ISSN No. 0976-5697
Volume 1, No. 4, Nov-Dec 2010
International Journal of Advanced Research in Computer Science
RESEARCH PAPER
Available Online at www.ijarcs.info

Enhanced Two-Way Directional Routing for MANETs

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Abstract: Mobile ad hoc networks poses a problem called asymmetry in the sense imbalance in the property of the network like connectivity, routing performance and packet loss. Asymmetry arises due to the formation of unidirectional links. The bidirectional wireless links in the MANET tends to unidirectional because of varying transmission power in the devices, non-uniform environmental noise, and other signal propagation phenomenon's. First we present a study of asymmetric links on network connectivity and routing performance. Then we present a framework called two-way routing algorithm that provides a bidirectional abstraction of the asymmetric network to routing protocols. Two-way routing algorithm works by maintaining multi-hop reverse routes for unidirectional links and provides three new abilities: improved connectivity by taking advantage of the unidirectional links, reverse route forwarding of control packets to enable off-the-shelf routing protocols, and detection packet loss on unidirectional links. Finally extensive simulations of AODV layered on two-way routing algorithm show that packet delivery increases substantially in asymmetric networks compared to regular AODV, which only routes on bidirectional links.

Keywords: Mobile ad hoc networks, AODV, DSR, asymetry, bidirectional networks, uni directional link, blacklist.

I. INTRODUCTION

The basic problems in MANETs are asymmetry. Asymmetry arises due to formation of unidirectional links. These are formed by varying transmission power in the devices that is transceiver capabilities of the nodes, noise sources near devices and environment condition. Recent real-world deployments of ad hoc networks designate a considerable presence of asymmetry in the network. Ganesan et al[1] report that up to 15% of the links in their deployment are unidirectional and no exterior radio sources exist. Likewise, De Couto et al.[2] report that up to 30% of links have asymmetric delivery rate in an indoor deployment of wireless odes. Lastly, Zhao et al. locate that more than 10% of links have considerable asymmetry in their packet delivery rates.

In asymmetric networks, two nodes may be connected through one or more unidirectional links have need of an additional path in the reverse direction.Otherwise, they may be connected only one direction with no route in the reverse direction. Ignoring the unidirectional links, and routing only on the bidirectional links. Typical routing protocols frequently fail to function or function ineffectually in an asymmetric network. Some routing protocols (e.g., TORA proposed by S. Nesargi and R. Prakash [3] were mainly proposed for bidirectional networks and hence break down in the presence of unidirectional links. Some other routing protocols (e.g., AODV proposed by C.E.Perkins. et. al [4] function by avoiding the unidirectional links and routing data only along the bidirectional links. Some other protocols (e.g., DSR proposed by Johnson, D.B. and D. A. Maltz[5] have the ability to incorporate unidirectional links in their routes through expensive mechanisms that give considerably decreased throughput in asymmetric networks.

In our two-way routing approach, inclusion of unidirectional links with short reverse paths significantly increases the stability of the routes and leads to better connectivity overall, without significant overhead. Most of the previous work on this problem concentrated on developing routing protocols or techniques such as tunneling S. Nesargi and R. Prakash [3] to allow the use of unidirectional links. But the resulting performance advantages and tradeoffs are not well understood. Our approach in this work is to study the influence of unidirectional links on routing performance. There is evidence in the literature that routing protocols finding unidirectional paths (paths with one or more unidirectional links) are subject to higher overheads than those finding only bidirectional paths.

Two-way routing approach comes up with discovering and maintaining the reverse paths for unidirectional links. This approach has an algorithm called reverse distributed bellman-ford algorithm which efficiently searches for reverse routes in a bounded search region around each node. It improves connectivity between nodes by finding new or better routes through unidirectional links. Alos, it gives reverse-route forwarding for unidirectional links which makes them appear as bidirectional links.

II. RELATED WORKS

Majority of the protocols developed for multihop wireless networks assume bidirectional links. But for correct operation in the presence of unidirectional links, they require additional mechanisms to eliminate unidirectional links from route computations.

There is evidence in the literature that routing protocols finding unidirectional paths (paths with one or more unidirectional links) are subject to higher overheads than those finding only bidirectional paths. For distance-vector protocols [5] and [6] independently make this observation. AODV is an on-demand routing protocol. It is loosely based on the distance-vector concept. In on-demand protocols, nodes obtain routes on an as needed basis via a route discovery procedure. Route discovery works as follows. Whenever a traffic source needs a route to a destination, it initiates a route discovery by flooding a route request (RREQ) for the destination in the network and then waits for a route reply (RREP). When an intermediate node receives the first copy of a RREQ packet, it sets up a reverse path to the source using the previous hop of the RREQ as the next hop on the reverse path. In addition, if there is a valid route available for the destination, it unicasts a RREP back to the source via the reverse path; otherwise, it re-broadcasts the RREQ packet. Duplicate copies of the RREQ are immediately discarded upon reception at every node. The destination on receiving the first copy of a RREQ packet forms a reverse path in the same way as the intermediate nodes; it also unicasts a RREP back to the source along the reverse path. As the RREP proceeds towards the source, it establishes a forward path to the destination at each hop. AODV also includes mechanisms for erasing broken routes following a link failure, and for expiring old and unused routes.

In the area of on-demand protocols for ad hoc networks also, similar observation can be made. DSR [7] requires two route discoveries to discover unidirectional paths — one from the source and the other from the destination, as opposed to a single route discovery to find bidirectional paths. Although pure link-state protocols such as OSPF may be able to support unidirectional links with least additional overhead, they already have very high overheads compared to other competing protocols for ad hoc networks [8].

The above route discovery procedure requires bidirectional links for correct operation. Only then RREP can traverse back to the source along a reverse path and form a forward path to the destination at the source. Many common MAC protocols check link bidirectionality only for unicast transmissions. The authors in [11][12][13][14], evaluate the benefit from utilizing unidirectional links for routing, as opposed to using only bidirectional links. The evaluations are based on three transmit power assignment models that reflect some realistic network scenarios with unidirectional links.

The author in [15] proposed a theoretical framework of a novel routing protocol called ORPUL (On demand Routing Protocol with Unidirectional Link support) for mobile ad hoc networks together with the changes needed to be accommodated in the IEEE 802.11 MAC layer protocol.

III. TECHNIQUES FOR HANDLING UNIDIRECTIONAL LINKS IN AODV

The three techniques have been described to improve this problem. The first two techniques blacklisting and hello are the known techniques. The third technique two-way routing approach is the proposed technique. Blacklisting this technique reactively eliminates unidirectional links. Nodes discover unidirectional links and add them to the black list whenever an RREP sent along the reverse path fails to return an expected acknowledgment. Once added, a unidirectional link is retained in the black list for a short lifetime. Nodes do not forward RREPs to any node in their black list.

The black-list mechanism enables AODV to approximately identify unidirectional links and avoid them. Marina and Das[9] propose an alternative technique called reverse path search to avoid unidirectional links in AODV. While the reverse path search is more efficient than the black-list technique employed by AODV, it does not enable routing protocols to use routes with unidirectional links. This technique is simple and has little overhead when there are few unidirectional links. However, when there are many unidirectional links, this approach is inefficient because these links are blacklisted iteratively one at a time.

Hello is the technique, in the contrast to the blacklisting technique. This technique proactively eliminates unidirectional links by using periodic one-hop hello packets. This technique is proposed by Clausen et al. [10] used to record only bidirectional links. In each hello packet, a node includes all nodes from which it can hear Hellos (i.e., its set of neighbors). If a node does not find itself in the hello packet from another node, it marks the link from that node as unidirectional. Just as in the blacklisting technique, every node ignores RREQ packets that come via such unidirectional links.

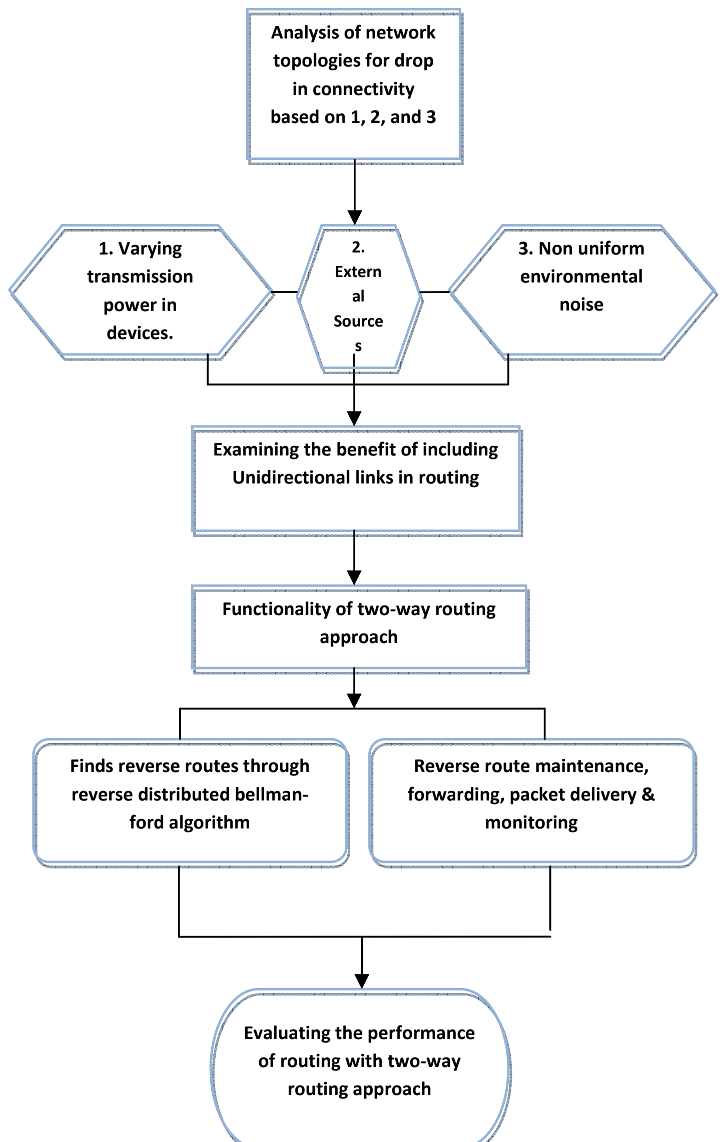

Figure 1. Handling unidirectional links in AODV

A. Two-Way Routing Approach

Two-way routing approach provides a bidirectional abstraction of the underlying unidirectional links. The mainl feature of two-way routing approach is an adaptive and scalable technique to maintain reverse routes for unidirectional links. It provides the necessary functionality to enable routing protocols to operate on asymmetric networks. Two-way routing approach finds reverse routes through reverse distributed bellman-ford algorithm.

Distributed bellman–ford algorithm is a well-known distance-vector algorithm to obtain the shortest routes between pairs of nodes in a bidirectional network. In this algorithm, each node broadcasts its currently known distances to other nodes in the network to its neighbors. In the case of reverse distributed bellman-ford algorithm, each node aims to find the shortest distance from other nodes to itself rather than from itself to other nodes.

B. Reverse Distributed Bellman-Ford Algorithm

The topology of a network is a directed graph, D= (V, E), where V is the set of nodes and E is the set of links in the network. A link A → B exists between two nodes A and B if B is within the transmission range of A. A link A → B Є E is bidirectional if B → A Є E and unidirectional if B → A not Є E. The reverse route of a link A → B is the shortest directed path from B to A, and the length of this shortest path is the reverse route length of the link.

Distributed bellman–ford algorithm is a well-known distance-vector algorithm to find the shortest routes between pairs of nodes in a bidirectional network. This algorithm has some benefits because it works asynchronously and is guaranteed to converge eventually if the network is not partitioned and remains stable for sufficient time. In this algorithm, each node B broadcasts its currently known distances to other nodes in the network to its neighbors. When a node A receives this distance-vector message from one of its neighbors, it recalculates its minimum distances to other nodes as follows: If the current known shortest distance from A to another node C is more than one hop longer than the distance advertised by B to C, then A discovers a new shortest path to C through B. But the above algorithm fails in the presence of unidirectional links. A would never receive the distance-vector message from B and thus will never be able to discover the shortest hop path to C through B.

Two-way routing approach finds reverse routes through a modified version of the above algorithm called the reverse distributed bellman–ford algorithm. This algorithm works by reversing the direction of route discovery. i.e each node wants to find the shortest distance from other nodes to itself rather than from itself to other nodes. In the previous example, node B tries to learn the shortest path through which other nodes can reach it. B achieves this when it hears A's reverse-distancevector broadcast saying that C can reach A in hops; B discovers that C can reach B through A in n hops since A → B. If, at B, the previous known route from C is longer than n+ 1 hop, B can now record the new n+1 hop route from C. Furthermore, if there is a unidirectional link, then C can learn about this new reverse route to B from B's next reverse-distance- vector broadcast. Each entry in the distance vector includes two values: the length of the shortest route from a node and the address of the first hop in the shortest route from that node.

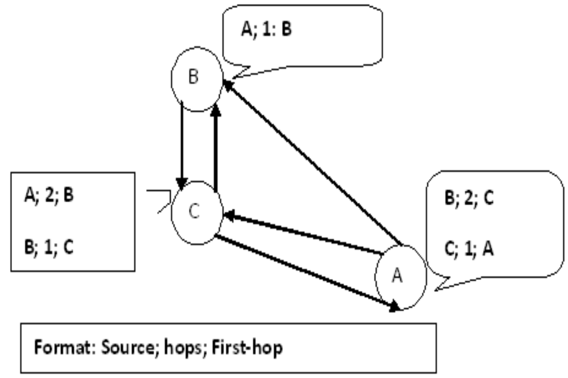

Figure 2. Reverse Distributed Bellman-Ford algorithm

Figure 2 illustrates how distance vectors are propagated in reverse distributed bellman–ford algorithm, enabling nodes to discover reverse routes for unidirectional links. In this example, node B discovers the reverse route B → C → A of unidirectional link A → B.

Step 1: Initially 'B' learns about 'A' (A→B), from the first message received from 'A'. But B does not yet know the reverse route to A.

Step 2: In the second update, 'B' broadcasts a distance vector message, which indicates to 'C' that 'A' can reach 'B' in one hop.

Step 3: In the third update, the message from 'C' carries two distance updates. Broadcasts: B→C and A→C.

Step 4: Finally, 'A' broadcasts the distance updates: C→A; B→A.

Step 5: When 'B' hears this distance update from 'A', the information cycle is complete, and 'B' discovers the two-hop reverse route to A. Also, B uses the first hop information in the distance-vector to compute the reverse route B→C→A.

Two-way routing approach uses the above algorithm for reverse route maintenance. The main services of this approach are reverse route forwarding, reliable packet delivery and helps the routing protocols top operate in the same manner on asymmetric networks. In this approach, the node finds the reverse routes for unidirectional links to reply back to the source node but the source doesn't know from which path the reply is coming. So source assumes all the links are bidirectional. Hence in this case no links are black listed.

On demand routing protocols require one modification to use bidrirectional routing approach. It needs to send the control packets such as the route reply packets (RREP) and the route error packets (RERR) through reverse route forwarding. The proposed two-way routing approach has been tested by extending AODV protocol. So, AODV derived some benefits using this approach. First, it is able to find additional routes not present in the bidirectional view of the network. Second, it does not require the blacklisting mechanism to identify and isolate unidirectional links. Lastly, it can reduce data forwarding delay by finding shorter routes including unidirectional links.

C. Experimantal Study

The simulation is implemented in network simulator. The simulation parameters are listed below in Table 1.

Table I Simulation Parameters for two-way routing approach

Number of nodes	100
Topology	1000*1000m
Traffic	CBR
Simulation time	300s
MAC protocol used	802.11
Routing protocol	AODV
Transmission Speed	220m
Bandwidth	2 MHz

The simulations presented are repeated for five different pause time values. The parameters used here is load, delay, overhead, packet delivery fraction and pause time. The simulation created with 100 nodes distributed uniformly at random in an area of 1000 m X 1000m. The nominal transmission range is 220m, bandwidth of 2 MHz and two-ray signal propagation model. We used constant bit rate generator (CBR) application to initate data transfers. We set up data transfers between 20 randomly chosen sources and destinations, where each data transfer started randomly between 50 s and 150 s periodically sent 200 data packets. We simulated at most 300 seconds. We used the usual random-waypoint model to simulate nodes in motion.

Then by varying the pause time, we calculate the performance of the network. Finally, the results show that when comparing AODV, two-way routing approach provides better performance. The results also show that inclusion of unidirectional links and their corresponding reverse routes improves the average connectivity provides better delivery ratio.

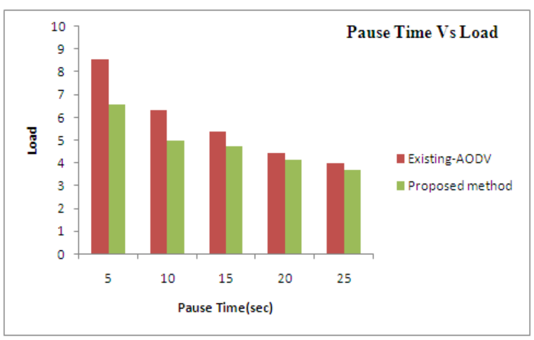

Figure 3. Pause Time Vs Load

AODV has less effective in identifying unidirectional links in the presence of mobility. Figure 3 shows the two-way routing approach has better performance than the existing AODV.

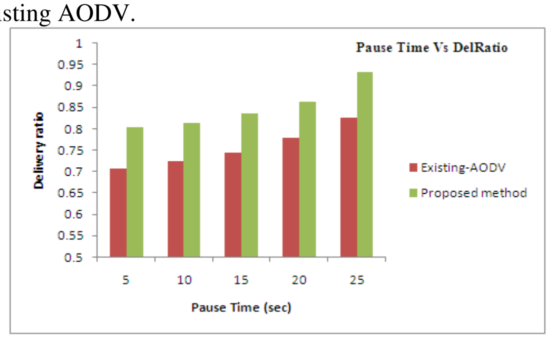

Figure 4. Pause Time Vs Packet Delivery Ratio

Figure 4 shows the packet delivery ratio for AODV and two-way routing approach. During asymmetry, the two-way routing approach discovering and maintaining reverse paths for unidirectional links. This approach obtains a significant increase in the number of reachable destinations in typical asymmetric networks compared to regular AODV, which only routes using bidirectional links. The result shows that the packet delivery ratio is increased in two-way routing approach when compared with AODV. From the graph, it can be noticed that the proposed two-way routing approach have better performance than the existing method AODV.

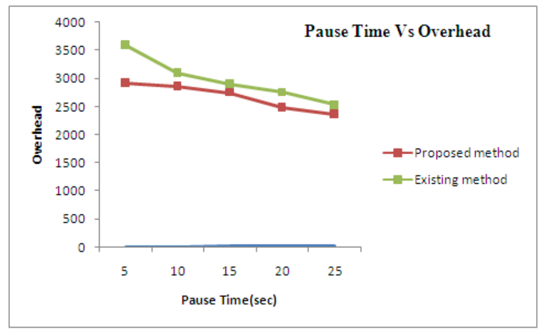

Figure 5. Pause Time Vs Overhead

The Figure 5 shows the overhead between AODV and the two-way routing approach. In AODV, additional route discovery is required when route break occurs. So, this approach handles the network asymmetry with high overhead. The total number of periodic packets sent during each trial is a constant in two-way routing approach. The average size of update packets increases in AODV when increases in network asymmetry. From the graph, it can be noticed that the two-way routing approach has less overhead than AODV.

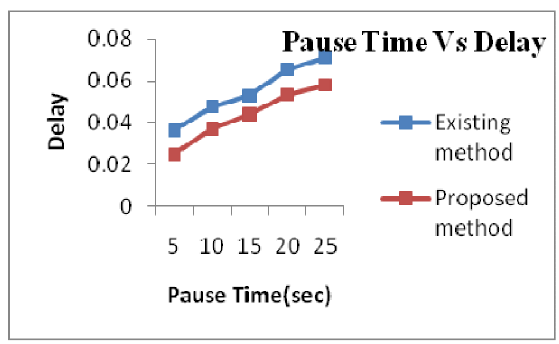

Figure 6. Pause time Vs Delay

In Figure 6 shows the delay between AODV and two-way routing approach. AODV induces more route discoveries during route breakages whereas two-way routing approach has better route finding ability by using unidirectional links. From the graph, it can be noticed that the two-way routing approach has less delay than the existing AODV.

IV. CONCLUSION

In this paper, we have developed a two-way routing approach for maintaining reverse routes for unidirectional link. Unidirectional links commonly occur in wireless ad hoc networks because of the differences in node transceiver capabilities or noise sources near devices or environmental conditions. Unidirectional links can benefit routing by providing improved network connectivity and shorter paths. The prior work indicates that routing over unidirectional links usually causes high overheads. The main observation from this study is that unidirectional links provide only incremental benefit.This work exhibits a dual advantage both in terms of immunity from unidirectional links and from mobility-induced link failures.

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