Survey of Stability Based Routing Protocols in Mobile Ad-hoc Networks

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***Abstract*—A Mobile Ad hoc Network (MANET) is an autonomous collection of mobile nodes forming a dynamic network and communicating over wireless links. With the rising popularity of MANETs and demand of users, Quality of Service (QoS) has become major issue to be discussed. One of the most important criteria determining the assurance of QoS support in such networks is link stability. Due to the mobility of the nodes, link failures occur frequently and the route involving those links would no longer work. Stability therefore is an important element to be considered in the design of routing protocols. Stable paths, also called the long-lived paths, can thus be discovered and used to reduce the overhead resulted from route maintenance in ad hoc networks. A number of stability based routing protocols have been proposed in the literature. This paper presents the overview of the different approaches used to find the stable paths and a survey of some of the stability based routing protocols along with their strengths and weaknesses. Finally, a comparative study of all routing protocols is provided.**

Keywords: Mobile Ad hoc Network (MANET), Routing Protocol, Link Stability, Signal Strength, Residual Lifetime

I. INTRODUCTION

A Mobile Ad-hoc Network (MANET) is a collection of mobile nodes that form a dynamic infrastructure-less communication network wherever it is required. The nodes in the network not only act as hosts but also as routers that discover and maintain routes to other nodes in the network. Mobile Ad Hoc Networks (MANETs) are becoming the crucial medium of present day communication owing to their self-configuring, easily deployable and infrastructure-less nature. These networks are particularly suitable for emergency situations like warfare, floods and other disasters where infrastructure networks are impossible to operate. Since mobile nodes move in various directions causing existing links to break and the establishment of new routes, routing in such networks is a challenging task. Routing protocols used in these dynamic networks should be designed in such a way that they can adapt fast and efficiently to unexpected changes in network layout. Many routing protocols have been developed for mobile ad hoc networks such as Ad hoc On-demand Distance Vector Routing Protocol (AODV) [1] Destination–Sequenced Distance Vector (DSDV) protocol [2], Wireless Routing Protocol (WRP) [3], Temporally-Ordered Routing Algorithms (TORA) [4], Dynamic Source Routing Protocol (DSR) [5], Associativity Based Routing Protocol (ABR) [6], and Zone Routing Protocol (ZRP) [7], etc. These protocols tend to establish a path with least number of hops. Also, all these routing solutions only deal with the best-effort data traffic.

Currently a lot of applications have been developed for wireless networks, their practical implementation and use in the real world has been limited so far. Many of these applications such as real-time audio and video are sensitive to the Quality of Service (QoS). Hence focus has been shifted from best-effort service to the provision of better defined QoS in ad hoc networks. The most commonly employed QoS metrics [8] are link stability, link reliability, end-to-end delay, node buffer space, delay jitter, packet loss ratio etc. The parameter 'link stability' i.e. the predicted lifetime of a link is the most important criteria determining the assurance of QoS support. Node movements cause link breakages in MANETs. Thus instead of selecting weak links which may break soon and introduce maintenance overhead one can find path involving stable links i.e. having longer predicted lifetime. Stability or lifetime of a path is determined by the number of links that compose the path and the stability of each link in the path. Many stability based routing protocols have been proposed in the literature that enhance network stability. The primary goal of most stability based routing protocols is to find and select the paths that will last longer. These protocols reduce routing overhead and improve QoS performance as compared to the shortest path routing protocols. A few of the routing protocols along with their strengths and weaknesses have been discussed in the paper. Finally, a comparison of the routing protocols has been done so as to explore the future areas of work.

The rest of the paper is organized as follows. Section II presents overview of different approaches used to find the stable paths. In Section III, survey of some of the stability based routing protocols has been presented. In Section IV, a comparison of the routing protocols has been done. Finally, Section V concludes the paper and gives possible future directions in this research field.

II. OVERVIEW OF THE DIFFERENT APPROACHES TO FIND STABLE PATH

In a mobile environment, because of the mobility of mobile nodes in MANETs, the shortest path is not necessarily the best path. If the stability of a routing path is not considered, then wireless links may be easily broken. Link stability indicates how stable the link is and how long it can support communications between two nodes. Stability of links can be estimated using many parameters like-Signal Strength [15,17], hello packets or pilot signals [6, 11, 13], relative speed between two nodes forming the link (by Global Positioning System) [10, 12], Residual Lifetime [6, 10, 11, 12]. These different approaches or techniques have been discussed below:

The Global Positioning System (GPS) [9] is a very popular technique used to detect the exact position of the mobile nodes. Each node can calculate its position and a protocol is applied, which disseminates or requests the position for other nodes. There are routing protocols [10, 12] using the information obtained from the GPS. Many researches assume that GPS can be simply utilized in an open area environment. However, in the urban area, buildings, walls, and trees etc. may be there to form shields against the GPS signals. Moreover the use of GPS is greatly limited by shadow effect and multipath fading, and thus the GPS-aided routing protocols do not work well in such environment.

The Received Signal Strength (RSS) [15, 17] can be also taken as an index of link lifetime. In signal strength based approach, the receiving node captures the control packet and forwards it if and only if the packet signal strength is above a certain threshold otherwise discards the packet. This approach is easy and most efficient because it utilizes signal strength values from MAC layer to compute link stability. Since pilot signals are not exchanged periodically to compute link stability, it uses less control overhead. The received signal strength can be an accurate index to measure the link lifetime in the open area. However, in the urban area, a link may fail abruptly because of shadow effect, and the prediction error may thus increase.

In Hello Packet or Pilot Signal [6, 11, 13] based technique**,** each node periodically broadcasts a one-hop and ack-free hello packet to identify itself. By continuously receiving the hello packets, a node can verify the existence of its neighbours. Number of hello packet received by neighbour is used to determine the lifetime of the link. If a neighbouring node moves out of the radio coverage, the receiving of hello packets would terminate and therefore the node can recognize that a link has failed. When a link fails, the corresponding two nodes of the link record this link failure event on their lifetime records along with the lifetime of the failure link. The idea of this scheme is to establish routes over stationary nodes as possible to prevent frequent route failures. The link lifetime of all links to a stationary node tend to be longer and, in the contrast, the link lifetime of all the links to a moving node tend to be shorter. When a moving node becomes stationary, longer-lived links are emerging more likely. Thus if a link whose age is greater than the lifetime of these links being stored in the link lifetime record, then that link is considered to be reliable and stable.

Residual lifetime [6, 10, 11, 12] is also an efficient approach to find the stable route. In this approach, lifetime of the link is measured with the help of recent hello messages or relative velocity and direction of mobile nodes. This link lifetime is used to construct stable path. The residual lifetime of the path is the minimum link expiration time of node on that path and the path which has maximum link expiration time is selected as primary path. For n paths (π1, π2, ... πn) from source to destination, lifetime of a path is bounded by the lifetime of all the nodes along the path. When a node dies along a path we can say that the path does not exist any longer.

III. Survey of Stability Based Routing Protocols

Many of the stability based routing protocols have been proposed in the literature. A few of these routing protocols having different approaches for finding stable paths are surveyed in this section. For each protocol, the functionality and main features are described briefly.

A. Associativity Based Routing (ABR)

C-K. Toh [6] proposed Associativity Based Routing (ABR) protocol which is probably the first protocol in the class of stability based routing protocols for MANETs. It uses periodically sent pilot signals to determine the link stability. In this protocol, a metric called *associativity* is defined to determine the link stability. The protocol is based on the idea that nodes which have been stationary for a threshold period are less likely to move away. It assumes that after the threshold period, nodes move with similar speeds in similar direction and and thus tend to stay together for a longer period of time. The ABR protocol consists of three phases, namely route discovery phase, route re-construction phase and route deletion phase. Initially when a source node desires a route, the route discovery phase is invoked. The route discovery phase consists of a broadcast query which is broadcasted by the source. The intermediate node appends its address/identifier at the intermediate node ID field of the query packet and broadcasts it to its neighbours (if it has any). The associativity ticks with its neighbours will also be appended, along with its relaying load, link propagation delay and the hop count. The destination, at an appropriate time after receiving the first broadcast packet, knows all the possible routes and their qualities. It can then select the best route and send a REPLY packet back to the source, via the route selected. However, if the overall degree of association stability of two or more routes are same, then the route with the minimum hops will be chosen. If multiple routes have the same minimum-hop count, then one of the routes is arbitrarily selected. When the link of an established route changes due to source, destination, intermediate nodes or mobile hosts (MH's) migration, the route re-construction phase is invoked. When source no longer desires the route, the route deletion phase is initiated.

Simulation results show that the property of having long-lived routes enhances the communication throughput considerably and the capability of the routing protocol to quickly locate an alternative shorter route enhances the response time to link changes. One of the problems with ABR is the choice of the threshold value. This value may vary depending on the mobility patterns.

B. *Flow Oriented Routing Protocol (FORP)*

W. Su *et al*. [10] suggested an approach based on the availability of GPS measurements. The Flow Oriented Routing Protocol (FORP) follows an approach of calculating a link's residual lifetime from a mobile's own speed and the speed and distance of the connected party. However, this method strongly depends on the assumption of a free space propagation model and on having GPS equipment to estimate the expiration time of the link between two adjacent mobile nodes. When the sender has a flow to send, it constructs a route to the destination on demand and injects the flow. The destination predicts the change in topology ahead of time and determines on the route, the Route Expiration Time (RET) can also be predicted. Based on this prediction, routes are reconstructed before they expire. Simulation results indicate that with mobility prediction enhancements, more data packets were delivered to destinations while the control packets were utilized more efficiently. Since GPS may not work properly in certain situations (e.g., indoor, fading, etc.), the link expiration time for a particular link may not always be accurately predicted.

C. *Stability and Hop-Count Based Approach for Route Computation (SHARC)*

K.N. Sridhar and M. C. Chan [11] propose Stability and Hop-Count based Approach for Route Computation (SHARC) in MANET that considers both the hop-count and stability metrics. DSR (which is hop-count based) is used as the basic routing protocol and the residual link lifetime is calculated using a simple histogram based estimator. The protocol finds the most stable route among the set of shortest hop routes. In order to distribute stability information, the route-request packet of DSR is changed to carry residual lifetime information. Every node stores the link duration values of its neighbours. By collecting this information and aggregating them into bins of 10s, each node maintains an estimate of the residual lifetime distribution using the samples collected so far. When the intermediate node receives the route request packet, it includes the residual lifetime value in the packet. The path structure is changed by associating every path with an additional stability value. This stability value of the path is the sum of all the residual lifetime divided by the length of the path. The cache structure is also enhanced to maintain the stability metric along with the addresses of intermediate nodes. The route selection mechanism is incorporated in all the nodes so as to be compatible with DSR routing mechanism.

Simulation results show that it performs better than purely stability based and purely hop count based algorithms in terms of throughput of long-lived flows and response time of short data transfers.

D. *Stable, Weight-based, On-demand Routing Protocol (SWORP)*

N-C. Wang *et al*. [12] propose a stable, weight-based, on-demand routing protocol (SWORP). The protocol uses the weight-based route strategy to select a stable route in order to enhance system performance. The weight of a route is decided by three factors: Route Expiration Time (RET), Error Count (EC) and Hop Count (HC) where RET is the minimum link expiration time (LET) for a feasible path where LET represents the duration of time for a packet to travel between two nodes, EC captures the number of link failures caused by a mobile node and HC is the number of hops for a feasible path. All the nodes are assumed to have their clocks synchronized using the Global Positioning System (GPS) clock, so that two adjacent nodes may predict the RET. Route discovery usually first finds multiple routes from the source node to the destination node with the different weight values. Then the destination selects the path with the largest weight value for routing. The simulation results show that the protocol selects a stable routing path and reduces the routing overhead and packet loss. While the proposed scheme may fight against link breaks due to mobility, but it does not consider link breaks due to the draining node energy that must also be accounted for when computing weights for stable routing.

E. *Stable and Delay Constraints Routing (SDCR)*

P. Yang and B. Huang [13] proposed another Stable and Delay Constraints Routing (SDCR) protocol which extends the DSR protocol and adopts source routing mechanism. In the route discovery phase, the protocol finds paths that meets delay requirement with great link stability factor. In the route maintenance phase, it effectively keeps monitoring the network topology changes through delay prediction and performed rerouting in time. The SDCR includes two major phase namely routing discovery and routing maintenance. In the routing discovery process the SDCR find feasible paths between source and destination node while in the routing maintenance phase SDCR monitors and predicts the future information about availability of link. Link stability factor and delay constraints are taken into consideration in their route discovery and maintenance phases. In the SDCR, the RREQ of original DSR is extended and added to new fields namely delay constraint, time stamp and link stability factor coupled with the location and velocity of nodes. In the routing cache, link stability factor and delay constraint are added. In the route maintenance phase, SDCR effectively keeps monitoring network topology changes by delay prediction and performs rerouting before the paths become unavailable. The SDCR significantly improves routing performance with these route discovery and maintenance mechanisms operating together and it also guarantees QoS request.

The performance of SDCR was compared with the original DSR and DQR [14] and the results show that SDCR outperforms than other two protocols. It reduces the packet losses and guarantees the reliable and rapid transmission. Its advantage is remarkable in high mobility. However, the extra computation for link stability factor in SDCR causes the slightly higher delay.

F. Route Stability based QoS Routing (RSQR)

Sarma and Nandi [15] proposed an on-demand AODV based Route Stability based QoS Routing (RSQR) protocol in MANETs. The protocol uses route stability along with throughput and delay. The routing algorithm forwards the route request through all the feasible paths from source to destination avoiding very weak links during its forwarding process. To compute a QoS route to a destination *D*, the source *S* generates a QoS Route Request (QRREQ) packet with values for B_{min} and D_{max} from the application's requirements. An intermediate node *i*, after receiving a QRREQ packet, checks the signal strength of QRREQ and simply drops the packet if its strength is very poor (less than a threshold).Otherwise, node *i* performs the delay and throughput admission control. If the QRREQ passes both delay and throughput admission control, node *i* makes a temporary reverse route entry in *RT* (*Routing Table*). After the processing, some fields in QRREQ are modified such that the modified values contain the route stability and end-to-end delay of the explored route up to the current node. When the destination node receives the first route request, it waits for a fixed small time interval, called Route Reply Latency (RRL), for more route request packets to arrive. The destination would then select, among all feasible paths, the one with the highest route stability value to reply to the source. Therefore, the use of route stability during route discovery yields the route that last longer and consequently increases the throughput while reducing the delay and routing overhead.

The performance of the protocol was compared with AQOR [16] under different mobility and network load conditions and the results show that the RSQR protocol performs better than AQOR in terms of packet delivery ratio, routing overhead, end-to-end delay especially in high mobility conditions with marginal decrease in traffic admission ratio.

The drawback of the protocol is that it does not consider the issues like detection of potential link breaks or QoS violations before actual link breaks or QoS violation takes place. This results in performance degradation as the mobility of the nodes increases.

G. Routing Based on Multiple Constraints

D.S. Thenmozhi and M. Rajaram [17] presented multi constraint based routing technique to incorporate Quality of Service based applications in MANETs. AODV routing protocol is extended to perform path finding that meets the application stipulated bandwidth requirement and link stability metrics. During the route discovery process, the source broadcasts Route Request (RREQ) packet. It includes application's channel bandwidth requirement (BWflow) computed by the source, link stability indicator (Pr-fail, Tr) pair where Pr-fail represents the expected route break probability and Tr represents the expected time duration of the flow. Another field Pa is also evaluated and added which represents the accumulated survival probability of all the selected links from the source node to the current node. Then the node rebroadcasts the route request. Recording the sequence of hops in RREQ packet enables to determine the lower bound of the contention count of the complete route and also it can be used to eliminate circular routes.

When the intended destination receives a route request, it receives the full route and sends a route reply (RREP) back to the source along the same route. The destination may get different routes. The destination gives the preference to the route having all links possessing positive indication for the link stability. Simulation results prove that this approach of routing algorithm improves QoS performance in a significant way.

IV. COMPARISON OF STABILITY BASED ROUTING PROTOCOLS

The comparison of the above discussed routing protocols is shown in Table 1 below.

TABLE 1 COMPARISON OF STABILITY BASED ROUTING PROTOCOLS

Protocol	Base Protocol	Approach/Metric used to Find Stable Routes	Stability Parameter	Disadvantage	Mobility Support
Associativity Based Routing (ABR) [6]	DSR	Hello packet, Residual Lifetime	Association of neighbouring nodes	Assume that older links are more stable which is not always correct. Choice of threshold value is difficult as it varies depending on the mobility pattern.	Moderate
Flow Oriented Routing Protocol (FORP) [10]	_	GPS, Residual lifetime	Link expiration time calculated with the help of free space propagation model and GPS.	Strongly depends on the assumption of a free space propagation model and on having GPS equipment mobile node.	Moderate
Stability and Hop-Count based Approach for Route Computation (SHARC) [11]	DSR	Hello packet, Residual lifetime	Hop count, stability of a path calculated using a simple histogram based estimator	Path stability depends on average value of residual lifetime which is not efficient	Performs well in both low and high mobility
Stable, Weight-Based, On-demand Routing Protocol (SWORP) [12]		GPS, Residual lifetime	Weight function which includes link expiration time, error count and hop count	Depends on GPS which is not efficient in MANETs due to limited resources.	Moderate
Stable and Delay Constraints Routing (SDCR) [13]	DSR	Hello packet	Link stability factor with delay constraint	Extra overhead in DSR RREQ field	High mobility
Route Stability based QoS Routing (RSQR) [15]	AODV	Signal strength based	Signal strength	Complex calculation at each node	Both low and high mobility
Routing Strategy based on multiple constraints [17]	AODV	Signal strength based	Time count of the neighbouring nodes	Extra control overhead	Both low and high mobility

V. CONCLUSION

In this paper, the basic approaches and a brief description of a few of the stability based routing protocols in MANETs has been presented. The protocols are selected in such a way so as to highlight the different approaches to stable path routing in MANETs, while simultaneously covering most of the important advances in the field. A comparison of all the routing protocols has been provided and the strengths and drawbacks of these protocols have also been summarized so as to explore the future areas of research. However, routing

protocols that are based only on link stability have either been shown to exhibit little improvement over hop-count based algorithm or the improvement comes when link lifetime can be accurately predicted. A crucial issue with stability based routing protocols is that much longer routes can be obtained as compared to hop-count based routing. Thus these protocols need to be further extended in the areas of multipath routing, load balancing, resource reservation, energy efficiency, security and cross layer design to improve their performance

REFERENCES

[1] C.E. Perkins, E.M. Royer and S.R. Das, "Ad hoc on-demand distance vector(AODV) routing protocol," IETF Draft, RFC 3561, February 2003.

[2] C. Perkins and P. Bhagwat, "Highly dynamic destination-sequenced distance vector routing (DSDV) for mobile computers," in *Proceedings of ACM SIGCOMM'94*, pp. 234-244, 1994.

[3] S. Murthy and J. J. Garcia-Luna-Aceves, "An efficient routing protocol for wireless networks,"*ACM Mobile Networks Applications, J. Special Issue on Routing in Mobile Communication Networks*, 1996.

[4] V.D. Park and M. S. Corson, "A Highly adaptive distributed routing algorithm for mobile wireless networks," in *Proceedings of IEEE INFOCOM'97*, pp. 1405-1413.

[5] D.B. Johnson, D.A. Maltz, and Y. Hu, "The dynamic source routing protocol for mobile ad hoc networks (DSR)," IETF Draft, July 2004.

[6] C-K. Toh, "Associativity-Based Routing for Ad Hoc Mobile Networks," *International Journal on Wireless Personal Communications*, vol. 4 no. 2, pp. 103-139, March 1997.

[7] Z.J. Haas and M. R. Pearlman, "The performance of query control schemes for the zone routing protocol," in *Proceedings of. IEEE Symp. Computers and Communication*, 1998.

[8] L. Hanzo and R. Tafazolli, "A Survey of QoS Routing Solutions for Mobile Ad Hoc Networks," *IEEE Communications Surveys*, vol. 9, no. 2, 2007.

[9] C-Y. Hsu, J.-L. C. Wu and S-T. Wang, "Finding Stable Routes in Mobile Ad hoc Networks," in *Proceedings of the 18th International Conference on Advanced Information Networking and Application*, *(AINA'04*), vol. 2, pp. 424-427, March 2004.

[10] W. Su, S. Lee, and M. Gerla, "Mobility Prediction and Routing in Ad Hoc Wireless Networks," *International Journal of Network Management, Wiley & Sons*, vol.11, no.1, pp: 3–30, 2001.

[11] K. N. Sridhar, & M.C. Chan, "Stability and Hop-count based approach for route computation in MANET," in *Proceedings of 14th International conference on computer communications and networks (ICCCN'05)*, San Diego, USA.

[12] N-C. Wang, Y-F. Huang and J-C. Chen, "A stable weight-based on- demand routing protocol for mobile ad hoc networks," *International Journal of Information Sciences*, vol.177, no. 24, pp. 5522–5537, Dec. 2007.

[13] P. Yang and B. Huang, "QoS Routing Protocol Based on Link Stability with Dynamic Delay Prediction in MANET," IEEE, Pacific-Asia Workshop on Computational Intelligence and Industrial Application, vol.1, pp. 515-518, 2008.
[14] M. Hashem and M. Hamdy, "Modified distributed quality-of-service routing in wireless mobile Ad-hoc networks," in Proceedings of MELECON 2002, pp. 368-378, 2002.
[15] N. Sarma and S. Nandi, "Route Stability Based QoS Routing in Mobile Ad Hoc Networks," in Wireless Personal Multimedia Communications (WPMC 2007), pp. 203-224, 2007.
[16] Q. Xue and A. Ganz, " Ad hoc QoS on-demand routing (AQOR) in mobile ad hoc networks", *Journal of Parallel and Distributed Computing*, vol. 63, no. 2, pp.154–165.
[17] D.S. Thenmozhi, M. Rajaram, "Contention Aware Multi-hop Stable Routing to Provide Quality of Service Based on Multiple Constraints in Mobile Ad Hoc Networks,**"** European Journal of Scientific Research, vol.48, no.4, pp.567-579, 2011.