Performance evaluation of four hybrid routing protocols for low- and high-density MANETs

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Abstract–Wireless ad-hoc networks are growing in popularity every day. MANETs, VANETs, and SENSOR are the examples of such networks. People are often unaware of the use of those different networks and sometimes it is not clearly understood which network type to deploy according to the requirements of users. Another problem is about which protocols best suits each type of wireless network's issues. To fill this gap, we compare these three types of networks and finally show that MANET is the best suitable for almost all user's requirements as it is easy to deploy anywhere at any time. Then using Energy, Accuracy, and Lifetime network parameters, we compare three types of routing protocols available in MANET PROACTIVE, REACTIVE, and HYBRID and choose the hybrid as the best routing protocol because it combines the features of both proactive and reactive protocols and is the only one which is provided with all these three parameters. These two performance evaluations finally lead us to the last evaluation with which, using three performance metrics, such as packet delivery ratio, throughput, and average end-to-end delay, we conduct a performance evaluation of four popular hybrid routing protocols ZRP, TORA, OORP, and ARPAM. The simulations are carried out using NS-2 simulator. The simulation results obtained for low- and high-density networks confirm that TORA performs better for networks with low node density in term of packet delivery ratio, end-to-end delay, and throughput whereas ZRP outperforms other protocols in term of the same metrics but in highly dense networks.

Keywords – MANETs, Routing Metrics, Routing Protocols, Performance Analysis, and simulation.

I. INTRODUCTION

A wireless ad hoc network represents any type of computer network whose topology does not rely on any pre-existing infrastructure. It is a decentralized type of wireless network as it is not managed by routers or access points; devices actually used in centrally managed wireless networks. Wireless ad hoc networks can be classified according to their application as VANET, MANET, and SENSOR networks. A VANET [5] is primarily a network with mobile nodes such as cars and any other vehicles situated approximately 100 to 300 meters of each other to connect and in turn, create a network with a broad range. A wireless sensor network [4] monitors physical and environmental conditions by using autonomous and distributed sensors. This type of network is generally used in day-to-day technologies where each node is connected to one or more sensors. The last ad hoc network type is Mobile Ad hoc Networks [1] which represents a system of wireless nodes which can freely self-organize into temporary highly dynamic and infrastructure-less mobile wireless network.

All these networks share almost the same objective of providing services to the mobile users without requiring cable connections but have different approaches and performances. Mobile Ad hoc networks have been proven to provide numerous advantages compared to other wireless networks. Development of a self-organizing network decreases the communication cost, improves flexibility, provides robustness and can be deployed at any place and time.

The remaining part of this paper focuses on Mobile Ad-hoc networks. Our goal is to conduct a systematic performance evaluation of different type of routing protocols available for MANET namely Proactive, Reactive and Hybrid and prove that Hybrid is the best one as it combines the best features of both Proactive and Reactive protocols. We finally evaluate four different hybrid routing protocols available in MANET ZRP, TORA, OORP, and ARPAM.

The remainder of this paper is divided into the following sections: Section II presents related work. A brief description of routing protocols that are used in the performance evaluation is presented in section III. In section IV, materials and methods used in performance evaluation as well as the simulation environment are explained. Results and discussions are discussed in section V and we conclude our work in section VI.

II. RELATED WORKS

Pravin Ghosekar et al. [2] discussed about Ad hoc networking and confirmed that it is at the center of the evolution towards the 4th generation wireless technology. Its intrinsic flexibility, ease of preservation, lack of required infrastructure, auto-configuration, self-administration capabilities, and important cost advantages make it a prime candidate for becoming the stalwart technology for personal pervasive communication. The opportunity and the importance of ad hoc networks are being increasingly recognized by both the research and industry community. In moving forward towards fulfilling this opportunity, they stated that successful addressing of open technical and economical issues will play a critical role in achieving the eventual success and potentiality of MANET technology.

Dr. S.S. Dhenakaran et al. [3] concentrated their researches on routing techniques which they consider as the most difficult issue due to the dynamic topology of unplanned networks. They proclaimed that there are different ways pre-planned for economical routing that claimed to produce improved performance. Their paper provides an outline of various routing protocols planned in literature and additionally presents a comparison between them.

Monika Roopak et al. [4] have described the four main aspects of wireless sensor network security: obstacles, requirements, attacks, and defenses. For each of those categories, they have also sub-categorized the major topics namely routing, trust, denial of service, etc. They presented Wireless Sensor Networks as self-organizing, self-healing networks of small "nodes" having a huge potentiality for manufacturing, military and many more sectors in the actual achievings of 20thcentury life.

Rakesh Kumar Jha et al. [1] described coincidental routing of both DSR and TORA routing protocols within the same network which they evaluated for security issues. Nodes were divided into two ways without proxy enabled and proxy disabledNode workstation. They found that TORA is better suited for both cases in without and with security purpose for 50 fixed node workstation environments. They then conclude that a proxy environment is suitable for TORA Routing because the network maintains the same behavior after proxy enabled too, but DSR routing is highly affected by proxy.

Sumit A. Khandelwal1 et al. [5] presented a detailed survey on topology-based routing attacks in Vehicular Ad-hoc Network -VANET-. They stated that in order to achieve this success, VANET-specific communication solutions are imperative. They also studied inter-vehicle communications and stated that drivers can be informed of crucial traffic information such as treacherous road conditions and accident sites by communicating with each other and/or with the roadside infrastructure. Again they found that with better knowledge of traffic conditions, it is plausible that the problem of accidents can be alleviated. Traffic monitoring and management can also be facilitated by vehicular communications. In their paper, they focused on various attacks in vehicular ad-hoc networks. The result of their work could guide a way to design a privacy preserve solution and present a trend of existing ones.

III. ROUTING PROTOCOLS FOR MANET

3.1. Routing protocols classification

A number of routing protocols have been created and implemented for MANET which are categorized into three different types according to their functionalities: Proactive, Reactive, and Hybrid. *Proactive* routing protocols [3] maintain the network topology information in the form of routing table at every node, thus keeping routes from each participating node to all other nodes in the networks also considering those nodes to which packets are not to be sent. They are using both link-state and distance-vector approaches. Routing protocols are *reactive* [10] in that they do not maintain network topology information. Necessary path are found when required. Hybrid protocols [11] combine the best features of both proactive and reactive protocols.

To emphasize the benefits of hybrid routing protocols over both proactive and reactive protocols, we have conducted a performance evaluation of these three protocols using parameters namely Energy, Accuracy and Lifetime as presented in Table 1.

Table 1. Comparison of routing protocols

Protocols	Energy	Accuracy	Lifetime
Proactive	no	no	yes
Reactive	no	yes	no
Hybrid	yes	yes	yes

We show that the hybrid protocol is the best as it is the only one which is provided with all those three attributes, and additionally combines the best features of both proactive and reactive protocols.

3.2. Hybrid routing protocols

3.2.1. TORA

TORA [7] is a distributed, source-initiated on-demand routing protocol which provides loop-free multi-path routing and uses link reversal algorithms. Each node maintains information about adjacent nodes and has capability to detect partitions; this is why it performs well in highly dynamic networks. One key feature of TORA is that it has a unique property of limiting control packets to a small region during reconfiguration process caused by path breaks. Route establishment function is performed when a node needs a path to destination; TORA then builds and maintains a Directed Acyclic Graph (DAG) rooted at the destination, so information may fall in downstream link direction. Route erasure phase is needed when a node detects a partition and accomplished by flooding a broadcast clear packet throughout the network to erase the invalid route detected.

3.2.2. OORP

The Order One MANET Routing Protocol [13] is an hybrid routing protocol which has been designed to operate in wireless mesh networks thanks to its capability to enable nodes communicating by digital radio to cooperate and can handle both highly dynamic and large networks. It uses hierarchical scheme for routing, so the amount of transmission including retransmission are limited to between 1% to 5% and remain unchanged even when the network size grows. Nodes are self-organized in a hierarchical scheme into a tree with the top root node at which the initial route is formed which then moves downward by cutting corners, the process continues until an optimum way is found and then maintained using Dijkstra's algorithm, thus, nodes always find route by pushing a route request to the root of the tree.

3.2.3. ZONE ROUTING PROTOCOL

ZRP [11] combines the best features of both proactive and reactive approaches. Its main goal is to maintain an up-to-date topological map of a zone centered on each node. It uses proactive routing scheme within this limited zone if the packet's destination is in the same zone as its origin, ZRP uses an already stored routing table to deliver packet immediately and uses reactive approach for nodes beyond this zone. ZRP consists of three parts IARP proactive part, IERP reactive part of it and BRP used with IARP to reduce the query traffic. ZRP is regarded as a framework rather than as an independent protocol.

3.2.4. ARPAM

ARPAM (Ad-hoc Routing Protocol for Aeronautical Mobile Ad-hoc Networks) [12] is primarily an on demand and distance-vector protocol which shares the features of the popular AODV protocol. ARPAM is able to detect and maintain routes available thanks to the geographical information made available by external aeronautical applications, to do so it uses various criteria like distance and number of hops. It combines both proactive and reactive functions and utilizes proactive approach in specific circumstances otherwise it by default performs an on-demand operation, route maintenance mechanism for example with which in combination with the error reporting mechanism included in AODV protocol provides reduced routing overhead. Nowadays, ARPAM is proposed to work efficiently in aeronautical MANETs as it exhibits a stable and high performance in such networks.

IV. MATERIALS AND METHODS

We next describe the materials and methodology we used to compare the different hybrid routing protocols.

4.1. Simulation environment

A detailed simulation model based on ns-2 is used to model the four hybrid protocols namely TORA, OORP, ZRP, and ARPAM. IEEE 802.11 for wireless LANs is used at the MAC layer with radio propagation model of Two-Ray Ground. The nominal bitrate is set to 2 Mb/sec. We also use both Omni-Directional Antenna and error-free wireless channel models. The individual simulation time chosen are 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 and 120 seconds for each and every protocol implementation's scenario.

4.2. Movement model

We use the random waypoint model to model node movements. Nodes move with a speed, uniformly distributed in the range [10m/s].

4.3. Network size and communication model

We consider 2 network sizes with 15 and 40 nodes in a rectangular field of size 825 x 371. We vary the number of nodes to compare the protocol performance for low and high node density. Source and destination nodes are randomly chosen. Connections begin at random times during the simulations. We use the identical traffic and mobility patterns for the different routing protocols. Data packets have a fixed size of 1500 bytes and the network interface queue size for routing and data packets is set to 50 packets for all six scenarios.

4.4. Routing metrics

We use the following three metrics to compare the performance of hybrid routing protocols for low- and high-density networks.

(i) Packet delivery ratio: Packet delivery ratio is defined as the ratio of data packets received by the destinations to those generated by the sources.

(ii)Throughput: It is defined as the total number of packets delivered over the total simulation time.

(iii) End to end delay: The average end-to-end delay of a data packet is the total amount of transmission delay of packets. It consists of propagation delays, queuing delay, retransmission delays, etc.

V. RESULTS AND DISCUSSIONS

We conduct a performance evaluation of four hybrid protocols for 15 and 40-node networks. For all experiments, we ran the simulation with time ranging from 0 to 120 seconds with pause time regularly taken either after 10 or 20 seconds. The maximum simulation time is 120 seconds.

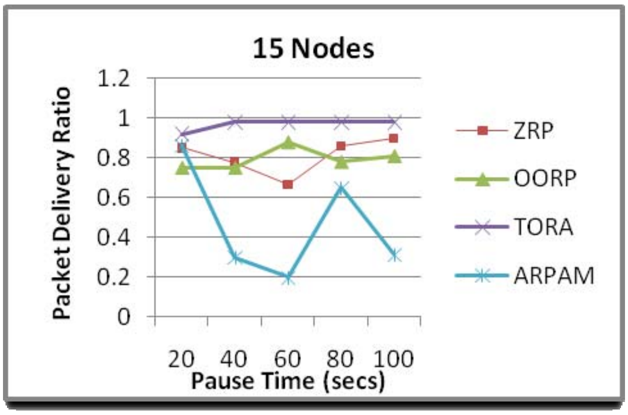

Figure 1. Packet delivery ratio for a low-density MANET

As we look at figure 1, taking into account packet delivery ratiometric for small network (a 15-nodes network), TORA performs better than the three protocols namely OORP, ZRP and ARPAM, this is due to its capability to detect partitions and delete invalid routes, thus minimizing packet drop. The packet delivery ratio of ARPAM is always smaller than other protocols' as at 60ms; nearly 80% of packets are dropped. ZRP and OORP's performances are mediumly and equally good as they do not change very much for the overall simulation time, each has an average packet drop fraction of nearly about 20%.

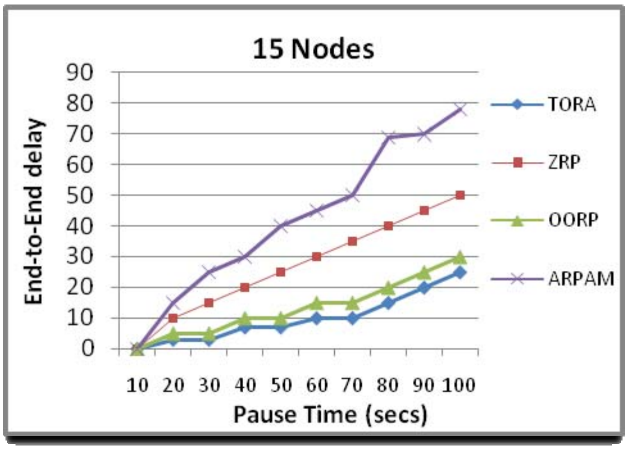

Figure 2. End-to-End delay for a low-density MANET

Considering end-to-end measurement for a low-density network, ARPAM has a higher average end-to-end delay than other protocols. For the overall simulation time, there is a smaller differential for both OORP and TORA. We find out that for all four protocols, the end-to-end delay keeps increasing as the simulation time progresses; this is due to abrupt interference and congestion in the network. TORA maintains a lower level which making it a better protocol in minimizing end-to-end delay for routing packets.

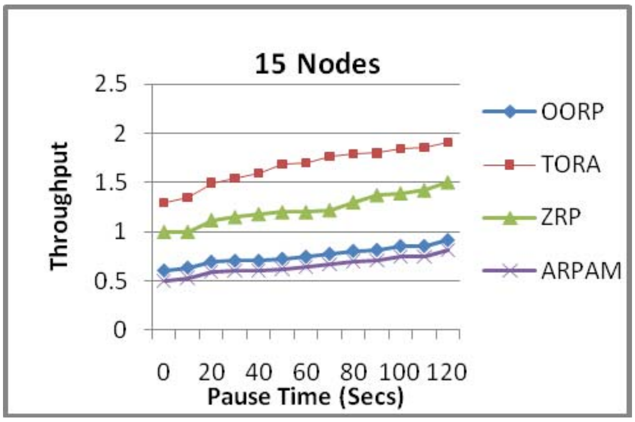

Figure 3. Throughput for a low-density MANET

For the network size of 15 nodes, the throughput of TORA is higher than other protocols'. OORP and ARPAM protocols have the lowest throughputs and their differential is always much small for the overall simulation time, this is due to their small fraction of bandwidth in routing most importantly for OORP which limits the bandwidth to be always lesser than 5% regardless of network size. From 20 seconds, if we increase the simulation time, the throughput of ZRP increases proportionally.

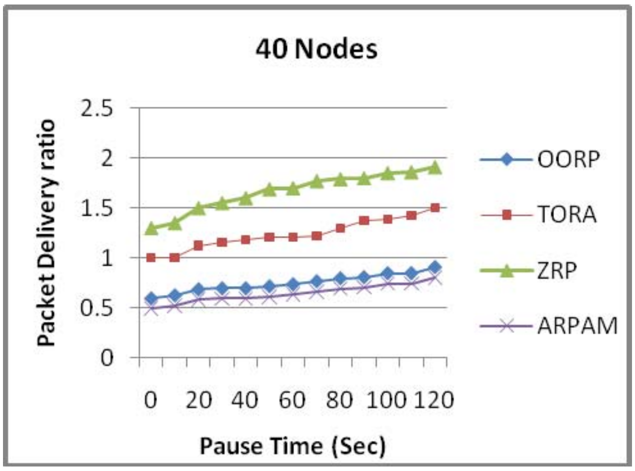

Figure 4. Packet Delivery ratio for a high- density MANET

When we increase the number of nodes to 40 nodes, the situation changes very much. Here, ZRP has a better packet delivery ratio than other three protocols namely OORP, TORA, and ARPAM, the reason is that each node has a higher level of topological information knowledge, stale routes are limited, thus minimizing packet drop. ARPAM and OORP perform on the lower level with nearly the same degree. For 0ms to 20 seconds, TORA maintains a steady packet delivery ratio which continuously increases latter as the simulation time progresses.

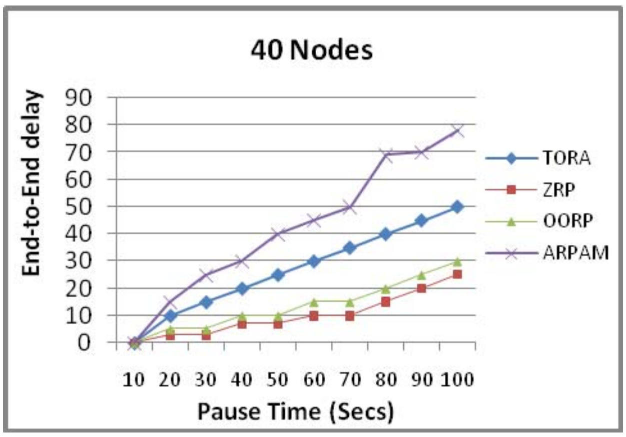

Figure 5: End-to-end delay for a high-density MANET

For a MANET of 40 nodes, the end-to-end delays of ARPAM protocol for each and every simulation time are higher than other three protocols'. Here, ZRP outperforms other three protocols as it maintains an average delay lower but with a minor differential with OORP. From 20 ms, TORA maintains a steady increasing average end-to-end delay proportional to simulation time due to congestion incurred in the network.

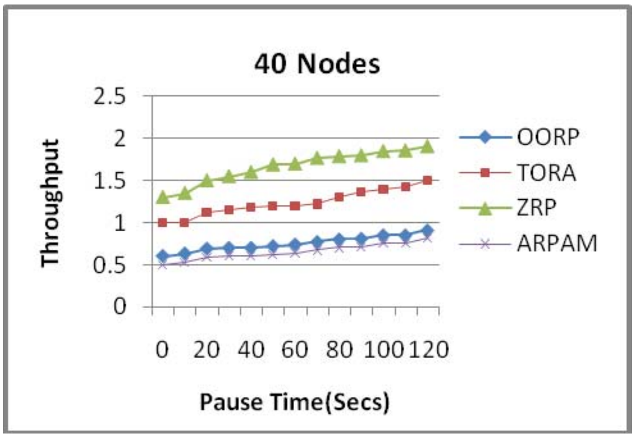

Figure 6. Throughput for a high-density MANET

Again for a high-density network, ZRP outperforms other three protocols as it has a better throughput. Both ARPAM and OORP have a lower throughput with a minor differential in performance as the simulation time increases. ARPAM performs badly as its packets have higher overhead due to excess geographical information included. TORA always maintains a middle-level throughput which never attains ZRP's as the simulation time increases.

VI. CONCLUSION

In this paper, we firstly conducted a performance evaluation of three different types of wireless ad hoc networks VANET, MANET, and SENSOR; we chose MANET because it is the most advantageous compared to other networks as it is easy to implement and can be deployed anywhere at any time. We then compared three types of protocols available for MANET Proactive, Reactive, and Hybrid; we found that Hybrid protocol is the best as it combines both features of the remaining two and can handle any network regardless its size and requirements. These prominent features of hybrid protocol leaded us to conduct a third performance evaluation for four hybrid protocols available in MANET for low- and high-density MANETs using ns-2 simulations. The experiments were conducted applying three performance metrics such as packet delivery ratio, end-to-end delay, and throughput. TORA performs better for the low-density networks in term of all the three performance metrics whereas ZRP exhibits a better performance with networks with high density. For all cases studied, ARPAM performs worse than other protocols for the low- and high-density MANETs. Concerned with packet delivery ratio and throughput in highly dense networks, OORP maintains a medium performance.

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