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RESEARCH ARTICLE

Abstraction for Asymmetric Mobile Ad Hoc Network Using Bidirectional Routing Protocols

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Abstract- Wireless links are often asymmetric due to heterogeneity in the transmission power of devices, non-uniform environmental noise, and other signal propagation phenomenon's. Unfortunately, routing protocols for mobile ad hoc networks typically work well only in bidirectional networks. This project first presents a simulation study quantifying the impact of asymmetric links on network connectivity and routing performance. It then presents a framework called BRA that provides a bidirectional abstraction of the asymmetric network to the routing protocols. BRA 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 detecting packet loss on unidirectional links. Extensive simulations of AODV layered on BRA shows that packet delivery increases substantially (two-fold in some instances) in asymmetric networks compared to regular AODV, which only routes on bidirectional links.

Index Terms- Ad hoc network; asymmetry; routing; unidirectional links

I. INTRODUCTION

A Mobile Adhoc network is an infrastructure less wireless network, in which nodes are autonomously self organized. In a mobile Adhoc network nodes move arbitrarily and causes frequent topology changes. In contrast to a stable linked wired network, wireless link capacity continuously varies because of the inputs from transmission power, receiver sensitivity, noise, fading and interference. Additionally because the nodes in the Mobile Adhoc network limited transmission ranges, some nodes cannot communicate directly with each other.

The presence of unidirectional links impacts the following in the network protocol stack 1) Data Link Layer, 2) Network Layer. At the data link layer, error and flow control protocols
Employ acknowledgments (ACKs) for the data packets exchanged between adjacent nodes. However, due to the unidirectional nature of the links, ACKs cannot travel back to the sender. As a result, the sender would time out and assume that the link between itself and the destination is down which would result in the link not being used for further communication. At the network layer, routing protocols like DSDV, AODV and TORA assume the links to be bidirectional. In these algorithms, information is exchanged between the neighbors to get information about the network topology. The unidirectional links causes Knowledge Asymmetry and Routing Asymmetry. Standard routing protocols often fails to function or function inefficiently in n asymmetric networks. Adaptive routing algorithms are able to adapt their routing information dynamically to current network topology. Distance_ Vector Routing Algorithms and Link State Algorithm discussed in ([2], [3]) have typical drawbacks when used in Mobile Adhoc networks. Frequent topology change will greatly increase control overhead and also routing information inconsistency appears and route lops are formed when used for dynamic networks.

The rest of this paper is organized as follows. Section II deals with Literature survey, where the previous routing algorithms are looked into. Section III deals with the new framework which is used to provide a bidirectional abstraction for the unidirectional links by finding out a reverse route where routing algorithms consider it as bidirectional link and transfers the control packets through it, and also deal with Reverse route maintenance protocol and Dynamic Bidirectional Routing. Section IV the implementation details are exposed. Section V, gives the conclusion and the scope for future work.

II. BACKGROUND AND RELATED WORK

One of the major challenges in designing routing protocols for the Mobile Adhoc networks stems from the fact that, to determine a packet route, a node needs to know at least the reachability information to its neighbors, and also in a Mobile Adhoc network, the network topology can change quite often. So, mobile Adhoc networks rely on special routing protocols that have to adapt to frequent topology changes.

A. Routing protocols and network asymmetry

Routing protocols are typically designed for efficient operation on bidirectional networks, efficient operation on bidirectional networks. Consequently, they either totally fail on asymmetric networks or operate with high overhead and low throughput. This section describes how the well-known routing protocols deal with network asymmetry.

1) Destination Sequenced Distance Vector Protocol

DSDV is the variant of distance vector routing suitable for mobile ad hoc networks. It addresses the drawbacks of poor loping properties in conventional distance vector routing. Each node maintains a routing table listing the "next hop" for each reachable destination as common in table-driven routing method. Each node advertises a sequence number which is recorded in the table. A higher sequence number is a more favorable route. Equal sequence number resorts to favoring lower metrics. Each node periodically broadcasts routing updates and the routing table along with a table to keep track of incremental updates. Periodic updates is of two kinds full Dump and Incremental updates [9]. DSDV Guarantees loop free path to each destination. The major drawback of this protocol is that periodic updates are regardless of the number of changes in the topology.

2) OLSR-Optimal Link State Routing Protocol

Normally when a node broadcast, all the neighbor nodes retransmit the message to other node and so on. So message overhead occurs. The key concept used here is the Multipoint Relays. MPRS is selected nodes which forward broadcast messages during the flooding process. In OLSR mechanism [3] nodes which are selected as MPRS alone broadcasts messages during flooding process. Thus number of control messages flow in the network is minimized. MPR nodes report only the links between itself and its MPR selector [3]. This information is used for route calculation. One of the optimization of OLSR routing is (1) Each node caches a new route it learns by any means (2) when node S finds a route it also finds other routes. The major advantages of this algorithm are: It provides optimal routes and suitable for large dense networks. The drawback of this protocol is the Message complexity which is $O(n^2)$ and is case of asymmetric network condition it works partially.

3) Dynamic source routing

DSR in an on demand protocol [9]. When a node S wants to send a packet node D but does not know the route to it, S initiates route discovery process. Assume Source node be S, it flood S Route Request (RREQ). Each node appends own identifier when forwarding RREQ.D does not broadcasts anymore because it is the destination node. Now D on receiving RREQ, sends a Route Reply (RREP). RREP is sent on the route obtained by reversing the route appended to receive RREQ.RREP includes route from S to D on which REQ was first received by D.S. on receiving RREP caches the route When S sends a data packet entire route is included in the packet header's if route is long packet header size will grow. In case of asymmetric condition, when asymmetry increases, this protocol gives a limited throughput.

4) AODV-Adhoc on Demand Distance Routing

AODV attempts to improve DSR. Routes are maintained only between nodes which need to communicate. When a node broadcasts a RREQ, it sets up a reverse path pointing towards the source. AODV assumes symmetric links. When destination route receives RREQ, it replies with RREP. RREP travels along reverse route set up when sequence number for the destination [15]. During link failure, a neighbor of node X is considered active for a routing table entry if the neighbor sent a packet with active-route-timeout-interval which was forwarded using that entry. Neighboring nodes periodically transmit hello packets. When the next hop link in the routing table entry breaks, all active neighbors are informed. The problem with AODV is that it avoids unidirectional links when routing.

5) ZRP-Zone Routing Protocol

Hybrid protocols such as ZRP [7] combine both proactive and on-demand routing methods. ZRP uses a proactive routing technique for nodes in a small region called zone around each node and an on-demand routing technique for inter-zone routing. Sinha et al. extend ZRP to handle unidirectional links by discovering reverse routes for links inside a zone. The resulting protocol has a higher control overhead as it needs to perform proactive routing in an extended zone of twice the earlier size. The following table shows the protocols and their reaction towards asymmetry.

TABLE1

COMPARISON of ROUTING PROTOCOLS TOWARDS ASYMMETRY

Protocols	Reaction towards asymmetry
LSR	Fails to react when topology
DVR	Fails to react when topology changes
DSDV	Fails in unidirectional links
DSR	Overhead when asymmetry increases, limited throughput
AODV	Avoids unidirectional links in its path
ZRP	Overhead when it has extended zones

III. BIDIRECTIONAL ROUTING FRAMEWORK

Bidirectional routing framework, is a framework that provides improved connectivity and routing performance in asymmetric networks. BRF seeks to improve the efficiency of off-the-shelf routing protocols typically designed for bidirectional networks to function efficiently on asymmetric networks. To that end, Bidirectional routing sublayer provides a bidirectional abstraction of the underlying unidirectional links. The central feature of BRF is an adaptive and scalable technique to maintain reverse routes for unidirectional links [2]. The rest of this section describes this central technique and explains how Bidirectional routing framework provides the necessary functionality to enable routing protocols to operate on asymmetric networks.

Distributed Bellman-Ford algorithm [2] is a well-known distance-vector algorithm to obtain the shortest routes between pairs of nodes in a bidirectional network. However, the above algorithm fails in the presence of unidirectional links. For instance, if but not, then 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. this protocol converges eventually if the network not partitioned and remains stable but fails in unidirectional links.

A. Reverse Distributed Bellman-Ford Algorithm

Finding revere routes for unidirectional links in an asymmetric network is non-trivial. While it may appear that a straightforward application of a standard distance-vector or link-state algorithm will provide the necessary reverse route information, several problems arise while applying them in an asymmetric network. For instance, the Distributed Bellman-Ford algorithm is a well-known distance-vector algorithm to obtain the shortest routes between pairs of nodes in a bidirectional network.

However, the above algorithm fails in the presence of unidirectional links. For instance, if but not, then 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. BRA finds reverse routes thorough a modified version of the above algorithm called the Reverse Distributed Bellman0-ford Algorithm (RDBFA).

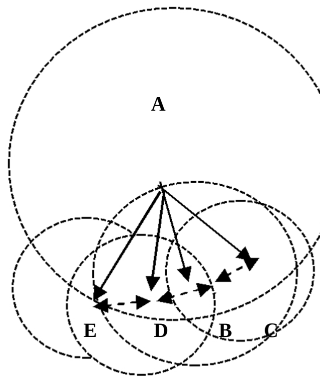

Fig.3.1 A unidirectional adhoc network A B is a unidirectional link, and B C A is its reverse route.

As the name implies, RDBFA operates by reversing the direction of route discovery; that is, each node aims 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 distance vector broadcast saying that C can reach A in hops; B discovers that C can reach B through A in hops. If, at B, the previous known route from C is longer than hops, B can now record the new hop route from C, 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. Including the first-hop information provides two benefits1) it enables a node to compute the reverse route to its in-neighbors based on local state even though the node cannot always compute the reverse route for other nodes' in neighbors due to the reversed direction of routing state. 2) it enables RDBFA to avoid routing loop and prevent the counting-to-infinity problem that affects classical distance vector algorithms; each node uses the first-hop information to detect routing loops and invalidates such routes from its computations.

At periodic intervals, each node broadcasts to all its out-neighbors a distance-vector message containing the shortest paths of its knowledge from other nodes to itself. A node B receiving a distance vector from one of its in-neighbors A extracts the following information:- The reverse route from B to A; B obtains this information from the entry for the route from B to A if the distance vector includes such an entry:- If the currently known route from node C to B is linger than the route from C to A followed then B sets the newly found shorter route from C to B through A. Fig. 3.2 illustrates the RDBFA algorithm with empty initial state at each node. First, B learns that from the first message it receives from A. However, B does not yet know the reverse route to A. In the second round, B broadcasts a distance- vector message, which indicates to C that A can reach B in one hop. The message from C in the third round carries two distance updates: B~>$_1$ C; A~>$_2$ C.

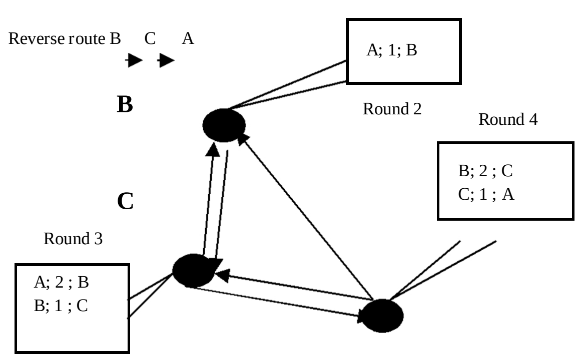

Fig. 3.2 Reverse Distributed Bellman-Ford algorithm

Finally, A; broadcasts the following distance updates: C~>$_1$ A; B~>$_2$ A. When B hears this distance update from A, the information cycle is complete, and B discovers the 2-hop reverse route to A. Additionally, B uses the first hop information in the distance- vector to compute the reverse route

B. Reverse Route Maintenance Protocol

Bidirectional routing abstraction uses the above distance-vector algorithm RDBFA for reverse route maintenance. Distance-vector algorithms are more efficient as they exchange an order of magnitude less information than link-state algorithms.

Bidirectional routing abstraction further reduces the overhead of reverse route maintenance by restricting the spread of distance vectors to a bounded region around each node called locality. The locality, defined by a radius, includes all nodes that A can reach in hops or fewer. For instance, locality radius 1 means the reverse routes found are all of one-hop length and only include bidirectional links. The radius also helps to control the maximum length of reverse routes discovered. Reverse route maintenance in Bidirectional routing abstraction is proactive. It proceeds through periodic exchanges of distance-vectors between nodes, once every update interval. A full distance vector update from node A as described earlier contains an entry for each node in whose locality A exists. But, unchanged entries are redundant across consecutive updates. BRA optimizes the protocol by letting each node broadcast only the changes in the route information rather than the complete information in each round.

C. Dynamic Bidirectional Routing

The performance and overhead of bidirectional routing hinges on the value of the locality radius, because nodes use the radius to prune the size of their updates. If a node A with radius has a path of length to node B, then node B need not store or broadcast any distance information about A. the analytical study suggests that a small value of 2 to 3 hops is a reasonable choice for the locality radius. However, the heavy-tailed nature of connectivity suggests that there may be occasions when reverse routes of even longer length might be required to obtain good connectivity. Moreover, using a single global value for the radius entails two high overheads: (a) the size of update packets typically increases polynomially with the radius (in a two dimensional topology), and (b) choosing a single global value for the locality radius in a dynamic manner would be quite expensive. Picking an independent value for each node keeps the overhead low because asymmetry that affects a local region is taken are of through local reverse route maintenance activity without a global Increase in the protocol overhead. DBR determines a suitable value for a node A's radius periodically based on two criterions namely.

1) Local Criterion

It takes into account the existence and length of reverse routes to the node's in –neighbors. If a node does not have revere routes to more than asymmetry-tolerance-threshold percentage of in neighbors, it chooses the max_ radius. Otherwise, it chooses a radius of the maximum reverse route length of A's in-neighbors. The tolerance threshold serves as a heuristic to ignore a few asymmetric links from consideration since there may be asymmetric links with no reverse routes in the network.

2) Global Criterion

DBR also takes into account the radius of other nodes in a node's locality in order to make sure that nodes help other nodes succeed in reverse route discovery. The radius of a node A must be at least for each node B with radius and path of length to A. this condition is necessary for B to obtain reverse routes for its in-neighbors; otherwise, node A might ignore some distance updates crucial to B. The final chosen radius of the node is the maximum of the values determined based on local and global criteria. Nodes broadcast their current radius as part of the distance-vector messages.

IV EVALUATION

Bidirectional routing abstraction can be done in existing AODV algorithm making it work in reverse route forwarding method. It has been implemented in Network Simulator (ns2)

A. Topology Models

First we experimented AODV's performance under unidirectional link conditions through the following scenarios.

P-model (probabilistic model): This model simulates unidirectional links created by random irregularities in signal propagation due to ambient conditions. This model takes a basic, bidirectional topology with a transmission range of 220 m for each node and then probabilistically converts links to become unidirectional.

N-model (Noise model): This model simulates unidirectional topologies created by external radio sources that increase noise and congest some nodes. In this model, the noise sources are randomly distributed throughout the network with uniform probability.

D-model (diversity model): Finally, the D-model stimulates unidirectional topologies caused by diversity in the transmission power of nodes. We define the diversity D of a topology as the difference between the maximum and the minimum transmission ranges of the nodes in the network. We then assign each node a transmission range picked randomly from a set of transmission ranges in the interval, where is the nominal transmission range.

We then evaluated the routing performance of AODV layered on BRF (BRF-AODV) and DBR (DBR-AODV). This section reports the observed performance in terms of the number of routes established, percentage of successful packet delivery, latency, and the control overhead for routing data packets and for maintaining reverse routes in various network conditions.

1) Protocol Parameters: We used the parameters for BRF and DBRF and standard parameters [14] for AODV.
2) Physical and MAC layers: We set the simulated radio to correspond to the Wavel LAN radio hardware with a transmission range of 220m, bandwidth of 2 MHz, and the two-ray signal propagation model. For the MAC layer, we used IEEE 802.11 for AODV and CSMA for BRFAODV. Our choice for the MAC protocols is restricted by the functionalities provided by the protocols; IEEE 802.11 is unsuitable for unidirectional routing in BRF-AODV where as CSMA does not provide the necessary collision avoidance or recovery for AODV.
3) Topology and Asymmetry: We simulated topologies similar to those used by the network asymmetry analysis and presented results for the topology of 80 nodes distributed uniformly at random in an area of 1300 m 1300m. the transmission range of each node was based on the D-model, that is, drawn randomly from the set for a nominal range m and diversity D.
4) Application: We used a Constant Bit-Rate Generator (CBR) application to initiate data transfers. We set up data transfers between 20 randomly chosen sources and destinations, where each data transfer started randomly between 50 sand 150 s, periodically sent 200 data packets of a size randomly chosen between 64 B and 1024B, and terminated after 200 a. That is, we simulated at most 100 seconds.
5) Mobility: we used the usual random-waypoint model to simulate nodes in motion, where nodes repeatedly move using the following algorithm. A node chooses a random destination point and a random speed (between a maximum and a minimum value), moves towards that destination with the chosen speed, and , after reaching the destination, waits for a specified pause time before repeating this random motion. We simulated two mobility scenarios: A low-speed or pedestrian-walking scenario and high speed.

V. CONCLUSION AND FUTURE SCOPE

This paper presented a bidirectional routing framework to handle unidirectional links that arise frequently in mobile ad hoc networks. BRF provides routing protocols with the familiar bidirectional abstraction that they are typically designed for and thus enables them to operate efficiently on asymmetric networks. Internally, however, it actively uses both unidirectional and bidirectional links to 1) find symmetric routes more effectively than conventional techniques; 2) find new, asymmetric routes substantially increasing the reach ability of the network; and 3) find alternate routes with shorter path length. This paper made three overall contributions: First, it presented a quantitative analysis of how network asymmetry caused by alien radio sources, heterogeneity in transmission power, and random fluctuations in signal propagation that affect conventional MANET routing protocols. Second it presented the design of BRF, based on a novel protocol to maintain reverse routes for unidirectional links in an efficient and scalable manner. Finally, it showed through extensive evaluation how a typical routing protocol, such as the well-known AODV, layered on BRF achieves superior connectivity in asymmetric networks.

The future work of this paper is to compare the performance of DSR and proactive protocol DSDV with Bidirectional Routing Framework. One of the advantage of Bidirectional routing framework is that it can adopt to both unidirectional and bidirectional link conditions according to the study given in Section III. Because DSR works with little overhead under asymmetric condition and also it does not avoid unidirectional links, this framework can be easily used to enhance the performance of the existing protocols. In future, this framework can be used as a general purpose framework for all the routing protocols used in Mobile Adhoc networks.

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