A Survey on Reducing Routing Overhead in Mobile Ad Hoc Networks

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Abstract: Due to high mobility in MANETs, there exist frequent link breakages which lead to frequent path failures and route discoveries. The overhead of a route discovery cannot be neglected. Broadcasting is a fundamental and effective data dissemination problem. Broadcasting can cause broadcast storm problem. Traditional routing protocols in Mobile Ad hoc Network (MANET) send periodic messages to recognize the topology changes. Sending periodic messages cause overhead. Compared to proactive routing protocols, reactive routing protocols can cause less overhead. This paper presents a survey of various techniques related to broadcasting that can lead to routing protocol overhead.

Key words: Broadcasting, Mobile Ad hoc Networks, Route discovery, Routing protocol.

I. INTRODUCTION

One of the major problems in ad-hoc network is the routing protocols. Broadcasting is a common problem in networks. In ad-hoc networks, broadcast plays an important role, relaying a message generated by one node to all other nodes. Broadcasting is an integral part of a variety of protocols that provide basic functionality and efficiency to higher-layer services.

MANETs consists of collection of nodes which can move freely. No base stations are supported in MANETs. These nodes can be dynamically self-organized into arbitrary topology networks without a fixed infrastructure. One of the fundamental challenges in the MANETs is the design of dynamic routing protocols with good performance and less overhead [1].

Routing protocols in ad-hoc networks are classified into proactive (table-driven) protocol and reactive (on-demand) protocol. Proactive protocols maintain routes between every host pair at all times. In proactive protocol, when a packet needs to be forwarded the route is already known. This protocol is based on periodic updates. They maintain up-to-date routing information for all nodes in the network even before it is needed. Because of this situation, proactive protocols will require low latency. This protocol incurs more overhead. Examples of this type include OLSR and DSDV routing protocol. Reactive routing protocols do not maintain routing information at the nodes if there is no activity between them. (i.e.) it determines the route if and when needed. This protocol incurs less overhead. Examples of this type include AODV, DSR routing protocol. Nodes in the reactive routing protocols are trying to minimize the overhead by only sending routing information as soon as the communication is initiated between them.

A. Flooding

Flooding in wireless networks is mostly achieved via each node send the request to its neighbors. In flooding, every incoming packet is sent through every outgoing link except the one it arrived on. Flooding utilizes every path through the network and it uses the shortest path. The conventional on-demand routing protocols use flooding to discover a route.

B. Broadcasting

The sending of a message from one host to other hosts in the network is known as the broadcast problem [6]. The characteristics of broadcasting are:

- The broadcast is spontaneous: Any mobile host can issue a broadcast operation at any time.
- The broadcast is unreliable: No acknowledgement mechanism will be used.

C. Broadcast Storm problem

Broadcasting is a common operation in a network to resolve many issues. In a mobile ad hoc network (MANET), due to host mobility, such operations will be executed more frequently (such as finding a route to a particular host, paging a particular host and sending an alarm signal). A straightforward broadcasting by flooding is usually very costly and will result in serious redundancy, contention, and collision, and it is known as the broadcast storm problem.

D. Broadcast storm problem caused by flooding:

A direct approach to perform broadcast is by flooding [6]. In a CSMA/CA network, the drawbacks of flooding include:

- Redundant rebroadcasts
- Contention
- Collision
E. Mechanisms to reduce redundancy, contention and collision

(i) Probabilistic scheme:
This scheme is used to reduce the rebroadcasts. Here, a node will broadcast with probability \( p = 1 \), on receiving a broadcast message for the first time. To reduce contention and collision, a small random delay is inserted before rebroadcasting the message.

(ii) Counter-based scheme:
In counter-based scheme, a node will determine whether it rebroadcasts the packet or not by counting how many identical packets it receives during a random delay.

(iii) Distance-based scheme:
In distance-based scheme, the relative distance between a mobile node and previous sender is used to make the decision that whether it rebroadcast a packet or not.

(iv) Location-based scheme:
Additional coverage concept is used to decide whether it rebroadcast a packet or not.

(v) Cluster-based scheme:
It is used to solve other problems in MANETs such as traffic coordination, routing and fault-tolerance of the network.

F. Neighbor knowledge methods:
It maintains the neighbor node information to decide whether it or the neighbor nodes have to rebroadcast or not [8]. The following methods are used for discover the neighbour knowledge.

(i) Flooding with Self Pruning:
The simplest method in neighbor knowledge method is flooding with self-promising. If there is any unreachability after receiving a broadcast packet then it doesn’t do rebroadcasting. Otherwise rebroadcast will occur.

(ii) Scalable broadcast algorithm:
In scalable broadcast algorithm (SBA), every node should have the knowledge of their neighbor nodes.

(iii) Dominant pruning
In dominant pruning, only the chosen nodes are allowed to rebroadcast.

(iv) Ad-hoc broadcast protocol (AHBP):
It utilizes the Multi Point Relaying approach. AHBP is used in high-mobility networks.

(v) CDS (Connected Dominating Set) based broadcast algorithm:

For selecting BRG’s (Broadcast Relay Gateways), it is more calculation intensive algorithm.

(vi) LENWB (The Lightweight and Efficient Network-Wide Broadcast (LENWB) Protocol:
LENWB protocol depends on 2-hop neighbor knowledge obtained from “Hello” packets. In LENWB, each node decides to rebroadcast based on knowledge of which of its other one and two hop neighbors are expected to rebroadcast.

II. TECHNIQUES FOR REDUCING ROUTING OVERHEAD IN MANETS

David B. Johnson, David A. Maltz [3] proposes a protocol for routing in ad hoc networks that uses Dynamic Source Routing (DSR). This protocol rapidly adapts to routing changes in ad hoc networks and it incurs less protocol overhead during frequent host movement. The basic operations performed in DSR protocols are route cache, route discovery and route maintenance. A number of optimizations are performed in the basic operation of route discovery and route maintenance, and that can reduce the number of overhead packets and can improve the average route efficiency of data packets. The optimizations are as follows:

(i) Full use of the Route Cache: Route cache is used to avoid propagating a route request packet received from another host.

(ii) Piggybacking on Route Discoveries: The route discovery delay and the total number of packets transmitted can be reduced by piggybacking of data on route request packets.

(iii) Reflecting Shorter Routes: During host communication using cached routes, it is possible to use shorter routes.

(iv) Improved handling of Errors: It is to support negative caching information in a host’s route cache.

It is concluded that, by combining other routing protocols such as distance vector or link state routing with ad hoc networks, then the nodes can be reachable by all the ad hoc network nodes and this paper does not addresses the security concerns in wireless networks or packet routing.

Sze-Yao Ni, Yu-Chee Tseng, Yuh-Shyan Chen, and Jang-Ping Sheu [6] proposes many schemes to reduce redundant rebroadcasts and differentiate timing of rebroadcasts to lighten the broadcast storm problem. It is concluded that, if the location information is available through GPS receivers, the location-based scheme is the best choice because, this approach will eliminate more redundant rebroadcasts without compromising reachability and Neighbor knowledge methods perform better than Area based methods, while Area based methods perform better than the Probability based methods.
Brad Williams, Tracy Camp [8] proposes the different broadcasting techniques. A simple flooding algorithm starts with a source node broadcasting a packet to all its neighbors, then the neighbor node broadcast the packets and it continues until all reachable network nodes have received the packet. If the probability parameter is high, then the nodes will receive all the broadcast packets with the probabilistic scheme. Some nodes will not rebroadcast in sparse area of the network. It is concluded that, the protocols in Probability Based and Area Based methods will fail to operate efficiently in congested networks. The difficulty in mobile environment is the Neighbor Knowledge methods, that do not use local information to determine whether to rebroadcast or not. The determination of next-hop rebroadcasting node was corrupted by the outdated 2-hop neighbor knowledge.

Zygmunt Haas Joseph Y. Halpern Li Li [2] proposes Gossip-based ad hoc routing technique to reduce the routing protocol overhead. Every node forwards a message with some probability. In some executions, the gossip dies out quickly and hardly any node gets the message and other nodes get the message in the remaining executions. Gossiping uses bimodal behavior and it follows the percolation theory.

**The Bimodal behavior of gossiping:**

The gossiping protocol is simple. A source sends the route request with probability p, it broadcasts the request to its neighbors and with probability 1-p it discards the request. A node broadcasts a given route request at most once. Gossips have a problem with initial condition. If the source has only a few neighbors, there will be chances of none of them will gossip and gossip will die. To make sure this will not happen, a modified protocol is used known as GOSSIP1(p,k).

**Heuristics to improve the performance of gossiping:**

The basic gossiping scheme can be optimized as follows:

(i) A two-threshold scheme

(ii) Preventing premature gossip death

(iii) Retries

(iv) Zones

It is concluded that, when compared to flooding, gossiping can reduce control traffic upto 35%. This gossiping protocol is simple and easy to incorporate into existing protocols, gossiping is very useful in large networks and it is robust and able to tolerate faults. It is easy to tune gossiping to particular networks.

Jae-soo Kim and Qi Zhang and Dharma P. Agrawal [5] proposes a dynamic probabilistic broadcasting approach with coverage area and neighbor confirmation. To discover the route better than broadcasting methodology rebroadcast can be done with the help of neighbor knowledge methods. If a mobile node is located in the area closer to sender, then it has small additional coverage and rebroadcast from this node can reach less additional nodes, so its rebroadcast probability will be set lower. On the other hand, if a mobile node is located in the area far from sender, then the additional coverage from this node is large, its rebroadcast probability will be set higher. By using the distance between the sender and receiver, the coverage area is calculated and the distance can be calculated by signal strength or global positional system. This approach combines the advantages of probabilistic and area based approach.

**Dynamic Probabilistic Broadcasting With Coverage Area And Neighbor Confirmation**

(i) **Shadowing effect:**

The neighbor nodes that are far away from the sender node will act as relays with high transmission probability. On the other hand, the neighbor nodes that are closer to sender node will be shadowed from relays with low transmission probability. The shadowing effect will reduce the number of rebroadcast packets.

(ii) **Dynamic Probabilistic Rebroadcast with Coverage Area:**

If a node is an outer node, then it has larger coverage area and if a node is an inner node, then it has smaller coverage area.

![Fig. 1: Rebroadcast probability is proportional to distance from sender.](image)

In Fig.1[5], Let $R$ be the communication range of node $s$, and $A$ be the covering area of node $s$. $A$ can be obtained by the equation: $A = \pi R^2$. $A_1$, $A_2$, and $A_3$ is sub area of $A$ with radii $r_1$, $r_2$, and $r_3$, respectively. The coverage ratio $\mu$ is defined as follows:

$$
\mu = \begin{cases} 
\frac{A_1 + A_2 + A_3}{A} & \text{for Area 1} \\
\frac{A_1 + A_2 + A_3}{A} & \text{for Area 2} \\
\frac{A_1 + A_2 + A_3}{A} & \text{for Area 3} 
\end{cases}
$$

When a node receives the broadcast message, its relative distance can be obtained by comparing the signal strength with maximum signal strength or by using GPS. Then the distance to sender can be estimated and the node can determine its coverage ratio $\mu$. The rebroadcast probability ($p$) is defined as Follows:
Where, \( a \) is a sensitivity parameter to control the rebroadcast probability. This approach gives a good approximation in the general distribution of mobile node.

(iii) Dynamic Probabilistic Rebroadcast with Coverage Area and Neighbor Confirmation

Large number of rebroadcasts guarantees high reachability and it causes high network bandwidth wastage and many packet collisions. On the other hand, the small number of rebroadcasts results in low reachability, because it causes the rebroadcast chain broken so that some hosts may not receive the broadcast packets. The neighbor confirmation scheme is applied to prevent from early die-out of rebroadcast.

![Fig. 2: The distribution of mobile nodes in MANET](image)

In fig. 2 [5], \( n_1 \) has the probability that it doesn’t rebroadcast the packet, so \( n_1 \) doesn’t receive the broadcast packet from its neighbor \( n_1 \).

Performance Measures

Four performance measures are used such as rebroadcast number, reachability, and collision, throughput to evaluate the performance of this approach.

(i) Rebroadcast number

Rebroadcast number is the number of rebroadcast packets. By comparing with other approach, our proposed approach can significantly reduce the number of rebroadcasts.

(ii) Reachability

Reachability is the sum of mobile node that receives the broadcast message directly or indirectly. This proposed approach is a good solution for maintaining good reachability.

(iii) Collision

Collision is the number of collided packet that mobile nodes send. The proposed scheme can reduce the collision packets more than 50% when compare with flooding scheme.

(iv) Throughput:

Throughput is defined as the amount of broadcast data (bits) transmitted during a second in the MANET. Our proposed scheme is good throughput which results in decreased rebroadcast node and reduced collision packets.

It is concluded that, a mobile host can dynamically adjust the value of the rebroadcast probability according to its additional coverage in its neighborhood. This scheme combines neighbor confirmation concept to prevent early die-out of rebroadcast. This approach generates fewer rebroadcasts than flooding approach. It also incurs lower broadcast collision without sacrificing high reachability.

Alireza Keshavarz-Haddad, Vinay Ribeiro, Rudolf Riedi [4] proposes a hybrid backbone, consists of a static Dominating Set(DS) and the dynamically computed set of connecting nodes and two deterministic timer based schemes such as DRB and DCCB. The broadcast forwarding over subset of nodes is called backbone. There are two different broadcast schemes: static backbone and dynamic backbone. Static backbone is one which use the same backbone and dynamic backbone is one in which the backbone is recomputed for each broadcast in order to adapt{\{ to broadcast state and network topology changes. Dynamic timer-based schemes are robust to node failure. Static schemes with sparse backbones are sensitive to the node failure. The timer-based scheme is used and which includes many probabilistic schemes and some deterministic schemes. An important feature of DRB and DCCB is their hybrid backbone and it consists of a fixed and a variable part. There is no full reachability guarantee in timer-based schemes. An efficient DS are constructed by using clustering algorithm.

**DRB Algorithm**

In DRB algorithm, the WCDS is computed and all network nodes know their WCDS neighbors. The WCDS nodes are dominators as neighbor are known as reflectors. In the DRB design, the dominator of the originating node will rebroadcast the packet. All dominators rebroadcast the packet once and all nodes are covered. In DRB, the number of rebroadcasts is less when compare with other timer-based schemes.

**DCCB Algorithm**

In DCCB algorithm, a DS will be computed and its members are called dominators. The connectors are the network nodes which have more than one dominator within 2 hops distance. The hybrid nature of both DRB and DCCB are done by combining efficiency from the static part and robustness from the dynamic part of the backbone. On any DS, there will be a full reachability guarantee exist from DCCB. While comparing to deterministic timer-based schemes, DRB and DCCB use small number of nodes. The
difference between DRB DCCB and other existing timer-based schemes is that their hybrid backbone consists of fixed and variable part.

Fred Stann, John Heidemann, Rajesh Shroff, and Muhammad Zaki Murtaza [7] proposes Robust broadcast propagation(RBP) and it is used to improve the reliability while balancing energy efficiency. Robust broadcast propagation (RBP) is a very simple protocol, and it is used to support the reliability of networks and it resides as a service between MAC and network layer.

RBP is based on two principles:

First, near-perfect reliability is achieved by exploiting the network density with moderate broadcast reliability and with many neighbor nodes.

Second, by identifying sparse connectivity area and bridge the important links with dense cluster of nodes and it maximizes the guaranteed reliability over these links. RBP is used to provide adaptive reliability for broadcasts and improve the end-to-end reliability of flooding. The cost of RBP is small and achieves greater efficiency. The problem associated with this protocol is timeliness because, a single flood have a higher probability of achieving global coverage.

In wired networking, RBP focuses on single-hop communication and any routing will be provided at higher layers. In wireless network, RBP supports a range of densities such as sparse, weakly connected clusters and variable density networks. RBP provides reliable single broadcasts with periodic resource discovery. The goal of RBP is to make reliable broadcasting. Four steps are used to achieve this goals:

(i) Tracking neighbors and floods.

(ii) Basic retransmission to reach a target reliability.

(iii) Adapting that target to network density.

(iv) Identifying important links that require successful transmission.

The RBP algorithm consumes unlimited memory and it supports any number of neighbors. In this paper mobility was not considered. The RBP mechanism focus only local density information.

Feng Xue and P.R.Kumar [10] proposes the problem of choosing the number of connected neighbors affects not only the connectivity of the network, but also the capacity of the network, i.e., how much traffic it can carry. When there are many links, a packet can get its destination in a fewer number of hops. If Interference is larger when the number of links is larger, the relaying burden is smaller. The number of nearest neighbors needs to grow like (log n). The number of nodes in a wireless network increases, the number of nearest connected neighbors should not remain constant. Otherwise a disconnected network will be obtained.

Xin Ming Zhang, En Bo Wang, Jing Jing Xi and Dan Keun Sung proposes[9] the NCPR(Neighbor Coverage based Probabilistic Rebroadcast Protocol) protocol to reduce the routing protocol overhead. The goal of this protocol is to make the quicker dissemination of neighbor knowledge. The number of rebroadcasts should be limited in order to optimize the broadcasting. The routing overhead is very large in high dynamic networks. The NCPR protocol is proposed as follows:

(i) Rebroadcast Delay: It is used to determine the rebroadcast order and also to make use of neighbor coverage knowledge.

The uncovered Neighbors set \( U(n_i) \) of node \( n_i \) is calculated as follows:

\[
U(n_i) = [N(n_i) \cap N(s)] - (s)
\]

Where \( N(s) \) and \( N(n_i) \) are the neighbors sets of node s and \( n_i \) respectively. S is the node which sends an RREQ packet to node \( n_i \).

The Rebroadcast delay \( T_p(n_i) \) node \( n_i \) is

\[
T_p(n_i) = 1 - \frac{|N(s) \cap N(n_i)|}{|N(s)|}
\]

\[
\text{MaxDelay} \times T_p(n_i)
\]

Where \( T_p(n_i) \) is the delay ratio of node \( n_i \) and MaxDelay is the small constant delay. \( |I| \) is the number of elements in a set.

(ii) Rebroadcast Probability: It is used to keep the network connectivity and reduce the redundant retransmissions.(i.e.) it includes additional coverage ratio and connectivity factor. The connectivity factor is to provide the node density adaptation.

The additional coverage ratio \( R_a(n_i) \) of node \( n_i \) is

\[
R_a(n_i) = \frac{|U(n_i)|}{|N(n_i)|}
\]

This metric indicates the ratio of the number of nodes that are covered by this broadcast to the total number of neighbors of node \( n_i \).

The minimum connectivity factor \( F_c(n_i) \) is defined as,

\[
F_c(n_i) = \frac{N_c}{N(n_i)}
\]

Where \( N_c = 5.1774 \log n \) and \( n \) is the number of nodes in the network.
III. SIMULATION ENVIRONMENT

Fig. 3 shows the effects of network density on the MAC collision rate. Compared with the conventional AODV protocol, the NCPR protocol reduces the MAC collision rate by about 92.8 percent on the average. Under the same network conditions, the MAC collision rate is reduced by about 61.6 percent when the NCPR protocol is compared with the DPR protocol. This is the main reason that the NCPR protocol could improve the routing performance.

Fig. 4 shows the normalized routing overhead with different network density. On average, the overhead is reduced by about 45.9 percent in the NCPR protocol compared with the conventional AODV protocol and 30.8 percent when the NCPR protocol is compared with the DPR protocol. When network is dense, the NCPR protocol reduces overhead by about 74.9 and 49.1 percent when compared with the AODV and DPR protocols, respectively. This result indicates that the NCPR protocol is the most efficient among the three protocols.

Fig. 5 shows the packet delivery ratio with increasing network density. On average, the packet delivery ratio is improved by about 11.9 percent in the NCPR protocol when compared with the conventional AODV protocol and 3.7 percent when compared with the DPR protocol. When network is dense, the NCPR protocol increases the packet delivery ratio about 21.8 and 6.3 percent when compared with the AODV and DPR protocols, respectively.

Fig. 6 measures the average end-to-end delay of CBR packets received at the destinations with increasing network density. On average, the end-to-end delay is reduced by about 60.8 percent in the NCPR protocol when compared with the conventional AODV protocol and 46.3 percent when the NCPR protocol is compared with the DPR protocol. When network is dense, the NCPR protocol reduces the average end-to-end delay by about 84.9 and 59.2 percent when compared with the AODV and DPR protocols, respectively.

Fig. 7 shows the normalized routing overhead with different packet loss rate. By reducing redundant rebroadcast of RREQ packets, both the DPR and NCPR protocols incur less routing overhead than the conventional AODV protocol.
FIG. 7. Normalized routing overhead with varied random packet loss rate.

It is concluded that, the NCPR protocol has good performance when there is high network density or heavy traffic load. During route discovery, the NCPR protocol will reduce the routing overhead in dense networks.

IV. CONCLUSION AND FUTURE ENHANCEMENT

In this paper, a detailed survey is carried out to reduce the routing protocol overhead in MANETs. The proposed techniques can be used in order to improve the routing performance. Because of less redundant rebroadcast, the NCPR protocol moderates the network collision and contention, which increase the packet delivery ratio and decrease the average end-to-end delay. In order to optimize the broadcasting, the number of rebroadcasts should be limited.

In the future, by adding channel awareness mechanism the uncovered neighbor set with higher signal strength can be selected for easier and fast retransmission of RREQ message and QoS can be improved.

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