International Journal of Computer Engineering Research Vol. 3(4), pp. 63-68, November, 2012
Available online at http://www.academicjournals.org/IJCER
DOI:10.5897/IJCER12.022
ISSN 2141- 6494 ©2012 Academic Journals

Full Length Research Paper

Simulation analysis of proactive, reactive and hybrid routing protocols in mobile ad hoc network using Qualnet simulator 5.0.2

Nitin Arora* and Suresh Kumar

Department of Computer Science and Engineering, Govind Ballabh Pant Engineering College, Pauri, India.

Accepted 11 April, 2012

Mobile ad hoc networks (MANETs) consist of a collection of wireless mobile nodes which dynamically exchange data among themselves without the reliance on a fixed base station or a wired backbone network. All nodes are mobile and can be connected dynamically in an arbitrary manner. There is no static infrastructure such as base station. All nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes in the network. There are various protocols for handling the routing problem in the ad hoc wireless network environment. In this paper, focus is given on studying the performance evaluation of various routing protocols using Qualnet simulator 5.0.2. The performance of the proactive, reactive and hybrid protocols are analyzed with different node densities for stationary nodes. The metrics used for the performance evaluation include throughput, packet delivery ratio and average end to end delay.

Key words: Proactive, reactive, hybrid, performance evaluation, Qualnet, end-to-end delay, throughput, packets delivery ratio.

INTRODUCTION

Wireless networks are an emerging new technology that will allow users to access information and services electronically, regardless of their geographic position. Wireless networks can be classified in two types:

1. Infrastructure Network and
2. Infrastructure less (ad hoc) Networks

Infrastructure Network consists of a network with fixed and wired gateways. A mobile host communicates with a bridge in the network or called base station within its communication radius. The mobile unit can move geographically while it is communicating. When it goes out of range of one base station, it connects with new base station and starts communicating through it.

A mobile ad hoc network (MANET) (Siva and Manoj, 2011) group has been formed within IETF (Internet Engineering Task Force). The goal of IETF is to support mobile ad hoc networks with hundreds of routers and solve challenges. MANET is a self-configuring infrastructure, with small network of mobile devices connected by wireless links. Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. An ad hoc network is a collection of mobile computers or mobile nodes that cooperate to forward packets for each other to extend the limited transmission range of each node's wireless network interface. Each node must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet. Active research work for mobile ad hoc networks is currently done mainly in the fields of Medium Access Control (MAC), routing, resource management, power control, and security. Because of the importance of routing protocols in dynamic multi hop networks, a lot of mobile ad hoc network routing protocols have been proposed in the last few years. Table 1 shows some of

*Corresponding author. E-mail: nitinarora47@gmail.com.

Table 1. Some routing protocols for MANETs.

Pro-active routing or table-driven protocols	DSDV, FSR, OLSR
Reactive routing or On-demand routing protocols	AODV, DSR
Hybrid (pro-active/reactive)	ZRP

the routing protocols for MANETs.

In this work performance evaluation of various routing protocols like Optimized Link State Routing (OLSR), Ad hoc On-demand Distance Vector routing (AODV), Dynamic Source Routing (DSR) and Zone Routing Protocol (ZRP) are studied using Qualnet 5.0.2 network simulator (www.scalable-networks.com) for 25, 50 and 100 stationary nodes.

Various routing techniques

Proactive routing technique (Table driven protocols)

Optimized link state routing (OLSR): It is a proactive routing protocol where the routes are always available when needed. OLSR is an optimized version of a pure link state protocol. The topological changes cause the flooding of the topological information to all available hosts in the network. To reduce the possible overhead in the network protocol multipoint relays (MPR) are used. Reducing the time interval for the control messages transmission brings more reactivity to the topological changes (Philippe et al., 2001).

OLSR uses two kinds of the control messages namely hello and topology control. Hello messages are used for finding the information about the link status and the host's neighbours. Topology control messages are used for broadcasting information about its own advertised neighbours, which includes at least the MPR selector list (Philippe et al., 2001).

Reactive routing technique (on-demand routing protocols)

Ad hoc on-demand distance vector (AODV): The Ad hoc on-demand Distance Vector (AODV) routing protocol (Baccala, 1997) is a reactive MANET routing protocol. Similar to DSR, AODV broadcasts a route request to discover a route in a reactive mode. The difference is that in AODV, a field of the number of hops is used in the route record, instead of a list of intermediate router addresses. Each intermediate router sets up a temporary reverse link in the process of a route discovery. This link points to the router that forwarded the request. Hence, the reply messages can find its way back to the initiator when a route is discovered. When intermediate routers receive the reply, they can also set up corresponding forward routing entries. To prevent old routing information being used as a reply to the latest request, a destination sequence number is used in the route discovery packet and the route reply packet. A higher sequence number implies a more recent route request. Route maintenance in AODV is similar to that in DSR (Boukerche, 2001).

One advantage of AODV is that AODV is loop-free due to the destination sequence numbers associated with routes. The algorithm avoids the Bellman-Ford "count to infinity" problem (Haas et al., 2002).

Therefore, it offers quick convergence when the ad hoc net-work topology changes which, typically, occurs when a node moves in the network (Haas et al., 2002). Similar to DSR, poor scalability is disadvantage of AODV (Aron and Gupta, 2001).

We use the example topology shown in Figure 1 to illustrate the discovery procedure of AODV. Note that Routers A and C are disconnected from each other while both of them connect to B. When Router A starts a route discovery to C, a route request is broadcast. The request packet contains the requested destination sequence number, which is 1 greater than the one currently kept at A. For example, assume that the destination sequence number for C at A is 0x00000000, then the destination sequence number in the route discovery packet is 0x00000001. The intermediate routers reply to the source if they know the route to that destination with the same or higher destination sequence number. We assume that B does not have a record for a route to C. Therefore, B first sets up a temporary link pointing back to A. In the second step, it increases the number of hops by 1 and rebroadcasts the request. When C receives that request, it creates a new destination sequence number. A route reply with that new sequence number is sent by C. The initiator and all intermediate routers build routing entries associated with this new sequence number when they receive the reply. The number of hop values can be used to find a shorter path if a router receives two replies with the same destination sequence number. AODV uses a similar scheme as DSR to handle unreliable transmission of control messages.

Dynamic source routing (DSR): When a node generates a packet to a certain destination and it does not have a known route to that destination, this node starts a route discovery procedure. Therefore, DSR is a reactive protocol. One advantage of DSR is that no periodic routing packets are required. DSR also has the capability to handle unidirectional links. Since DSR

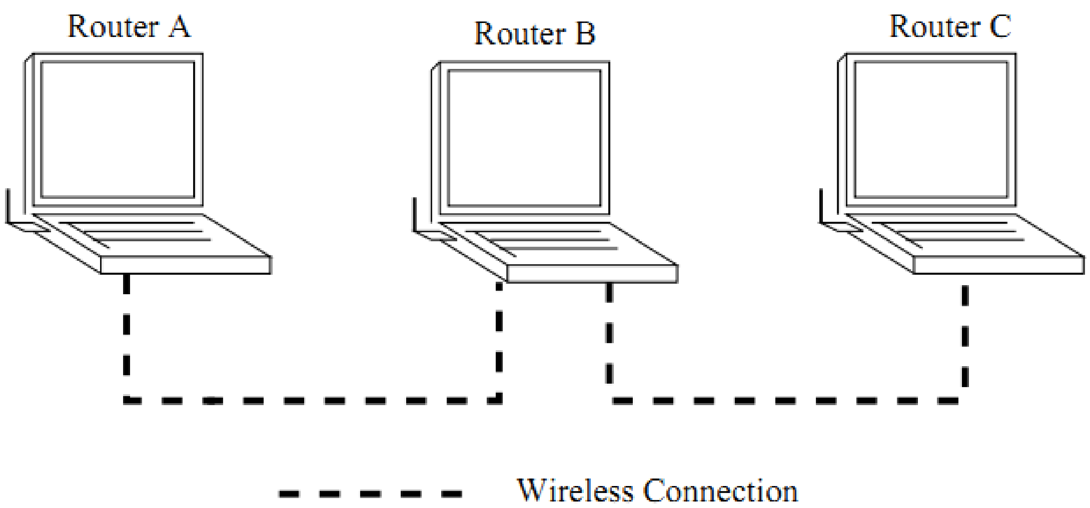

Figure 1. Example of DSR and AODV routing protocols.

discovers routes on-demand, it may have poor performance in terms of control overhead in networks with high mobility and heavy traffic loads. Scalability is said to be another disadvantage of DSR (Aron and Gupta, 2001), because DSR relies on blind broadcasts to discover routes.

There are two main operations in DSR, route discovery and route maintenance. Figure 1 shows a simple example for DSR. Routers A, B, and C form a MANET. Routers A and C are disconnected, while both of them connect to router B. Assume that at the beginning, the route caches that memorize previous routes in the routers are empty. When Router A wants to send a packet to Router C, it broadcasts a route request to start the corresponding route discovery procedure. Router B receives the request since it is within the radio range of A. Router C is the destination in the request and B does not have a route entry to C in its cache at this time. Hence, Router B appends its own ID to the list of intermediate router IDs in the request and rebroadcasts it. When C receives the broadcast route request message originated by B, it determines that the destination ID matches its own ID. Thus, the route from A to C is found. To help the initiator and all intermediate routers construct proper routing entries, Router C sends a reply back to A using source routing if links are bi-directional. This procedure is feasible because all intermediate routers are in the ID list of the corresponding route request. Intermediate routers construct proper routing tables when they receive the reply originated from C. Thus, a route from A to C is built. During the route discovery procedure, routers maintain ID lists of the recently seen requests to avoid repeatedly processing the same route request. Requests are discarded if they were processed recently since they are assumed to be duplicates. If a router receives a request and detects that the request contains its own ID in the list of intermediate routers, this router discards the request to avoid loops. The route maintenance procedure is used when routes become invalid due to the unpredictable movement of routers. Each router monitors the links that it uses to forward packets. Once a link is down, a route error packet is immediately sent to the initiator of the associated route. Therefore, the invalid route is quickly discarded (Boukerche, 2001).

Hybrid routing technique

Hybrid Routing Protocols combines the merits of proactive and reactive routing protocols by overcoming their demerits. In this section some light on hybrid routing protocol is given.

Zone routing protocol (ZRP): The Zone Routing Protocol (ZRP) is a prototype routing protocol. ZRP is formed by two sub-protocols, the Intra zone Routing Protocol (IARP) and the Inter zone Routing Protocol (IERP). IARP is “a limited scope proactive routing protocol used to improve the performance of existing globally reactive routing protocols” (Haas et al., 2002). It relies on the service of a certain neighbor discovery protocol (NDP) to provide neighbor information. IARP may use a scheme based on the time-to-live (TTL) field in IP packets to control the zone range. (When a broadcast packet passes a router, the value of TTL is decremented by one before it is rebroadcast, and when TTL equals to zero, the packet is not rebroadcast). IERP is the reactive routing component of ZRP (Haas et al., 2002). This scheme is responsible for finding a global path. It avoids global queries for destinations that would be sent to surrounding r-hop neighbors. When global queries are required, “the routing zone based broadcast service can be used to efficiently guide route queries outward, rather

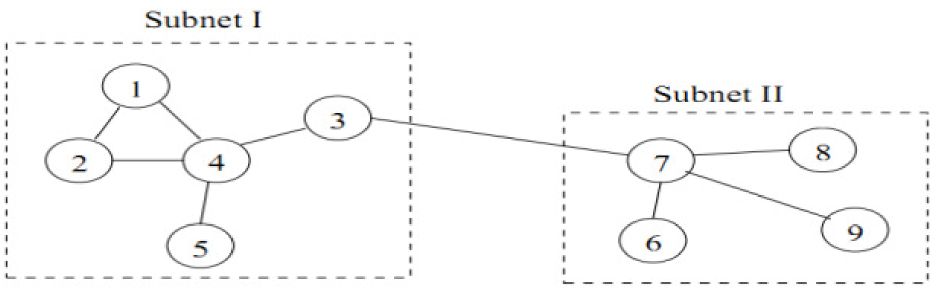

Figure 2. Example of ZRP.

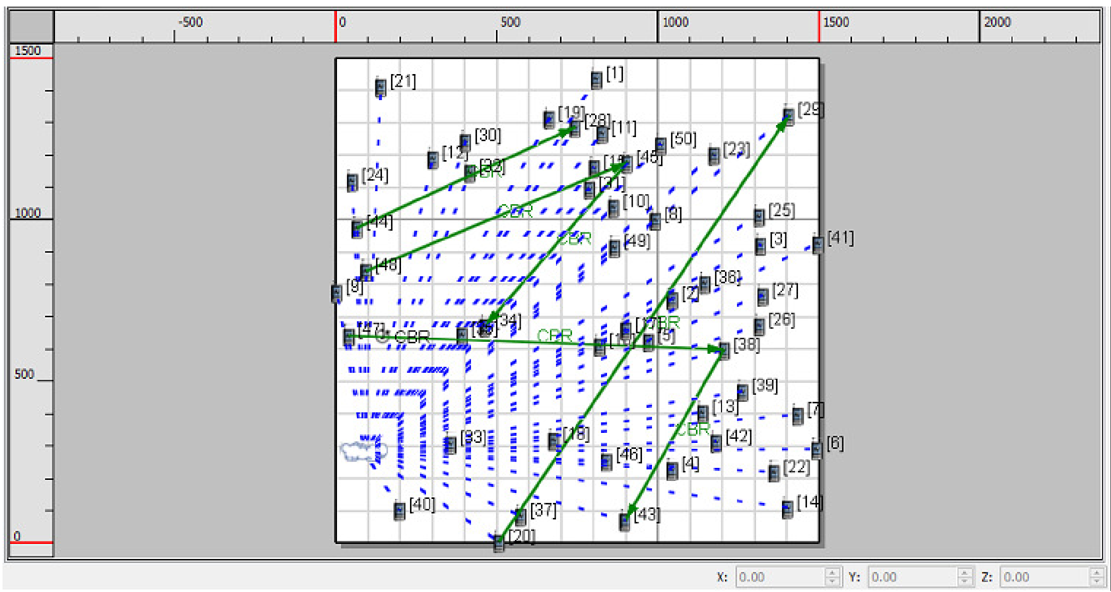

Figure 3. Node placement scenario.

than blindly relaying queries from neighbor to neighbor" (Haas et al., 2002). ZRP tries to combine the advantages of reactive and proactive routing protocols. The potential disadvantage is the lack of route optimization. We use the example network in Figure 2 to briefly show the concept of ZRP. The range of the zone is set to one. So routers in Subnets I and II use proactive IARP to find routes to other routers in the same subnet. For routes to the other subnet, reactive IERP is used.

The performance of the routing protocols OLSR, AODV, DSR and ZRP are compared using Qualnet 5.0.2 Network Simulator with the metrics like throughput, end-to-end delay and packets delivery ratio.

METHODS

Node placement scenario and simulation environment

Qualnet 5.0.2 network simulator (www.scalablenetworks.com/products/Qualnet/download.php#docs) has been used to evaluate the performance of OLSR, AODV, DSR and ZRP routing protocols of mobile ad hoc networks. The physical medium used is 802.11 PHY with a data rate of 2 Mbps. The MAC protocol used is the 802.11 MAC protocol, configured for MANET mode. The simulations are carried out for network densities of 25, 50 and 100 nodes respectively. The area considered for the above network densities are 1500 m × 1500 m for stationary nodes. Simulations are configured for the performance evaluation of different routing protocols with the metrics like packet delivery ratio, end to end delay and throughput. Figure 3 shows the node placement scenario for the 50 nodes. Network environment is described in Table 2.

Performance metrics

We compared the performance of OLSR, AODV, DSR and ZRP under 25, 50 and 100 stationary nodes. We evaluate the performance according to the following metrics as shown in the Table 3.

RESULTS

The variation of PDR of various routing protocols for

Table 2. Scenario parameter.

Routing protocols	OLSR, AODV, DSR, ZRP
Radio type	802.11b
No. of channels	1
Channel frequency	2.4 GHz
Mobility	Stationary
Path loss model	Two way
Energy model	Mica Motes
Shadowing model	Constant
Pause time	30 s
Simulation time	300 s
Battery model	Linear Model
Simulation area	1500 × 1500
Number of nodes	25, 50, 100

Table 3. Performance matrices.

Packet delivery ratio	The ratio of the number of data packets received by the destination to the number of data packets sent by the source.
End-to-end delay	The average end-to-end latency of data packets.
Throughput	Average rate of successful message delivery over a communication channel.

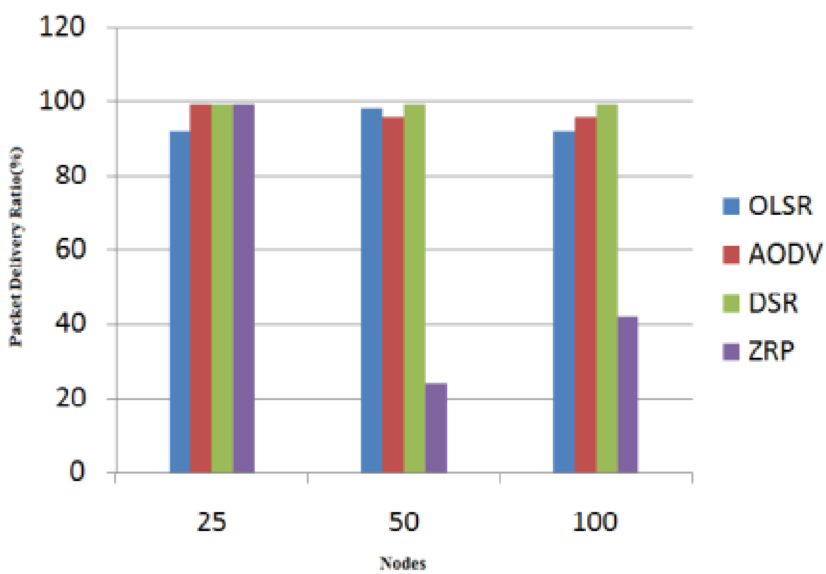

Figure 4. Plot of packet deliver ratio (%) vs node.

stationary nodes with respect to node densities 25, 50 and 100 nodes is given in Figure 4.

Figure 5 shows the variation in end-to-end delay for stationary nodes with respect to node densities 25, 50 and 100 nodes.

Figure 6 shows the variation in throughput of various routing protocols considered for stationary nodes with respect to node densities 25, 50 and 100 nodes.

Conclusion

The performance evaluation of proactive (OLSR), reactive (AODV, DSR) and hybrid (ZRP) routing protocols for stationary nodes are studied by varying the node density (25, 50 and 100) using Qualnet 5.0.2 network simulator. From the results it can be observed that reactive routing protocols AODV and DSR are suited for

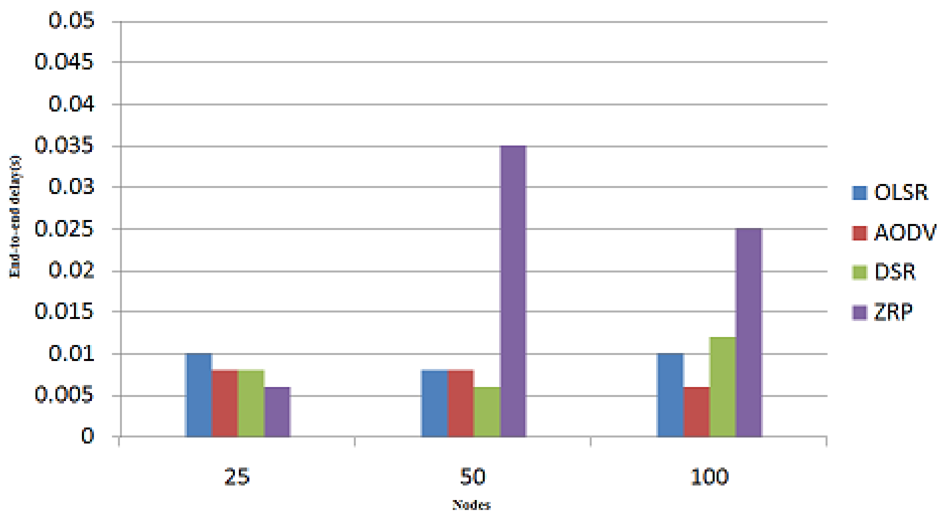

Figure 5. End-to-end-delay(s) vs nodes

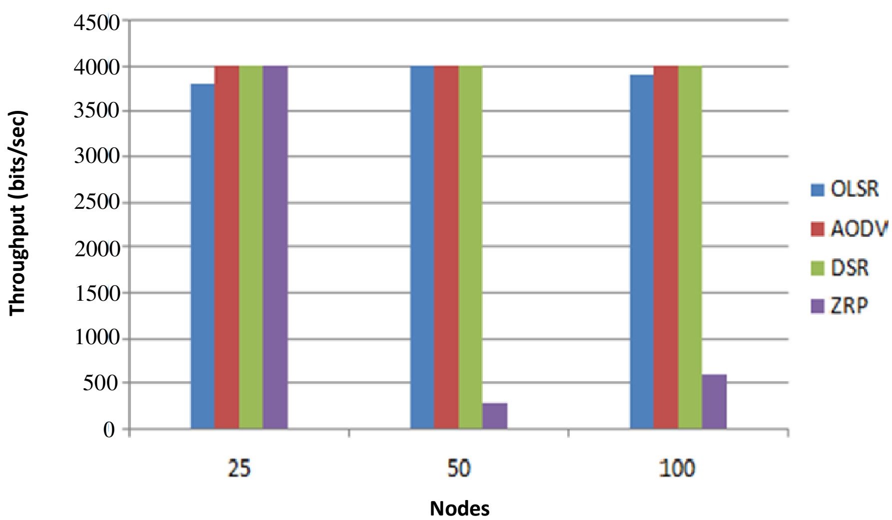

Figure 6. Throughput (bits/sec) vs nodes.

applications where throughput are very critical. ZRP and OLSR being the location based protocols need sufficient time to establish route discovery and route maintenance; hence for large range mobile applications they are best suited.

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