Comparative Study on Routing Protocol for Ad Hoc Network

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Abstract. Three typical routing protocols, Destination Sequence Distance Vector (DSDV), Dynamic Source Routing (DSR) and Ad-Hoc On-Demand Distance Vector (AODV), are analyzed and studied. In addition, three network performance indicators, which are end-to-end average delay (E2EAD), routing overhead (RO) and packet reception rate (PRR), are used to evaluating advantages and weaknesses of these three routing protocols. The simulation results, which are based on the NS2 (Network Simulator Version 2), show that AODV has balanced property in both E2EAD and PRR. However, AODV is inferior to DSDV and DSR in terms of RC. In addition, in view of feature of AODV, a modified AODV (MAODV) routing protocol for the environment of network topology that changes frequently is proposed in this paper. The experimental results show that the MAODV has superior properties in terms of E2EAD and RC.

1. Introduction
The property of mobility, self-organization and multi-hop make Ad hoc network build practical network at anytime and anywhere. Hence, Ad hoc network is especially needed in special environments for example military communications and sensor network. One of the research hotspots of Ad hoc network recently is routing protocol. Therefore, the paper analyzes the DSDV, DSR and AODV based on the NS2 simulation platform is analyzed in this paper. In addition, the paper proposes a more superior MAODV protocol.

2. Typical Ad Hoc Network Routing Protocol
The routing protocol of the Ad hoc network can be classified into three types according to route discovery mechanism and route maintenance mechanism: routing table driven routing, on-demand routing, in addition the above two combinations routing [1].

2.1. DSDV Protocol
The DSDV routing algorithm [2] belongs to the routing table driven routing. In DSDV, each node periodically broadcasts its own routing table, which can be all content or updated part, therefore can be adapted to changes of network topology. The unique serial number in DSDV is used to distinguish the original route and the new route in the routing table, therefore can prevent the formation of a loop [3]. In a network environment where the network topology changes greatly, although RO of DSDV is hardly affected. However its routing table driving mechanism will increase E2EAD as the network topology change rate increases, furthermore the PRC decreases with the increase of network topology change rate.
2.2. DSR Protocol
The DSR belongs to the on-demand routing protocol [4], which ensures the validity of the transmission by recording the source route. Initially, DSR is well adapted to wireless mobile network. When the nodes in the network are moving, the network topology changes, in addition the packet is sent to the destination correctly. Furthermore, routing load is reduced by DSR in use of a route caching strategy. If the intermediate node receives the route request packet, it matches the destination address of the packet. If intermediate node finds that there is the same destination address as the destination address of the packet in its routing cache, which can create a reply packet directly without forwarding the route request packet. In addition add routing information is added to the reply packet and forwarded to the source node.

The operation mechanism of the DSR routing protocol [5] consists of route discovery and route maintenance. When the source node does not cache the associated route, route discovery is started. In the data transmission process, if an intermediate node discovers that the link between itself and the next hop node is invalid, route maintenance is started. The source node establishes a route to the destination address. In addition the corresponding route request packet is flooded in the network. In a wireless mobile network, there will be a case of node failure. In addition, a DSR route maintenance mechanism is required [6]. A data packet is sent to the destination node by the source node according to the route of its own route cache. Whether the next hop is reachable before forwarding is determined by each node. PRR of DSR is higher than that of DSDV; however its average latency performance is significantly worse if the network topology changes greatly.

2.3. AODV Protocol
AODV is part of the combination of routing table driven routing and on-demand routing [7]. AODV continues the DSR route request packet, route response packet and error packet mechanism, furthermore adds a sequence number and hop count which are similar to DSDV. The old and new routes are reflected by the sequence. In particular, the destination sequence number is requested in the route request message. The destination sequence number can distinguish the old and new routes. Hence the destination node can smoothly transmit the loop by the response packet [8].

The route discovery of AODV consists of route discovery [9] and route maintenance [10]. Owing to AODV continues the operating mechanism of DSDV and DSR; its network performance is basically superior to DSDV and DSR. However, if the network topology changes drastically, it inherits the on-demand routing of the DSR. In addition there may be cases of rerouting and detecting invalid routes. The more the network topology changes, the more the situation occurs. Finally the RO increases.

2.4. Modified AODV
Considering improving the performance of AODV in an environment with large changes in network topology and reducing its routing overhead, the improved protocol based on AODV is named MAODV. Considering that in the environment where the mobility of the node is large or the network topology changes greatly, part of the routing information of the node cache may actually be invalid before the expiration time. At this point, if more nodes are given "routing opportunities", in another word, which shortens the routing information lifetime, therefore the detection of the cached routing information is skipped; hence the average routing can be reduced.

3. Design of Simulation Environment
The experiments are conducted on the Linux operating system and NS2 simulation platform.

3.1. Experiments Scene
The Ad hoc network is a mobile ad hoc network; in addition the simulated scene should be a physical scene of random motion of the nodes. The scene size of this simulation experiment is uniformly set to 1000×1000, furthermore the unit is meter. The number of network nodes is uniformly set to 50; in addition
the simulation time is set to 100s. In an Ad hoc network, the scene residence time reflects the network topology change rate during network operation. If the residence time is extremely low, it represents an infinite running state and the network topology is always changing. However, when residence time is extremely high, which represents a situation in which the network topology is unchanged. The node movement speed reflects the mobile performance of the environment in which the network components are located. If the maximum speed of the node is 0, it indicates the limit of the static network. When the maximum speed of the node is 30, which indicates the network status of the node running at high speed. In addition, the residence time of the motion scene and the maximum motion speed of the node are used as independent variables, which are not uniformly set and are only set in the respective comparative experiments.

3.2. Traffic Scene
In order to simulate the Ad hoc network better, the time or amount of data transmission between nodes is random. The data flow of this simulation experiment is set to CBR (California bearing ratio) type, the number of nodes is 50, and in addition the maximum number of node connections is set to 30 during the simulation. Packet transmission rate reflects the frequency of information transmission in the network. The larger the packet transmission rate, the more busy the network is. The packet transmission rate is set as independent variable according to different contrast experiments. The Ad hoc network mainly consists of network components for example a link, an interface queue, a MAC (Media Access Control) layer. These components use the configuration file to set the relevant business traffic scenarios.

3.3. Related Parameter Settings
To reflect their different adaptive network environments, the experiment will set three independent variables (motion scene residence time, node maximum motion speed and packet transmission rate) for the network environment. The detailed scene parameters are shown in Table 1. Comparative analysis will carry out, which is based on extracting the average of the network performance indicators.

| parameter                  | First group                  | Second group                 | Third group                  |
|----------------------------|------------------------------|------------------------------|------------------------------|
| Topological range (m²)     | 1000x1000                    | 1000x1000                    | 1000x1000                    |
| Number of nodes            | 50                           | 50                           | 50                           |
| Scene residence time (s)   | 0-100                        | 100                          | 100                          |
| Maximum speed of node (m/s)| 20                           | 0-30                         | 20                           |
| Simulation time (s)        | 100                          | 100                          | 100                          |
| Service type               | CBR                          | CBR                          | CBR                          |
| Maximum node connection    | 30                           | 30                           | 30                           |
| Packet transmission rate   | 2.0                          | 2.0                          | 1.0-5.0                      |
3.4. Network Performance Indicator

The paper evaluates the advantages and disadvantages of routing protocols from three network performance indicators.

1) **End-to-end average delay (E2EAD):** refers to the average time required for a data packet to be successfully sent from the source node to the destination node reflecting whether the network is unblocked. The smaller the average delay, and the smoother the network.

2) **Packet reception rate (PRR):** refers to the ratio of the number of data packets received by each node in the network. If the routing protocol used by the network makes the success rate too low, therefore the routing protocol will seriously affect network communication.

3) **Routing overhead (RO):** refers to the ratio of the total number of route discovery and routing packets to the transmitted data packet. It reflects the energy consumption and efficiency of the routing protocol. When the routing overhead is too high, which means that most of the time the network is running. There is almost no data transmission part; in addition the communication function is almost lost.

4. Analysis of Experimental Results

4.1. Comparative Analysis of AODV, DSDV and DSR

4.1.1. Simulation of different residence time. In an Ad hoc network, the network topology change rate is reflected by the scene residence time during network operation. If the residence time is 0, it represents an infinite running state; in addition the network topology is changing all the time. Otherwise, when it is 100, it represents a case where the network topology is unchanged.

a) **End-to-end average delay**

It can be clearly seen from Fig. 1 that the data of AODV and DSDV are not much different. The E2EAD of DSDV is basically below 0.058s; furthermore the E2EAD of AODV is about 0.04s larger than that of DSDV. However, the DDSV of DSR is very different from that of other two protocols. In addition with the increase of residence time, the average delay shows a downward trend, especially if the residence time is 0s -20s, the span is 0.27s.

![Figure 1. E2EAD at different residence time.](image)

The reason why the average delay of DSR shows such a trend is because that its mechanism is based on on-demand routing. When the residence time is short, that is, when the network topology changes too fast, which takes a long time to route, therefore the end-to-end delay increases. DSDV is more advantageous, for that in the network regularly maintains the routing table to all reachable nodes is maintained regularly by each own node. When node needs to send data, it does not take a lot of routing time. Hence the average delay is relatively low.
Although AODV extends DSR’s on-demand routing mechanism, it does not show high latency. For hop-by-hop routing of DSDV is also used by AODV, yet a complete sequence of routing nodes is cached by the nodes in DSR. Hence AODV routing time is superior to DSR.

b) Packet reception rate

It can be clearly seen from Fig. 2 that the trends of AODV and DSR are similar; in addition the two data are very close. The successful rate of packet reception of AODV is basically between 55% and 60%, however that of DSR is between 52% and 60%. In Fig. 2, the RPP of DSDV is very different from that of AODV and DSR. As the residence time increases, the successful receiving rate of data packets will gradually increase at the same time. The PRR of DSDV has almost a linear relationship with respect to the residence time. If almost network topology is unchanged, the maximum can only reach 55%.

![Figure 2. PRR with different residence time.](image)

The PRR of DSDV packets shows a gradual increase trend, especially in the case of very low residence time when the success rate reaches about 20%. This is because DSDV can only cache one route for a destination node. If residence time becomes short, the saved route is easy to invalidate, in addition the packet loss rate will increase significantly. The PRR of DSR show a steady state for its on-demand routing reduces the invalidation of cached routes and maintains more than one route cache.

AODV and DSR also exhibit stable PRR, for its on-demand routing mechanism, in addition for hop-by-hop routing when routing is established to make routing more efficient, resulting in a reduced packet loss rate.

c) Routing overhead

![Figure 3. RO for different residence time.](image)
4.1.2. Simulation of different maximum mobility of nodes. The mobile performance of the environment is reflected by the node movement speed in which the network components are located.

a) End-to-end average delay
It is can be seen from Fig. 4 that the trend of DSDV is basically stable, in addition the average delay of DSDV is maintained at 0.014s-0.020s. The AODV shows an upward trend; therefore E2EAD of AODV is generally higher than that of DSDV from Fig. 4. If the maximum moving speed is 1m/s-15m/s, the average delay span is about 0.06s. If the maximum moving speed of the node is 1m/s-10m/s, the average delay of DSR is very close to that of AODV. Furthermore, the greater the mobility of the node, the larger the difference of average delay. It can be seen from Fig.4 that when the moving speed of the node is less than 15m/s, the average delay of the DSR is basically maintained at 0.04s. However, if the node moving speed is greater than 15m/s, the average delay of the DSR is basically maintained at 0.13s.

![Figure 4. E2EAD of different maximum moving speed of nodes.](image)

DSR shows a gradual increase in the simulation results for the more mobile, the more routes will be discarded, hence, the more time need to route, the greater the end-to-end average delay. DSDV is relatively low-performance for it regularly maintains its own routing table, in addition the average latency is lower is data packets is needed to be sent. AODV does not exhibit the same average delay as DSR because AODV has a hop-by-hop routing mechanism for DSDV. Compared to DSR, nodes need to cache a complete routing node sequence; hence, the average delay of AODV is smaller than that of DSR.

b) Packet reception rate
It can be clearly seen from Fig. 5 that the AODV and DSR fold lines are close; in addition they all show a basically stable state. PRR of AODV is basically maintained between 54% and 60% furthermore PRR of DSR is still basically maintained between 51% and 60%. From Fig. 5, we can see that PRR of DSDV is smaller than that of AODV and DSR. Moreover, when the moving speed of the node increases, the PRR gradually decreases, meanwhile the minimum reached nearly 21%.

Although the routing table is regularly maintained by DSDV, yet there is only one routing information in the routing table, which lead to that the PRR of DSDV is gradually decreasing. If the node moves at a relatively high speed, those maintained routing information will soon become invalid, in addition the packet loss rate will increase significantly. PRR of DSR shows a steady state because its on-demand routing reduces the cached route invalidity furthermore there are several backup routes in the node.
Figure 5. PRR with different maximum moving speed of nodes.

The simulation results of AODV and DSR are close. This is because AODV retains the on-demand routing mechanism of DSR; in addition has a DSDV hop-by-hop routing mechanism in its route discovery mechanism, which enhances the validity of the route. Thus the data packets are dropped more.

c) Routing overhead

It can be seen from Fig. 6 that AODV is particularly more prominent than the other two routing protocols. DSDV and DSR have similar RO trends, therefore it can be seen from the Fig. 6 that the overall span of DSDV is approximately 0.5, meanwhile the span of DSR is approximately 2.0.

Figure 6. RO for different maximum moving speed of nodes.

Small changes relative to the other two routing protocols are maintained relatively by DSDV. For DSDV periodically updates the route when the node moves regardless of its routing overhead. The routing overhead of DSR shows an upward trend. In addition if the maximum moving speeds of the node is between 15m/s and 30m/s, its routing overhead is always bigger than that of DSDV. The reason is that if the node moves the higher degree of network, the larger network topology changes. Furthermore the route failure of node cache will re-establish route. If the maximum speed of the node moves from 1m/s to 15m/s, the routing overhead is still less than that of the DSDV. The reason is that if the node mobility is weak and the network topology is basically stable, the node of the DSR is not needed to re-establish the route. However the routing is on-demand, therefore the routing overhead becomes smaller.

AODV is also a protocol for on-demand routing, however the routing overhead of AODV is higher than that of DSR. The reason is that AODV’s hop-by-hop routing mechanism will result in higher RO than that of DSR.
4.1.3. Simulation of different packet transmission rates. The frequency of information transmission is reflected by the packet transmission in the network. The higher the packet transmission rate, the more busy the network.

a) End-to-end average delay
It is apparent from Fig. 7 that the average delay of the DSDV in the environment of different packet transmission rates is basically maintained at 0.02s. In addition the average delay of AODV gradually increases as the packet transmission rate increases. It is can be seen from Fig. 7 that E2EAD span of AODV is about 0.51s, furthermore the average delay of DSR increases even more. Further its span is nearly 1.0s.

DSDV is a table-driven routing protocol, thus its routing is not affected by the increase of network load. It only makes the network busier; however the average latency does not become higher. In the case of DSR with high packet transmission rate, that is, if the network traffic is large, a large number of packets will always be in a state to be transmitted for the reason of routing delay, in addition the overall average delay will increase.

![Figure 7. E2EAD of different packet transmission rates.](image)

AODV has a hop-by-hop routing mechanism for DSDV, thus it is better than DSR in terms of average latency. However its average latency is larger than that of DSDV.

b) Packet reception rate
It can be seen from Fig. 8 that the PRR of DSDV increases with the increase of the packet transmission rate. Furthermore it shows a slow downward trend, and remains in the range of 20% to 30%. The PRR changes of AODV and DSDV are very similar. It can be seen from Fig.8 that when the packet transmission rate is between 1.0 and 5.0, the PRR of AODV is about 16%, in addition the span of DSR is 30%.
The network load has little effect on the table-driven routing protocol, thus the PRR of DSDV protocol will only gradually increase as the network traffic increases. The DSR changes relatively large for its partial route caching mechanism. When the network load is larger and the route cache is too large, which cause some of its routes to be invalid, thereby increasing the packet loss rate. AODV and DSR also have an on-demand routing mechanism and a route caching mechanism, thus in the same packet transmission rate environment. Their PRR difference is about 10%.

c) Routing overhead

It can be seen from Fig. 9 that DSDV shows a tendency of decreasing slowly as the packet transmission rate increases, in addition the max falling span reaches 1.0. However, DSR shows a slight upward trend, further the rising span is about 0.5. The routing overhead of AODV is basically kept at around 3, which is higher than that of other two routing protocols. DSDV is a table-driven routing protocol, besides the node periodically updates the route, thus its routing part is basically unchanged. Nevertheless, when the packet transmission rate increases, the ratio of the routing part to the data part decreases resulting in that the routing overhead reduce. For DSR, the larger the packet transmission rate, the larger the routing part. However the smaller the growth relative to the data packet part, thus which shows a tendency to rise slowly. For AODV, the forward routing and reverse routing mechanisms in its route discovery mechanism increase the routing load, hence the result is higher than that of DSDV.
The above comparative analysis shows that DSDV and DSR present two extreme results in terms of E2EAD and PRR. E2EAD of DSDV is always much lower than that of DSR. In addition the PRR of DSDV is always lower than that of DSR. DSDV presents a great disadvantage in terms of the PRR. Besides it is the difference between the routing table-driven routing protocol and the on-demand routing protocol. For AODV absorbs their respective advantages, which exhibits balanced characteristics in both E2EAD and PRR. However, AODV is always greater than DSDV and DSR in terms of routing overhead.

4.2. Comparative Analysis of AODV and MAODV

The above comparison analysis shows that AODV presents a balance between E2EAD and PRR, however there is a shortcoming in routing overhead. The routing overhead between AODV and MAODV will be mainly compared in the following experiment.

4.2.1 Simulation of different residence time. A comparison of routing overhead between AODV and MAODV at different residence time is shown in Fig. 10. To presents the experimental results in an environment where the network topology changes rapidly. Hence the span of the scene residence time in the experiment is set to 0-10s.

![Figure 10. RO for different residence time.](image)

It can be seen from Fig. 10 that during the experiment with a residence time of 0-10s, the RO of AODV and MAODV are always in a floating state. When the residence time is 4-10s, there is an intersection between RO of AODV and RO of MAODV. However, when the residence time is 0-4s, the crossover point does not exist. In addition RO of MAODV is significantly less than that of AODV and basically kept below AODV. Besides the gap between AODV and MAODV remains between 0.3 and 2.4.

From the above data analysis, we can see that the RO of MAODV is slightly less than that of AODV when the residence time is very small. The number of retransmission routing request packet of MAODV is reduced in comparison with AODV, and the lifetime of the routing request packet is increased, resulting in reducing the number of times of that, the routing request packet is sent, and increasing the probability of successful routing, thus the final routing load result of MAODV is smaller than that of AODV slightly.
4.2.2. Simulation of Different Maximum Mobility of Nodes. A comparison of routing overhead of AODV and MAODV at different maximum moving speed is shown in Fig. 11. It can be seen that the routing overhead of AODV and MAODV is basically on the rise. When the maximum moving speed is 1m/s-17m/s, the routing overhead of AODV is less than that of MAODV. However, when the maximum moving speed is greater than 17m/s, the routing overhead of MAODV is less than that of AODV.

![Figure 11. RO for different maximum moving speeds](image)

The larger the maximum moving speed, the larger the change of network topology. From the above data analysis, the maximum load speed of MAODV reaches a certain level; in addition the routing load presented will be slightly smaller than that of AODV. These results verify the advantages of MAODV in an environment too where network topology changes rapidly.

5. Conclusion

Based on the NS2 simulation platform, the performance of AODV, DSR and DSDV routing protocols is analyzed in Ad hoc network in this paper. Meanwhile, the MAODV protocol with better performance is proposed. The comparison analysis shows that the routing overhead of MAODV is smaller than that of AODV when the network topology changes greatly. However, the improved protocol proposed in this paper also has its limitations, that is, when the network topology changes greatly, MAODV will show its superiority.

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