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Reactive Routing Protocols in Mobile Ad hoc Networks: A Survey

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Abstract. *A mobile ad hoc network (MANET) is a dynamic wireless network that consists of mobile nodes communicating in the routing without any infrastructure. Routing is one of the interesting areas in MANETs. Routing in the MANET is a challenging task and selecting one routing protocol with all suitable features is difficult. A growing attention in MANETs is providing stable routes with long route lifetime, low control overhead, low end to end delay and high packet delivery ratio and etc. In this paper, we provide an overview and comparison of different reactive routing protocols for MANETs*

Keywords: Mobile ad hoc network, Reactive routing, Mobile node, route discovery, route maintenance

1. Introduction

A mobile ad hoc network (MANET) is a network consisting of a set of mobile nodes with no centralized administration like base stations or mobile switching center. These networks can be deployed without any fixed infrastructure.MANETs are more unstable than wire networks because of the lack of a centralized entity and transmission channel [1,2,3]. Ad hoc networks have no stable routers; all nodes are capable of movement, thus network topology changes frequently. Usually, these nodes operate not only as a host but also as a router and forwarding data packets for other nodes. In order to see these peculiar schemes and design constraints, an efficient routing protocol is essential for MANET in which Designing an efficient routing protocol for MANETs is a very challenging task [4,5]. Many routing protocols have been proposed and these protocols can be classified as proactive and reactive and hybrid. In proactive routing protocols, each mobile node keeps its routing information in a routing table. These tables are periodically updated by transmitting routing information among mobile nodes.Since periodically routing information transmitted, a proactive routing protocol raises a large number of control messages in the network. Due to excessive network traffic and computation overhead of proactive routing protocols, reactive routing protocols have been preferred for MANETs. In reactive routing protocols, a source requires to discovery and maintenance a route between itself and destination before sending data. Nodes using reactive routing protocols, delay the route discover until a demand for a route is made [6,7,8]. Reactive routing protocols consist of two main mechanisms: (a) route discovery and (b) route maintenance. The route discovery mechanism uses flooding mechanism to find all the available paths to a destination. Hence, the destination node selected one path among all feasible paths to be the main routing path. Also, in MANETs links usually breaks due to the mobility of the nodes. Hence there must be route maintenance mechanism to repair routes when links break [5,9]. As a result, the reactive routing protocol needs more time for discovers a route than the proactive protocol.

In this paper our motivation is to provide survey and comparison of seven typical reactive routing protocols such as dynamic source routing (DSR), ad hoc on-demand distance vector (AODV), location-aided routing (LAR), stable weight-based on-demand routing protocol (SWORP), on-demand geographic path routing protocol (OGPR), reliable on-demand routing protocol (RORP), Dynamic backup routes routing protocol (DBR^2P) for mobile ad hoc networks.

The remainder of this paper is organized as follows. In section 2 present the preliminaries to the system. In section 3, we briefly review the seven routing protocols and detailed operational description of the routing protocols will be discussed. Section 4, provides a guideline for choosing a routing protocol. Finally, we

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conclude this paper in Section 5.

2. Preliminaries

In this section, we first introduce the expected region and the request region. Then we describe the duration of time.

2.1 Expected region and request region

We will introduce some notations and terminologies that are used in location-aided routing (LAR). LAR uses location information for mobile nodes to flood a request packet for destination in a request region. We first need to find an expected region. If the source node S wants to find a path to the destination node D, we assume that node S knows that node D was at location $D(X_d, Y_d)$ at time t. Lett_1 be the current time. Because node S knows that the information of node D includes average velocity (v), node S may assume that the expected region is a circular region of radius √ (t_1-t). An example of an expected region is shown in Fig.1.
We determine the request region after we determine the expected region. As shown in Fig1. We assume that node S knows the average speed √ of node D. Node S can plan the expected region. We define the request region as a rectangular area that include the current location of node S. The request region is the rectangle whose corners are S, P, Q and R. When the source node S want to search a path to the destination node D, node S sends a route request (RREQ) packet to its neighboring nodes. Let node N receives a RREQ packet, because node N is located in the rectangular request region, this node will forward the packet to its neighbors. Otherwise, if the node *i* receives a RREQ packet, node *i* discards the packet because node *i* is not located in the request region [3,10].

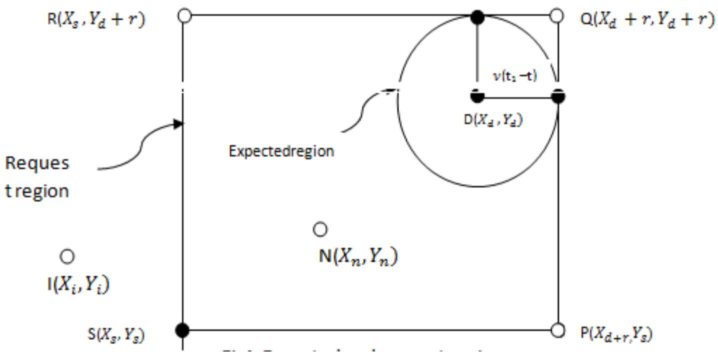

Fig1-Expected and request region

2.2 Duration of time

Because the two neighbors obtain each other motion values, such as position , velocity, and transmission range, the duration of link between these nodes can be determined based on their location information provided by GPS, velocities of movement and radio range. If we know the motion parameters of two nodes, we can calculate the duration of time these two nodes remained connected and provide stable routes.
We assume that two nodes A and B are in the same transmission range(r). We let (x_1, y_1) be the position of mobile node A and (x_2, y_2) be the position of mobile node B. We let $√_1$ and $√_2$ bespeeds of movement andθ_1 and θ_2 (0≤θ_1, θ_2<2л) be the moving directions. We can obtain the duration of time between A and B by using the following equation:

$$D_t = \frac{-(ab+cd)+\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \tag{1}$$

Note that $a = v_1 \cos\theta_1 - v_2 \cos\theta_2$, $b = x_1 - x_2$,$c = v_1 \sin\theta_1 - v_2 \sin\theta_2$,$d = y_1 - y_2$
When a source node sends a request route packet, the packet adds its location, direction, and speed. The next hop of the source node receives the RREQ packet to predict the duration of time between it and the source node [3,11].

3. Reactive routing protocols

Techniques, such as DSR and AODV [12], attempt to reduce network traffic by initiating a rout request on-demand. This type of routing protocols establishes communication links by flooding the network to find a route to the destination node. This strategy is simple and robust; however, it is not energy efficient and can cause severe media congestion.

Another approach to reduce network flooding is to use location information. LAR uses location information to limit the area of flooding, thereby reducing the number of rout request messages. These schemes result in better energy conservation and improve network scalability [12].

We propose RORP [3] to increase route reliability and reduce the effects of dynamic topology. In this scheme, we determine the duration of time between two connected nodes and discover a request region between the source node and the destination node for routing discovery. We select the routing path with the longest duration of time for transmission.

DBRP [13] is an on-demand routing protocol and it can set up many routes to reach a destination node in a given period. When a link fails, a backup node mechanism for quick reconnection is proposed.

We introduce a stable weight-based on-demand routing protocol (SWORP) for MANETs [14]. This protocol uses the weight-based route strategy to select a stable route in order to enhance system performance. Rout discovery first finds multiple routes from source node to the destination node. Then the path with the largest weight value for routing is selected.

OGPR[15] is efficient and scalable routing protocol. In this protocol nodes locate the destination on-demand by flooding a PREQ message in the network. The PREQ message collects geographic positions of the intermediate node from the source to the destination. When the destination receives a PREQ message, it finds a geographic path which represents a route from the source to the destination, in the PREQ message. When the path breaks, nodes use a path-healing technique. In this technique each packet traces the geographic path from source to destination. This path may be different from the geographic path found by the source during PREQ phase.

3.1. Dynamic Source Routing (DSR) Protocol

DSR [6,5] is a simple and efficient routing protocol. Each packet in DSR protocol carries the full address from source to destination. In this protocol, the nodes can store multiple routes in their cache and the source node can check its cache for a valid route before initiating route discovery, and if a valid route is found there is no need for route discovery. And if a route is not found in its cache, the source node broadcasts a request packet to all of its neighbors. If the nodes receiving this message are neither a destination nor does it have a route in the route cache to that destination, they add their address in the route and rebroadcast the message to their neighbors. If a receiving node D is the destination, D sends a REPLY message back to the source after copying the accumulated routing information contained in the route request packet into a route reply packet. After receiving one or several routes, the source node chooses a path that is the shortest one, stores it, and starts to send messages along this route. If the network topology changes due to broken links,the links are removed from the route cache and source node S attempt to use any other routes that initiatedbyroute request to find a new route. This is referred to as route maintenance.

3.2. Reliable On-demand Routing Protocol (RORP)

RORP [3] is on-demand routing protocol. We give a relation of the computation route discovery process. We assume that the source node knows the information of the destination location before the routing process. Each node can know its location by using GPS. Thus, we calculate the request region and expected region (see section 2.1) before we send the search packet. We define two parameters: the link duration time (LDT) and the route duration time (RDT). The LDT represents the length of time between two nodes, which is calculated by using$Eq(1)$; and RDT is equal to the minimum of the LDTs for the routes. In this protocol the RREQ packet and the RREP packet must append more entries includes the coordinate, velocity, and transmission range. When a source node wants to send data to the destination node, it first checks its routing table to determine if it has a route to the destination node, if the route has been found, it will use the route to send the data packet. Otherwise the source node S broadcasts a RREQ packet to its neighboring nodes. After they receive the packet, the neighboring nodes calculate the duration of time and conclude whether they are in the request region. If a neighboring node is in the request region, the node forwards the packet to its neighboring nodes and adds its information and LDT for the last link of the RREQ packet to the packet entry. Otherwise, if the node is not in the request region the packet will be discarded. When the destination node D receives a RREQ packet, it waits for a length of time to receive other RREQ packet. Node D calculates the RDT for the path. Then node D selects the path with the maximum RDT to be the primary path. Node D sends a RREP packet to the source node along the primary

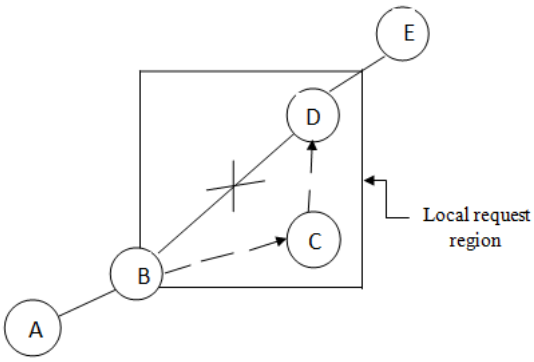

Fig. 2. Route maintenance [3]

3.3 Stable Weight-based On-demand Routing Protocol (SWORP)

In SWORP [14], the route discovery process has begun when a source node wants to transmit with another node for which it has no routing information in its table. For routing discovery process source node S broadcasts a RREQ packet to its neighboring nodes. If the receiver node is within the transmission radius, it sends the RREQ packet to its neighboring nodes and adds its ID, the route duration time, the error count, and the hop count of the RREQ packet to the packet entry. When the destination node receives a RREQ packet, it waits for a waiting time to receive other RREQ packets. Then destination node computes the weight value using a weight function. The weight function includes three factors: the route duration time (RDT), the error count (EC), and the hop count (HC). The RDT is described in the previous protocol. EC is used to show the number of link failures. When an intermediate node receives a RREQ packet, it compares the error count in the route entry of the packet with the error count in its route cache, and assigns the larger error count as the new error count in the packet. The destination node records the error count values along all routes. HC is the number of hops for a route. A route with low HC is preferred.

In the weight function, we first normalize each item and then mixture these three factors.

$$W_i = C_1 \times \left(\frac{RDT_i}{MaxRDT}\right) + C_2 \times \left(\frac{EC_i}{MaxEC}\right) + C_3 \times \left(\frac{HC_i}{MaxHC}\right) \quad (2)$$

C_1, C_2, C_3 are weight factor which can be chosen according to the system requirement. For, example, route duration time is very important. Thus, the weight of that factor can be larger. Afterwards, destination node selects the path with the maximum weight value as the main path between all possible paths. Finally, destination node sends a RREP packet to source node along the main path.

Due to the high mobility of nodes in MANETs, many links fail occur. When a link failure occurs, the route maintenance process is triggered. This process is to overhear RREP packets transmitted by a neighboring node. It stores this neighboring node as a next hop to the destination node in its alternative route table. We assume that node N is selected to be the transmitting node. When a link is broken, node N sends a RERR packet to the source node and the source node stops sending the data and then restart the route discovery process of searching an alternative path for routing.

3.4. Dynamic Backup Routes Routing Protocol (DBR^{2}P)

DBR^{2}P [13] includes three phases: route discovery, backup node setup, and route maintenance. This approach requires two kinds of cache: RD-request-Cache, and Backup-Routes-Cache. A source node sets a unique identification number for each RD-request packet. The RD-request-Cache of a node is used to store counters, which record how many times (n) this node receives the RD-request packet with the same identification number (#RD). The entity<#RD, n> is used to present that idea.

In the route discovery phase, source node S broadcasts RD-request to neighboring nodes. The RD-request includes a sequence number field, and a route content field to record all the address of nodes along the path. When a node receives a RD-request from its neighbor, it will check whether the RD-request is received for the first time according to the sequence number of the RD-request in the records of its RD-request-Cache. If this node receives the RD-request for the first time, then the entity <#RD,1> is stored in the RD-request-Cache. Also, the timer t_c, is started. Then, this node inserts its address into the route content field of the RD-request, and broadcasts this RD-request to its neighboring nodes.If a node receives the RD-request with duplicate sequence number, this node continues to check whether the route content field includes its address; if so, the node discards this RD-request to avoid the loop infinitely. On the other hand, if the address of this node is not included in the route content field, the node will then check whether the value of n is not smaller

than three, or whether the timer, t_c, is timeout; if so, the node discards this RD-request. Otherwise, the node increases the value n of <#RD,n> and inserts its address into route content field and broadcasts this adjusted RD-request packet to its neighboring nodes. After the destination node D receives the first RD-request, it waits for a waiting time to receive other RD-request packet and sends a RD-reply back to the source node S.
In backup node setup phase, the backup nodes are nodes with at least two different paths to their neighboring nodes in those routes from S to D. A set of backup nodes can be gathered from any two routes.The backup nodes store the partial paths from the backup node to the destination node in their backup-route-cache.
In route maintenance phase, when a link failure is detected, that node will pass a "Link-Fail-Message" to the neighboring node until the message is received by a backup node. The backup route of backup-route-cache in the backup node is fetched to replace the route and the source node is informed to change the route and sends packets along the new route.

3.5. A self-healing On-demand Geographic Path Routing (OGPR) Protocol

The basic idea of the OGPR [15] is as follows: when a source node wants to send data packets to a destination, if the source node knows a path to the destination in its table, it routes the packets to the destination using the geographic path. Otherwise, it saves data packets in its buffer and sends a PREQ for the destination and start a PREP-WAIT timer. When the intermediate node which is not destination receives a PREQ, stores the PREQ message in its PathRequestSeen cache, add its position in the geographic path in the packet, and decrease the PREQ TTL (an entry in PREQ packet). If PREQ TTL is greater than zero, then broadcast the message. An intermediate node discards a PREQ if the PREQ TTL is zero or it has already stored the PREQ in its PathRequestSeen cache. When the destination node receives the PREQ, it appends its position to the geographic path, insert the geographic path in its OGPRGeoPath and send a PREP message that consist of source ID, destination ID, geographic path (list of positions) to the source node. Unlike other on-demand protocols, in OGPR, only the destination node answers to PREQ message. If the PREP-WAIT timer be timed out before the source node receives the PREP, it re-broadcasts PREQ. When a source node receives PREP packet, it achieves geographic path and stores it in its OGPRGeoPath cache. Then the source node takes each packet from its buffer and inserts the geographic path to the packets and sends them for the destination node. Due to node mobility, in the maintenance phase, a node uses a path-healing mechanism. In this mechanism, each packet sent by the source, using greedy forwarding that shown in Fig. 3 (delivers packets from source to destination by forwarding the packet to the node closest to each of the node that is occurring on the geographic path) along a geographic path, may follow a path that is geographically close to the geographic path.

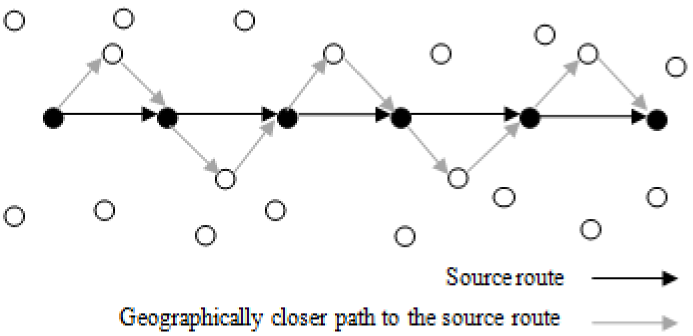

Fig. 3. Greedy forwarding

3.6. Ad-hoc On-demand Distance Vector (AODV) Routing Protocol

AODV [9] is on demand routing protocol. In the route discovery process, when a source node wants to send a data to a destination node, first it checks its table. If the table does not a route to the destination, the source node broadcast a RREQ message to the network. If the node receiving the message is the destination or it has a route to the destination, the node sends back a route reply (RREP) to the source node along the reverse route. When the source node receives the first RREP, it sends data to the destination. If the node is not a destination and does not have a route to destination, it rebroadcasts the RREQpacket. In addition, AODV utilizes per node sequence numbers to prevent routing loops and ensure selection of the most recent routing path to a destination. To achieve this issue, each mobile node maintains an increasing sequence number. (Sequence numbers provides a relative measure by which the timeliness of the routing information can be evaluated; information known to be stale must be ignored). A node increases its sequence number when it begins a new route request. If a node receives a route request for itself, it adjusts its sequence number to the maximum of its current sequence number and destination sequence number and then sends a route reply. In the route maintenance, if a link breaks while a node attempt to forward a packet, it sends the RERR packet to all sources using the packet. When the source node receives a RERR packet, it initiates a new route discovery process.

3.7. Location-Aided Routing (LAR) Protocol

In this protocol [6,10], each node is required to carry a GPS. LAR reduces the overhead of route discovery by using location information in all packets. LAR uses location information nodes to flood the route request packet in a request-region (see section 2.1) instead of on the entire network. The route request packets can travel the nodes that have a smaller distance to the destination. When the destination node receives the route request packet, it replies by sending a route reply message. When the source node receives this route reply message, it records the location of destination node and uses this information to determine the request region for a future route discovery. If a node detects a broken link, it attempts to retransmit the data packet using an alternative path from its own cache. If the alternative path is also broken, it sends route error packet to the source node to let it know about the broken link for future transmissions and the source node rebroadcasts the request packet to the destination node. This scheme results in better power conservation and improve network scalability.

4. Comparison of discussing routing protocols

The routing protocols discussed in the previous section have their own advantage and disadvantages [5]. We briefly compare these protocols in the below table and has been provided as a guideline to select a suitable routing protocol.

Table1. Checklist for choosing a routing protocol

Criteria / Protocols	End-to-End Delay	Packet delivery ratio	Overhead	Control message	reliability
DSR	Low	Low	Medium	Low	Low
RORP	Low	High (in high node) Low (in low node)	Low	Low	High
SWORP	High	High	High	Low	High
DBR^2 p	Low	High	Medium	Medium	Low
OGPR	Medium	High	Low	Low	Medium
AODV	Medium	High	Medium	High	Low
LAR	High	High	Low	High	Low

5. Conclusion

In this paper, seven reactive routing protocols investigated. We summarize the performance characteristics of these routing protocols in Table1. A good routing protocol wants to give reliability and energy efficiency and high packet delivery ratio with low overhead and low delay. It is a great effort to find a single protocol that can obtain all these performance metrics. Selection of a routing protocol depends on criteria and applications.

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