Dynamic Source Routing (DSR) Protocol with Euclidean Effect in Mobile Ad Hoc Networks

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Abstract– **Node mobility in mobile ad hoc networks (MANETs) can cause frequent topology changes, therefore finding and maintaining the route(s) in such an environment is a challenging problem. In recent years, numerous ad hoc routing protocols have been proposed. This paper investigates the routing problem in a MANET by utilizing Euclidean effect to improve performance of routing protocols for MANETs. By using Euclidean information the proposed Euclidean Effect Routing (EER) protocols minimize disruptions of mobile multimedia when the network topology changes. One important feature of our protocol is the intermediate nodes of a route can perform rerouting before a path becomes invalid similar to that in well-studied cellular networks when it roams away to keep a route alive. This makes routes in the MANET more stable and insensitive to node mobility. We present an protocol based on the EER to choose the route that best meets the strict requirements of multimedia applications.**

1 Introduction

A mobile ad hoc network (MANET, for short) consists of a number of mobile nodes which may occasionally communication with each other. No base station is needed in the network and it operates without the aid of any fixed network infrastructure or centralized administration. The network is dynamically self-organizing and self-configuring. As node mobility can cause frequent topology changes, therefore finding and maintaining the route(s) in such an environment is a challenging problem. In such situation, ad hoc routing is critical and has to be iron out the details of the routing before any applications can be deployed for MANETs.

The applications of MANETs range from military operations (communication in a hostile environment) to civilian operations (e.g., communication in collaborative and distributed computing), rescue operations (rapid deployment of a communication network where infrastructures do not exist or have been damaged such as flood, earthquake, and fire), and sporadic happening coverage (intense utilization of a communication network for a very limited time).

In this paper, we suggest an approach to minimize disruptions of mobile multimedia when the network topology changes. We demonstrate how Euclidean information may be used by means of Euclidean Effect Routing (EER) protocol for rerouting before a path becomes invalid. The EER protocol use Euclidean distance to improve quality of service routing in ad hoc networks.

2 Related Work

Routing protocols such as link state [13] and Bellman-Ford [3] use in conventional wired networks are not well-match for the mobile nodes behavior due to the large amount of overhead produced by periodic route update messages and their increased sensitiveness to continuous topology changes.

Numerous ad hoc routing protocols have been proposed to the Internet Engineering Task Force (IETF) Mobile Ad Hoc Networks (MANET) Working Group [9], each based on different assumptions and intuitions. There are two main types of protocols, namely pro-active an reactive. Pro-active protocols continuously maintain updated routes so that they are immediately available when needed. They include the Destination-Sequenced Distance-Vector (DSDV) protocol [17], the Wireless Routing Protocol (WRP) [14], and the Clusterhead Gateway Switch Routing (CGSR) [4]. A different approach from pro-active is reactive protocols which discover routes only when desired by the source node, in short on-demand nature. They include the Dynamic Source Routing (DSR) [10], the Associativity-Based Routing (ABR) [20], the Signal Stability-Based Adaptive Routing (SSA) [6], the Temporally-Ordered Routing Algorithm (TORA) [15], and the Ad Hoc On-Demand Distance Vector Routing (AODV) [18]. Haas and Pearlman [8] proposed a hybrid scheme called the Zone Routing Protocol (ZRP), by initiating route discovery phase on-demand, but limits the scope of the pro-active procedure only to the initiator's local neighborhood. Other ad hoc routing protocols such as the Location-Aided Routing (LAR) [12] and the Distance Effect Algorithm for Mobility (DREAM) [2] utilize location information (e.g. geographic coordinates that can be obtained using the Global Positioning System (GPS) [11].

Dynamic Source Routing (DSR) protocol is one of the important ad hoc routing protocols and is a direct descendant of the source routing scheme used in bridged LANs. It uses source routing instead of hop-by-hop packet routing. The key advantage of source routing is that intermediate nodes do not need to maintain up-to-date routing information in order to route the packets since the packets themselves already contain all the routing decisions. This fact, coupled with the on-demand behavior eliminates the need for the periodic route advertisement and neighbor detection packets present in other protocols [10]. DSR consists of two phases: (a) route discovery and (b) route maintenance, each of which operates using entirely on-demand nature. When a node in the MANET attempts to send a packet to some destination, if it does not already know a route to that destination, it uses Route Discovery to dynamically discover one. The route is cached and used as needed for sending subsequent packets, each of which utilizes the Route Maintenance procedure to detect if the route has broken, for example due to two nodes along the route moving out of wireless transmission range of each other. Route Discovery is only invoked when needed, and Route Maintenance operates only when actively using the route to send individual packets. If a route does not exist, the node drops the packets and does not begin a new Route Discovery of its own. These can cause frequent disruption of the packet flow.

3 Location Information

Our main assumption is that each node is aware of its own current geographic location. Dommety and Jain [5] briefly suggest use of location information in ad hoc networks, though they do not explain on how the information may be used. Other researchers such as Spreitzer and Theimer [19], and Weiser [21] have also suggested that location information should be used to improve performance of a MANET. Location information can be obtained by equipping a node with a Global Positioning System (GPS) [16] receiver, which is nowadays commercially available and reliable. With such devices, it is possible for a mobile host to know its physical location. Current GPS provides accurate three-dimensional position, velocity, and precise time traceable to Coordinated Universal Time (UTC). Later its will be called a node's location attributes (LOC). In this paper, we assume that the entire network nodes are moving in a two-dimensional plane.

Since MANETs neither exists a wired backbone nor a centralized control, every node in the network is accountable for disseminating its LOC to all other nodes. This can be obtained by periodically flooding the network with a packet containing the LOC of the node. When a node Y received a LOC packet from X, it will updates its LOC cache. The size of the packets used to disseminate the LOC are very small. A node's latitude and longitude need no more that 16 bytes, the velocity and transmission radius need 4 bytes, the time these informations were taken needs 2 bytes, and only a few bytes needed for the node identifier depending on the size of the network. Secondly, frequency a node needs to disseminate its LOC ought to consider its Euclidean distance (EUC) relative to transmission radius (RAD) and its velocity since it is reasonable assumptions to reduce flooding traffic. For instance, a node is consider transient if mobility rate is high and EUC is near to RAD and its needs more frequent dissemination. On the contrary, a node is consider stationary and it stops the dissemination totally. Thus, each node can locally adjust its dissemination frequency according to its states. This dissemination mechanism can meet the requirements of MANETs, where the minimization of bandwidth and energy usage are important goals. The effectiveness of dissemination according to its mobility rate in MANETS has been presented and applied in [1, 2].

4 Network Topology

A node easily compute which nodes are inside its transmission range in the network by obtaining a snapshot of the entire network topology through the of its LOC cache. LOC may be obsolete at the time those attributes were transmitted especially for high mobility nodes. However more frequent periodical dissemination will over come these problems.

In graph theoretic terms, a network topology is modeled as a set V of network nodes, that are interconnected by a set E of full-duplex directed communication links, $G = (V, E)$, where $|V| = n$ and $|E| = m$. Numbers of n and m are changing over time when nodes move, join, or leave. Each node has a unique identifier and has at least one transmitter an one receiver. A link l in E between two nodes say X and Y in V means that node X and Y are in the transmission range of one another, according to the attributes stored in say S's LOC cache for X and Y. Table ?? shown an example that the content of X and Y's entries in S's LOC cache is depicts at the time S want to send a packet.

There is a link between X and Y in the network graph G if and only if

$$UEC(X, Y) \leq \min[RAD(X), RAD(Y)] \quad (1)$$

Therefore, there is a link between nodes X and Y if and only if the Euclidean distance between X and Y is less or equal to the minimum of X and Y's transmission radius.

Time complexity of computing the network topology graph G from the LOC cache is polynomial in n. But it is adequate to only examine node entries $j > i$ whether (1) is satisfied, since the interconnection are full-duplex directed communication links for each node entry i, $i = 1, 2, \ldots, n-1$, of the LOC cache. Therefore, time complexity is $O(n^2)$ because only $n(n-1)/2$ of these checks are needed. Further, time complexity is linear in n if graph G can constantly maintained and updated each time a new location packet is received at each node.

5 The Euclidean Effect Routing Protocol

Given the network topology graph, k shortest paths between any two nodes can locally computes. This issue is a very well investigated by Eppstein in [7], where various related references on this issue can be found. If we can determine the link distance (LD), $d(i)$ where $i = 1, 2, \ldots, m$. along each hop on the route, we will be capable to procure the route distance (RD), $D(j)$ where $j = 1, 2, \ldots, k$ of the route.

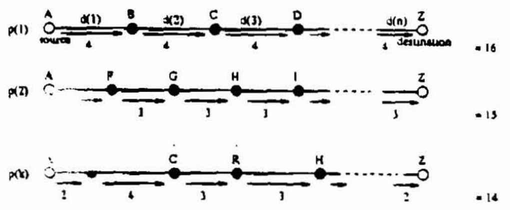

Figure 1: The setup process

When a source needs to send a data to the destination, it will first check its routing table to see if it has an unexpired route to the destination. If it does, it will send data packets using the routing immediately. Otherwise, it broadcasts a request message (REQ). This REQ message is processed similarly to the route request message in DSR [10]. The message contains a sequence number, source id, and destination id. A node upon receiving this message, will forward it to all of its neighbors if (a) the message contains a higher sequence number than any of the previously received source and destination id pairs, or (b) the message contains the same sequence number, but the message arrives from a better route. Example, the route has a smaller RD with the same or fewer number of hops. When a node is forwarding a REQ, it also appends its own id and the LD for the last link that the message traveled through. When a REQ message arrives at the destination, it contains the list of nodes along the route it has traveled and the LDs for each hop along the path. The destination can then determine the RD for the route by using the minimum of the set of LDs along the path.

$$D(j) = \sum d(i) \quad j = 1, 2, \ldots, k \quad (2)$$

$$RD_{best} = \min[D(j)] \quad (3)$$

If the received route is more stable than the one currently in use, the destination sends a reply message (REP) back to the source along the chosen path. The intermediate nodes setup the LD when they receive the REP message. The setup process is shown in Figure 1.

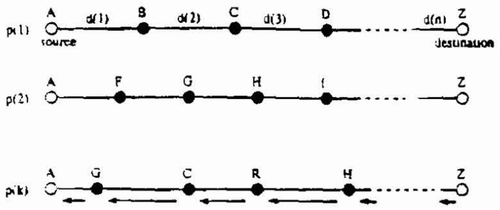

Figure 2: The REP message back to the source.

In Figure 1, the source node A sends a REQ for destination node Z. Nodes such as B, C, D, and etc. will forward the REQ and append information such as their own ID and the LD of the last hop that the message was received. In this example, k REQ messages arrive at node Z. The first one contains path $(A, B, C, D, \ldots, Z)$ say with $RD = 16$, while the other contains path $(A, F, G, H, I, \ldots, Z)$ with $RD = 15$, and for the last path $(A, G, C, R, H, \ldots, Z)$ with $RD = 14$. In our example, path $(A, G, C, R, H, \ldots, Z)$ is best route since it has minimum Euclidean distance. Therefore it is chosen as the route to setup the flow. As shown in Figure 2, node Z then sends a REP message back to the source along the chosen path. The intermediate nodes setup the flow states when they receive the REP message.

It is rational to assume that as soon as a single link on a route is disconnected, the entire path will be disconnected as well. During the connection, intermediate nodes append LDs to each data packet, so the destination continues to receive RD predictions from the data packets. When the destination has determined the termination criteria is reached, a critical distance message (CRI) is propagated via flooding in the same way as the REQ.

In EER protocol, we define the critical distance, D_{CRI} by

$$D_{CRI} \leq D_{RAD} - \max[d(i)] \quad (4)$$

where $\max[d(i)]$ is the maximum link distance experienced by the packet which has arrived along the route. Since network topologies will change from time to time during the connection, the Euclidean distance also changes accordingly. By using the latest packet to compute D_{CRI}, the protocol adapts to changing network conditions and the source is informed in a promptly manner for a hand-off. Thus, packet loss is minimized.

After the source receives a CRI message, it determines the best path on which to reroute the flow to based on the information contained in the CRI message. If an intermediate node move away and the link broken, error message (ERR) will sends back to the source along the chosen path. When the source node received ERR message, it will choose a best route from cache of it has learned or overheard from REQ or broadcasts a new REQ packet.

6 Conclusions

This paper presented a new protocol that allows nodes in an MANET to select routes to given destinations based on the Euclidean effect that the route is still available when a packet has to be sent through it. We have described the basic steps that S has to perform in order to retrieve network topology information, to efficiently compute up to k routes to the intended destination and finally to associate with each route the Euclidean distance.

By using Euclidean information the proposed Euclidean Effect Routing (EER) protocols minimize disruptions of mobile multimedia when the network topology changes. One important feature of our protocol is the intermediate nodes of a route can perform rerouting before a path becomes invalid similar to that in well-studied cellular networks when it roams away to keep a route alive. This makes routes in a MANET more stable and insensitive to node mobility. We present an algorithm based on the EER to choose the route that best meets the strict requirements of multimedia applications.

Further study is going to be pursued in this direction, as well as in the direction of combining Euclidean effect with other measures related to each route, such as bandwidth and local conditions at each node of the route. Simulation tests have yet to be performed in order to demonstrate the effectiveness of the proposed scheme with respect to various parameters of MANETs, such as node velocity, node placement strategy, and mobility patterns, etc.

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