Performance Evaluation of TORA Protocol Using Random Waypoint Mobility Model

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Abstract
Mobile ad hoc network is a kind of dynamic network. In this network the mobile nodes dynamically form a temporary network without any centralized administration or the use of any existing network infrastructure. A number of routing protocols like Ad Hoc On-Demand Distance Vector Routing (AODV), Dynamic Source Routing (DSR) and Destination-Sequenced Distance-Vector (DSDV) have been proposed. TORA is a reactive routing protocol for multi-hop networks with some proactive features. It uses distributed and loop-free routing as nodes need only maintain one-hop information in the routing table. TORA is developed to reduce the communication overhead related to adapting to network topological changes. In this paper TORA Protocol was studied and its characteristics with respect to the Random Waypoint Mobility Model are analysed based on the packet delivery fraction, routing load, end-to-end delay, PDF, number of packets dropped, throughput and jitter using Network Simulator (NS2) that is employed to run wired and wireless ad hoc simulations. Analyses of the trace files are done in Tracegraph with Matlab.
Keywords— **TORA, MANET, Wireless, Performance Evaluation, Mobility.**

I. Introduction

Mobile Ad hoc Network presently is the emerging area of research with the rapid growth of mobile handheld devices. A Mobile Ad hoc Network (MANET for short) is a network where a number of mobile nodes work together without the intervention of any centralized authority or any fixed infrastructure. MANETs are self-configuring, self-organizing network where the topology is dynamic. With the increase of mobile devices and wireless communication, such type of ad hoc networking is gaining importance with the increasing number of widespread applications [1]. Ad hoc networks are normally used where there is little or no communication infrastructure or the existing infrastructure for communication is expensive.

II. MANET Applications

Qualities like quick deployment, minimal configuration and absence of centralized infrastructure make MANETs suitable for medical, combat and other emergency situations. All nodes in a MANET have the capability of moving in a given space and establishing connection between themselves. Mobile Ad-Hoc Networks allow users to access and exchange information regardless of their geographic position. In contrast to the infrastructure networks using access points, all nodes in MANETs are mobile and their connections are dynamic.

In the absence of any centralized authority in such a network, we consider each node as a host and a potential router at the same time. A sample scenario of wireless nodes of a Mobile Ad hoc Network is presented here in Figure 1

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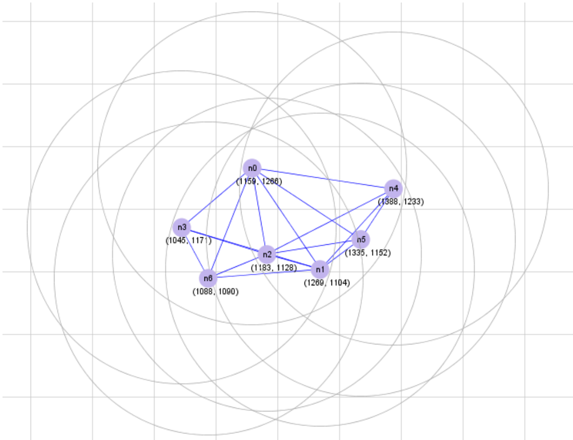

Figure 1: An Example of Mobile Ad hoc Network (MANET)

Applications for MANETs are wide ranging they are used in many critical situations: An ideal application of MANET is in search and rescue operations. Another application of MANETs is wireless sensor networks. A wireless sensor network is a network composed of a very large number of small sensors. These small sensors can be used to detect any number of properties in a given area. Examples include pressure, temperature, toxins, pollutions, etc.

III. ROUTING IN MOBILE AD HOC NETWORK

An ad-hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any stand-alone infrastructure or centralized administration [2]. Mobile Ad-hoc networks are self-organizing and self-configuring multi-hop wireless networks, where the topology of the network changes dynamically. This is mainly due to the unpredictable mobility of the node [3]. Nodes in these networks utilize the same wireless channel and engage themselves in multi-hop forwarding. The nodes in this network not only act as hosts but also as routers that route the data from/to other nodes in network [4]. Classification of routing protocols in MANET's can be done on the basis of routing strategy and network structure [3, 5]. According to the routing strategy the routing protocols can be categorized into Table-Driven and Source-Initiated protocols, while on the basis of the network structure these protocols are classified as flat routing, hierarchical routing and geographic position assisted routing [3].

Flat routing protocols are of two types; proactive routing (table driven) protocols, and reactive (on-demand) routing protocols. They further can be classified according to their design principles; proactive routing follows LS strategy (link state) while on-demand routing follows DV (distance-vector). Proactive protocols continuously learn the topology of the network by exchanging topological information among the regular nodes. Thus, when there is a need for a route the data to a particular destination, such route information is available immediately [6]. Hence there is minimum delay in determining the route to be chosen which is important for time-critical traffic. Proactive protocols suits well in networks where the nodes transmit data frequently and have low node mobility. Examples of Proactive MANET Protocols include:

- Optimized Link State Routing, or OLSR [7]
- Topology Broadcast based on Reverse Path Forwarding, or TBRPF [8]
- Fish-eye State Routing, or FSR [9]
- Destination-Sequenced Distance Vector, or DSDV [10]
- Landmark Routing Protocol, or LANMAR [11]
- Clusterhead Gateway Switch Routing Protocol, or CGSR [12]

Reactive / On Demand routing is a relatively new routing style that provides solution to relatively large network topologies. These protocols are based on some sort of query-reply packet exchange. In this type of routing there is no need of periodic transmission of topological information. Common for most on-demand routing protocols are the route discovery phase where packets are flooded into the network in search of an optimal path to the destination node in the network. Examples of Reactive MANET Protocols include:

- Ad hoc On-Demand Distance Vector, or AODV [17]
- Dynamic Source Routing, or DSR
- Temporally Ordered Routing Algorithm, or TORA

IV. TEMPORALLY ORDERED ROUTING ALGORITHM PROTOCOL (TORA)

The Temporally-Ordered Routing Algorithm (TORA) [17] is an adaptive, distributed, loop-free routing protocol for multi-hop networks which has minimum overhead against topological changes. TORA is distributed because here node needs to maintain information about neighbouring routers only (i.e., one-hop knowledge). TORA maintains routing table entries on a per-destination basis like a distance-vector routing approach. TORA supports a mixture of reactive and proactive routing on a per-destination basis. In reactive operation, sources, initiate the route establishment to a given destination on-demand. This mode of operation is required in dynamic network topology with comparatively intermittent traffic patterns, since it is not always required to maintain routes between every source/destination pair at all times. At the same time, certain destinations (e.g., servers or gateways to hardwired infrastructure) can initiate proactive operation, just like traditional table-driven routing approaches. This allows network to proactively maintain routes to certain destinations for which routing is frequently required.

TORA assigns directions ("upstream" or "downstream") to the links between nodes to forward data grams to the destination based on the relative values of a metric associated with each router. The metric used by the node/router to specify the links can conceptually be thought of as the router's "height" (i.e., links are directed from the higher node to the lower node). The significance of the "height" field is that the node will only forward data grams downstream. Node links with an unknown or undefined height are considered un-directed and cannot be used for forwarding.

The TORA protocol performs four basic operations: (a) Route Creation, (b) Route Maintenance, (c) Route Erasing and (d) Route Optimization. Route creation corresponds to the selection of heights to form a directed sequence of links leading to the destination in a previously un-directed portion of the network. Route Maintenance refers to the adapting of network topology changes, for example, due to the loss of some node's last downstream link, some directed paths may no longer lead to the destination node. This event triggers the re-selection of router heights, which re-orients the topology such that all directed paths again lead to the destination node. In cases where the network becomes partitioned, links in the cluster of the network that has become partitioned from the destination must be marked as un-directed to erase invalid routes. Finally, TORA runs a parallel mechanism for optimizing routes, in which routers re-designate their "heights" in order to optimize the routing structure.

V. RANDOM WAYPOINT MOBILITY MODEL

Random Waypoint Mobility (RWP) model is a commonly used model for providing mobility in ns2. It is the most basic model which describes the movement pattern of independent nodes in simple terms.

Briefly, in the Random Waypoint Mobility model:

- Each node moves along a zigzag line from one waypoint Pi to the next Pi+1 where Pi is the position of a particular node.
- The waypoints are uniformly distributed over the given deployment area, e.g. unit disk.
- At the start of each round a random speed is drawn from the speed distribution. (In the basic case the velocity is constant 1)
- Optionally, the nodes may have so-called "thinking times" when they reach each waypoint before continuing on the next round, where durations are independent and identically distributed random variables.

VI. SIMULATION OF ROUTING PROTOCOL

Simulation of the TORA routing protocol has been done to evaluate the performance of the network with respect to the varying number of nodes. Various network parameters that are taken for the simulation are listed in Table 1.

TABLE I: Network Parameter Definition

Parameter Name	Value
Channel Type	Channel/Wireless Channel
Netif	Phy/Wireless Phy
Mac Protocol	Mac/802_11
Queue Length	50 Packets
Number of Nodes	3/4/5/6/7
Routing Protocol	TORA
Grid Size	500 x 500
Packet Size	512
Simulation Time	200 Sec
Pause Time	2.0 Sec
Max. Speed	10.0 m/s
Max. Connections	No. of Nodes/ 2
Mobility Model	Random Waypoint Mobility Model

VII. RESULTS, PERFORMANCE EVALUATION & ANALYSIS

Experiments are carried out in Network Simulator 2 (NS2 [16]) with programming done in Tcl script language. Two output files with *.nam and *.tr extension were further analysed. NAM is a Tcl/TK based animation tool for viewing network simulation traces and real world packet traces. NAM supports topological layout, packet level animations, and various data inspection tools. Trace files (with *. tr extension) can be analysed by trace graph [15] tool that runs within Mat lab. We also evaluate the performance of TORA by varying the number of nodes. We are able to analyse the simulation of TORA with different number of nodes, with the help of 2D and 3D graphs generated with trace graph. The simulation is divided in five parts based on the number of nodes that vary:

- TORA with 4 nodes.
- TORA with 8 nodes.
- TORA with 12 nodes.
- TORA with 16 nodes.
- TORA with 20 nodes.

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The comparison of performance of TORA, based on the number of nodes is done on following parameters like packet sent, packet received, packet dropped, packets lost, packets forwarded, throughput and average end-to-end delay, Normalized Routing Load, and Packet Delivery Fraction.

VIII. Comparison of Performance of AODV Based Upon Number of Nodes

As we increase the number of nodes for performing the simulation of TORA protocol, number of sent and delivered packets changes, which results in a change in throughput and average end-to-end delay. Throughput is defined as the ratio of data delivered to the destination to the data sent by the sources. Average end-to-end delay is the average time a packet takes to reach its destination. The table II shows the difference between sent packets, received packets, lost and dropped packets, the average end-to-end delay when the number of nodes is increased.

Packet Size--------------------- 512 Bytes

Simulation Time--------------- 200 Sec.

Table II: Comparison of Various Parameters v/s No. of Nodes

No of Nodes→ / **Parameters**	**3**	**4**	**5**	**6**	**7**
Packets Sent	21282	22937	22815	20142	19564
Packets Received	21215	22694	22129	19113	18967
Packets Forwarded	0	0	209	839	244
PDF	0.9962	0.9899	0.9799	0.9653	0.9633
End to end delay	0.2434	0.5216	0.7504	0.7657	0.8967
Throughput	663.65	664.01	660.15	650.79	648.09

The data in Table 2 are plotted in MS Excel

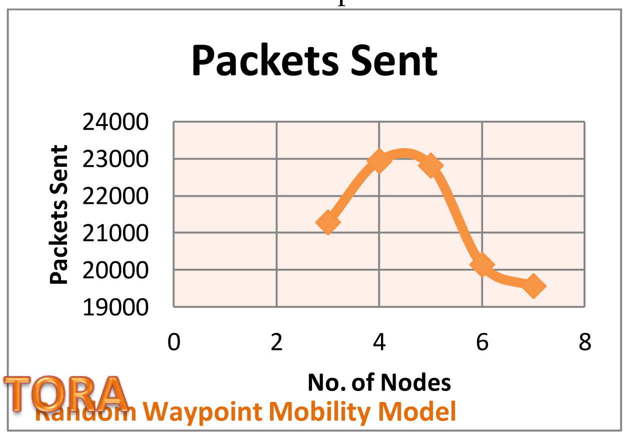

Fig. 2: Plot of Packets Sent against no. of Nodes

Fig. 2 shows the total number of packets sent vary with increasing number of nodes. As the number of nodes goes on increasing, the packets sent first increases then, decreases.

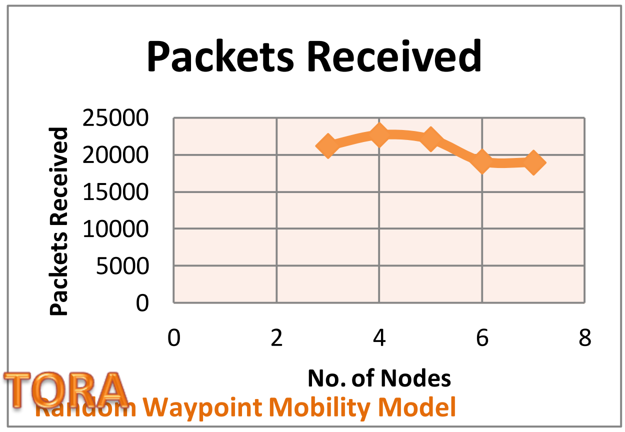

Fig. 3: Plot of Packets Received against no. of Nodes

Fig. 3 shows the graphical representation of Packet Received versus number of nodes of TORA protocol. As the number of nodes goes on increasing, the number of packets received decreases.

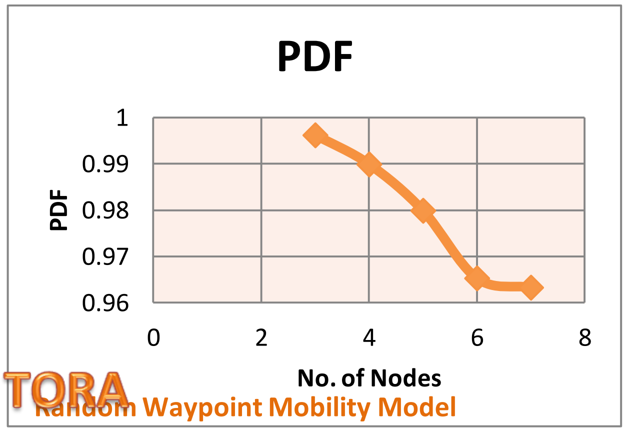

Fig. 4: Plot of PDF against no. of Nodes

$$\text{PDF} = \frac{\text{Number of Received Packets}}{\text{Number of Sent Packets}}$$

Figure 4 shows the graphical representation of PDF versus the number of nodes of TORA protocol. As the number of nodes goes on increasing, the PDF value decreases.

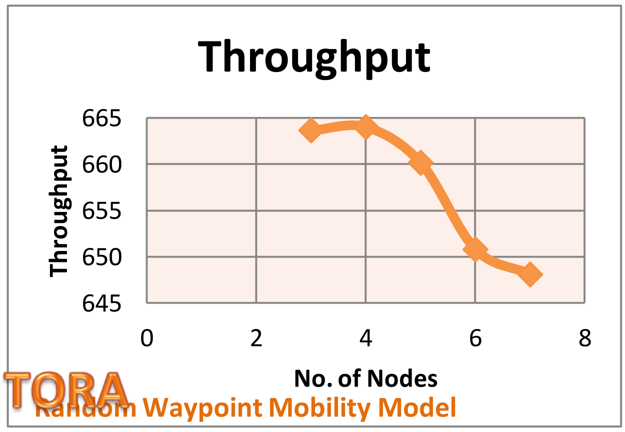

Fig. 5: Plot of Packets Received against no. of Nodes

Figure 5 shows the graphical representation of Throughput versus the number of nodes of TORA protocol. As the number of nodes goes on increasing, the Throughput value decreases.

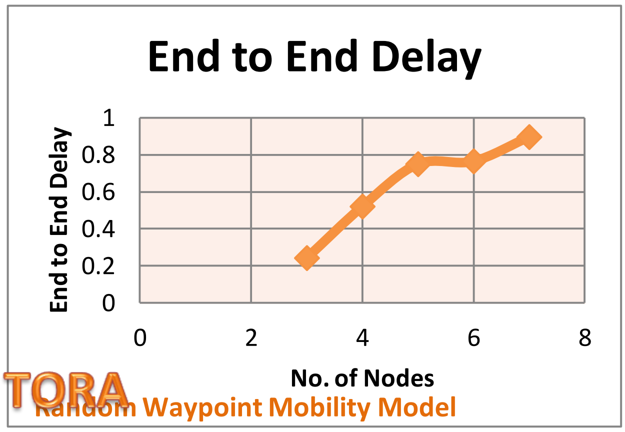

Fig.6 : Plot of Average E2E delay against no. of Nodes

Figure 6 shows the graphical representation of Average End to End Delay versus the number of nodes of TORA protocol. As the number of nodes goes on increasing, the E2E delay value increases.

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