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An Analysis of Ad hoc Routing Protocols

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ABSTRACT

The wireless ad hoc networks have no proper fixed topology. These networks therefore face multiple challenges regarding medium access scheme; routing and multicasting; transport layer protocol; pricing scheme; quality of service provisioning; security; energy management; scalability etc. To resolve the routing problem, many protocols have been developed for ad hoc networks which are table driven protocols, reactive protocols and hybrid protocols. Every protocol has its own pros and cons. This paper presents an implemented comparison of three ad hoc routing protocols i.e. AODV, OLSR and DSR on the basis of parameters: media access delay, network load, retransmission attempts and throughput in the OPNET MODELER simulation tool. The implemented results of this paper will help readers to get a good overview of routing protocols used in ad hoc networks.

INTRODUCTION

An ad hoc wireless network is a gathering of multiple devices having wireless communications and networking competence. The devices in such networks, can communicate with another node inside their radio range or outside their radio range but within the network only. To deliver the packets in the latter case, an intermediate node works as router. Such type of networks can organise themselves and can acclimatize. This denotes that there is no need for management in these networks and establishment and distortion can easily be accomplished without any supervision. Ad hoc networks require to have some necessary properties. The nodes should be proficient enough to sense the presence of other devices and should be able to execute the basic handshaking mechanism which is mandatory for communication. The nodes in ad hoc networks can be of different types, and the capabilities and features of these nodes can vary up to a large extent. Ad hoc networks are mobile, infrastructure less, and generally have low battery capacity. [1][11][12] These features of ad hoc networks impose a large number of challenges. The main challenges faced by ad hoc networks are:

1. **How to design a robust Medium access scheme:** MAC (Medium access control) is used to effectively share a communication medium in a network. MAC also plays an important role in deciding the performance of a network. The main motive of a MAC protocol is fair distribution and efficient use of bandwidth. It means that every competitor for the medium should have equal chance of accessing it and a minimum amount of bandwidth should be used in control messages. A good

MAC protocol should be able to minimize the access delay and maximize the throughput. The MAC protocol should be able to support real-time traffic. The operation in ad hoc networks is disseminated among nodes, hence the power control competencies should be proficient.

2. **How to provide Quality of service:** The effect of service performance determining the degree of satisfaction of a user of the service. The QoS includes a number of concepts including: traffic performance in the network; service support performance; service operability performance; service security performance. To satisfy QoS related to traffic performance, values of traffic engineering variables are used and assigned to nodes. The provision of QoS requires the negotiation between the host and a network, resource reservation schemes, priority scheduling and call admission control.
3. **Energy management:** Energy management can be performed via shaping the energy discharge pattern, using routes with minimal total energy consumption, using special task scheduling schemes, with proper handling of the processor and interface devices. The energy savings can be attained by the transmission power management, the management of battery energy, managing the power of processor or power management of interface.
4. **Routing:** The responsibilities of any routing protocol: determining a feasible path to a destination based on a certain criterion; discovering, storing, and exchanging routing information; gathering information about path breaks and updating route information accordingly.

Challenges faced by the routing protocol in ad-hoc networks:

1. Mobility.
2. Bandwidth constraints.
3. Resource constraints.
4. Erroneous transmission medium.
5. Location-dependent contention.

Requirements of a routing protocol in ad-hoc networks:

1. Minimum route acquisition delay.
2. Quick route reconfiguration.
3. Loop-free routing.
4. Distributed routing.
5. Low overhead.
6. Scalability.
7. Privacy.
8. Support of time-sensitive traffic.

Various routing algorithms are proposed thereby trying to overcome the routing problem in ad hoc networks. The next section discusses these protocols.

ROUTING PROTOCOLS IN ADHOC NETWORKS

There are many ways to classify the MANET routing protocols (Figure 1), depending on how the protocols handle the packet to deliver it from source to destination. However, Routing protocols are broadly classified into three types such as Proactive, Reactive and Hybrid protocols [5].

1. **Proactive Protocols:** These types of protocols are called as table driven protocols in which, the route to all the nodes is maintained in the routing table. Packets are transferred over the predefined route specified in the routing table itself. In this scheme, the packet forwarding is done faster but the routing overhead is greater because all the routes have to be defined before transferring the packets to the destination. The Proactive protocols have lower latency because all the routes are maintained at all the times.

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Example protocols: DSDV, OLSR (Optimized Link State Routing).

2. **Reactive Protocols:** These types of protocols are also called as On Demand Routing Protocols where the routes are not predefined for routing but are created on demand. A Source node calls for the route discovery phase to determine a new route whenever a transmission is needed. This route discovery mechanism is based on the flooding algorithm which employs the technique that a node just broadcasts the packet to all of its neighbours and intermediate nodes just forward that packet to their neighbours respectively. This is a repetitive technique until it reaches the destination. Reactive techniques have smaller routing overheads but higher latency. Example Protocols: DSR, AODV.
3. **Hybrid Protocols:** Hybrid protocols are termed as the combinations of reactive and proactive protocols and take advantages of these two protocols and as a result, routes are found quickly in the routing zone. Example Protocol: ZRP (Zone Routing Protocol) [4][6][10][17][21][22][23].

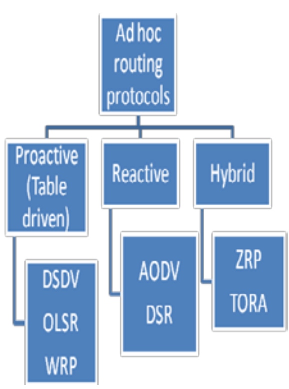


Fig: MANET routing protocols

Dynamic Destination-Sequenced Distance-Vector Routing Protocol (DSDV): DSDV is created on the basis of Bellman–Ford routing algorithm with some modifications. In this routing protocol, each mobile node in the network keeps a routing table with itself. Each of the routing table contains the list of all available destinations and the number of hops to each destination respectively. Every table entry is tagged with a sequence number, which is originated by the destination node. Periodic transmissions of updates of the respective routing tables help maintaining the topology information of the network. If there is any new significant change for the routing information, the updates are transmitted immediately to the routing tables. Therefore, the routing information updates might either be periodic or event driven.[16] DSDV protocol requires every mobile node in the network to advertise its own routing table to its current neighbours. The advertisement is performed either by broadcasting or by multicasting. By the advertisements, the neighbouring nodes can know about any change that has occurred in the network due to the movements of nodes. The routing updates could be forwarded in two ways: one is called a “full dump” and another is termed as “incremental update” In case of full dump, the entire routing table is forwarded to the neighbours, where as in case of incremental update, only the entries that require significant changes are sent. [1]

Optimized Link State Routing Protocol: OLSR is a proactive routing protocol, so the routes are always immediately available when required. OLSR is an optimization form of a pure link state protocol. So, the topological changes cause the flooding of the topological information to all the available hosts in the entire network. To reduce the possible overhead in the network, protocol employs Multipoint Relays (MPR). MPRs are selected nodes which forward broadcast messages in the network during the flooding process. MPRs assure the shortest path to a destination by declaring and exchanging the link information periodically for their MPR’s selectors. By doing so, the nodes are able to maintain the network topology information. The MPR is employed to reduce the number of nodes that broadcasts the routing information throughout the network. To forward the data traffic, a node selects the one hop symmetric neighbours, referred to as MPR set that covers all nodes that are two hops away. The MPR set is calculated from information gained about the node's symmetric one hop and two hop neighbours. This information in turn is extracted from the HELLO messages. Just similar to the MPR set, a MPR Selectors set is maintained at each node. A MPR Selector set is termed as the set of neighbours that have chosen the node as a MPR. Upon receiving a packet, a node checks its MPR Selector set to see if the sender has chosen the node as a MPR or not. If yes, the packet is forwarded, however, the packet is processed and discarded otherwise. This technique substantially reduces the message overhead when compared to a classical flooding mechanism (where every node retransmits each message it received).[15]

OLSR uses another kind of the control messages: Topology Control (TC) messages. TC messages are broadcasted in the entire network. TC messages are used for broadcasting information about own advertised neighbours which includes at least the MPR Selector list. The TC messages are broadcasted periodically and only the MPR hosts can forward the Topology Control messages [9].

Wireless Routing Protocol (WRP): The Wireless Routing Protocol (WRP) is a proactive, destination-based protocol. The WRP belong to the class of path finding algorithms. The typical feature of these algorithms is that these utilize information about distance and second-to-last hop (predecessor) along the path to each destination. Path-finding algorithms eliminate the counting-to-infinity problem of distributed Bellman-Ford-algorithms by using the predecessor information, which can be used to access an implicit path to a destination and thus detect routing loops.

In WRP there is a complicated table structure. Every node maintains four different tables as in many other table-driven protocols only two tables are needed. The four tables are: 1) distance table, 2) routing table, 3) link cost table and 4) message retransmission list (MRL) table. Each entry of MRL consists of the sequence number of the update message, a retransmission counter, an acknowledgement-required flag with one entry per neighbour and a list of updates sent in the update message. The MRL records which are updated in an update message need to be retransmitted and also should be determined that which neighbours should acknowledge the retransmissions. In WRP, nodes exchange routing-table update messages only from a node to its respective neighbours. An update message consists of such components as an update list. An update list entry contains a destination, a distance to the destination and a predecessor to the destination. When a link fails or a link-cost changes, the node recalculates the distances and predecessors to all the affected destinations, and sends this to all its neighbours an update message for all the destinations whose distance or predecessor values have changed. [6][10]

(AODV) Ad hoc On-Demand Distance Vector routing protocol: The AODV algorithm provides an easy way to get change in the link situation i.eif a link fails notifications are forwarded only to the affected nodes in the network. This notification denies all the routes through this affected node. It establishes the unicast routes from source to the destination and that's why the network usage is least. AODV does not allow keeping extra route which is not in use. If two nodes wish to establish a connection in an ad hoc network then AODV helps enabling them to establish a multi hop route. AODV uses Destination Sequence Numbers (DSN) to avoid counting to infinity which is why it is loop free. When a node sends request to the destination, it sends its DSNs together with all routing information it has. It also selects the most favourable route depending on the sequence number.[2][8][9][13]

There are three AODV messages- Route Request (RREQs), Route Replies (RREPs), and Route Errors (RERRs). The number of hops of routing messages in ad hoc network is discovered by Time-To-Live (TTL) value in the IP header. When the source node wants to create a new route to the destination, the requesting node broadcast an RREQ message in the network. The neighbour node will verify if it has an active route to the destination or not. If it has a route, it will forward a RREP to the source node. If it does not specify an active route to the destination it will broadcast the RREQ message in the network again with an incremented hop count value.

When a link fails, an RERR message is generated. RERR message has the information about nodes that are not reachable like the IP addresses of all the nodes which are as their next hop to the destination. All the routing information about the network is stored in the routing table. This routing table have these following route entries; (i) destination IP address, (ii) Destination Sequence Number (DSN), (iii) Valid Destination Sequence Number flag (iv) other state and routing flags (v) network interface (vi) hop count (vii) next hop (viii) the list of precursors and lifetime.

DSR (Dynamic Source Routing) protocol:

Dynamic Source Routing Protocol is a reactive on demand routing protocol. The DSR network is self-organizing and self-configuring. The DSR keeps track of the regular updates of the route cache for the new available easy routes. If some new available routes were found, the node will forward the packet to that route. This packet has to know about the route direction. So the information about the route was packaged in the packet to reach its destination from its sender. DSR has two basic mechanisms i.e. route discovery and route maintenance.[14]

In route discovery, it consists of two messages i.e. route request (RREQ) and route reply (RREP). When a node wishes to send a message to a particular destination, it broadcasts the RREQ packet in the network. The neighbour nodes in the broadcast range receive the RREQ message and add their own address and again broadcast it in the network. This RREQ message reaching from source to the destination, is the route to the specific destination. In the case if the message did not reach the destination then the node which received the RREQ packet will look for a route used previously for the specific destination or not. Each node maintains its route cache for the discovered route. The node will give a check out for its route cache for the desired destination before rebroadcasting the RREQ message. By maintaining the route cache at every node in the network, it reduces the memory overhead which is generated by the route discovery process. If a route is found that node will not rebroadcast the RREQ in the whole network, it will forward the RREQ message to the destination node rather. This route is considered the best shortest path taken by the RREQ packet. The source node now has the complete information about the route in its route cache and can start transferring the packets.

The next mechanism is the route maintenance. The route maintenance consists of two kind of messages i.e. route error (RERR) and acknowledgement (ACK). The messages which are successfully received by the destination nodes send an acknowledgement ACK to the sender. If there is some problem in the communication network, a route error message denoted by RERR is transmitted to the sender, informing that there is some problem in the transmission. In other words, if the source didn’t get the ACK packet due to some problem, the source gets the RERR packet thereby reinitiating a new route discovery. By receiving the RERR message the nodes remove the route entries.

Zone Routing Protocol (ZRP): Zone Routing Protocol or ZRP was the first hybrid routing protocol with both a proactive and a reactive routing component in it. ZRP was first introduced by Haas in 1997. ZRP was proposed to reduce the control overhead of proactive routing protocols and decrease the latency caused by the routing discovery in reactive routing protocols. ZRP defines a zone around every node consists of its k neighbours (e. g. k=3). In ZRP, all nodes within k-hop distance from particular node belongs to the routing zone of a that node. ZRP is formed by two sub-protocols, a proactive routing protocol: Intra-zone Routing Protocol (IARP), used inside routing zones and a reactive routing protocol: Inter-zone Routing Protocol (IERP), used between routing zones, respectively. A route to a destination within the local zone can be created from the proactively cached routing table of the source by IARP, therefore, if the source and destination is in the same zone, the packet can be delivered immediately. Most of the existing proactive routing algorithms can be employed as the IARP for ZRP. For routes beyond the reach of the local zone, route discovery happens reactively. The source node sends a route requests to its border nodes, specifying its own address, the destination address and a unique sequence number. Border nodes are the nodes which are exactly the maximum number of hops to the defined local zone away from the source node. The border nodes check their local zone for the destination node. If the requested node is not a member of the local zone, the node adds its own address to the route request packet and forwards the packet to its border nodes. If the destination node is a member of the local zone of the node, it sends a route reply on the reverse path back to the source node. The source node uses the path saved in the route reply packet to forward the data packets to the destination.

Temporally Ordered Routing Algorithm: TORA falls under the category of algorithms called "Link Reversal Algorithms". TORA is an on demand routing protocol. Unlike other algorithms, the TORA routing protocol does not uses the concept of shortest path for creating the paths from the source to the destination as it may take huge amount of bandwidth in the network. Instead of using the shortest path for calculating the routes, the TORA algorithm maintains the "direction of the next destination" to forward the packets. Thus, a source node maintains one or more "downstream paths" to the destination through multiple intermediate neighbouring nodes. TORA reduces the control messages in the network by having the nodes to query for a path only when it needs to forward a packet to a destination. In TORA three steps are followed in establishing a network. A) Creating routes from source to destination, B) Maintaining the routes and C) Erasing the invalid routes. TORA employs the concept of "directed acyclic graph (DAG) to establish downstream paths to the destination". This DAG is termed as "Destination Oriented DAG". A node marked as destination oriented DAG is the last node or the destination node and no link originates from this particular node. It has the lowest height. Three different messages are used by TORA for establishing a path: the Query (QRY) message for creating a route, Update (UPD) message for creating and maintaining routes and Clear (CLR) message for erasing a route. Each of the nodes is concerned with a height in the network. A link is created between the nodes based on the height. The establishment of the route from source to the destination is based on the DAG mechanism thereby ensuring that all the routes are loop free. Packets move starting from the source node having the highest height to the destination node with the lowest height.

COMPARISON OF VARIOUS PROTOCOLS

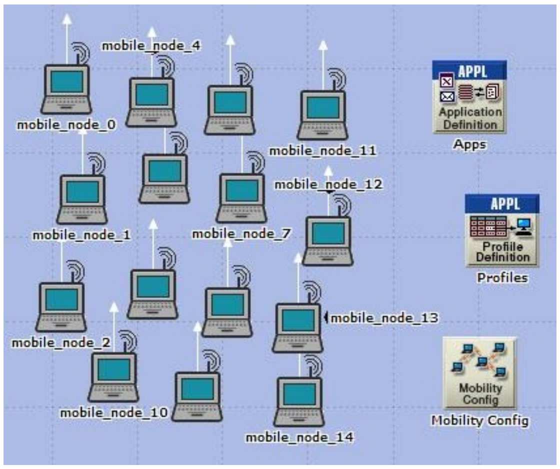
In this section, a brief summary of behaviours of the above mentioned protocols is provided. This includes their update information, update destination, mode of forwarding the packets, their routing philosophy, update transmissions, whether sequence numbers and Hello messages are involved or not and which routing metric is used by which particular protocol respectively.[3][19] All these aspects are depicted with respect to the different protocols in the table given below:

Parameter	DSDV	OLSR	WRP	AODV	DSR	ZRP	TORA
Update information	Topology information	Link information	Distance and predecessor information	Route error	New available easy routes	distance	Node’s height
Update destination	Current Neighbours	Symmetric one hop neighbour	Neighbours	Source	Neighbours	Neighbours	Neighbours
Method	Broadcasting or Multicasting	With and without broadcasting	Broadcast	Unicast	Broadcast	Broadcast	Broadcast
Topology	Full	Reduced	Full	Full	Full	Full	Reduced
Routing philosophy	Flat	Hierarchical	Flat	Flat	Flat	Flat or hierarchical	Flat
Multicast Capability	Yes	No	No	Yes	No	No	No
Update Transmissions	Periodically and as needed	Periodically	Periodically and as needed	Periodically and as needed	Periodically and as needed	Periodically and as needed	Only when needed
Sequence numbers	Yes	No	Yes	Yes	No	Yes	No
“Hello” Messages	Yes	Yes	Yes	No	No	No	No
Routing Metric	Shortest Path	Shortest Path	Shortest Path	Freshest shortest path	Fresh shortest path	Shortest path	Direction of the next destination

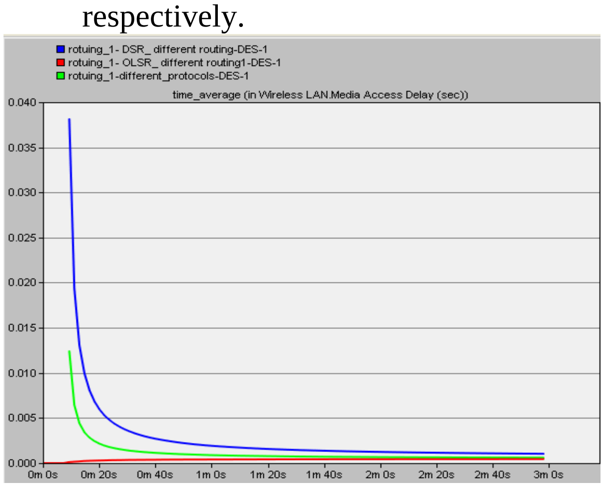
SIMULATION RESULTS

A simple network is created in the OPNET MODELER simulation tool. In this network, the three protocols AODV, OLSR and DSR are compared on the basis of four different parameters i.e. media access delay, network load, retransmission attempts and throughput of the network.

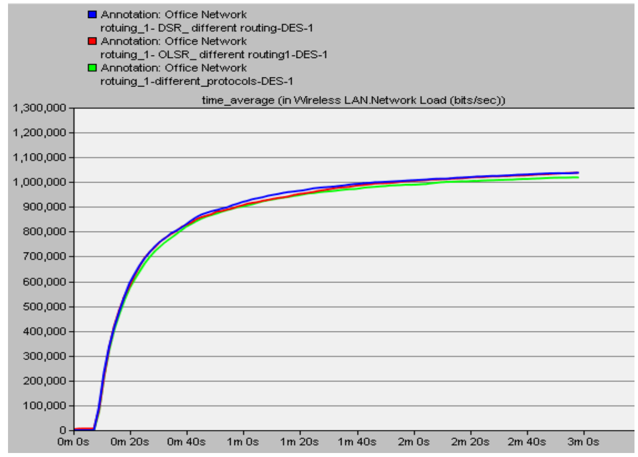
Network Scenario: Here, 15 mobile nodes are placed randomly in the network. An application config, mobility config and profile config and an object node is also placed in the same network in order to configure the mobile nodes with the traffic in the network. Video conferencing application is used to generate the traffic in the network. The simulation time is set to 180 seconds. Due to the mobility of the nodes, the trajectory of the nodes is set to VECTOR.



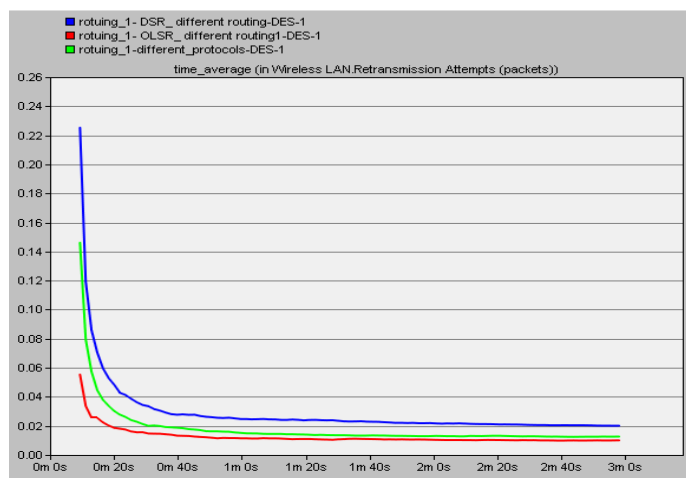
1. Media access delay: The delay caused in the addressing and channel access is termed as media access delay.The maximum and least delay is caused by the DSR protocol and OLSR protocol respectively.



2. Network Load: The load caused during various processes running in the network is known as network load. DSR and AODVprotocol causes the maximum and minimum load of all the protocols being compared.

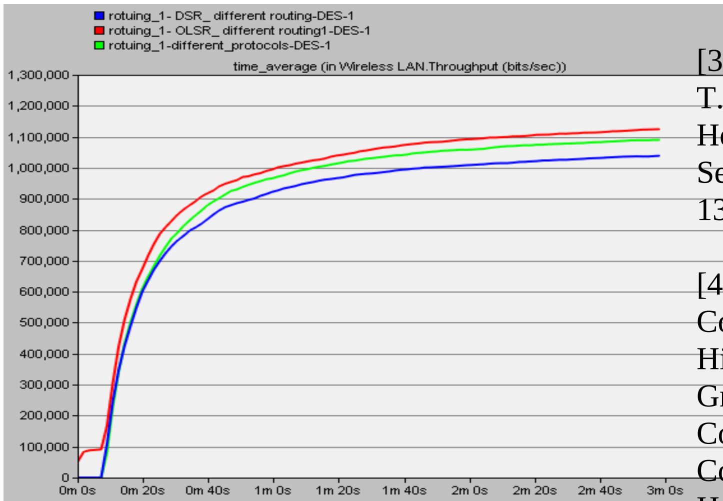


3. Retransmission attempts: The number of times the packet is sent again due to the traffic in the network. DSR protocol causes maximum number of retransmission attempts for sending the packets to the exact destination. The largest and least number of retransmissions performed for sending the packets to the destination are caused during DSR and AODV protocol respectively.



4. Throughput: The number of packets sent should be equal to the number of packets received or vice versa in order to get high performance is known as throughput of the network. DSR protocol bears the least

throughput of all the protocols compared here. The maximum and minimum throughput is attained by the OLSR and DSR protocols respectively.



CONCLUSION

In this paper, firstly, various ad hoc routing protocols are compared on the basis of several parameters. Also, a simple network of 15 mobile nodes is created and analysed in the OPNET MODELER simulation tool. Here, three protocols are compared on the basis of four parameters i.e. media access delay, network load, retransmission attempts and throughput respectively. The simulated results show that OLSR protocol bears the highest throughput of all the three protocols. Whereas, on the other hand, DSR protocol achieves the least throughput of all the protocols compared thereby causing maximum delay, load and retransmissions in order to forward the packets successfully to the destination.

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