Efficiency Analysis and Comparative Performance Evaluation of Routing Protocols in Mobile Ad Hoc Networks

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Abstract: MANETs are a group of wireless computers in the form of communication network which do not have predetermined structure. Administration and configuration of these kinds of networks are not dependent on any special user. **Approach:** There are many problems in the creation of Mobile Ad hoc Networks, such as routing, wireless media, energy consumption, transportability and efficiency. **Results:** Although there are several routing protocol proposals for MANETs, applied sensitivity increase the importance of efficiency related considerations. For example in the case of military field activities, many industrial and vehicular control and monitoring applications some crucial efficiency parameters should be considered such as packet delivery ,shortest available path and routing overhead. In this paper we have investigated efficiency of the routing protocols (DSR, AODV, DSDV, TORA, FSR, CBRP and CGSR) so that an engineering methodology could be constructed depending on requirements, restrictions and availabilities. **Conclusion/ Recommendation:** We have also given details of efficiency comparison factors of the routing protocols used in seamless networks which yields these results. From the detailed simulation results and analysis, a suitable routing protocol can be chosen for a specified network and goal.

Keywords: Routing protocols; Mobile Ad Hoc Network; Table-driven protocols; On-demand protocols, Comparison in efficiency

1. Introduction

Mobile Ad Hoc Networks (MANETs) indicate composite distributed systems such as the Internet, World Wide Web, social networks, and biological systems that include wireless mobile nodes that can dynamically and freely self-organize into temporary and arbitrary ad-hoc network topologies. This type of network allows people and devices to seamlessly internetwork in areas with no pre-existing communication base station [1]. In MANET, the network nodes are mobile and have the freedom to join or leave the network at any time. Efficiency in MANETs is very important from both military and commercial views, where packet delivery and data communications are required [2].

There are two types of topology for MANET: heterogeneous mobile devices and mobile host network. The first network has been comprised of different kinds of mobile devices such as PDAs, smart signals and mobile hosts, while, second type of the network has been only comprised of mobile hosts. Figure 1 indicates an example of MANET in which the left side shows a heterogeneous network and right side shows a network with mobile host [3].

Such networks back up calculations at any time and in any place, and their structures can change automatically. In such networks, each mobile host acts as a router. For this reason, peer-to-peer communication as well as peer-to-remote communication is possible in this kind of network. In MANETs, mobility of routes is a complex problem and for this reason,

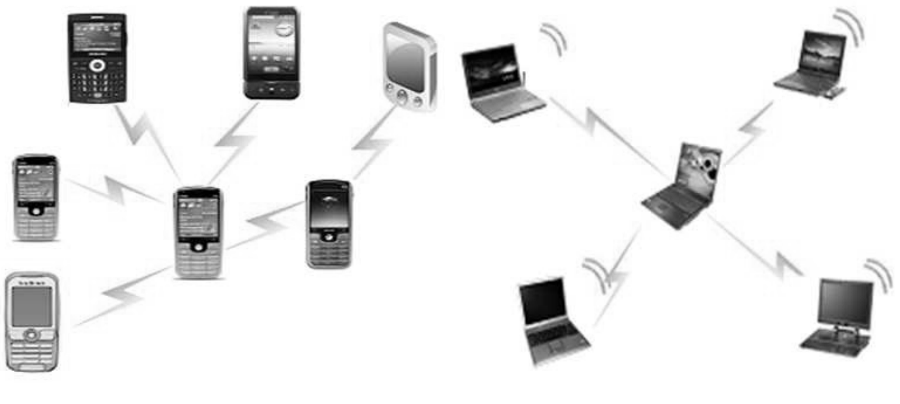


Figure 1. An example of a Mobile Ad hoc Network

communication may change frequently. Due to the communication links should be updated continually and their messages should be sent frequently; hence this control creates traffic [4]. Delivering the packets on time, data lost, routing overhead and finding shortest available path are current challenges in this type of networks. In this article we have investigated efficiency of the considered routing so that an engineering methodology could be constructed depending on requirements, restrictions and availabilities.

This paper is organised as follows: In Section 2 we give a brief description of some of the most important routing protocols in mobile ad hoc networks. Section 3 describes simulation environment and some parameters used in simulations. Section 4 shows the comparison of MANET routing protocols in terms of efficiency. We followed this by performing simulations, and results are described in Section 5. Finally, Section 6 presents our conclusions and future work.

2. Mobile Ad Hoc Network Routing Protocols

In the performance evaluation of protocols for an ad hoc network, the protocols should be tested under realistic conditions. This paper is a research in which mobile ad hoc networks are described and some routing protocols are explained. During simulation, different results were given by changing the selected parameters. Firstly we have a technical look at these types of protocols and their specifications [5].

As shown in Figure 2, routing protocols in mobile ad hoc networks are classified into two classes: table-driven and on-demand [6]. The table-driven, or proactive, method is used for alternate updating links and can use both the distance vectors and link statuses used in fixed networks.

In the on-demand method with reactions, other nodes do not update the route and the routes are determined at the origin of the request. The advantage of this method is that bandwidth is used effectively. In this paper, the table-driven and the on-demand protocols are explained and then compared with different parameters [7].

2. 1 On-demand protocols

In comparison with table-driven routing protocols, all updated routes are not maintained in each node in this group of protocols; instead, routes are constructed only when it is necessary. When an origin node wants to send something to a destination, it makes a request to the destination for the route detection mechanisms. For this reason, this type of protocol is known as a reactive protocol. This route remains valid until the destination is accessible. This section explains some of the on-demand routing protocols [8].

2.1.1 AODV (Ad-Hoc On-demand Distance Vector Routing)

This protocol can be regarded as an improvement of DSDV. AODV is an on-demand routing algorithm that builds routes only when desired. It makes use of sequence numbers to ensure the novelty of routes. To find a path to a destination, a node using AODV broadcasts a route request (RREQ) packet. AODV route selection is regulated by a

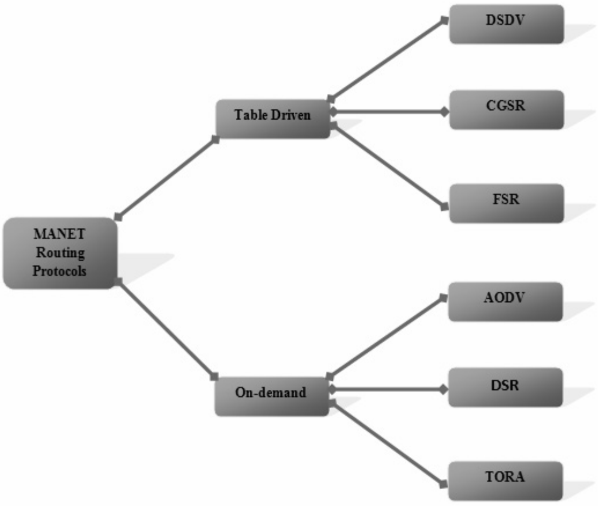
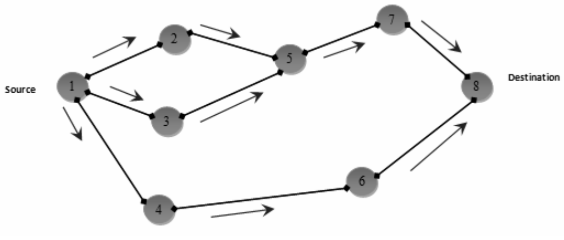
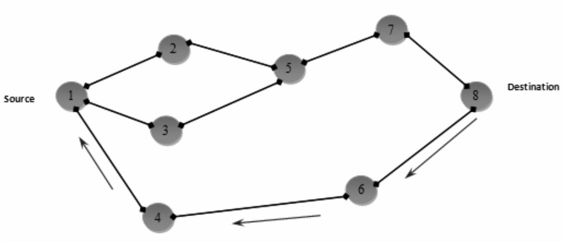


Figure 2. Categorization of MANET routing protocols

distributed grouping mechanism, which divides the mobile nodes logically into different groups to reduce and distribute routing traffic over the network [9].



(a) Distribution packet among neighbours

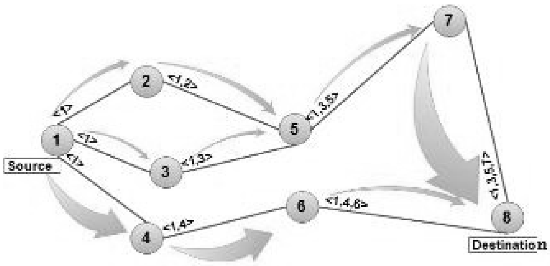


(b) Process of reply to demand

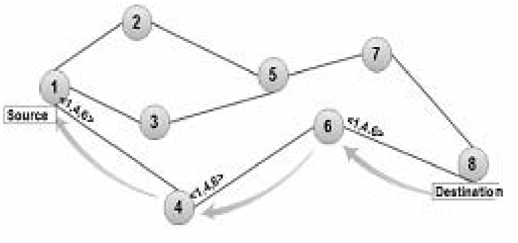
Figure 3. Detection of route in AODV

2.1.2 DSR (Dynamic Source Routing Protocol)

The Dynamic Source Routing protocol (DSR) is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. DSR allows the network to be completely self-configuring and self-organising, without the need for any existing network infrastructure or administration.



(a) Distribution of demand packets



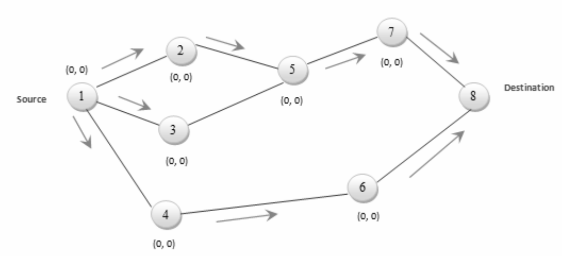
(b) Reply packets

Figure 4. An instance of route detection in DSR

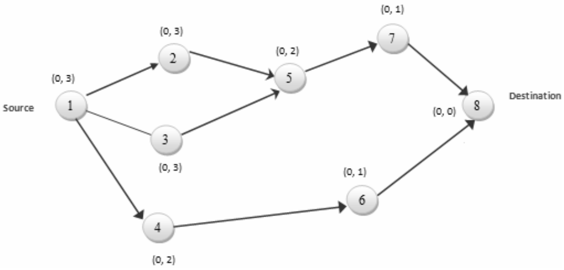
DSR uses the source routing strategy. In this technique, the source node determines the complete sequence of nodes through which the data packets will be sent [10]. Figure 4(a) shows how the route demand packet is distributed in the network and indicates its route record section. Figure 4(b) indicates the state in which the destination node itself has sent a route reply [3].

2.1.3 TORA Protocol (Temporally-Ordered Routing Algorithm)

The main characteristic of TORA is the centralisation of control messages in a very small set of near local nodes in which topological changes have been made. To achieve this property, nodes maintain routing information for the adjacent nodes for some interval. This protocol has three duties: route formation, route renovation and route cleaning [11]. Route formation is performed with QRY[1] and UPD[2]. A route formation algorithm starts by determining a zero set for height of destination node and empty set for height of other nodes.



a)Broadcast QRY



b) Distribute UDP packet

Figure 5. Detection of route in TORA

The origin distributes a QRY packet in which destination node identifier is located. In this method, a non-circular graph is created from origin to destination. Figure 5 indicates a process of route formation in TORA. As shown in Figure 5(a), node 5 receives the QRY packet

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[1] Query protocol

[2] User Datagram Protocol

from node 3 but it doesn't publish it because this packet has reached this node through node 2 previously. In Fig.5(b), the origin, i.e., node 1 can receive the UPD packet from node 2 or node 3 but it doesn't receive it from node 4 of which the height is lower.

2.1.4 CBRP (Cluster based Routing Protocols)

In these protocols, clusters are formed by dividing the whole network into self-managed groups of nodes .These groups are dynamically rearranged when the topology of the network is changed. To form these clusters, the following algorithm is used. When a node enters the network, it enters an indefinite state. In this state, it adjusts a timer and distributes a Hello message for all other nodes. When a cluster head receives this Hello message, it replies with a Hello message immediately. When the unknown node receives this message, it changes its state to member. If the indefinite node does not receive a reply after the defined time, it introduces itself as a cluster head in the case that it has a two-sided conductive linkage with a node or nodes that are its neighbours. Otherwise, it remains in the indefinite state and repeats the procedure [12].

2.2 Table-driven protocols

Table-based protocols are characterized by their ability to maintain routing tables that store information about routes from one node in the network to the rest of the others. Obviously, this requires that, all nodes update their tables to preserve compatibility by exchanging routing information between the participating nodes and to give upgraded viewpoints of the network. When the topology of the network changes, the nodes distribute update messages across the network [6]. Although, in general, the table-based protocols may be easy to implement, the major limitation with these protocols is that, due to the inherently highly mobile and dynamic nature of ad-hoc networks, the maintenance of routing information in these tables is challenging. The following sections explain some of these routing protocols [8].

2.2.1 DSDV (Dynamic Destination-Sequence Distance –Vector Routing Protocol)

This protocol is based on the BELLMANFORD routing idea, with a series of improvements [8]. Each mobile base maintains a routing table that includes all accessible destinations, the number of hops necessary for reaching that destination and the sequence of the digits appropriate to that destination. Routing table entries are tagged with sequence digits which are originated by the destination nodes [14]. This sequence of digits is used to distinguish new routes from old routes and to determine the creation of a ring. Route updates are transmitted either periodically or immediately after a significant topology change is detected. This protocol generates a supplementary traffic that adds to the real data traffic. [15]

2.2.2 CGSR Protocol (Cluster head Gateway Switch Routing Protocol)

This protocol is based on the DSDV routing algorithm [16]. Mobile nodes are collected inside packets, and a cluster head is selected. A gateway node is a node in a communication interval between two or more cluster heads. In a dynamic network, the idea of a cluster head can decrease the efficiency resulting from the frequency of selecting cluster heads.

The CGSR protocol uses a distributed algorithm called LCC[3]. The LCC algorithm is considered stable since the clusterheads will change only under two conditions: when two clusterheads come within the range of each other or when a node gets disconnected from any other cluster .In this state, the origin sends the packet to its cluster head; the cluster head sends this packet to the gateway node to which it and the node which is located in the route of destination are connected. The gateway sends the packet to another cluster head and this action continues until the cluster head receives the destination node of packet. Finally, the destination cluster head sends the packet to the destination node [8].

2.2.3 FSR Protocol (Fisheye State Routing)

FSR protocol took inspiration from the ‘‘fisheye’’ technique of graphic information compression where the technique was used to reduce the size of information required to represent graphical data [17]. In an FSR, an updating message does not include information about all of the nodes. Instead, it exchanges information with the adjacent nodes with a

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[3] Least Cluster Change

higher frequency more than it does with farther nodes, leading to a decrease in the size of the updating message. Thus, each node has accurate information about its neighbours, and the details and accuracy of the information decrease when the distance between two nodes increases. Figure 6 defines the area of a fisheye for a central node that has been indicated in red [18].

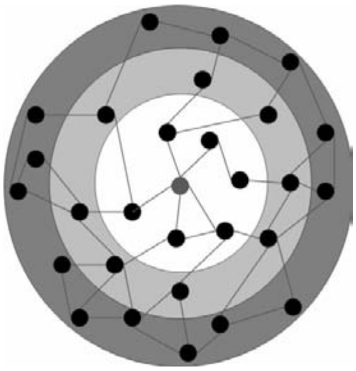


Figure 6. Accuracy of information in FSR protocol

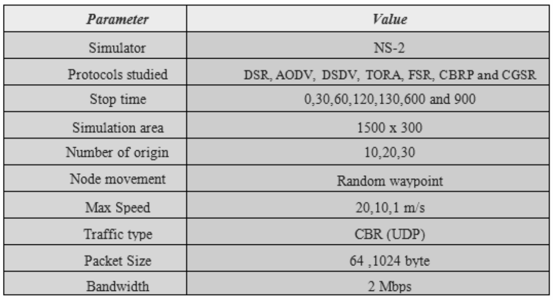
The central node should know more detail about the nodes that are located inside the white circle. FSR is suitable for massive networks, because in this method, overload is controlled. Also FSR is simple, efficient and scalable routing solution in a mobile environment [8].

3. Simulation Environment and Parameters

In this section, we present the details of the simulation environment: The simulation was performed with two values: a maximum speed of 20 m/s (average speed of 10 m/s) and 1 m/s. At first, seven protocols - DSR, AODV, DSDV, TORA, FSR, CBRP and CGSR - have been simulated with a maximum node speed of 20 m/s, followed by a simulation with a maximum node speed of 1 m/s.

The basic model parameters that have been used in the simulation given details in this section are summarised in Table 1.

Table 1. Simulation Parameters



Parameter	*Value*
Simulator	NS-2
Protocols studied	DSR, AODV, DSDV, TORA, FSR, CBRP and CGSR
Stop time	0,30,60,120,130,600 and 900
Simulation area	1500 x 300
Number of origin	10,20,30
Node movement	Random waypoint
Max Speed	20,10,1 m/s
Traffic type	CBR (UDP)
Packet Size	64 ,1024 byte
Bandwidth	2 Mbps

3.1 Movement model

An NS2 simulator was used to perform the simulation. In the simulation, nodes move on the basis of the Random Waypoint model [13], so that movement scenarios include a stop time specification. A node moves toward a randomly selected destination in area of 1500×300 sq meters with unsteady speed between zero and its maximum speed. Once the node reaches the destination, it stops for a portion of its stop time (per second) and then selects another destination. This behaviour persists throughout the simulation. Each simulation is implemented for 900 s, and the stop times considered in this simulation were 0, 30, 60, 120, 130, and 600 and 900 seconds; a 0 second stop time represents a continuous movement while a 900 second stop time represents a static network. Because the efficiency of protocols is dependent upon the nodes' movement model, 70 different movement models have been considered for nodes so that for each stop time, 10 different implementations are performed, and two different values have been considered for the maximum node speed. In the following sections, the simulation results with maximum speeds of 20 m/s and average speeds of 10 m/s are shown, along with results obtained from simulations with a maximum speed of 1 m/s, are shown.

3.2 Communication model

For implementing the simulations, the following parameters have been considered: traffic origins with a constant bit rate (CBR); the sending rate equal to 1, 4 and 8 packets per second; the number of origins equal to 10, 20 or 30; and packet sizes of 64 and 1024 bytes. Changing the number of CBR origins is similar to changing the sending rate, and therefore, in these simulations, a constant sending rate of four packets per second has been considered, and three different models have been created with a change in the number of CBR origins between 10, 20 and 30 origins. All communication models are peer to peer, and primary links have been distributed steadily between 0 and 180 seconds. Three communication models (10, 20 and 30 origins) are combined with 70 movement models to form 210 different scenarios for each possible maximum node speed (1 m/s and 20 m/s) [19].

3.3 Work methodology

The final aim of this simulation is to measure how the efficiency of routing protocols is affected by topological changes of the network as long as the packets are successfully sent to their destinations. To measure this ability, a basic simulation has been considered that is compared to results obtained from other simulations. In the basic simulation, 50 moving nodes have been placed in a simulation environment of 1500×300 sq meters over 900 seconds of implementation.

3.4 Movement models specifications

To show the difference between how the models performed on routing protocols, the length of the route of each protocol has been measured for the delivery of packets and the total number of topological changes in each scenario. When each packet is produced, an intermediate mechanism calculates the shortest path between the packet sender and the receiver and places it inside the packet. This value is compared with the number of real hops that the packet has made in reaching the destination. Figure 7 shows the distribution of the shortest paths for all 210 scenarios for node speeds of 1 and 20 m/s. The height of each rod shows the number of packets for each destination, each of which has a definite distance at the time of packet production. On average, the data packets in the simulation should traverse 2.6 hops to reach the destination, and the longest possible distance is a route with 8 hops.

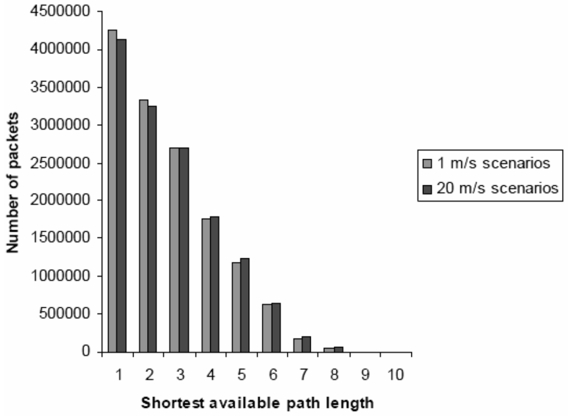


Figure 7. Distribution of the shortest available path for each packet produced in all scenarios

Table 2 shows the average number of link connection changes that occur during the simulation for each stop time.

Table 2. Average number of link connection changes during simulation based on the stop time function

Number of Link connection changes		Stop time
20 m/s	1 m/s	
11857	898	0
8984	908	30
7738	792	60
5390	732	120
2428	512	300
1270	245	600
0	0	900

A special scenario arises with lower connection changes for a stop time of 30 s and a speed of 1 m/s than for a stop time of zero seconds.

3.5 Measurement criteria

In comparing the routing protocols, three parameters and the following criteria are assessed:

- Rate of packet delivery: ratio of the number of packets produced by origin nodes in the application layer to the number of packets received by the final destination.
- Routing overhead**:** total number of routing packets sent throughout the simulation
- Route optimum: difference between the numbers of hops made to reach the destination and length of the estimated shortest path at the time of packet production.

It is necessary to note that 40 to 150 packets are produced in each second, and the total time of simulation is 900 s [20].

4. Comparisons in Terms of Efficiency

To perform a better comparison of the seven protocols examined in the second section - DSR, AODV, DSDV, TORA, FSR, CBRP and CGSR - the following sections compare them in terms of rate of packet delivery, routing overhead, path optimality and movement speed of nodes.

4.1 Comparison of protocols on rate of packets delivery

Figure 8 shows the amount of deliverable packets each protocol had, based on movement (stop time function) and network load (amount of origin nodes). For CGSR, CBRP, FSR, AODV, and DSR, the rate of packet delivery is independent of traffic load and is between 95% and 100% for all modes. For DSDV, a stop time longer than approximately 300 seconds causes a failure, and only a small amount of packets can be delivered [20]. As mentioned in previous sections, DSDV holds just one path for each destination, therefore, when the route is destroyed, packets are not deliverable and so they are eliminated [21].

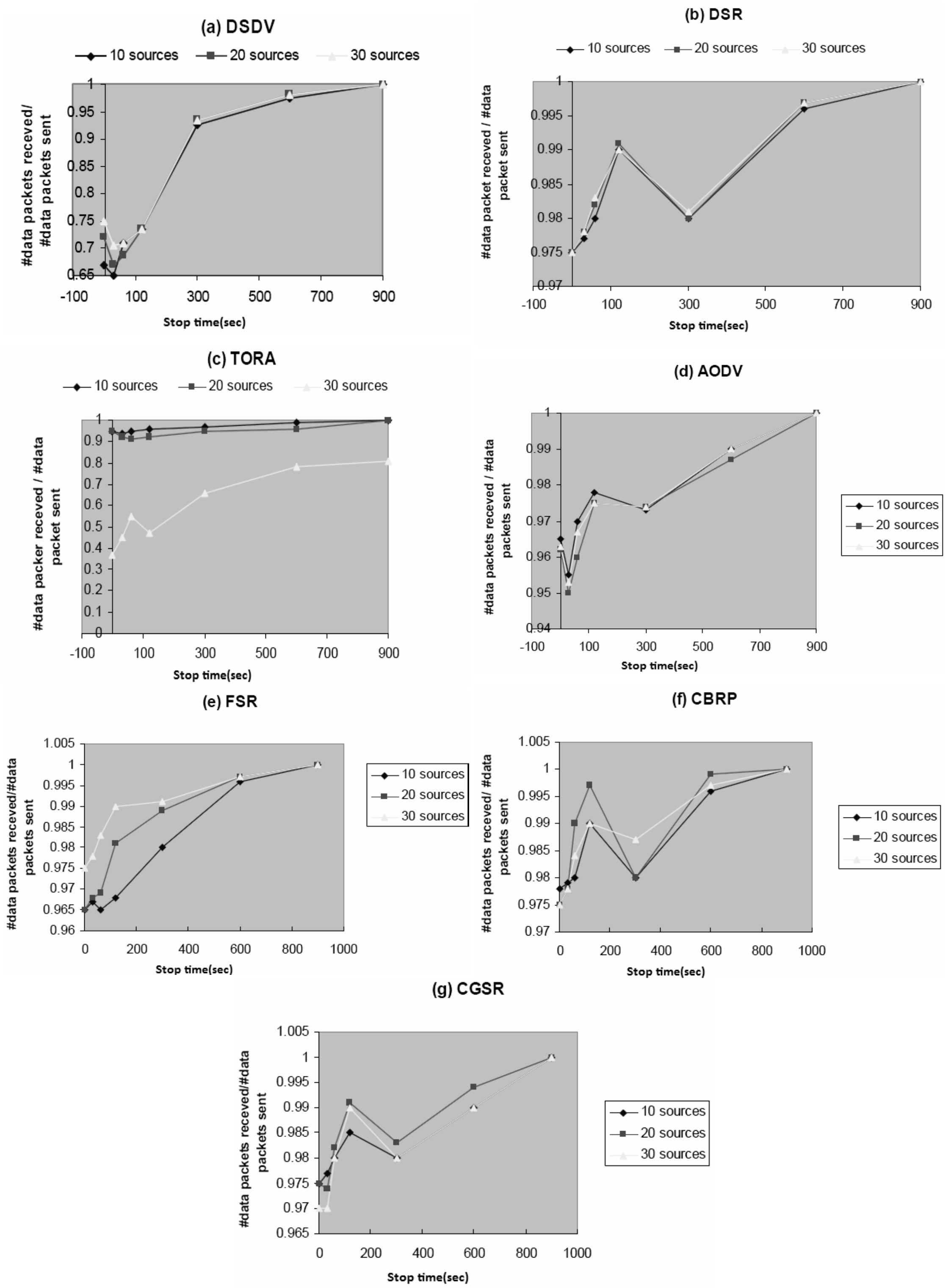


Figure 8. Rate of packet delivery as a function of stop time

4.2 Comparison of protocols based on routing overhead

Figure 9 shows the number of packets sent by each routing protocol to obtain the rate of delivery. It is expected that when increasing the number of origins, the number of packages in the routing protocols needs to increase because many paths must be kept. DSR, AODV and CBRP use only on-demand packets and are very similar to basic mechanisms; therefore, the curve is shaped very similarly to the curve of the basic mechanisms. However, the overhead of AODV is approximately 5 times that of DSR. This increase in overhead of AODV is due to broadcasting of packets to all nodes in a special network by each path discovery [3].

The overhead of FSR is less than DSR and more than AODV, so it indicates the similarity of these two protocols which belong to different groups. The overhead of TORA is the sum of two overheads: independent to mobility (stable) and dependent on mobility (variable).

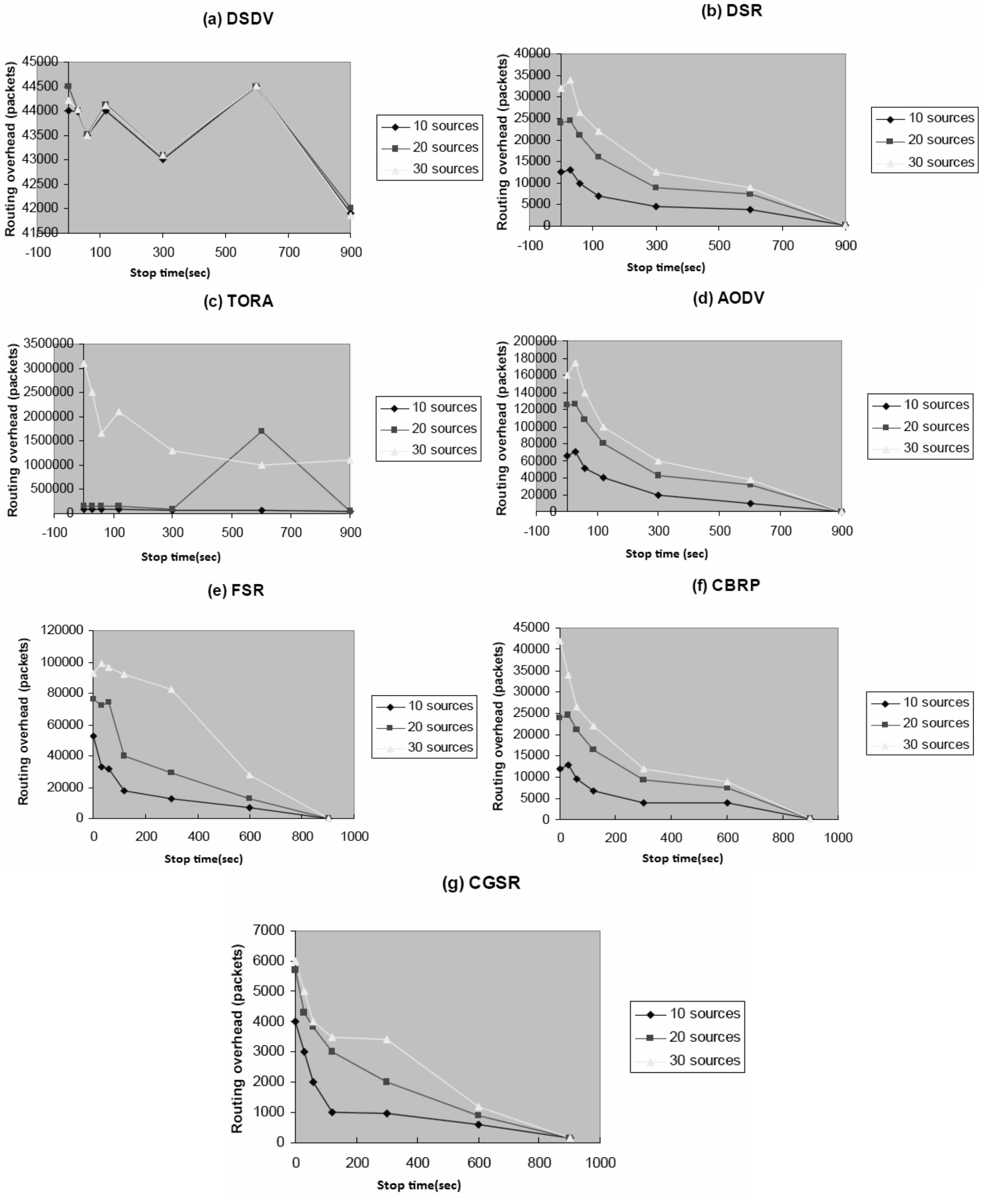


Figure 9. Routing overhead as a function of stop time

The stable overhead arises from the IMEP neighbour discovery mechanism for which it is required that each node sends at least one hello message in the range of conducting waves. By simulating this in 900 second with 50 nodes, this matter adds at least 45000 packets to the overhead. The variable section of the overhead includes TORA routing packets used in path discovery and maintenance produced by multiplying the number of resends and acknowledge packets together.

Apart from mobility or traffic rate, DSDV in this simulation has an almost constant overhead [22]. This constant behaviour is due to broadcasting update packets every 15 seconds along with new sequence number by each destination node like as D. Therefore, in this simulation, at least one node among these 50 uncoordinated nodes commits this. Thus, according to the manner of performing this work which has been explained in previous section, the overhead of this protocol in a 900 second simulation using 50 nodes is about 45000 packets.

4.3 Comparison of protocols based on path optimality

As described in the previous sections, a middle mechanism in the simulation calculated the shortest path between nodes and placed the information in all produced packets. Figure 10 shows the difference between the shortest path length and actual journey taken by the packet. A difference of zero means that the packet took the shortest path, whereas a difference greater than zero indicates the number of additional hops taken in the real path.

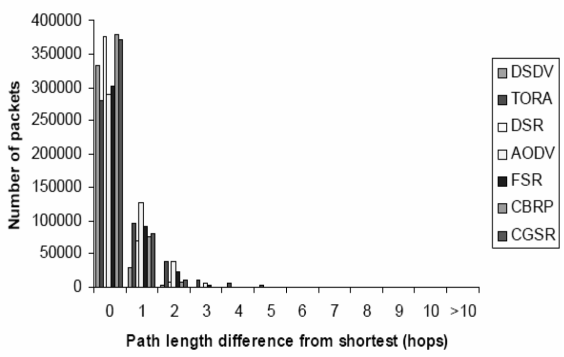


Figure 10. Difference between actual path length and the shortest path

DSDV, DSR and CBRP use a path close to the optimum path. TORA, AODV, FSR and CGSR use a path for some packets which is longer than the optimum path by around four HOPs or more, although TORA has not been designed based on finding the shortest path [23]. For more clarity, Figure 10 indicates data congestion in all stop times using one graph.

4.4 Comparison of protocols on the basis of movement speed of nodes

To determine how much the rate of topological change has an effect on efficiency of the protocols, the speed of nodes was decreased from 20 m/s to 1 m/s, and the scenarios are evaluated for the seven protocols. Figures 11 and 12 show the results of this simulation using 20 origin nodes.

All protocols deliver more than 95.5% of packets in this case. In contrast to the scenario with a speed of 20 m/s, in which DSR could not approach such values, the efficiency of DSR in this simulation is high. Moreover, at a low rate of movement, each of the protocols shows a considerable difference for the routing parasite.

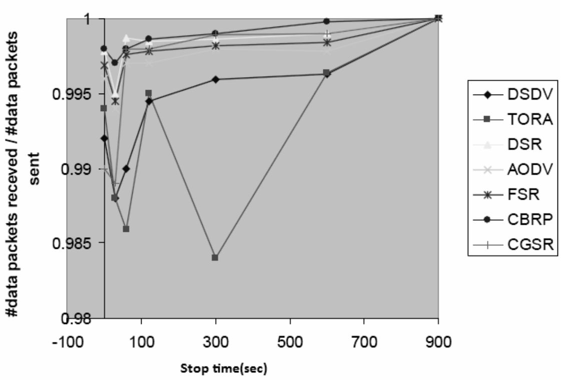


Figure 11. Rate of packet delivery

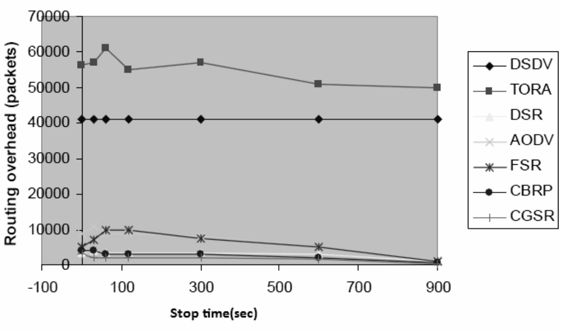


Figure 12. Number of routing packets sent

Neither DSR nor AODV has shown a significant difference in these scenarios, and an increase in the routing parasite depends only on a decrease in the stop time.

Figure 13 and 14 show the efficiency of the seven routing protocols with a traffic load of 20 origins and a maximum speed of 20 m/s. All protocols deliver a high percentage of packets produced when the movement of nodes is low (for example, with a high stop time), and this value reaches 100%, when the movement of nodes reaches zero.

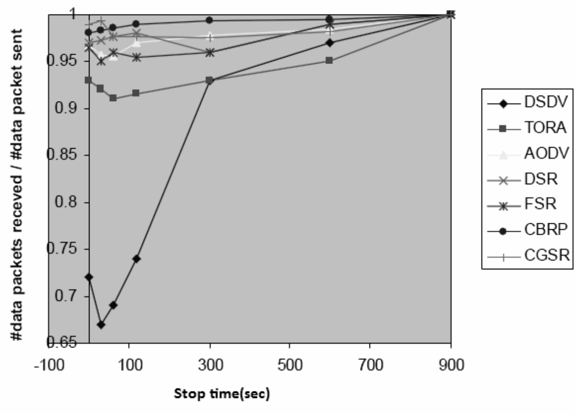


Figure 13. Comparison of the rate of packet delivery

5. Results and Discussion

We can summarise our final conclusion from our experimental results as follows:

A comparison has been made between the protocols on the basis of their efficiency, and these comparisons have been performed in different states. In order to show a general result, a simulation has been performed with a traffic load of 20 origins and a maximum speed of 20 m/s. All protocols delivered a high percentage of the produced packets when the movement of nodes was low (for example, in the case of a high stop time), and this value reaches 100% when the movement of nodes reaches zero. The DSR, AODA, FSR, CBRP and CGSR protocols deliver more than 95% of the packets for each rate of movement. In these scenarios, DSDV has failed at stop times below 300 s. The seven routing protocols have different values for the routing parasite. Generally, one can say that DSR has the lowest parasite while TORA has the highest parasite. TORA, DSR, CBRP and AODV are on-demand protocols, and their parasite changes with changes in the movement rate. However, the table-driven protocols, DSDV, FSR and CGSR, are not highly dependent on the rate of movement and show constant behaviour. The results shown in this section of the simulation for the TORA protocol have average values of nine scenarios for a stop time of 600 s, while the parasite in the tenth scenario has not been included because it is the highest of all other scenarios.

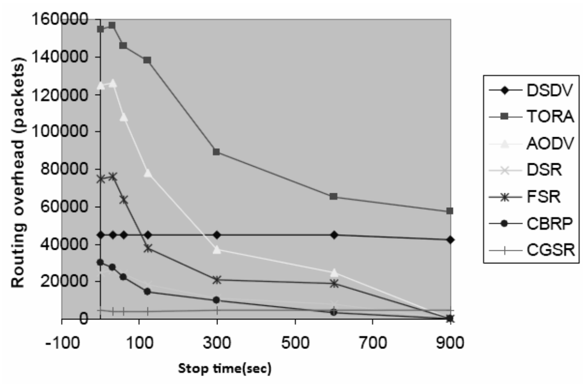


Figure 14. Comparison of routing parasite

6. Conclusion

In this article, Mobile Ad Hoc Networks are described, and some of the most important routing protocols are studied. The results obtained from the assessment and comparisons of the efficiency were shown for DSR, AODV, DSDV, TORA, FSR, CBRP and CGSR protocols. Parameters were considered for a MANET, as well as a basic state. Different results were given by changing the selected parameters. Based on these results, the DSR and AODV protocols have shown better performance than other protocols, and for all scenarios, TORA has had the worst result. DSDV has fixed behaviour in all scenarios due to its table driven specification.

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