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Performance Evaluation of TORA Protocol using NS2 Simulator

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Abstract: ***Mobile ad hoc networks (MANETs) represent complex distributed systems that comprise wireless mobile nodes which can dynamically self-organize into arbitrary and temporary, "ad-hoc" network topologies. This allows people and devices to seamlessly internetwork in areas with no pre-existing communication infrastructure. One interesting research area in MANET is routing. Routing in the MANETs is a challenging task and has received a tremendous amount of attention from researchers. This has led to development of many different routing protocols for MANETs. A mobile node is a collection point in the network which uses a particular protocol to forward data from source to destination. The nodes are free to move about and organize themselves into a network. The requirement of routing protocol is to send and receive information among the nodes with best suited path with the minimum delay. Correct and efficient route establishment between a pair of nodes is the primary goal of routing protocol. This paper is a simulation based analysis of Temporally Ordered Routing Algorithm (TORA). The mobility models used in this work is Random Waypoint using network simulation tool NS2. The results presented in this work illustrate the performance of TORA routing protocols in an ad hoc environment.***

Keywords: ***MANET, Reactive protocols, TORA, Performance metrics.***

I. INTRODUCTION

In Computer terminology, the definition for networks is similar as a group of computers logically connected for the sharing of information or services (like print services, multi-tasking, etc.). Initially Computer networks were started as a necessity for sharing files and printers. Later this has moved from that particular job of file and printer sharing to application sharing and business logic sharing. Networks can be classified into two categories wire and wireless networks. Wireless networks are also named as ad hoc networks. In ad hoc networks all nodes are mobile and can be connected dynamically in an arbitrary manner. All nodes of these networks behave as routers and take part in discovery and maintainers of routes to other nodes in the network. The main advantages of ad hoc networks are flexibility, low cost, and robustness. MANET is a collection of mobile nodes, which forms a temporary network without the aid of centralized administration or standard support services regularly available on conventional networks. The nodes are free to move randomly and organize themselves arbitrarily; thus the network's wireless topology may change rapidly and unpredictably. The most basic operation in MANET is to successfully transmit data packets from one source to one destination. Routing has been a challenging task ever since the wireless networks came into existence. The major reason for this is the constant change in network topology because of high degree of node mobility. A number of routing protocols have been developed for accomplish this task. Routing protocols can be classified into three major categories based on the routing information update mechanism. They are Proactive, Reactive and Hybrid protocols.

The focus of our study is on-demand routing protocols. TORA (Temporally Ordered Routing Algorithm) is a source initiated on demand routing protocol. It is a highly adaptive, efficient, loop-free and scalable routing protocol based on link reversal algorithm. The main objective of TORA is to limit message propagation in the highly dynamic mobile computing environment. It means, it is designed to reduce communication overhead by adapting local topological changes in ad hoc network. Another main feature of TORA routing protocol is the localization of control packets to a small region (set of nodes) near the occurrence of a topological changes due to route break. Hence, each node of the network required to contain its local routing and topology information about adjacent nodes. TORA supports multiple routes to transmit data packet between source and destination nodes of mobile ad hoc network. In short, TORA exhibits multipath routing capability. The protocol starts reacting only when all routes to the destination are lost. In the occasion of the partition of the network, the protocol detects the partition and erases all invalid routes. The protocol has three basic functions: Route creation, Route maintenance and Route erasure.

The primary objective of this paper is to evaluate the performance of TORA protocol and study its effects with respect to performance metrics that may influence network performance. The metrics like Packet Delivery Ratio, End to End Delay, Route Overhead, Throughput, and Energy Consumption are verified using the number of nodes, Simulation Time, Packet Size and Mobility. The paper is organized as follows: Section 2 presents the overview of TORA. Section 3 provides the Network Simulators (ns2). The simulation parameters and metrics are described in Section 4. Section 5 presents the Simulation Results. Finally Section 6 concludes the paper.

II. OVERVIEW OF TORA

TORA is an algorithm for routing data across Wireless Mesh Networks or Mobile ad hoc networks. It was invented by Vincent Park and M. Scott Corson from university of Maryland in 1997 for wireless ad hoc network. Park has patented his work, and it was approved by Nova Engineering, who is marketing a wireless router product based on Park's algorithm. TORA attempts to achieve a high degree of scalability using a "flat", non-hierarchical routing algorithm. In its process the algorithm attempts to contain to the best level possible, the creation of important control message broadcast. In order to attain this, the TORA does not use a shortest path solution.

TORA builds and maintains a Directed Acyclic Graph (DAG) rooted at a destination. No two nodes may have the same height. Information may flow from nodes with higher heights to nodes with lesser heights which can then be thought of as a fluid that may only stream downward. By maintaining a set of completely planned heights TORA achieves loop-free multipath routing, as information cannot 'flow uphill' and so cross back on its. The key design concepts of TORA are localization of control messages to a very small set of nodes near the occurrence of a topological transform. The node that wants to communicate with the destination sends query message to the destination, which contains the destination node id. On receipt of query message at the destination the update message is sent to the sender which contains the destination field. To achieve this, nodes have to preserve the routing information about adjacent (one hop) nodes. The protocol performs three fundamental functions:

- Route creation
- Route maintenance
- Route erasure

During the route creation and maintenance phases, nodes use a height metric to set up a directed acyclic graph (DAG) rooted at destination. Then links are assigned based on the relative height metric of nearest nodes. During the period of mobility, if the DAG is broken, the route maintenance unit comes into picture to reestablish a DAG routed at the destination. Timing is an important factor for TORA because the height metric is dependent on the logical time of the link failure. TORA's route erasure phase basically involves flooding a broadcast clear packet (CLR) throughout the network to erase invalid routes.

Route Creation

Figure1 show that the source node (28th) requires a route to a destination node. It initiates route creation where query packets are flooded out to search for possible routes to the destination. Finally a query packet reaches either a node that has a route or the destination itself or the node replies with an update packet. On receipt of an update packet, it sets its link as directed from itself to the sender of the update packet. Link between these two nodes are set.

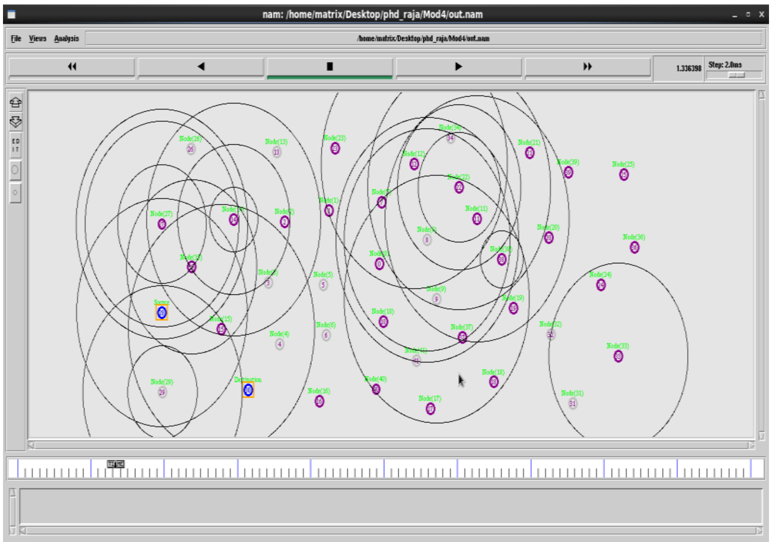


Figure 1: TORA - RREQ – Network Animator with 42 nodes

As source node gets an update packet from a nearest node, it sets a link between the nodes and start sending the packets. Route 1 node (28th) and node are nearer and is shown in fig. no 2.

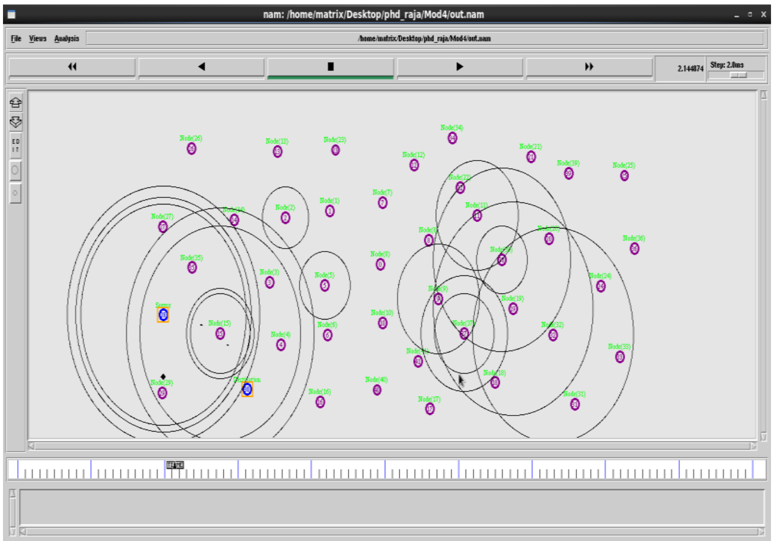


Figure 2: TORA – PATH-1 – Network Animator with 42 nodes

Route 2 is shown in figure 3. In this way the protocol changes the route

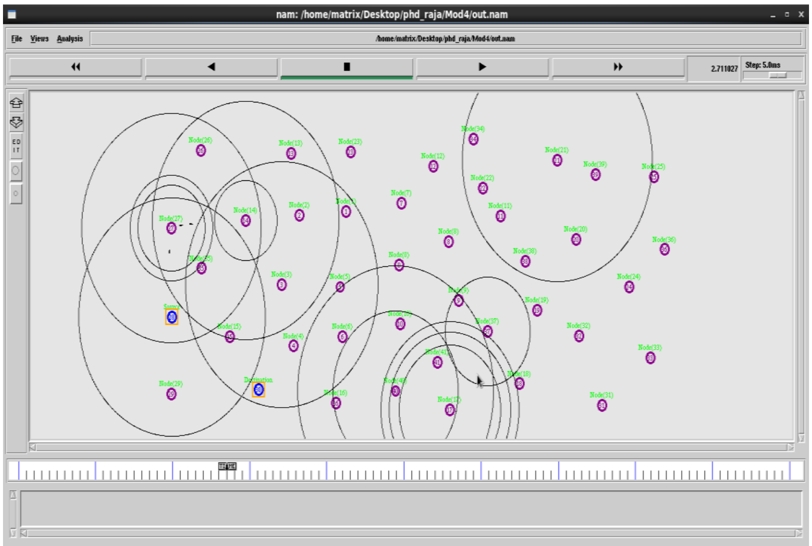


Figure 3: TORA – PATH-2 – Network Animator with 42 nodes

A. Route Maintenance

Route maintenance occurs when a node loses its entire outgoing links. During the detection of a link failure the node propagates an update packet which reverses the links to all of its neighboring nodes. Intermediate nodes that receive the update packet then reverse the links of their neighboring nodes. Links are reversed only for neighboring nodes that do not have any out-going links and have not performed recent link reversal. The link reversal needs to be continuous until each node in the network has at least one out-going link and it is depicted in below figure 4.

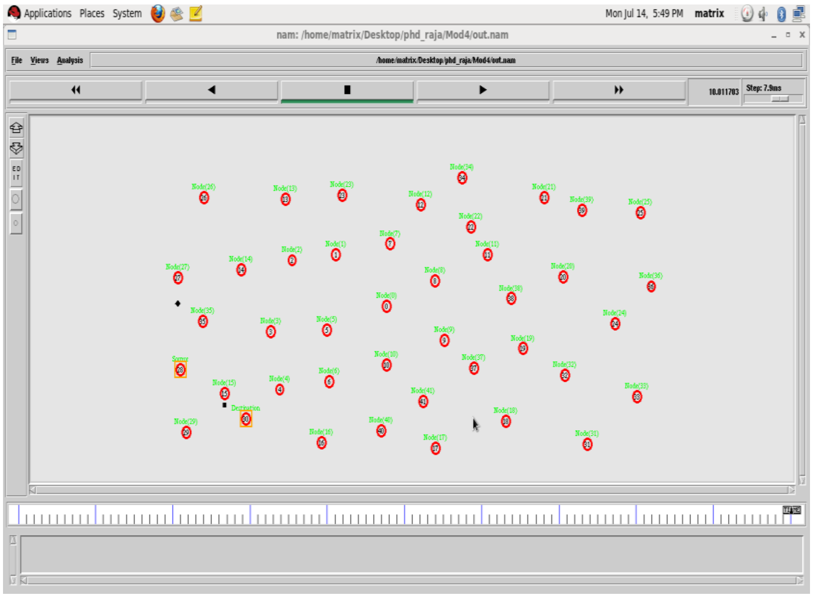


Figure 4: TORA-END PATH - Network Animator with 42 nodes

B. Route Erasure

In the event that a node in a network partition is without a route to the destination, route removal is initiated. The recognition of a network partition is undertaken by the node that first initiated route maintenance. During route maintenance, the node sends out update packets to reverse links to all its neighboring nodes and attempts to find a route to the destination node. It is capable of establishing the presence of a network partition if a similar update packet is sent back to it by another node. This way all nodes in the present network partition cannot find a route and are trying to find a route through the new node. Route erasure is next performed by the node by flooding clear packets all over the network. On receipt of a clear packet, it sets the links to its neighbors as unassigned. These clear packets broadcast through the network and erase all routes to that unreachable destination.

III. Network Simulators (NS2)

Ns-2 is a discrete event simulator targeted at networking research. It provides substantial support for simulation of TCP, routing and multicast protocols over wired and wire-less networks. The network simulator (ns) contains all commonly used IP protocols. Ns-2 fully simulates a layered network from the physical radio transmission channel to high-level applications. NS2 (2.34 & 2.35) simulator is used for simulating different reactive routing protocols. The simulator is written in C++ and a script language called OTcl. NS uses an OTcl interpreter towards the user. This means that the user writes an OTcl script that defines the network (number of nodes, links) the traffic in the network (sources destinations, type of traffic) and which protocols it will use. This script is then used by ns during the simulations.

The result of the simulations is an output trace file that can be used to do data processing (calculate delay, throughput etc) and to visualize the simulation a program called Network Animator (NAM) used. NAM is a very good visualization tool that visualizes the packets as they propagate through the network. NAM is a Tcl/AWK based animation tool for viewing network simulation traces and real world packet trace data. The first step to use NAM is to produce the trace file. The trace file contains topology information, e.g., nodes, links, as well as packet traces. During an NS simulation, a user can produce topology configurations, layout information, and packet traces using tracing events in NS. When the trace file is generated, it is ready to be animated by NAM. Upon startup, NAM will read the trace file, create topology, pop up a window, do layout if necessary.

IV. Simulation Parameters

The goal of our experiments is to examine and quantify the effects of various factors and their interactions on the overall performance of ad-hoc networks. Every run of the simulator accepts a scenario file as input that describes the exact motion of each node using Random Waypoint mobility model. The exact sequence of packets originated at each node together with exact time during change in packet or motion origination occurs. In all our experiments we considered five sample points of a particular factor and verified for AODV (TROA) protocol. Therefore 15 simulation runs were conducted to analyze the performance. Standard statistics of the packet delivery ratio, packet end to end delay, routing overhead, throughput and energy consumption for the entire MANET is examined. In our simulations, the MAC layer runs on the IEEE 802.11 Distributed Coordination Function (DCF). The bandwidth is set to 2 Mbps and the transmission range is set to 250 m. The evaluations are conducted using 42 nodes that are randomly distributed in an area covering 1050m x 600m. The traffic sources are CBR (continuous bit –rate). The mobile nodes and the server were spread randomly within the geographic area. In this project, we used TCP traffic to study the effects of the ad hoc protocol.

Table 1: Simulation Parameter

Experiment Parameter	Experiment value	Description
Simulation Time	0 – 10 mps	Simulation Duration
Terrain Dimension	[1050*600]m	X,Y Dimension of motion
No. of mobile nodes	42	No. of nodes in a network
Node Placement	Random Waypoint	Change Direction randomly
Mobility Speed	0 – 10 mps	Mobility of nodes
Packet Size	256,512,625,712,850	Size of packets
Mobility Model	Random	Mobility direction
Routing Protocols	AODV, DSR, TORA	Path-finding
MAC Protocol	802.11	Wireless Protocol
Channel Type	Wireless Channel	Types of Channel
Maximum Packets	50	No. of packets

In the Random Waypoint model, each node starts to move from its location to a random location with a randomly chosen speed from a minimum speed equal to 5 m/s and maximum speed equal to 30 m/s. In each test, the simulation lasts for 600 seconds. Once the destination node is reached, the node takes a break for a certain period of time in seconds and another random destination is chosen after that pause time. The model parameters that are used in the experiments are summarized in Table 1. The size of each Constant Bit Rate (CBR) packet is 1000 bytes and packets are generated at a fixed interval rate of 4 packets per second. 15 flows were configured to choose a random source and destination during the simulation.

4.1 Performance metrics

Packet delivery ratio: The ratio between the number of packets originated by the CBR sources and the number of packets received by the CBR sink at the final destination. It describes the loss rate seen by the protocol.

End-to-End Delay: Average amount of time taken by a packet to go from source to destination. This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission on delays at MAC, and propagation and transfer times.

Route overhead: The total number of routing packets transmitted during the simulation. If control and data traffic share the same channel, and the channels capacity is limited, then excessive control traffic often impacts data routing performance. This is the ratio between the total control packets generated to the total data packets during the simulation time.

Throughput: It is defined as total number of packets received by the destination. It is a measure of effectiveness of a routing protocol. There is two representations of throughput one is the amount of data transferred over the period of time expressed in kilobits per second (Kbps). The other is the packet delivery percentage obtained from a ratio of the number of data packets sent and the number of data packets received.

Energy Consumption: Energy consumption of a node is mainly due to the transmission and the reception of data or controlling packets. To measure this amount of energy consumed during the transmission process (noted txEnergy), we should multiply the transmission power (txPower) by the time needed to transmit a packet:

txEnergy = txPower x (packetsize/bandwidth)

And for a received packet:

rxEnergy = rxPower x (packetsize/bandwidth)

V. Simulation Results

5.1 TORA Performance with respect to Simulation Time

The performance of AODV (TORA) routing protocol is evaluated in same simulation environment with 42nodes. Simulation results are collected from different scenarios of reactive protocols. They are revealed in the subsequent section in the form of X-graph taking simulation time along X-axis and the performance metrics in Y-axis. A study of performance metrics of AODV (TORA) reactive protocol is done with respect to Simulation time 5, 10, 15, 20 and 25seconds. A table of performance metric values with respect to simulation time was created & shown below Table 2.

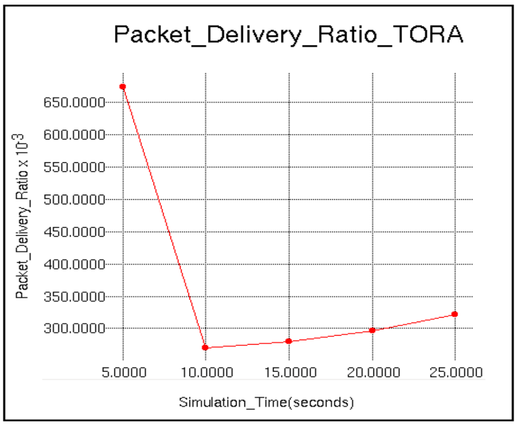
Table.2: TORA – Simulation Time

TORA-Simulation Time					
Values	**PDR**	**E2E**	**Rout-over-head**	**Throughput**	**Egy-consump**
5	0.6739	458.108	62.652	2522.96	40.8373
10	0.2708	1368.4	275.175	5094.90	96.4708
15	0.2793	1867.52	279.203	4632.42	108
20	0.2963	878.451	262.209	5162.02	108
25	0.3214	675.876	245.655	4765.32	108

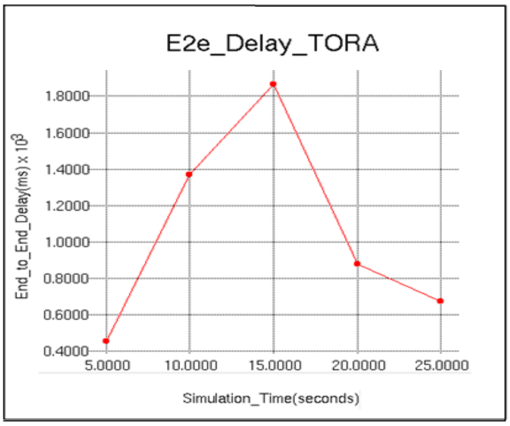
The X-Graphs Shown in figure 5 represents performance metrics of TORA Vs Simulation time. Figure (a) illustrates the results of Packet Delivery Ratio with Simulation time, taking Simulation time along the X-axis and Packet Delivery Ratio in the

Y-axis. This graph shows about PDR which is very poor. There is always very high packet loss i.e. the number of packet received decreases according to simulation time. As the simulation time increases the packet loss increases substantially.

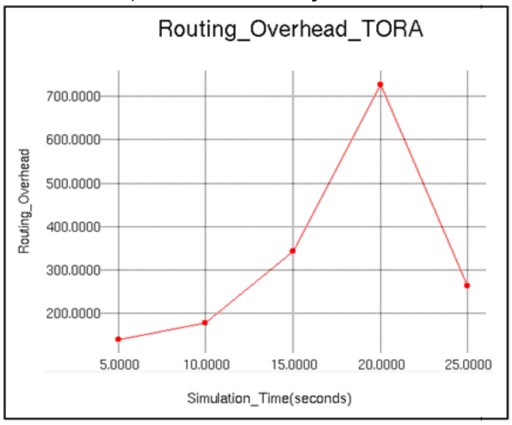
Figure (b) shows the results of End to End Delay with Simulation time, taking Simulation time along the X-axis and End to End Delay in the Y-axis. This graph indicates End to End Delay in ms. the delay is more when the simulation time is 15s and the delay reduces as the simulation time increases.



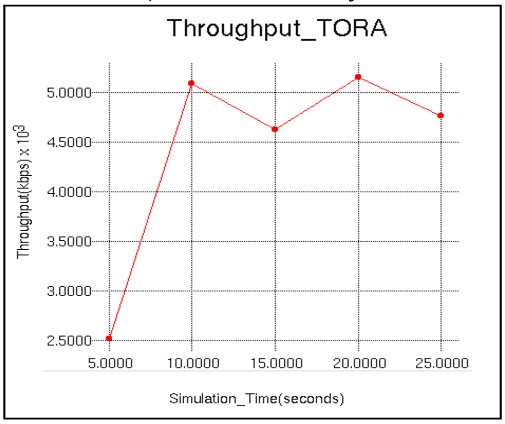
a). Packet Delivery Ratio



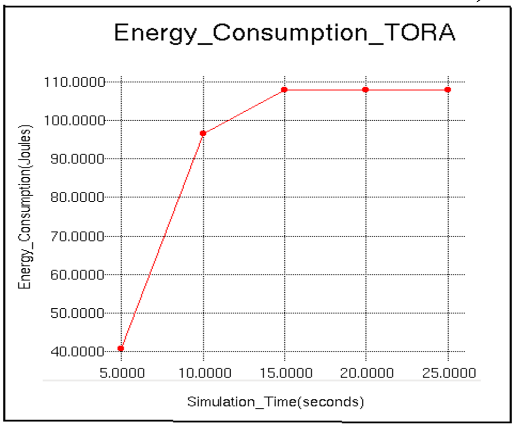
b). End to End Delay



c). Routing Overhead



d). Throughput



e). Energy Consumption

Figure 5: Graphical representation of performance metrics in TORA Vs Simulation Time

Figure (c) illustrates the results of Route Overhead with Simulation time, taking Simulation time along the X-axis and Route Overhead along the Y-axis. In this Route Overhead increases at 20sec and gradually decreases as simulation time is increased. Figure (d) illustrates the effect of Throughput with Simulation time, taking Simulation time along the X-axis and Throughput in the Y-axis. This graph shows Throughput in kbps. Here the throughput behaves irregularly high at 10s and less at 15s and high at 20s and less at 25s. In overall TORA has high throughput value. Figure (e) illustrates the results of Energy Consumption with Simulation time, taking Simulation time along the X-axis and Energy Consumption in the Y-axis. This graph shows the Energy Consumption in joules which increases as simulation time increases

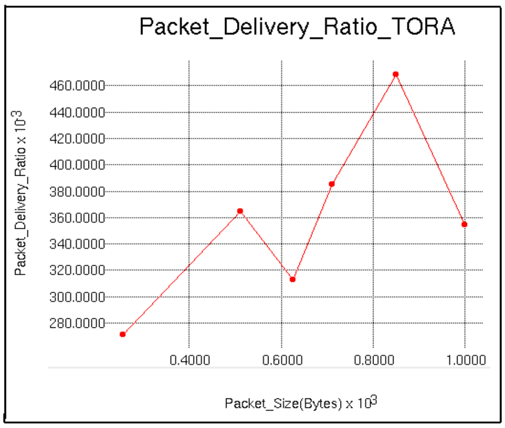
5.2 TORA Performance with respect to Packet Size

The performance of AODV (TORA) routing protocol is evaluated in same simulation environment with 42nodes. Simulation results are collected from different scenarios of reactive protocols. The effects of simulation are exposed in the subsequent section via X-graph. X-axis shows the packet size and y-axis shows the metrics. A study of performance metrics of AODV (TORA) reactive protocol is done with respect to packet size 256, 512, 625, 712, 850 & 1000 bytes. A table of performance metric values with respect to packet size was created & shown in below table 3.

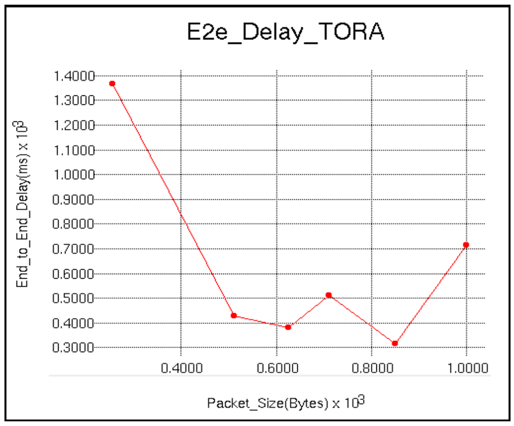
Table 3: TORA – Packet Size

TORA-Packet Size					
Values	**PDR**	**E2E**	**Rout-over-head**	**Throughput**	**Egy-consump**
256	0.2708	1368.4	275.175	5094.90	96.4708
512	0.3646	427.195	202.667	5267.19	97.3477
625	0.3125	382.678	233.085	5367.00	97.534
712	0.3854	512.873	178.541	4291.02	97.0954
850	0.4688	317.965	149.530	4291.02	97.092
1000	0.3542	716.118	212.599	4958.01	97.607

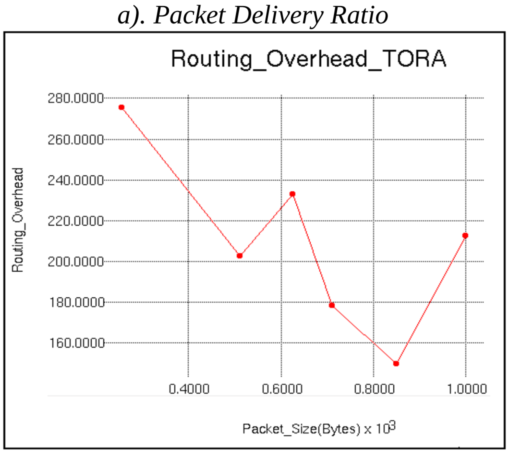
The X-Graphs Shown in figure 6 represents performance metrics of TORA Vs Packet Size. Figure (a) illustrates the results of Packet Delivery Ratio with Packet Size, taking Packet Size along the X-axis and Packet Delivery Ratio in the Y-axis. This graph shows about PDR which is very poor. In this always there is very high packet loss and the number of packet received decreases according to increase in packet size. Figure (b) shows the results of End to End Delay with Packet Size, taking Packet Size along the X-axis and End to End delay in Y-axis. The unit is in ms. In this the delay is decreased at 512bytes and 850bytes and the delay slightly reduces as the packet size increases to 1kb. Figure (c) illustrates the results of Route Overhead with Packet Size, taking Packet Size along the X-axis and Route Overhead along the Y-axis. In this Route Overhead decreases at 512bytes and gradually increases at 612bytes and decreases at 850bytes and increases at 1kb.



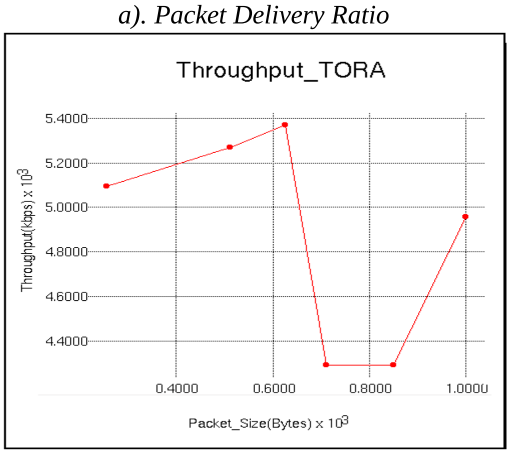
a). Packet Delivery Ratio



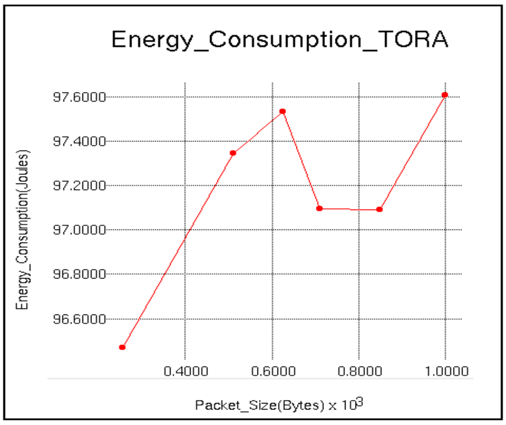
a). Packet Delivery Ratio



c). Routing Overhead



d). Throughput



e). Energy Consumption

Figure 6: Graphical representation of performance metrics in TORA Vs Packet Size

Figure (d) illustrates the results of Throughput with Packet Size, taking Packet Size along the X-axis and Throughput in the Y-axis. This graph shows Throughput in kbps. Here the throughput behaves irregularly high at 625bytes and less at 712bytes & 850bytes and once again high at 1kb. Figure (e) illustrates the results of Energy Consumption with Packet Size, taking Packet Size along the X-axis and Energy Consumption in the Y-axis. This graph shows the Energy Consumption in joules which increases at 625bytes and decreases at 712 & 850bytes and increases at 1kb.

5.3 TORA Performance with respect to Mobility

The performance of AODV (TORA) routing protocol is evaluated in same simulation environment with 42nodes. Simulation results are collected from different scenarios of three reactive protocols. The simulation results are revealed in the subsequent section via X-graph taking mobility along X-axis and the performance metrics in Y-axis. A study of performance metrics of AODV (TORA) reactive protocol is done with respect to mobility speed 5, 10, 15, 20 & 25m/s. A table of performance metric values with respect to mobility speed was created & shown below Table 4.

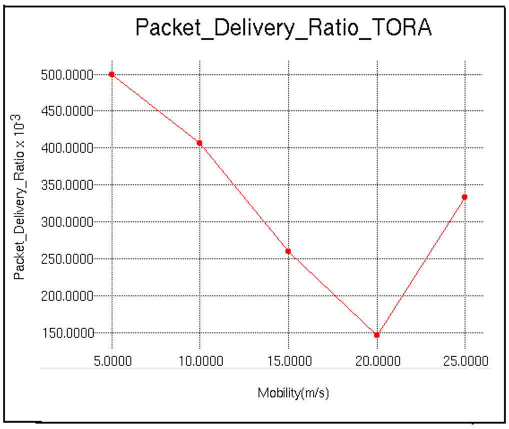
Table 4: TORA – Mobility

TORA-Mobility					
Values	**PDR**	**E2E**	**Rout-over-head**	**Throughput**	**Egy-consump**
5	0.5000	292.591	138.459	5136.68	96.9539
10	0.4062	256.634	178.212	4492.41	96.4266
15	0.2604	404.678	343.638	4278.09	97.4329
20	0.1458	803.306	727.779	6086.48	97.2775
25	0.3333	631.626	262.702	5114.67	97.2998

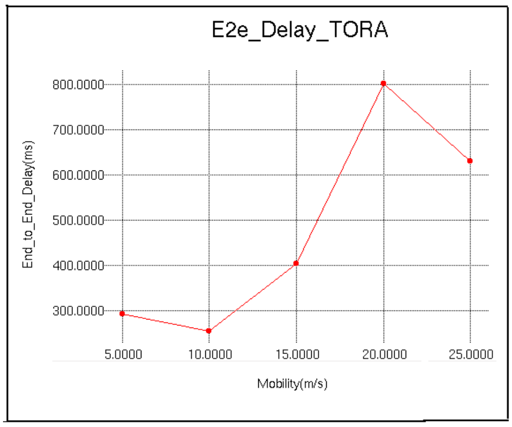
The X-Graphs Shown in figure 7 represents performance metrics of TORA Vs Mobility. Figure (a) illustrates the results of Packet Delivery Ratio with Mobility, taking Mobility along the X-axis and Packet Delivery Ratio in the Y-axis. This graph shows about PDR which is very poor. PDR is only 0.5 for low mobility and the ratio decreases even lesser for high mobility speed. Figure (b) shows the results of End to End Delay with Mobility, taking Mobility along the X-axis and End to End Delay in the Y-axis. This graph indicates End to End Delay in ms. The delay gradually raises at 20m/s and decreases at 25m/s.

Figure (c) illustrates the results of Route Overhead with Mobility. X-axis represents Mobility with Route Overhead in Y-axis. In this Route Overhead increases at 20sec and gradually decreases as mobility increases. Figure (d) illustrates the results of Throughput against mobility. X-axis represents mobility with Throughput in Y-axis. This graph depicts Throughput in kbps.

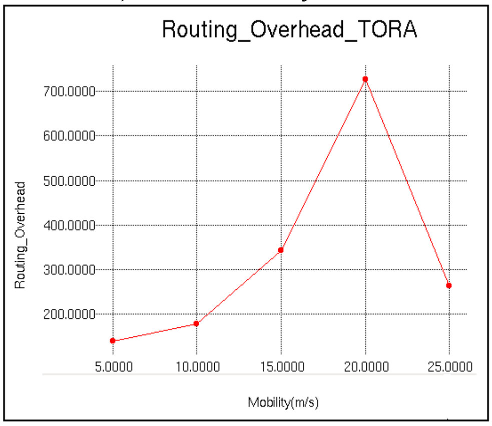
Here the Throughput behaves irregularly. It is lower at low mobility and high at 20m/s and moderate at 25m/s. Figure (e) illustrates the results of Energy Consumption with Mobility, taking Mobility along the X-axis and Energy Consumption in the Y- axis. This graph shows the Energy Consumption in joules. In this Energy Consumption is high at high mobility speed.



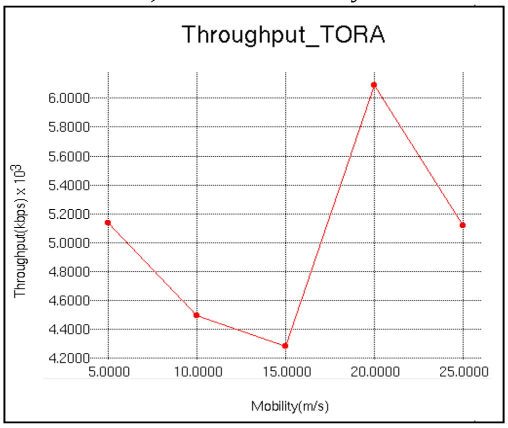
a). Packet Delivery Ratio



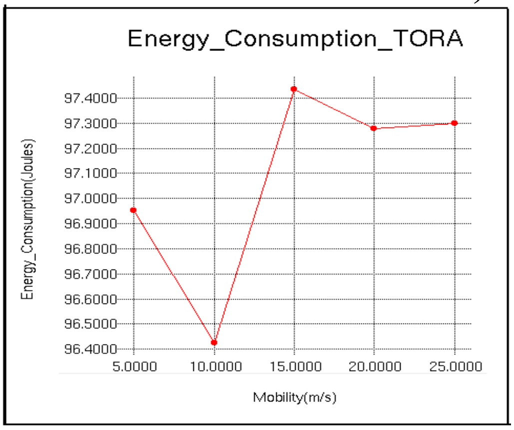
b). End to End Delay



c). Routing Overhead



d). Throughput



e). Energy Consumption

Figure 7: Graphical representation of performance metrics in TORA Vs Mobility

VI. CONCLUSION

This work is an attempt towards a comprehensive performance evaluation of TORA routing protocols using the latest simulation environment NS 2. The simulation characteristics used in this research are unique in nature, and are very important for detailed performance evaluation of any networking protocol. Implementation of TORA reactive routing protocol is done. Basically the five performance metrics packet delivery ratio, end to end delay, routing overhead, throughput and energy consumption are discussed. The trace files are generated and results are shown via X-Graphs. The results are projected by varying the simulation time, packet size and mobility using trace files. TORA has its excellent support for multiple routes and multicasting.

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