Chapter XIV
FSR Evaluation Using the Suboptimal Operational Values

Osama H S Khader
The Islamic University of Gaza, Palestine

ABSTRACT

In mobile ad hoc networks, routing protocols are becoming more complicated and problematic. Routing in mobile ad hoc networks is multi-hop because of the limited communication range of wireless radios. Since nodes in the network can move freely and randomly, an efficient routing protocol is needed in order for such networks to be able to perform well in such an environment. In this environment the routing strategy is applied such that it is flexible enough to handle large populations and mobility and be able to minimize the use of the battery. Also it should be designed to achieve maximum packet delivery ratio. Furthermore, the routing protocol must perform well in terms of fast convergence, low routing delay, and low control overhead traffic. In this paper an improved implementation of the Fisheye State Routing (FSR) protocols is presented, where a new selection routing criteria that utilizes a minimum number of hops is a selection metric. The results obtained from simulation indicate that the fewer number of hops used the better and more efficient the output for packet delivery ratio was generated.

INTRODUCTION

A mobile ad-hoc network is a collection of mobile nodes with no pre-established infrastructure. Each of the nodes has a wireless interface and communicates with others over radio frequency (RF). Laptop computers and personal digital assistants that communicate directly with each other are some examples of nodes in an ad-hoc network. Nodes in the ad-hoc network are often mobile but also can consist of stationary nodes. An ad-hoc network uses no centralized administration. This ensures that the network will not cease functioning just because one of the mobile
nodes moves out of the range of the others. Nodes should be able to enter and leave the network as they wish. Ad hoc networks are often characterized by a dynamic topology, due to the fact that nodes change their physical location by moving around. Another characteristic is that a node has limited central processing unit (CPU) capacity, storage capacity, battery power, and bandwidth. This means that power usage must be limited, leading to a limited transmitter range. Every node in an ad hoc network must be willing to forward packets for other nodes. Thus every node acts both as a host and as a router. The topology of ad-hoc networks varies with time as nodes move, join, or leave the network. This topological instability requires a routing protocol to run on each node to create and maintain routes among the nodes.

The rest of the article is organized as follows. A survey of most existing wireless routing protocols is given in the MANET Routing Protocols section. The next section describes the FSR protocol. This is followed by the performance results section. The last two sections are the conclusion and future work.

**MANET ROUTING PROTOCOLS**

Existing wireless routing schemes can be classified into four categories: (a) distance vector based, (b) link state (LS) based, (c) on-demand based, and (d) location based. Historically, the first type of routing scheme used in early packet networks, such as the ARPANET, was the distance vector type. The main advantages of the distance vector approach are simplicity and computation efficiency. However, this approach suffers from slow convergence and a tendency to create routing loops. While several approaches were proposed that solved the looping problem (Murthy & Garcia-Luna Aceves, 1996; Bhagwat, 1994). None of them overcome the problem of slow convergence. The solutions to both convergence and looping come in the form of the LS approach. LS is the preferred scheme for wired nets. In LS, global network topology information is maintained in all routers by the periodic flooding of LS updates by each node. Any link change triggers an immediate update. As a result, the time required for a router to converge to the new topology is much less than in the distance vector approach. Due to global topology knowledge, preventing a routing loop is also easier.

Unfortunately, as LS relies on flooding to disseminate the update information, excessive control overhead may be generated, especially when mobility is high and frequent updates are triggered. In addition, the small update packets make for inefficient use of the wireless medium access control (MAC) layer. When mobile ad hoc network (MANET) size and mobility increase (beyond certain thresholds), current proactive routing schemes (i.e., the distance vector and LS) become infeasible, since they will consume a large part of network capacity and node processing power to transmit update control messages just to keep up with the topology changes. The most recent addition to the family are the on-demand routing schemes. These have been specifically introduced in order to overcome some limitations of the proactive protocols in mobile environments. Examples include ad hoc on-demand distance vector by Perkins and Royer (1999), temporally ordered routing algorithm by Park and Corson (1997), and dynamic source routing by Zhong and Yuan (2003). The basic idea behind these reactive protocols is that a node discovers a route in an “on demand.” It computes a route only when needed. In on-demand schemes, query/response packets are used to discover (possibly more than) one route to a given destination. These control packets are usually smaller than the control packets used for routing table updates in proactive schemes, causing less overhead. However, since a route has to be entirely discovered prior to the actual data packet transmission, the initial search latency may degrade the performance of interactive applications (e.g., distributed database queries).
Moreover, it is impossible to know in advance the quality of the path (e.g., bandwidth, delay, etc.) prior to call setup. Such a priori knowledge is very desirable in multimedia applications, since it enables more effective call acceptance control. If the route breaks down because of mobility, a packet may need multiple route discoveries on the way to destination. Since flooding is used for query dissemination and route maintenance, on-demand routing tends to become inefficient when traffic load and mobility are high and network size grows large. A recent proposal that combines on-demand routing and conventional routing is zone routing protocol (ZRP) (Haas, 1997; Pearlman, 2000). For routing operations inside a local zone, an arbitrary proactive routing scheme (e.g., distance vector) can be applied. For interzone routing, on-demand routing is used. The advantage of zone routing is its scalability, as “global” routing table overhead is limited by zone size. Yet, the benefits of global routing are preserved within each zone. The performance of ZRP is dependent on a key parameter: the zone radius. The choice of radius is determined by network characteristics (e.g., node density, relative node velocity, etc.), which dynamically change in MANET.

Moreover the inter-zone route discovery packets may loop back into zones already queried. This must be avoided to prevent overhead, which can be potentially worse than for flooding based queries. The advent of (GPS) global positioning system has made it possible to provide reliable and accurate information for the nodes mobility. For example (Kaplan, 1996) has proposed a routing protocol based in this technology (GPS). With the knowledge of node position, routing can be more effective at the cost of overhead that is required to exchange location information. They broadcast to the nodes in the direction of the destination using only location information stored at the sender.

FSR

Topology Representation in FSR

The MANET is modeled as an undirected graph G = (V, E), where V is a set of |V| nodes and E is a set of |E| undirected links connecting nodes in V. Each node has a unique identifier and represents a mobile host with a wireless communication device with transmission range R and large storage space. Nodes may move around and change their speed and direction independently. An undirected link (i, j) connecting two nodes i and j is formed, when the distance between i and j becomes less than or equal to R. Link (i, j) is removed from E, when node i and j move apart and out of their transmission ranges.

In the FSR routing implementation, for each node i, one list and three tables are maintained. They are: a neighbor list Ai, a topology table TTi, a next hop table NEXTi, and a distance table Di. Ai is defined as a set of nodes that are adjacent to node i. Each destination j has an entry in table TTi that contains two parts: TTi.LS(j) and TTi.SEQ(j). TTi.LS(j) denotes the LS information reported by node j. TTi.SEQ(j) denotes the time stamp indicating the time node j has generated this LS information. Similar, for every destination j, NEXTi(j) denotes the next hop to forward packets destined to j on the shortest path, while Di(j) denotes the distance of the shortest path from i to j.

Description of FSR Protocol

FSR is an implicit hierarchical routing protocol. It uses the “fisheye” technique proposed by Kleinrock and Stevens (1971), where the technique was used to reduce the eye of a fish captures with high detail the pixels near the focal point. The detail decreases as the distance from the focal point increases. In routing, the fisheye approach translates to maintaining accurate distance and path quality
information about the immediate neighborhood of a node, with progressively less detail as the distance increases. FSR is functionally similar to LS routing in that it maintains a topology map at each node. The key difference is the way in which routing information is disseminated. In LS, LS packets are generated and flooded into the network whenever a node detects a topology change. In FSR, LS packets are not flooded. Instead, nodes maintain a LS table based on the up-to-date information received from neighboring nodes, and periodically exchange it with their local neighbors only (no flooding). Through this exchange process, the table entries with larger sequence numbers replace the ones with smaller sequence numbers. The FSR periodic table exchange resembles the vector exchange in a distributed Bellman-Ford (DBF) (or, more precisely, destination-sequenced distance vector\([\text{DSDV}]\)), where the distances are updated according to the time stamp or sequence number assigned by the node originating the update. However, in FSR, LSs rather than distance
vectors are propagated. Moreover, like in LS, a full topology map is kept at each node and shortest paths are computed using this map.

In a wireless environment, a radio link between mobile nodes may experience frequent disconnects and reconnects. The LS protocol releases a LS update for each such change, which floods the network and causes excessive overhead. FSR avoids this problem by using periodic, instead of event driven, exchange of the topology map, greatly reducing the control message overhead. When network size grows large, the update message could consume a considerable amount of bandwidth, which depends on the update period. In order to reduce the size of update messages without seriously affecting routing accuracy, FSR uses the fisheye technique. Figure 1 illustrates the application of fisheye in MANET. The circles with different shades of grey define the fisheye scopes with respect to the center node (node 11). The scope is defined as the set of nodes that can be reached within a given number of hops. In our case, three scopes are shown for 1, 2, and > 2 hops, respectively. Nodes are color coded as black, gray, and white, accordingly. The number of levels and the radius of each scope will depend on the size of the network.

The reduction of routing update overhead is obtained by using different exchange periods for different entries in the routing table. More precisely, entries corresponding to nodes within the smaller scope are propagated to the neighbors with the highest frequency.

In Figure 2, entries in bold are exchanged most frequently. The rest of the entries are sent out at a lower frequency. As a result, a considerable fraction of LS entries are suppressed in a typical update, thus reducing the message size.

This strategy produces timely updates from near stations, but creates large latencies from stations afar. However the imprecise knowledge of the best path to a distant destination is compensated by the fact that the route becomes progressively more accurate as the packet gets closer to destination. As the network size grows large, a “graded” frequency update plan must be used across multiple scopes to keep the overhead low.

The FSR concept originates from global state routing (GSR) (Iwata, Chiang, Pei, Gerla, & Chen, 2000). GSR can be viewed as a special case of FSR, in which there is only one fisheye scope level, and the radius is ∞. As a result, the entire topology table is exchanged among neighbors. Clearly, this consumes a considerable amount of bandwidth when network size becomes large. Through updating LS information with different frequencies, depending on the scope distance, FSR scales well to large-sized networks and keeps overhead low, without compromising route computation accuracy when the destination is near.

By retaining a routing entry for each destination, FSR avoids the extra work of “finding” the destination (as in on-demand routing) and, thus, maintains low single packet transmission latency. As mobility increases, routes to remote destinations become less accurate. However, when a packet approaches its destination, it finds increasingly accurate routing instructions as it enters sectors with a higher refresh rate.

**PERFORMANCE EVALUATION OF ROUTING SELECTION CRITERIA**

This section is devoted to studying packet delivery ratio versus mobility speed. Recent simulation studies show that the FSR protocol, which uses the shortest path, suffers from performance degradation as the network mobility increases. After extensive simulation studies and performance comparisons with other routing selection methods, it was found that the reason behind this degradation is that FSR uses the shortest path as a routing selection method, so when the mobility increases the number of hops increases. Therefore, it has a better chance of having route breaks.
A New Route Selection Criteria

In this section, a new scheme for route selection is introduced. In this scheme, the node selects the route with a minimum number of hops, instead of the shortest path. When there are multiple routes that have the same number of hops, the destination selects the route with the shortest path. Figure 3 describes each scheme. The shortest path scheme simply adds the routing distance of each intermediate node and selects the route with the least sum. For example, Figure 3 has three routes from the source S to the destination D; route X has the sum of 17 (i.e., 6 + 4 + 3 + 4 = 17); route Y has the sum of 14 (i.e., 2 + 2 + 3 + 2 + 2 + 3 = 14); and route Z has the sum of 16 (i.e., 5 + 3 + 3 + 2 + 3 = 16). Therefore, route Y is selected and used as the route between source S and destination S.

The minimum number of hops scheme is similar to the shortest path scheme, however, instead of using the least sum as a routing method, it selects the route with the minimum number of hops.

Considering Figure 3 again, route X has 3 intermediate nodes (B, F, I ) from the source S to the destination D; route Y has five intermediate nodes (A, E, H, J, L) from the source S to the destination D; and route Z has four intermediate nodes (C, G, K, M) from the source S to the destination D.

Therefore, route X is selected and used as the route between source S and destination S.

SIMULATION MODEL

The following configuration was used in a GloMoSim simulator (UCLA, 2001). IEEE 802.11 MAC protocol with distributed coordination function (DCF) (Nadeem & Agrawala, 2004; Buttyan & Hubaux 2003) is assumed as the MAC media access control layer. The simulation study is conducted for networks of 100, 200, and 300 mobile hosts; each of them is migrating within a range of 300x300 and 500x500 meters. The radio transmission range is assumed to be 120 meters; and the channel capacity is 2 Mbps. The random waypoint model is used in the simulation runs.

In this model, a node selects a destination randomly within the roaming area and moves towards that destination at a predefined speed. Once the node arrives at the destination, it pauses at the current position for five seconds. The node then selects another destination randomly and moves towards it, pausing there for five seconds, and so on. Note that the pause time is not considered in

Figure 3. Example network

Route X: (S, B, F, I, D)
Route Y: (S, A, E, H, J, L, D)
Route Z: (S, C, G, K, M, D)
FSR Evaluation Using the Suboptimal Operational Values

Figure 4. Packet delivery ratio of shortest path versus minimum number of hops in case of old parameters

Figure 5. Packet delivery ratio of shortest path versus minimum number of hops in case of new parameters
computation of node speed. The size of data payload is 512 bytes. Each simulation was executed for 600 seconds of simulation time. Multiple runs with different seed numbers were conducted for each scenario; and measurements were averaged over those runs.

SIMULATION RESULTS

The two schemes were evaluated by comparing the performance with the new scheme that uses the minimum number of hops and the second scheme, which uses the shortest path, taking into account the old operational parameter values and the new values. The new values for FSR protocols where explored and proposed in previous work by El-Gamal, El-Adb and, Khader (2003).

Minimum Number of Hops by Means of Old Parameters Values

Figure 4 shows the packet delivery ratio versus the mobility speed of each scheme using the old parameter values of FSR.

As it is clear from the figure that the shortest path scheme does not perform when the mobility speed increases. This is because the shortest path method is not appropriate when the mobility speed increases. In the second scheme, the minimum number of hops performs well when the mobility increases, however in the very low mobility the new scheme performs at almost the same level of the one using the shortest path.

Minimum Number of Hops by Means of New Parameters Values

Figure 5 reports the packet delivery ratio versus the mobility speed of each scheme using our new parameters values of FSR, introduced previously Khader (2003). We can easily recognize, when viewing Figure 5, that the results are similar to the previous experiment, however, the new used parameters values have a much better performance than the old parameter values.

CONCLUSION

Wireless ad-hoc networks can be deployed in areas where a wired network infrastructure may be undesirable or unavailable. What makes FSR perform well under large network sizes and high mobility rates is that FSR generates accurate routing decisions by taking advantage of the global network information. However, this information is disseminated in a method to reduce overhead control traffic caused by traditional flooding. Instead, it exchanges information about closer nodes more frequently than it does about nodes farther away. So, each node gets accurate information about neighbors, and the detail and accuracy of information decreases as the distance from the node increases. A performed evaluation of different styles of FSR protocols was conducted in this article. FSR was analyzed in diverse network scenarios to assess its relative strength and weakness. The results gave meaningful indications to protocol designers in this area. A novel routing selection criteria that considers the minimum number of hops was introduced in this article. This scheme was applied to the FSR protocol. Simulation results indicate that the new scheme performs much better than the shortest path, especially when the mobility rate is high and the network size is large.

FUTURE WORK

Researches are designing MANET protocols, comparing and improving existing MANET protocols. However, it is not clear that any particular protocol is the best for all scenarios; each protocol has definite advantages and disadvantages and is well suited for certain situations.
Future work can test performance of other routing protocols, such as DSDV, DSR, and hybrid ad-hoc routing approaches against the FSR protocol. In order to optimize the use of constrained resources in an ad-hoc network, mobility prediction and battery power conservation techniques can be developed and experimented to test the effect of these ad-hoc routing protocols in a real application.

REFERENCES


*This work was previously published in Int. Journal of Information Technology and Web Engineering, Vol 2, Issue 1, edited by G. Alkhatib and D. Rine, pp. 47-56, copyright 2007 by IGI Publishing (an imprint of IGI Global).*