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Analysis of Routing Protocols in Ad-hoc Networks Using NS2 Simulator

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Abstract: **A mobile ad-hoc network is an infrastructure-less network that connects mobiles nodes. Frequent changes in the location of these nodes require best possible performance management mechanisms. Various routing protocols are available that perform optimal routing of data. These protocols are categorized as proactive and reactive. This paper presents an analysis of application specific performance metrics of these protocols. In this proposed work, DSDV and DSR routing protocols are implemented using NS2 for variable queue length and performance is compared. We also highlight the efficiency of AODV, a reactive routing protocol which is a combination of DSDV and DSR.**

***Keywords*: Ad-hoc networks, mobile nodes, proactive routing, reactive routing, DSDV, DSR, AODV.**

1. INTRODUCTION

With the development of communication networks the need for wireless networks has increased over time with effective capabilities for efficient communication and mobility between nodes. A wireless network is composed of a collection of nodes using a wireless data connection for communicating between the nodes. These nodes are primarily responsible for sensing the environmental data and further transmit the data over the network to other nodes.

A wireless network can be categorized as an infrastructure based network and infrastructure less network. The network which requires wired components along with gateways and base stations form the infrastructure based network. The base stations are similar to central sink nodes which collect the data from over several nodes across the network. On the other hand the infrastructure less network, also called as ad hoc network consists of ad hoc nodes. The functionality of each node is to collect the sensed data and transmit the same all over the network such that sensed data reaches the concerned destination nodes. The characteristic features of ad-hoc networks are that they are robust in nature making the network as flexible as possible. The mobile nature of each node aids in the transmission of data in a very competent manner. In order to carry out this there is a need for routing protocols which facilitate in establishing efficient, possible and shortest route such that overall energy consumption in the network in minimized. The routing protocol has to also take care of resource utilization and resource conservation in the network. Ad hoc networks can be widely used in applications like search and rescue operations, data acquisition in case of terrestrial or unreachable landmarks, human policing and personal area networking [1].

Many routing protocols have been proposed so far involving the characteristic features of ad-hoc networks namely self configuration and maintenance capabilities, flexible scalability and decentralized architecture. The basic constraints required for the design of routing protocols are preserving the energy of the nodes along with estimation of an optimal path. The behavior of a routing protocol is better understood when it is implemented and a comparison is done with other protocols. This gives us an avenue for enhancements for a protocol. The paper is organized as follows: Section 2 deals with the detailed categorization of the routing protocols along with the prominent ones that are currently in use. Section 3 provides performance overview of existing routing protocols along with the associated set of routing metrics. Section 4 provides the parameters used for implementation including experimental results showcasing the most effective routing protocols in terms of throughput and end-to-end delay as the routing metrics, followed by conclusion and the open research issues is Section 5.

2. ROUTING PROTOCOLS

Routing is defined as the act of data transmission from a source to a destination through an optimized path. The activity of routing involves the discovery of an optimal path, establishment of the path followed by transmission of data to each node constituting the network. Based on these activities routing can be categorized as static routing and dynamic routing [2]. When the complete knowledge about the network is known prior to the routing activity then it is termed as static routing. The localized knowledge about the network is maintained in the form of routing table at each node. This table holds the necessary details required for routing. The dynamic routing on the other hand requires the complete status of the network where each node in the network is solely responsible for the data transmission in the network [3]. The ad-hoc networks are dynamic in nature and they can be further classified into three major categories namely proactive protocols, reactive protocols and hybrid protocols. Proactive routing protocols or table-driven routing protocols require each node of the network to be aware of the network status with respect to which all the nodes undergo periodic updations of their routing tables [4]. Though only a few nodes participate in the routing process, this category of routing requires all nodes in the network to be updated and be ready to participate in the routing process. The effect of this is the reduction in overall performance of the network which can be expressed in terms of energy efficiency and bandwidth consumption. A classic example of a proactive protocol is the Destination-Sequenced-Distance-Vector (DSDV) routing protocol [5, 6, 7].

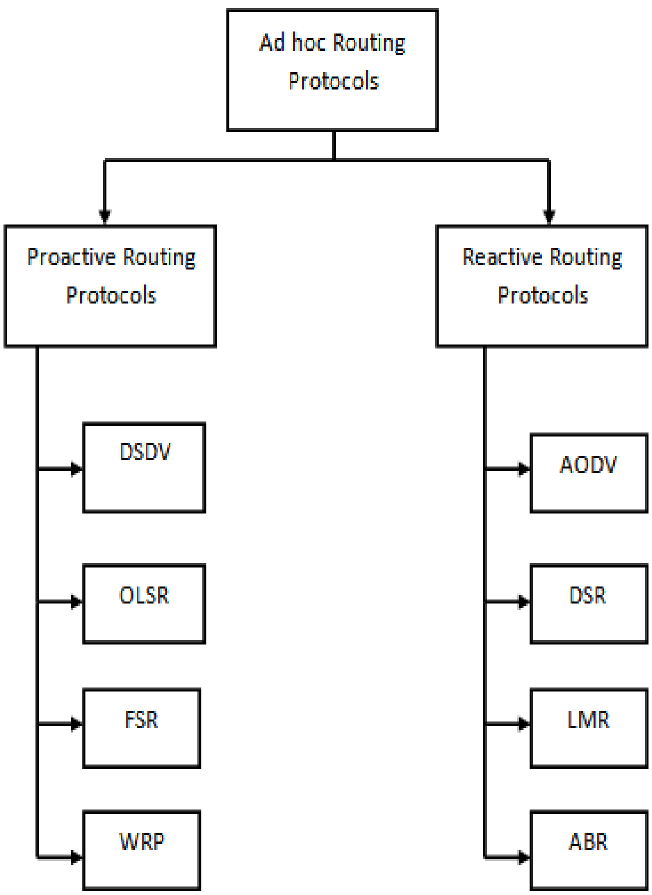

Fig. 1. Classification of routing protocols [1, 5, 9].

In reactive or On-demand routing, the routing process is initiated by the routing source node only when there is a need for data transmission in the network. This requires an estimation of all possible routes from source node to the destination node and finally selecting the shortest optimal route for routing. The Ad-hoc On Demand Distance Vector (AODV) [8] and the Dynamic Source Routing (DSR) protocols are examples of reactive protocols. A detailed categorization of the routing protocols is represented in Fig 1.

Another class of routing protocols is the Hybrid protocols which are adaptive in nature and is a combination of the features of both proactive and reactive routing schemes.

3. EXISTING SYSTEM

The development of a suitable routing protocol for the application under development requires a detailed analysis of all the existing routing protocols in Wireless networks. The routing protocols proposed for ad-hoc networks are evaluated on various parameters such as throughput, packet delivery fraction (pdf), end-to-end delay, processing overhead and others.

A Review of current Routing Protocols for Ad-hoc Mobile Wireless Networks proposed by Elizabeth M Royer et al [1] provides a comparison of eight different routing protocols by taking into account the updates required to each node to perform an effective routing. Both bandwidth and battery power are considered as the scarce resource and performance analysis has been carried out with an aim of minimizing the use of these resources. This work provided an overview of the application areas based on the evolution of the routing protocols. The performance comparison of ad hoc routing protocols for the networks with node energy constraints was proposed by Anne Aaron et al [10] which reviewed the performance of two routing protocol classes with respect to energy consumption at each node of the ad hoc network in terms of its battery life and the maximum threshold reached. The evaluation of the protocols is dependent on the attributes namely mobility, traffic pattern, physical layer architecture, and the Medium Access Control (MAC) layer interfaces. The review was supported with simulation results which have proved that the reactive routing protocols perform better than a proactive routing protocol in case of high node densities. This is because of the occurrence of overhead due to more number of message exchanges between the nodes involved in routing. Xin Zhang [11] conducted the performance evaluation of the routing protocols in case of networks which are densely populated with around 50, 000 nodes. The primary routing metrics considered here were the size of the network, traffic load and mobility. The analysis included the study of reactive AODV and DSR using the Georgia Tech N/w Simulator (GTNets) [12, 13]. The effect of mobility on scalability of the network was investigated in terms of packet delivery ratio along with the variations in maximum speed and pause time. Based on the observations conducted the parameters selection was optimized.

The metric based study of the routing protocols was carried out in [14] using the NS2 [17, 18] simulator. The routing protocols considered for the study were AODV, DSR and DSDV and the behavior of the routing protocols were understood by changing the number of nodes, data rates, mobility rate of each node and the pause time. Packet delivery ratio, average end - to - end delay and routing load were the metrics taken into account. The performance analysis for Multicast routing protocols [15] like the On - Demand Multicast Routing Protocol (ODMRP), Multicast Ad-hoc On-Demand Distance Vector (MAODV), Protocol Independent Multicast (PIM), Multicast Open Shortest Path First (MOSPF) and Distance Vector Multicast Routing Protocol (DVMRP) were performed using Qualnet 6. 1 simulator. to understand the etiquettes with respect to the size of the multicast group and corresponding metrics achieved with multicast throughput, average end - to - end delay, average jitter, packet delivery ratio, control overhead and link utilization.

The performance evaluation of the routing protocols depends on the combination of the metrics because of which no clear result about the best routing protocol can be obtained. So there is a need for the analysis of the protocols to obtain a stable performance under variable network conditions.

4. PROPOSED SYSTEM

The proposed system involves the comparison of a proactive protocol i. e. DSDV and reactive protocols namely DSR and AODV. When a specific set of conditions are considered, the analysis [16] has shown that none of the proposed protocols outperforms the other under all the conditions. So it is very much necessary to understand behavior of these protocols under complex, dynamic topologies with nodes having high mobility speed. The features that are taken into account are the number of nodes, maximum moving speed of the mobile node, maximum number of connections, pause time of the node, data rate and range of movement of each node.

All these features are set for varying network conditions such that protocol has to provide a stable performance, higher efficiency, strong adaptability towards a large scale or small scale network topology. The overall system design involves the activities associated with the Data link layer, Network layer and Application layer. The network layer is responsible for laying down the topological constraints along with route calculation and packet forwarding, while the application and data link layer exchanges the data with other respective layers. The connectivity between the nodes is brought about as a peer-to-peer network using wireless links.

A modular approach of the proposed system provides us with detailed architecture of the system. The important modules identified are:

- Node Configuration
- Link development
- DSR
- DSDV
- AODV

A. Node Configuration

The network includes mobile ad-hoc nodes with bi-directional connection links. The queue interface type that is set for each node is either Queue, Drop Tail or a Priority queue. In this case Drop Tail condition is chosen to check whether the buffer capacity of the output queue has exceeded because of which the last packet received is dropped. If e new queue type is required it can be explicitly defined by the user. As each node is a wireless transceiver, it is designed as an Antenna model to transmit and receive the radio waves equally in all directions as in case of Omni directional antennas or in respective directions as seen in the directional antennas. This is provided with supporting APIs which uses the General Operation directors to create the suitable interface with number of nodes specified by the user.

B. Link

The link i. e. set up between the nodes is basically a wireless channel used to send data from one location to the other. In some cases, multiple nodes may have to access the same channel and this is taken care by the Medium Access Protocol (MAC) which brings about a co-operative usage of communicating bands. The network interface layer is a hardware interface using which a mobile node can access the channel. For a wireless application, the interface used is the Phy/Wireless Phy which has to facilitate in propagating the radio signals. The radio signals can either be data signals carrying messages, connecting signals and disconnecting signals. The strength of the signal transmitted is formulated as the radio propagation model which takes into account the frequency, distance coverage between the nodes and several other conditions.

C. DSR

The Dynamic Source Routing protocol is a simple and efficient on-demand routing protocol which is mainly suitable for Wireless Mesh Networks. Instead of using the localized routing table information, this protocol follows source - routing at the intermediate nodes between the source node and destination node are collected there by enabling an easier route discovery. Based on the collected information, an analysis is carried out for route selection. The routed packets have to include the address of all the intermediate paths along with the address of the destination node but this scenario results in a very high overhead in case of long paths. In order to overcome this problem, DSR protocol forwards the data packets on a hop-by-hop basis. This protocol constitutes two major phases which are Route Discovery and Route Maintenance.

D. DSDV

Destination-Sequenced Distance-Vector (DSDV) Routing is a table-driven routing scheme for Ad-Hoc mobile networks based on the Bellman–Ford algorithm. It is adapted from the conventional Routing Information Protocol (RIP) to Ad-Hoc networks routing. It adds a new attribute, sequence number, to each route table entry of the conventional RIP. Using the newly added sequence number, the mobile nodes can distinguish stale route information from the new and thus prevent the formation of routing loops. In this protocol, each mobile node of an Ad-Hoc network maintains a routing table, which lists all available destinations, the metric and next hop to each destination and a sequence number generated by the destination node. Using such routing table stored in each mobile node, the packets are transmitted between the nodes of an Ad-Hoc network. Each node of the Ad- Hoc network updates the routing table with advertisement periodically or when significant new information is available to maintain the consistency of the routing table with the dynamically changing topology of the Ad-Hoc network.

F. AODV

Ad-hoc on demand distance vector routing protocol (AODV) is a reactive on-demand routing protocol which works towards providing an efficient routing protocol for transfer of data within a MANET. The functionality of this protocol is similar to that of Bellman-Ford algorithm [19] where a routing path establishment is initiated based on the request from the source node. This loop free routing protocol is made suitable for a mobile atmosphere but the route once selected has to be maintained until the end of data transmission of last data packet. The sequence numbers of the nodes are used as the primary entities for carrying out routing process and this enables in keeping the nodes active and loop free. The overhead caused during the routing process can be reduced to a great extent in this protocol as it uses a standard predefined set of control messages and does not follow source routing. We do not see a periodic updation of the protocol parameters as routing is not initiated unless there is a requirement. Each node is associated with a routing table which contains the details like destination IP address, sequence number of nodes that is followed along the path to be traversed, neighbor nodes that are capable of becoming a part of routing process and the termination time for each route. The overall functioning of this protocol is understood in terms of the usage of control messages which are defined as follows:

Route discovery: This control message is initiated whenever a source node has to transfer some data to the destination node placed elsewhere in the network. So when the request is initially generated, routing table of the source node and its neighbor nodes are checked to search if there is a path that is already existing and in case if a path is present the packets are readily transferred to destination node. If in case there is no path existing between the source and destination, then a route request (RREQ) [20] message is transmitted to the neighbor nodes in return of a reply from those neighbor nodes within a predefined time or a timer. RREQ is composed of source node ID, destination node ID and a broadcast ID. The broadcast ID is used if a RREQ is transmitted more than once in the network for a particular transmission. The destination node on accepting the RREQ replies back sending back a route reply (RREP) therefore conforming the route that can be followed for data transmission. The traversal path of RREP back to the source node is made possible by maintaining an entry of the source node IP address, number of neighbor nodes existing on the path and the sequence number of nodes that are followed. Upon receiving RREP, the source node starts with data packet transmission.

Route maintenance: This feature is very much important as we are taking into consideration the nodes in an ad-hoc network which are dynamic in nature. The basic requirement of data transmission in such networks is that it requires the nodes to be stable, such that data transmission is made possible without any link breakages. The route error messages are used to indicate the erroneous conditions in the network. The source node has to stop with data transmission in case if a RERR message is generated.

5. SIMULATION RESULTS

The simulation setup for the proposed system with associated parameters and data transmission details are listed in the table 5. 1. For a queue length of 50, we can observe a huge difference in the average end-to-end delay.

TABLE 1: Throughput achieved for a queue length of 50.

Parameter	**DSR**	**DSDV**
No of packets generated	6259	13602
No of packets received	6206	13298
No of packets dropped	0	67
Packet delivery ratio	99. 1532%	97. 765%
Average end-to-end delay	79. 2549 ms	125. 8 ms

There is a minimal variation in case of packet delivery ratio but a huge difference is seen in case of the packets dropped. Similar tests are conducted for a queue length of 10 and the results are shown as in table 5. 2.

TABLE 2: Throughput achieved for a queue length of 10.

Parameter	DSR	DSDV
No of packets generated	6963	18986
No of packets received	6776	18348
No of packets dropped	87	258
Packet delivery ratio	97. 3144%	96. 6396%
Average end-to-end delay	57. 6259 ms	57. 8193 ms

When the queue length is 10, we can see that the packets dropped difference is much higher than when the queue size was 50. There is one percent change in packet delivery ration when the queue size is 10. The average end-to-end delay is not substantial.

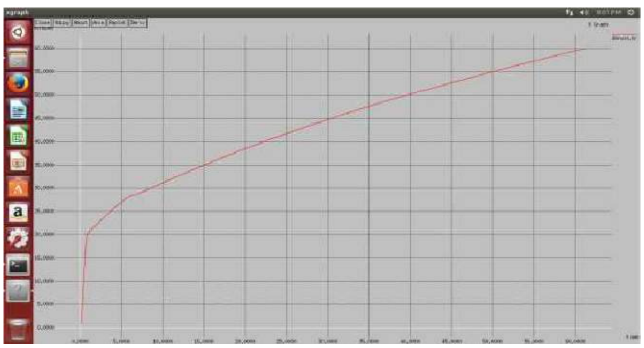

Fig. 2. Transmission Window vs Time for DSDV.

This graph shows that in the beginning there is high packet delivery ratio as the transmission begins almost instantaneously. This is because DSDV maintains Routing tables at every node from the starting itself.

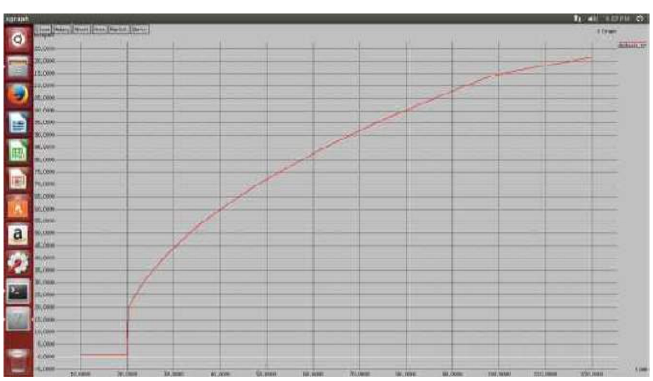

Fig. 3. Transmission Window vs Time for DSR

The graph below shows that it takes DSR protocol some time to create paths, once created the packet delivery ratio is quite high with less packet drops.

6. CONCLUSION

After performing the above experimentations and simulations and referring to the results in tables and graphs, it has been observed that when the number of nodes is less – DSR is more effective whereas when the number of nodes increases, DSDV performs better.

The Dynamic Source Routing protocol (DSR) provides excellent performance for routing in multi-hop wireless ad hoc networks. DSR has very low routing overhead and is able to correctly deliver almost all originated data packets, even with continuous, rapid motion of all nodes in the network. Hence, DSR has a better Delivery Ratio. A key reason for this good performance is the fact that DSR operates entirely on demand, with no periodic activity of any kind required at any level within the network and also because it exploits aggressive caching and maintains multiple routes to destinations. This cache can become a problem if we increase the mobility and simulation time as then routes will be changing more frequently and cache will have stale routes mostly, therefore, in that case it will not help DSR in better performance. This entirely on-demand behavior and lack of periodic activity allows the number of routing overhead packets caused by DSR to scale all the way down to zero, when all nodes are approximately stationary with respect to each other and all routes needed for current communication have already been discovered.

The Destination Sequenced Distance Vector (DSDV) can work with High frequency of updates and High routing overheads. Random Waypoint Mobility Model has been used in this study to generate node mobility; where we take an average of 10 randomly generated scenarios so to make a detailed Performance analysis. We find that the performance varies widely across different network sizes and results from one scenario cannot be applied to those from the other scenario. As far as Throughput is concerned, DSR performs better than DSDV even when the network has a large number of nodes. Overall, the simulations performed here shows that, DSR performs better when the number of nodes is small. Average End-to-End Delay is the least for DSDV and does not change if the number of nodes is increased.

Ad-hoc on demand distance vector routing protocol (AODV) is a combination of DSR and DSDV. Its performance is closely comparable with DSR because of its reactive nature. Route discovery is initiated only when there is a demand. The destination node replies to the first RREQ message that it receives thereby decreasing the end-to-end delay when compared to DSR. Further studies show that average packet loss rate and throughput of AODV are the key parameters that prove it to have higher efficiency and adaptability making it suitable for small scale networks. Each of these protocols can be used in their own scenarios and must be used in the same way to get the best results for that network. Thus, no one protocol completely puts down any other.

7. OPEN RESEARCH ISSUES AND FUTURE ENHANCEMENTS

In future, this study can be improved by comparing more number of protocols under each group of protocols. More On-Demand protocols can be compared to add on to this study. Hybrid Protocols such as TORA (Temporally Ordered Routing Algorithm) can be evaluated and compared with these results. Also, more varying parameters like jitter, number of traffic sources, and other traffic than CBR (like TCP transfers); simulation area, measurements and estimation of power and energy consumption along with processing costs, route length, type of traffic, pause time, routing overheads, etc can be checked. We also look forward to further development of the protocols for quality of service (for real-time and non-real-time traffic), analysis of interworking functions for Mobile IP, intermediate route rebuilding and various interconnection topologies with fixed networks and the internet. Future search can be done on increasing the lifetime of the nodes by energy efficient load balancing techniques. As this study will grow, in the future, we can be able to know for certainty that which protocol would be under which circumstances or even with a creation of such a protocol, by learning from such comparative studies, which outperforms all the other protocols and works more efficiently under all possible conditions. Although the field of Ad-Hoc networks is rapidly growing and new developments are coming day by day, it might even give rise to many challenges that would then need to be tackled and evaluated.

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