15.81	15.77	10.87	10.86	10.84
	6	16.01	15.95	15.89	11.12	11.09	11.05
	8	16.18	16.09	16.01	11.31	11.25	11.19
	10	16.34	16.23	16.14	11.54	11.39	11.47
Packet Delivery Ratio (PDR)	0	0	0	0	0	0	0
	2	0.3866	0.3500	0.3538	0.8955	0.9833	0.9615
	4	0.7000	0.6831	0.7000	0.7444	0.7881	0.7549
	6	0.6900	0.7000	0.7000	0.8209	0.8621	0.8355
	8	0.6963	0.7000	0.7000	0.8727	0.8966	0.8762
	10	0.7000	0. 7000	0. 7000	0.8979	0.9167	0.9008
Average Throughput (Kbps)	0	0	0	0	0	0	0
	2	23.08	97.25	17.06	97.25	97.25	97.25
	4	33.44	93.91	25.90	97.90	93.92	90.78
	6	33.40	141.61	25.60	139.07	141.61	139.58
	8	33.26	125.22	25.45	124.19	125.22	123.56
	10	33.38	27.81	24.36	139.67	141.81	140.61

TABLE 4

COMPARISON OF ENUM IN LOSSY AND LOSSLESS MOBILE AD-HOC NETWORKS WITH DIFFERENT DATA RATES

Parameters	Time (Sec)	ENUM in Lossy MANET's			ENUM in Lossless MANET's		
		0.3	0.4	0.5	0.3	0.4	0.5
Average Delay (in Sec)	0	0	0	0	0	0	0
	2	317.39	8.49	373.8	317.98	370.05	374.63
	4	263.24	7.12	316.61	261.42	309.21	306.12
	6	184.79	850.32	214.81	178.99	210.47	209.74
	8	139.54	886.42	164.08	137.26	161.14	161.12
	10	114.31	704.64	134.56	112.29	132.36	131.75
Energy Spent (in Joules)	0	0	0	0	0	0	0
	2	16.32	16.27	16.30	15.62	15.60	15.59
	4	16.56	16.32	16.51	15.85	15.81	15.77
	6	16.75	16.49	16.64	16.01	15.95	15.89
	8	16.92	16.78	17.77	16.18	16.09	16.01
	10	17.10	16.92	16.90	16.34	16.23	16.14

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Packet Delivery Ratio (PDR)	0	0	0	0	0	0	0
	2	0.3866	0.2000	0.3538	0.3866	0.3500	0.3538
	4	0.6624	0.2000	0.6706	0.7000	0.6831	0.7000
	6	0.6453	0.3552	0.6803	0.6900	0.7000	0.7000
	8	0.6663	0.6181	0.6851	0.6963	0.7000	0.7000
	10	0.6700	0.6340	0.6841	0.7000	0. 7000	0. 7000
Average Throughput (Kbps)	0	0	0	0	0	0	0
	2	23.11	15.26	17.08	23.08	97.25	17.06
	4	32.27	14.77	25.14	33.44	93.91	25.90
	6	31.89	19.01	25.09	33.40	141.61	25.60
	8	32.26	26.63	25.07	33.26	125.22	25.45
	10	32.37	27.03	25.96	33.38	141.81	24.36

TABLE 5

RATES COMPARISON OF RENUM IN LOSSY AND LOSSLESS MOBILE AD-HOC NETWORKS WITH DIFFERENT DATA RATES

Parameters	Time (Sec)	RENUM in Lossy MANET's			RENUM in Lossless MANET's		
		0.3	0.4	0.5	0.3	0.4	0.5
Average Delay (in Sec)	0	0	0	0	0	0	0
	2	0	0	0	0	0	0
	4	10.56	9.34	8.60	3.16	3.13	3.10
	6	12.93	13.30	12.52	4.30	4.39	4.30
	8	12.67	12.26	12.58	5.36	5.34	5.35
	10	13.26	12.05	13.15	6.36	6.34	6.36
Energy Spent (in Joules)	0	0	0	0	0	0	0
	2	3.62	3.62	3.62	1.75	1.75	1.75
	4	12.76	12.74	12.72	10.87	10.86	10.84
	6	12.99	12.95	12.91	11.12	11.09	11.05
	8	13.10	13.08	13.01	11.31	11.25	11.19
	10	13.29	13.26	13.21	11.54	11.47	11.39
Packet Delivery Ratio (PDR)	0	0	0	0	0	0	0
	2	0	0	0	0.8955	0.9833	0.9615
	4	0.4887	0.4407	0.3824	0.7444	0.7881	0.7549
	6	0.8159	0.7931	0.7763	0.8209	0.8621	0.8355
	8	0.7416	0.8491	0.7475	0.8727	0.8966	0.8762
	10	0.7598	0.9028	0.9048	0.8979	0.9167	0.9008
Average Throughput (Kbps)	0	0	0	0	0	0	0
	2	89.39	89.89	89.89	97.25	97.25	97.25
	4	101.14	93.56	95.10	97.90	93.92	90.78

	6	142.44	136.90	135.18	139.07	141.61	139.58
	8	124.49	125.63	120.60	124.19	125.22	123.56
	10	134.76	139.16	130.24	139.67	141.81	140.61

VI. CONCLUSION

One of the main challenges in lossy Mobile Ad-hoc Networks is how to achieve the conflicting goal of increased network utility and reduced power consumption, while without following the instantaneous state of a fading channel. To solve this problem Network Utility Maximization is used. In this paper the comparison between ENUM and RENUM is performed with four parameters like Average Delay, Average Throughput, Packet Delivery Ratio and Energy Spent with different data rates that are 0.3, 0.4 and 0.5 for both lossy and lossless Mobile Ad-hoc Networks. From the analysis of all the results in both the lossy and lossless Mobile Ad-hoc it can understand that data rate 0.4 is gives better performance in all the accepts like Average Delay, Average Throughput, Energy Spent and Packet Delivery Ratio (PDR) , and another important observation is Lossless RENUM gives better performance in all the accepts compared to Lossy RENUM.

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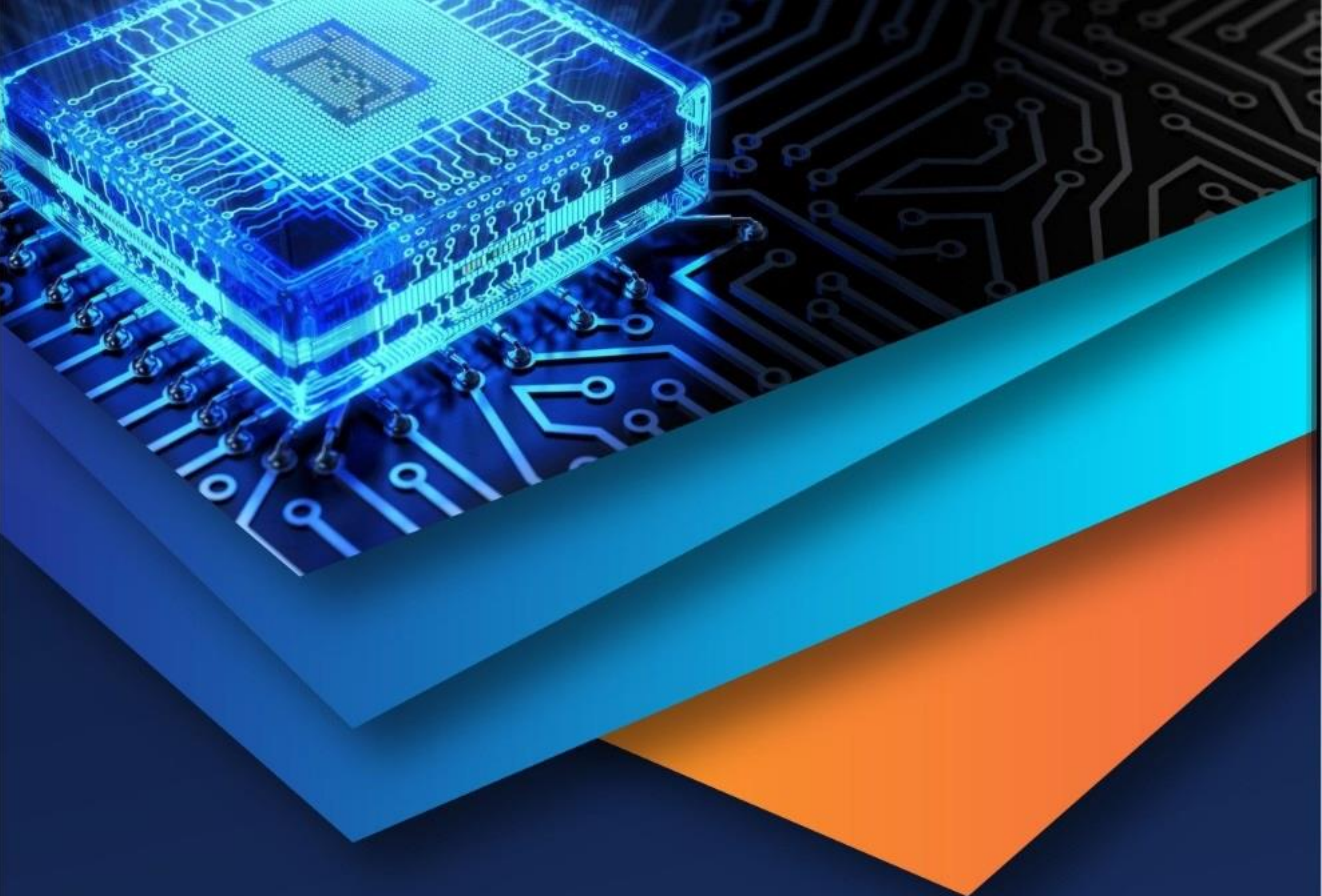

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