A-DSR: A DSR-Based Anycast Protocol for IPv6 Flow in Mobile Ad Hoc Networks

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Abstract— **IP anycast allows a source node to transmit IP packets to a single destination node, out of a group of destination nodes. It can be an important paradigm for an ad-hoc network in terms of resource, robustness and efficiency for replicated service applications. DSR is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. This paper proposes a novel anycast protocol for Ipv6 flow in mobile ad hoc networks, which is based on the DSR protocol. We also test its performance with different network parameters and the simulation results show that the anycast protocol can balance the network load efficiently and reduce the delay of packet and improve the network throughput. Anycast service can also improve performance of ad hoc network when mobility is high and a link may get disconnected frequently without the servers of repair/re-discovery due to ad-hoc network environment.**

I. INTRODUCTION

In order to increase service availability and provide efficient load distribution in a network, it is common practice to replicate servers on the network. Examples of such services include World-Wide-Web ”mirror” sites, video-on-demand, SOCKs servers, compute-servers, and proxy servers in the Internet [1]. A new network routing model, anycast routing, has been proposed [2], which is to find a path from an IP source to any one of a group of IP receivers. The anycast service has been defined as a standard service in IPv6 [3].

Anycast is different from unicast and multicast. IP unicast allows a source node to transmit IP packets to a single destination node. The destination node is identified by a unicast address. IP multicast allows a source node to transmit IP packets to a group of destination nodes. The destination nodes are identified by a multicast group, and we use a multicast address to identify the multicast group. IP anycast allows a source node to transmit IP packets to a single destination node, out of a group of destination nodes. The set of destination nodes is identified by an anycast address [4]. Anycast routing protocol has been widely studied in the wired networks recently [5], [6].

In the wired networks, anycast has been investigated from two different layers: network-layer anycast routing and application-layer anycasting. In [7], an application-layer anycasting communication paradigm was proposed to support server replication. Specifically, the authors developed and evaluated an implementation based on the use of anycast resolver to map anycast domain names into one or more IP addresses. In [8], the authors presented an optimal algorithm for mapping each anycasting query from clients into the ”best” video distribution server of replicas. Their algorithm was developed at application-layer of the network based on economic models and queuing theory. In [1], the authors investigated how the IP anycast service is exploited by hosts connected in the Internet without significantly impacting the routing and protocol processing infrastructure already in place. They designed and implemented a network-layer anycasting service for load distribution in the context of the IBM Olympic Web site on the Internet. In [5], the authors proposed and analyzed a routing protocol for anycast message. It is composed of two subprotocols: the routing table establishment subprotocol and the packet forwarding subprotocol. In the routing table establishment subprotocol, they proposed four methods (SSP, MIN-D, SBT and CBT) for enforcing an order among routers for the purpose of loop prevention. In the packet forwarding subprotocol, they proposed a weighted-random selection (WRS) approach for multiple path selection in order to balance network traffic. Anycast routing issue in wireless network has not been studied widely recently.

This paper discusses the anycast routing protocols for Mobile Ad Hoc Network. Mobile Ad Hoc Network (MANET) is a collection of wireless mobile hosts forming a temporary network without the aid of any centralized administration or wired infrastructure. In such a network, each mobile node operates not only as a host but also as a router and moves in an arbitrary manner [9], [10].

Anycast can be an important paradigm for an ad-hoc network in terms of resource, robustness and efficiency for replicated service applications. Since the individual nodes in ad-hoc network posses very limited resource, sending packets along the shortest path is the common practice because less nodes involved in the transmission may save the power, network bandwidth and collisions during the messages in transmission. Anycast service can also improve performance of ad hoc network when mobility and link disconnection are frequent.

While many anycast protocols are deployed in wired network, developing an anycast routing protocol for ad hoc

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network is primary difficult. Servers of an anycast group in wired networks have fixed location, they never change their location and IP address, so the route from a user to a server is almost fixed once it is discovered. Since every node in ad hoc networks is moving all the time, therefore, the routes from users to servers are not stable. Routing protocols in wired networks cannot be used in ad hoc networks and ad hoc networks use totally different routing protocols – dynamic, shortest-path based protocols. Feature of high mobility and frequently changing routes are also the most critical issues when developing an anycast routing protocol for ad hoc network.

Some related works have been done for ad hoc networks. In [11], [12], Extensions to link-state, distance-vector and link reversal unicast routing protocols are all conceptually realized through the representation of an anycast service as a ”virtual node” in a graph based on the network topology. It demonstrates how anycast routing techniques can provide a one-to-any communication capability with greater efficiency than traditional unicast based techniques. In [13], the authors use the concept of a virtual node to enable anycast in three existing routing protocols for mobile ad hoc networks (DSR,AODV, TORA). In [14], a sink-based anycast protocol was proposed. When a node wants to join the anycast group, it floods its interest so that potential sources may determine routes to this sink. Route failures are repaired using a link-level route repair mechanism. However, complete protocol details were not specified. Moreover, the performance evaluations presented were not comprehensive. In [15], the authors consider the problem of providing a geocast service, which is useful for sending messages to everyone in a specified geographical region in mobile ad hoc networks. TORA (unicast) routing protocol is modified to be able to perform anycasting service. The geocasting algorithm is then obtained using a small variation on the anycasting protocol. Their idea is to consider all nodes in anycast (geocast) group as sink and connect all the sink with undirected links. In their implementation, only one anycast group is considered and shortest path and loop free are not guaranteed. Ref. [16] extended the existing AODV routing protocol to support anycast services. In their protocol, each anycast group consists of a number of anycast servers and multiple anycast groups can coexist with different services, e.g. providing a different routing path to a destination.

In this paper, we propose a novel anycast routing protocol based on DSR protocol and test the performance of the protocol. Section II introduces the DSR protocol and describes the anycast routing protocol A-DSR. In section III, the simulation environment, simulation results and performance analysis are given to demonstrate the efficiency of our protocol. Section IV concludes the paper.

II. EXTEND DSR TO SUPPORT ANYCAST 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 [17].

In order to support anycast services in DSR protocol, firstly each node needs Anycast Group Table to record the information about anycast group. The Anycast Group Table of each node has the following fields: Destination IP Address, Anycast Group ID and Lifetime.

Assume that each node only belongs to one anycast group, thus the Anycast Group Table may have n entries, where n is the number of node in ad hoc networks. We may design that the Anycast Group ID is a 4-bit unsigned integer, which is unique for each anycast group. Lifetime is the time when the entry was created or updated. In order to maintain the Anycast Group Table, some operations must be done:

(1)Create a new anycast group

When a node receives a request for creating a new anycast group, it adds a new entry into the local Anycast Group Table and broadcasts an information, announcing the existence of the entry.

(2)Join an anycast group

When a node receives a request for joining an anycast group, it adds a new entry into the local Anycast Group Table and broadcasts the information about this entry.

(3)Leave an anycast group

When a node receives a request for leaving an anycast group, it deletes the entry from the local Anycast Group Table and broadcasts the information about this entry.

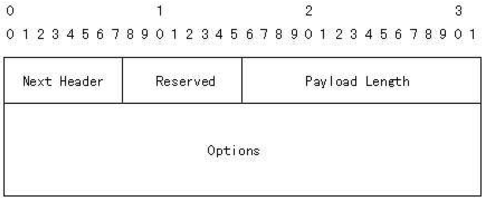


Fig. 1. DSR header format

When any node receives the packet about creating or updating the Anycast Group Table, it first checks to determine whether it receives a duplicate or old packet. If such a packet has received, it just discards the packet, otherwise updates its Anycast Group Table and rebroadcasts the packet.

In order to identify a packet used for anycast or unicast, we can add a flag (A) into the fixed portion of the DSR header by using the Reserved field [18]. As shown in Fig. 1, the first bit of Reserved field is used for flag A. If A is 0, then the packet is used for unicast services, otherwise it is used for anycast services.

Route Discovery operates entirely on demand, with a node initiating Anycast Route Discovery based on its own origination of new packets for some destination address to which it does not currently know a route. A node initiating a Route Discovery for some target creates and initializes a Route Request option in a DSR header in some IP packet. The Target Address field in the option must be set to the Anycast Group ID for supporting anycast services.

When a node v_i receives a packet containing a Route Request option, it first checks where the flag A in DSR header.

If $A = 1$, the Route Request packet is used for anycast. The detail of processing the packet is illuminated in Fig. 2.

```
If flag A=0 in DSR header
    Processing the Route Request as unicast
Else
    Check Anycast Group Table for getting all Destinations G(A) where the Anycast Group ID is equal to that in the Route Request.
    Update the route cache if necessary.
    If the current node $v_i \in G(A)$ or $v_i$ has at least one route to G(A)
        Creates the Route Reply packet
        If $v_i \in G(A)$
            Copy the Address[1…n] in Route Request to the corresponding Address[1…n] in Route Reply.
        Else
            Choose the destination Aj from G(A) to which vi has the minimum hop count.
            Appending the route from vi to Aj to the Address[1…n] in Route Request and then fill them into the Address[1…m] in Route Reply.
        Endif
        Send the Route Reply packet back the source node.
    Else
        Appending the IP addresss of vi to the list of Address[k] and rebroadcast the Route Request packet.
    Endif
Endif
```

Fig. 2. Processing the Route Request packet in A-DSR protocol

III. SIMULATION AND PERFORMANCE ANALYSIS

A. Simulation Environment

We test the performance of A-DSR protocol based on a widely used simulation model - ns2. The physical, data link and medium access control (MAC) layers models in ns2 have been completed by the Monarch research group at Carnegie-Mellon University recently. All these workings ensure the correctness and precision of simulation results. The Distributed Coordination Function (DCF) of IEEE 802.11 for wireless network LANs is adopted as the MAC layer model. Physical layer protocol, similar to a commercial interface, Lucent WAVELANs, can provide a 2Mb/s bandwidth and a 250m effective distance for wireless communication [19]. DSR protocol module in ns-2 use in Ref. [18] as its specification. The protocol finds the transmission paths by the loops of sending RREQ (Routing Request) packets and accepting RREP (Routing Reply) packets. The implementation of anycast protocol matches the description in section II. However, the methods of the error-routing handling and routing recovering in the original protocol are still kept in the new protocol. A-DSR protocol and DSR protocol both have a 64-packet large sending-buffer. All the packets waiting for their routing reply should be buffered in and a packet in the buffer will be dropped after waiting over 30 seconds without any usable routing information. All the data packets and routing packets sent by the routing layer are queued in the FIFO interface queue waiting for scheduling by the MAC layer. The interface queue, with the maximum size of 50 packets, is a priority queue with two priorities. Routing packets have higher priority that data packets in it.

The traffic model and mobility model are similar to Ref. [19] in ns-2 simulation platform. We use a 50 nodes mobile wireless Ad hoc network in a $1500m * 300m$ rectangular area to test the network performance. There is only one anycast protocol server group, including 5 anycast group servers, in the simulation network. All the anycast group members have their own different addresses individually and share an specific anycast group address at the same time. During the 900 seconds length simulation process, all the data packets, with the size of 512-byte, in the network are sent by the continuous bit rate (CBR) traffic sources. The offered load of whole network will be controlled by changing the number of traffic sources and the rate of sending data packets. Every data packet originated by traffic sources uses anycast group address as its destination address and is transmitted to a certain destination server eventually after the anycast routing process. A node starts from a random location in the regular area at the beginning of the simulation to the next random location with a random speed (uniformly distributed between 0-20m/s). It will wait for a pause time when it reaches a destination and then leave for another random destination. To compare the performance of original protocol and anycast protocol, we also carried out another group of tests on the original protocols with the same traffic and mobility scenarios as well as the different connections scenarios. In the comparative tests, the number of source nodes and server nodes are not changed, but all the source nodes are distributed equally to the servers, that is, the numbers of source nodes connected to every server and the loads on every server are identical. So the load of entire network is artificially balanced. In the plots, every data point stands for the average value of results in at least 5 tests with the same traffic model, but with different randomly generated mobility distribution.

B. Performance Metrics

In the simulation, three important metrics of protocol performance are evaluated:

(1) Packet delivery fraction: The ratio of the data packets reached the destination to those originated by the traffic sources. And another metric is received throughput with kilobits per second as its unit.

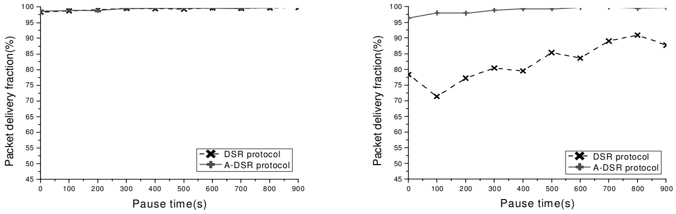
(2) Average end-to-end delay of data packets: The duration from a data packet being generated by CBR source to it being received by the destination, which includes route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and the propagation and transfer time.

(3) Normalized routing load: The number of routing packets used by per data packet, which is successfully transmitted to the destination. And routing packet's count will increase 1 every time when a routing packet is delivered to the next hop.

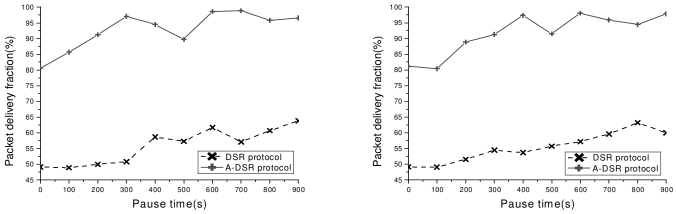
In the above three metrics, the first two application-oriented metrics directly reflect the quality of network service and the third one, which establishes the theoretic benchmark for deploying the protocol in practice, measures the routing overhead. At the same time, packet delivery fraction, average end-to-end delay and normalized routing load are not independent of one another. Generally speaking, the longer the average end-to-end delay of data packets is, the easier the data packet gets lost, the lower the packet delivery fraction will be. On the other hand, normalized routing load indirectly indicates the efficiency of the network protocol. And higher efficiency of routing protocol brings about a higher packet delivery fraction and a longer average end-to-end delay of data packets in most cases.

C. Simulation Results

There are 10 different mobility models in the simulation on the ad hoc network with 50 nodes. We use $100k|k = 0, 1, , 9$ seconds as the pause time of node mobility. At the same time, we use 4 different traffic models. In case of 10, 20, 30 sources, every source sends the data packets at the rate of 4 packets/s and in the case of 40 sources, the speed is 3 packets/s. On the condition of moderate network traffic load and varying pause time, we test the performances of the anycast protocol.



(a) 10 sources (b) 20 sources

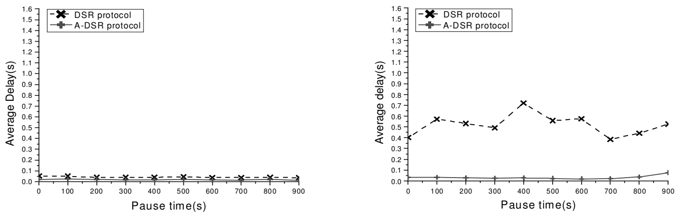


(c) 30 sources (d) 40 sources

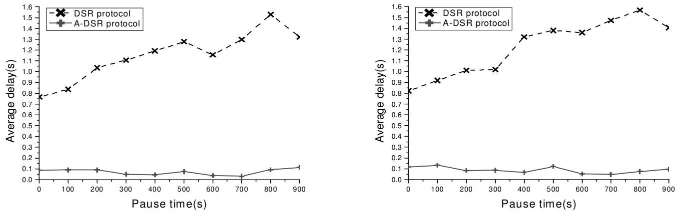
Fig. 3. Packet delivery fractions with various numbers of sources

1) Packet delivery fraction: As shown in Fig. 3(a), when the traffic source is 10, the data packets delivery fraction of A-DSR and DSR are kept above 95%, and varies a little with different node mobilities. From Fig. 3(b), it can be found that when the source is 20, the difference between A-DSR and DSR is obvious. The data packets delivery fraction of A-DSR is still kept on 95% and that of DSR is vibrated and decreased about 18%. In Fig. 3(c)(d), the fraction of A-DSR and DSR are both fluctuated and A-DSR gets higher packet delivery fractions than that of DSR obviously.

2) Average end-to-end delay of data packets: It can be seen from Fig. 4 that when number of traffic sources is 10,20,30,40, the average end-to-end delay of data packets on A-DSR protocol is under 0.03 seconds, 0.05 seconds, 0.1 seconds and 0.15 seconds respectively. However, except that the performance of DSR protocol is closed to that of A-DSR with 10 traffic sources, DSR protocol has evidently longer delay than A-DSR.

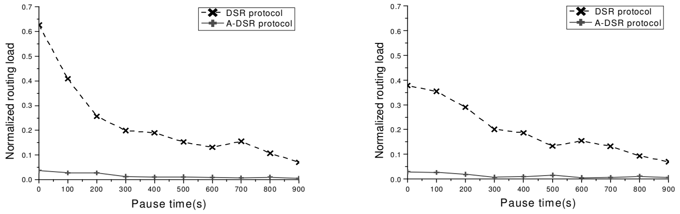


(a) 10 sources (b) 20 sources

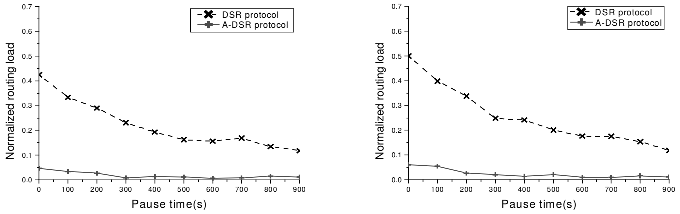


(c) 30 sources (d) 40 sources

Fig. 4. Average delay with various numbers of sources



(a) 10 sources (b) 20 sources



(c) 30 sources (d) 40 sources

Fig. 5. Normal routing load with various numbers of sources

3) Normalized routing load: We find a very stable performance of normalized routing load on A-DSR protocol while the traffic sources is changed from 10 to 40. As shown in Fig. 5, when the mobility is very high (pause time is:0 seconds, 100 seconds and 200 seconds respectively) and the traffic load is smallest in all test cases, the difference between DSR and A-DSR protocol on normalized routing load approaches to the maximum value almost 0.6 and it becomes smaller with the increase of pause time. However, the smallest difference is about 0.06.

D. Performance Analysis

Based on the comparison of A-DSR and DSR, we have the observations that A-DSR protocols improve the performance of original protocol, except the cases under the lowest traffic loads. The reason mainly lies in that every server node have the same priority in routing process. We found that the members of anycast group migrate in and out of a cluster range are relatively stable. A-DSR efficiency is very high because of its routing method-multi paths for multi- destinations. When the present path breaks down, A-DSR node will use the other records destined to the same destination or other members. So the A-DSR need not search route frequently and that is way its performance is very high.

It is a very important characteristic of mobile wireless ad hoc network that the data link may change from time to time because of the mobility of the nodes. The connecting and breaking down of data link will lead the establishment and disappearance of transmission path. And some old routing record in the routing will be dropped or updated and some new routing record will be added. So the times of routing searching will be increased as the node mobility increased. The more drastic the node mobility is, the more the searching time is. On the other hand, the effect of node mobility on the packet delivery fraction and average delay suggests the routing efficiency of protocol. DSR uses source routing and caches a group of routing records for on destination in the routing table. And the DSR node collects the routing information from every packet it received. When the mobility of the node is very high, A-DSR protocol will make full use of the routing information delivered in the whole network and receives more effective routing records destined to anycast group so that the routing searching times may be reduced and delivery fraction and average delay are improved substantially.

However, when the number of sources is 40, the average delay and packet delivery fraction of the A-DSR protocol is abnormally changed to some extend. Currently, DSR original routing protocol has no mechanism to achieve traffic load balance. However A-DSR is able to achieve the load balance due to scattered destinations.

IV. CONCLUSION

We have designed a novel anycast protocol in mobile wireless ad hoc networks based on on-demand routing protocols DSR. And to test the packets delivery fraction, average end-to-end delay of data packets and normalized routing protocol performance of anycast protocols, we have done substantial simulation with ns-2 on different traffic models, node mobility models and connection models.

DSR performs poorly when the traffic load is unbalanced in the network. In contrast to DSR, A-DSR achieves good load balance . Since the members in the anycast group sharing one anycast group address makes all members equally share of the traffic load. This provides the transmission path with multiple shortest lengths. With scattering of anycast server in the geographical area, the traffic load is obviously distributed in the network and consequently, A-DSR enhances the performance of message routing. Therefore, anycast protocol can effectively improve the performance and enhance the service availability of mobile wireless ad hoc network through the distributed the traffic load, especially for the replicated services of a group of peer nodes.

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