Comparative analysis of routing protocols for wireless area networks and evaluation of the effectiveness

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Abstract

A Mobile Ad Hoc Network (MANET) is a gathering of mobile nodes that want to communicate without any preplanned infrastructure and fixed organization of available links. Each node in MANET operates as a router, forwarding information packets for other mobile nodes. There are many routing protocols that possess different performance levels in different scenarios. The main task is to evaluate the existing routing protocols and finding by comparing them the best one. In this article been compared AODV, DSR and DSDV routing protocols in mobile ad hoc networks (MANETs) to specify the best operational conditions for each MANETs protocol. I study these three MANETs routing protocols by different simulations in NS-2 simulator. We describe that pause time parameter affect their performance. This performance analysis is measured in terms of Packet Delivery Ratio, Average End-to-End Delay, Normalized Routing Load and Average Throughput.

Keywords: Mobile Ad Hoc Network (MANET), The Simulation Parameters, AODV, DSR, DSDV.

1. Introduction

With the widespread rapid development of computers and the wireless communication, the mobile computing has already become the field of computer communications in high-profile link. Mobile Ad Hoc Network (MANET) is a completely wireless connectivity through the nodes constructed by the actions of the network, which usually has a dynamic shape and a limited bandwidth and other features, network members may be inside the laptop, Personal Digital Assistant (PDA), mobile phones, MP3 players, and digital cameras and so on.

The task of finding and sustaining routes in Mobile Ad-hoc Networks (MANETs) is an important factor in determining the efficiency of any MANET protocol. MANET characteristically is an autonomous system of mobile nodes connected by wireless links without any centralized infrastructure. Absence of fixed infrastructures and host mobility thus network may experience rapid and unpredictable topology changes. Hence, routing is required in order to perform communication among the entire network. There are a lot of routing protocols which may

be divided as proactive, reactive and hybrid. The thesis is the active research work to studying these routing protocols and its performance evaluation. Main technique to analysis is theoretical analysis and a simulation approach, which is more suitable to this kind of analysis.

2. Network Protocols in AD-HOC Networks

2.1. Proactive Routing Protocols

Proactive protocols perform routing operations between all source destination pairs periodically, irrespective of the need of such routes. These protocols stem from conventional link state or distance vector routing algorithms, and attempt to maintain shortest-path routes by using periodically updated views of the network topology. These are typically maintained in routing tables in each node and updated with the acquisition of new information. Proactive protocols have advantages of providing lower latency in data delivery and the possibility of supporting applications that have quality-of-service constraints. Their main disadvantage is due to the wastage of bandwidth in sending update packets periodically even when they are not necessary, such as when there are no link breakages, or when only a few routes are needed.

2.1.1. Destination-Sequenced Distance-Vector Routing (DSDV)

DSDV [1] is based on the classical Bellman-Ford algorithm with adaptations that are specifically targeted for mobile networks. The Bellman-Ford algorithm uses the distance vector approach, where every node maintains a routing table that records the “next hop” for every reachable destination along the shortest route, and the minimum distance (number of hops). Whenever there is any change in this minimum distance, the information is reported to neighboring nodes and the tables are updated if required.

To make this algorithm adequate for mobile ad hoc networks, DSDV added a sequence number with each distance entry to indicate the freshness of that entry. A sequence number is originated at the destination node, and is incremented by each node that sends an update to its neighbors. Thus, a newer routing table update for the same destination will have a higher sequence number. Routing table updates are periodically transmitted throughout the network, with each node updating its routing table entries based on the latest sequence number corresponding to that entry. If two updates for the same destination have identical sequence numbers but different distances, then the shorter distance is recorded. The addition of sequence numbers removes the possibility of long-lived loops and also the counting-to-infinity problem, where it takes a large number of update messages to ascertain that a node is not reachable [1].

2.1.2. Optimized Link State Routing Protocol (OLSR)

OLSR is a comparatively newer proactive routing protocol [2]. It is an adaptation of conventional link-state routing in which each node tries to maintain information about the network topology. Each node determines the link costs to each of its neighbors by broadcasting HELLO messages periodically. Whenever there is a change in the link costs, the node broadcasts this information to all other nodes. In classical link-state algorithms, this is done by each node flooding the whole network with update packets containing updated link costs. Nodes use this information to apply a shortest path algorithm (such as Dijkstra’s shortest path algorithm) to determine the best route to a specific destination.

OLSR optimizes the link-state protocol in two ways. First, it reduces the size of the update packets sent during the broadcasts by including only a subset of links to its neighbors. These are the links to a select set of neighbors known as the multipoint relays (MPR). The set of MPRs of a node consist of the minimum set of one hop neighbors of that node so that the node can reach all of its two hop neighbors by using these nodes as relay points. Each node computes its MPR set from the exchange of neighborhood information with all its neighbors. Second, instead of every neighbor broadcasting the update packets sent out by a node, only the MPR nodes participate in broadcasting of these packets in OLSR. This minimizes the traffic of control packets during flooding. However, the savings of bandwidth achieved using these two techniques come at a cost of propagating incomplete topology information in the network. The updates include only MPR sets and not the sets of all neighbors of the broadcasting nodes. Hence, a shortest path algorithm based on this partial topology information will generate routes containing the MPR nodes only. When the network is dense, i.e., when each node has many neighbors, OLSR will work out to be efficient due to the reduction of control traffic for updates in the network.

2.1.3. Fisheye State Routing (FSR)

FSR is an enhancement of GSR. The large size of update messages in GSR dissipates a substantial amount of network bandwidth. In order to overcome this problem, FSR will use a method where each updated messages would not include information about all nodes. As an alternative, it swaps information about neighboring nodes regularly than it does about farther nodes, thus reducing the update message size. In this way, each node gets accurate information about near neighbors and accuracy of information decreases as the distance from the node increases. Even though a node does not have accurate information about distant nodes, the packets are routed correctly because the route information becomes more and more accurate as the packet moves closer to the destination [3].

2.2. Reactive Routing Protocols

Reactive protocols are designed to minimize routing overhead. Instead of tracking the changes in the network topology to continuously maintain shortest path routes to all destinations, these protocols determine routes only when necessary. Typically, these protocols perform a route discovery operation between the source and the desired destination when the source needs to send a data packet and the route to the destination is not known. As long as a route is live, reactive routing protocols only perform route maintenance operations and resorts to a new route discovery only when the existing one breaks.

The advantage of this on-demand nature of operation is that it usually has a much lower average routing overhead in comparison to proactive protocols. However, it has the disadvantage that a route discovery may involve flooding the entire network with query packets. Flooding is wasteful, which can be required quite frequently in case of high mobility or when there are a large number of active source-destination pairs. Moreover, route discovery adds to the latency in packet delivery as the source has to wait till the route is determined before it can transmit. Despite these drawbacks, on-demand protocols receive comparatively more attention than proactive routing protocols, as the bandwidth advantage makes them more scalable.

2.2.1. Dynamic Source Routing (DSR)

DSR is a reactive routing protocol that uses a concept called source routing [6]. Each node maintains a route cache where it lists the complete routes to all destinations for which the routes are known. A source node includes the route to be followed by a data packet in its header. Routes are discovered on demand by a process known as route discovery. When a node does not have a route cache entry for the destination to which it needs to send a data packet, it initiates a route discovery by broadcasting a route REQUEST or QUERY message seeking a route to the destination. The REQUEST packet contains the identities of the source and the desired destination. Any node that receives a REQUEST packet firs route discovery by broadcasting a route REQUEST or QUERY message seeking a route to the destination. The REQUEST packet contains the identities of the source and the desired destination. Any node that receives a REQUEST packet first checks its route cache for an existing entry to the desired destination. If it does not have such an entry, the node adds its identity to the header of the REQUEST packet and transmits it. Eventually, the REQUEST packet will flood the entire network by traversing to all the nodes tracing all possible paths. When a REQUEST packet reaches the destination, or a node that has a known route to the destination, a REPLY is sent back to the source following the same route that was traversed by that REQUEST packet in the reverse direction. This is done by simply copying the sequence of node identities obtained from the header of REQUEST packet. The REPLY packet contains the entire route to the destination, which is recorded in the source node's route cache.

When an existing route breaks, it is detected by the failure of forwarding data packets on the route. Such a failure is observed by the absence of the link layer acknowledgement expected by the node where the link failure has occurred. On detecting the link failure, the node sends this information back an ERROR packet to the source. All nodes that receive the ERROR packet, including the source, delete all existing routes from their route caches that contain the specified link. If a route is still needed, a fresh route discovery is initiated.

2.2.2 Ad Hoc On Demand Distance Vector Routing (AODV)

AODV [7] can be described as an on-demand extension of the DSDV routing protocol. Like DSDV, each route maintains routing tables containing the next hop and sequence numbers corresponding to each destination. However, the routes are created on demand, i.e., only when a route is needed for which there is no "fresh" record in the routing table. In order to facilitate determination of the freshness of routing information, AODV maintains the time since when an entry has been last utilized. A routing table entry is "expired" after a certain predetermined threshold of time.

The mechanism for creating routes in AODV is somewhat different from that used in DSR. Here, when a node needs a route to some destination, it broadcasts a route REQUEST packet in which it includes the last known sequence number for that destination. The REQUEST packet is forwarded by all nodes that do not have a fresher route (determined by the sequence numbers) to the specified destination. While forwarding the REQUEST packet, each node records the earlier hop taken by the REQUEST packet in its routing table entry for the source (originator of the route discovery). Hence, a propagating REQUEST packet creates reverse routes to the source in the routing tables of all forwarding nodes. When the REQUEST packet reaches the desired destination or a node that knows a fresher route to it, it generates a route REPLY packet that is sent back along the same path that was taken by the corresponding REQ

UEST packet. The REPLY packet contains the number of hops to the destination as well as the most recent sequence number. Each node that forwards the REPLY packet enters the routing information for the destination node in its routing table, thus creating the forward route to the destination.

Routing table entries are deleted when an ERROR packet is received from one of the intermediate nodes on the route forwarding a data packet to the destination. When such an ERROR packet reaches the source, it may initiate a fresh route discovery to determine a fresh route to the destination.

3. Simulation

3.1 Network Simulator NS-2

NS-2 [Network Simulator version 2] is a discrete event simulator which provides support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks. It is the most popular network simulator used by researchers. The Network Simulator began as a variant of the REAL network simulator in 1989 and has evolved over the past years. REAL is a simulator for studying the dynamic behavior of flow and congestion control schemes in packet switch data networks.

NS-2 is written in C++ and is based on two languages: C++ which is used to extend the simulator (i.e., to define protocol behaviors), and OTcl [9], an object-oriented extension of Tcl developed at Massachusetts Institute of Technology, which is used for scenario configuration, manipulation of existing C++ objects, periodic or triggered actions, etc.

In NS-2, to create the topology of the network for simulation some of topology generators may use they are Inet Topology Generator, GT-ITM (Georgia Tech Internetwork Topology Models) topology generator or Tiers Topology Generator and convert their outputs to NS-2 format.

Generation of topologies by hand is another option. The simulation event scheduler of the simulator, contained in OTcl script interpreter, is either a non-real-time scheduler or a real time scheduler which is mainly used for real-time synchronization of an emulated network. The user indicates in the event scheduler when network elements should start or stop transmitting packets. In order to visualize a network simulation in NS-2, traffic and movement patterns should be generated and references as inputs into the OTcl code configuring the simulation scenario. The simulation can then be visualized by NAM (Network Animator) [10] which is shown in figure 1.

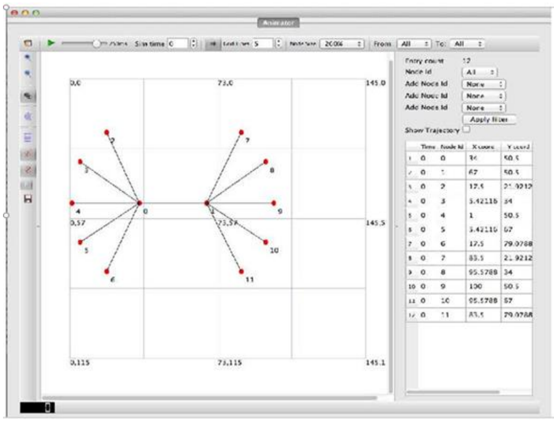

Fig 1. NAM of NS-2

Using the trace file generated by the simulator. However, states that Nam cannot be used for accurate simulation analysis. Node appearance can be changed according to node's inner state, but it is limited. Extended Nam Editor can be used to graphically create simple scenarios and save them as script files. For statistics plotting, external tools like Gnuplot [12] or Xgraph [11] must be used. There is a function in OTcl configuration file which can periodically call itself to collect statistical data of simulation and write them into a file. The file generated by the function can be referenced as input into external tools for plotting of data like Xgraph and Gunplot.

3.2.The Simulation Parameters

Number of nodes	2
Number of sending nodes	10
The pause time	0,10,20,30&40(sec)
Routing protocol	DSDV/AODV/DSR
The maximum node speed	20m/s
Topography	X=500 y=500
Propagation	Two ray ground

3.3. Performance Analysis of Routing Protocols

The MANET routing protocols DSDV and DSR are two of the promising routing protocols. They can be used in MANET to route packets between mobile nodes. The main objective of comparing the performance of DSDV, AODV and DSR routing protocols under following metrics:

A. Throughput: It is defined as total number of packets received by the destination. It is a measure of effectiveness of a routing protocol. Finally what matters is the number of packets delivered successfully.

B. Packet delivery ratio: the ratio between the number of packets received by the TCP sink at the final destination and the number of packets originated by the "application layer" sources. It is a measure of efficiency of the protocol.

C. Routing overhead: The total number of routing packets transmitted during the simulation. For packets sent over multiple hops, each transmission of the packet (each hop) counts as one transmission. Since End-to-end Network throughput (data routing performance) is defined as the external measure of effectiveness, efficiency is considered to be the internal measure. To achieve a given level of data routing performance, two different protocols can use differing amounts of overhead, depending on their internal efficiency, and thus protocol efficiency may or may not directly affect data routing performance. If control and data traffic share the same channel, and the channels capacity is limited, then excessive control traffic often impacts data routing performance.

D. Path optimality: The difference between the number of hops a packet took to reach its destination and the length of the shortest path that physically existed through the network when the packet was originated.

E. Packets lost: it is a measure of the number of packets dropped by the routers due to various reasons. There a son we have considered for evaluation are Collisions, time outs, looping, er

F. Packets Delay (Jitter): It is a metric which is very significant with multimedia and real-time traffic. It is very important for any application where data is processed online.

G. Power consumption: The total consumed energy divided by the number of delivered packet.

3.4. Figure and Result Table of Performance Metrics of routing protocols for AODV, DSR and DSDV

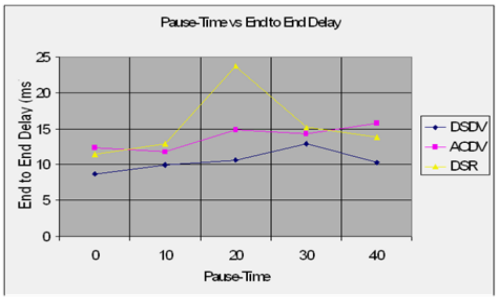

Fig 2. End-to-End delay for AODV, DSDV and DSR

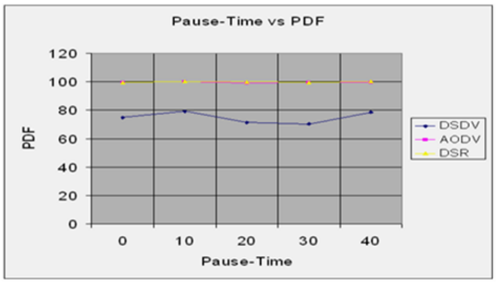

Fig 3. Average throughput for AODV, DSDV and DSR

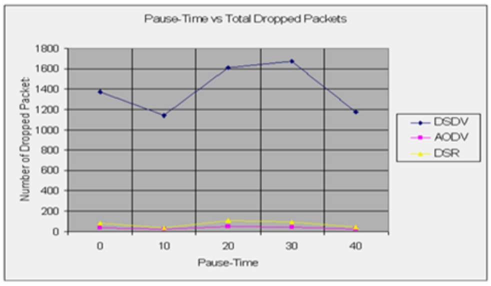

Fig 4. Packets dropped for AODV, DSDV and DSR

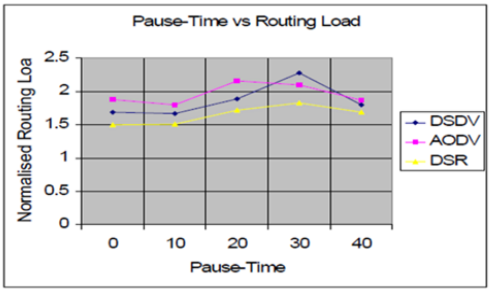

Fig 5. Packet delivery fraction for AODV, DSDV and DSR

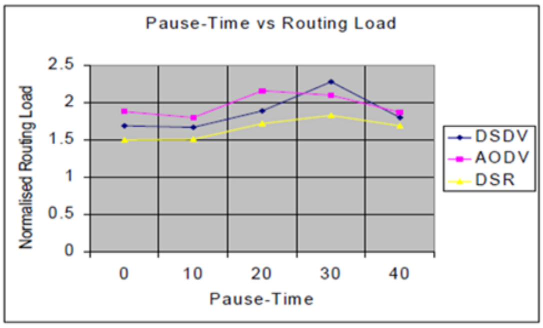

Fig 6. Packet routing load for AODV, DSDV and DSR

Table 1. Ad Hoc On Demand Distance Vector Routing (AODV)

Pause Time(sec)	PDF	Normalized Routing Load	End to End Delay (ms)	Total Dropped Packets	Throughput	Jitter
0	99.25	1.88	12.3	42	102.09	7.03
10	99.56	1.8	11.72	24	102.26	6.05
20	99.15	2.16	14.87	52	102.12	9.07
30	99.23	2.1	14.28	48	103.31	7.96
40	99.46	1.87	15.76	27	103.25	12.3

Table 2. Dynamic Source Routing (DSR)

Pause Time(ms)	PDF	Normalized Routing Load	End to End Delay (ms)	Total Dropped Packets	Throughput	Jitter
0	99.29	1.5	11.44	84	102.24	7.53
10	100	1.51	12.95	41	103.2	11.54
20	99.69	1.72	23.77	111	102.27	32.14
30	99.22	1.83	15.18	96	101.82	12.53
40	99.93	1.69	13.82	46	102.54	11.49

Table 3. Destination-Sequenced Distance-Vector Routing (DSDV)

Pause Time(sec)	PDF	Normalized Routing Load	End to End Delay (ms)	Total Dropped Packets	Throughput	Jitter
0	74.7	1.69	8.72	1375	76.88	3.98
10	78.9	1.67	9.94	1137	80.73	5.43
20	71.1	1.89	10.56	1613	72.94	5.91
30	70.0	2.28	12.86	1672	72.61	9.85
40	78.4	1.8	10.28	1170	80.11	5.56

4.Conclusions

The architecture of wireless mobile network based on Manet technology, methodological principles of computer modeling and routing algorithms in such networks and examined the implementation of the three commonly used MANET routing protocols (DSDV, AODV and DSR) in respect of a group of mobile models (RPGM) and nature (RW, GM and MG).

Simulation results have indicated that the relative ranking of routing protocols may vary depending on mobility model. The relative ranking also depends on the node speed as the presence of the mobility implies frequent link failures and each routing protocol reacts differently during link failures.

The proactive protocol DSDV experiences the most stable performance with all mobility models. This protocol performs best with entity models that have lower level of randomness (GM and, particularly, MG).

AODV performs best with the group model RPGM. With entity models, AODV experiences the highest routing overhead with the increase of node speed, but has acceptable average delays.

DSR experiences the lowest routing protocol overhead, on the count of higher average delays, particularly with MG and GM models, at higher node speeds. This protocol performs best with the RW model. Future work should be focused to extending set of the experiments by taking into consideration energy-consumption reduction, different propagation models and MAC protocols

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