Contention-Based Distance-Vector Routing (CBDV) for Mobile Ad-Hoc Networks

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***Abstract*— Position-based routing protocols forward packets in a greedy manner from source to destination without having to maintain routes through the network. Contention-based routing strategies improve upon position-based routing in that they do not even require to maintain neighbor tables at the nodes. This makes them very robust in highly mobile networks. However, neighbor tables are essential in the recovery mechanisms that are used when greedy routing fails. In this poster proposal we outline "Contention-Based Distance-Vector Routing (CBDV)", a recovery strategy for contention-based routing protocols that works when no neighbor tables are present. We describe the basic idea and give a simulative analysis of its performance.**

I. Introduction

Routing algorithms that exploit position information have a number of interesting properties and are very promising candidates for routing in mobile ad-hoc networks (MANETs). While one class of position-based routing protocols explicitly selects the next forwarder based on the node's own position, the position of the destination, and the position of the direct neighbors, an alternative approach is to broadcast the packet and have the receivers decide which of them is most suitable to further forward the packet. The latter strategy, which we call contention-based forwarding [3] (CBF) does not base the routing decision on neighbor information (which is usually obtained through the exchange of periodic beacon messages). In CBF, suitable forwarders compete for the "right" to forward a packet by setting a timer corresponding to their suitability (i.e. forwarding progress). If this timer expires and no other node started to transmit, the node begins with it's transmission. CBF is very robust in highly mobile environments where neighbor information changes quickly and is rapidly outdated. It was shown to dominate beacon-based approaches especially in dense networks where it can cope with high mobility at a significantly lower resource usage [4].

The basic forwarding mode of both the beacon- and the contention-based routing mechanism is to minimize the remaining distance to the destination in a greedy fashion. While this heuristic allows to base the forwarding decision on local information only, there are cases where it will not reach the destination even though a valid route exists. [1], [5] propose recovery strategies based on the distributed planarization of the neighborhood graph that achieve theoretical completeness (i.e. they always find a route if one exists). The planarization requires neighbor table information which is not present in CBF-like protocols. Therefore, such mechanisms are not applicable in the context of CBF.

In this paper, we propose a recovery scheme for CBF-like protocols. It is based distance-vector routing [7] that is specifically adapted adapted for contention-based operation. It allows to recover from local optima of the greedy forwarding while maintaining the desirable property of relatively low resource consumption.

II. Contention-Based Distance-Vector Routing

This section describes CBDV as an on-demand and strictly topology-based routing method. For now, we do not assume that the nodes know about their positions. When a node *S* wants to communicate with destination *D*, the protocol enters a route discovery phase by flooding the network with a route request to *D*. This can be done in an adaptive manner (i.e. with increasing hop limits). Every node has a local routing table which stores tuples of (node to reach, number of hops, time stamp, sequence number) and fills this table with the corresponding values while rebroadcasting the route request packet. Per-discovery sequence numbers are used to avoid loops in case of mobility as in [7]. When the route request reaches *D*, it answers with a route reply packet which is also forwarded by undirected broadcast. The reply contains the hop distance between *D* and *S*. Every node that receives the reply checks its routing table to see if it is on a route from *S* to *D* (i.e. it has an entry with a lower hop distance from *S*). In this case, it sets a timer reciprocal to the remaining number of hops to *S*. When the timer expires and no previous rebroadcast indicating a smaller hop count is overheard, the packet is forwarded. (Obviously, multiple nodes with the same remaining hop distance and thus the same calculated timer value are quite likely. Thus, an underlying random serialization, for example through carrier sensing as in 802.11, becomes important.) Like with every packet that is broadcasted, the information contained in the packet is used to update the routing tables. When the reply packet finally reaches *S*, the information in the local tables allows to forward packets from *S* to *D*.

Figure 1 gives a simple example of a topological route from *S* to *D*. The boxes next to the nodes contain the distance vectors from each node to *S* and *D*. Note that there are two alternate routes from *S* to 3.

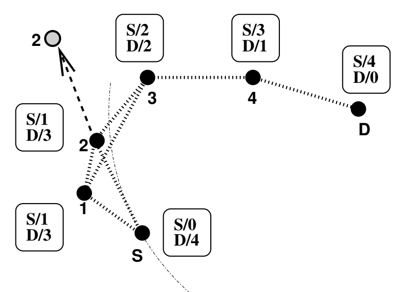

Fig. 1. Routing Example

The routing method outlined above differs from the route discovery in AODV [7] in that it does not explicitly select the next-hop on a route. The route reply packet is broadcasted and potential forwarders compete by greedily minimizing the remaining hop distance to the source node. This allows other forwarders to step in when the original forwarder is not available any more, which may occur frequently in the presence of mobility. Revisiting the example in Figure 1, let us assume that node 2 moved up (see gray arrow) and is no longer in direct reach of node *S*. In this case, 1 will accept the packet from *S*, being 3 hops away from *D*, and will forward it to 3. In this case, the route length remains the same, but the algorithm will also use backup routes if they are longer than the original route.

Certainly, packet duplicates are likely to occur when forwarders do not overhear each other. Such packet duplications can be handled with an active suppression scheme as described, where instead of directly broadcasting the packet, a node broadcasts a request to forward. From the replies it receives, it selects a suitable node and then forwards the packet directly to it [3].

III. CBDV as a Recovery Strategy for CBF

While the algorithm described above could be used as a stand-alone routing protocol, we expect it to bring the highest benefit when used as a recovery strategy for CBF. This way, packet forwarding is greedy by default and only when this fails, it is based on hop distance discovered by CBDV.

The complete algorithm works as follows: To forward a packet, the source node needs to know about its own position and the position of the destination node. The former is obtained by means of a positioning system such as GPS, the latter through a so-called *location service* [6]. Both positions are stored in the packet header before the packet is broadcasted. Every node receiving the packet calculates the progress the packet would make if forwarded by it. In case the node provides forward progress, a timer with timeout value reciprocal to the progress is set (i.e. it expires early with high and late with low expected packet progress). The packet is rebroadcasted when the timer fires and the node did not overheard the packet's retransmission by another node. Since it is possible that potential forwarders do not overhear each others packets, additional duplication avoidance strategies are necessary [3].

CBF has proven to be very effective in scenarios with high node density and mobility. However, in scenarios with lower density, the probability that a route cannot be found in a greedy manner increases. The failure is passively detected by a node not overhearing a rebroadcast of the packet it just forwarded. In this case the node shifts to CBDV mode and starts a local flooding of the network. In contrast to the location-unaware protocol described in Section II, the "recovery route discovery process" terminates when a node with a lower remaining distance to the destination node is found. Once the topological information is acquired, it can either be used separately from greedy forwarding or the topological contention period can be arranged immediately after the geographical contention time. This allows topological forwarders to immediately compete for a packet when no geographic forwarder exists. Either way, the topology-based routing is only used to find a route to a position from which CBF greedy routing is possible again.

Applied to the example in Figure 1, this would mean that node *S* would enter recovery mode after greedy routing fails. This is the case because all neighbors in direct reach have a larger geographical distance to *D* than *S*. Recovery mode terminates when node 3 is reached since 3 is closer to *D* than *S*, the node where we entered recovery mode. Greedy forwarding is then used to cover the remaining hops to the destination.

IV. Simulative Evaluation

To analyze protocol performance on a statistically significant number of random graphs, we have implemented it in a custom simulator. The random graphs were created using uniformly distributed node positions on a two-dimensional rectangular plane of size 2000m$\times$2000m. We use the unit disk graph model [2] to determine connectivity within the radio range of 250m.

In a first study, we investigate how well the recovery mechanism copes with the failure of greedy routing. We analyze how often these situations occur and when they do, how many non-greedy hops a packet must travel until greedy forwarding can resume. The curve "Connectivity" in Figure 2 shows the ratio of node pairs that are able to communicate over all node pairs. The other three curves show the connectivity provided by the respective forwarding algorithm w.r.t. to the topologically connected node pairs (i.e. a value of 1 indicates that the routing mechanism finds all available routes).

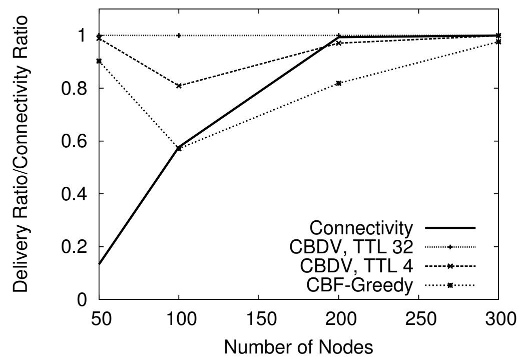

Fig. 2. Network Connectivity

The line "CBF-Greedy" denotes the percentage of greedy routes out of all topological routes. The remaining two curves show CBDV with different flooding-scopes of the route request. CBDF with a TTL of 32 allows to find all possible routes, whereas a TTL of 4 can only cope with limited void sizes. The poster will also show—among other simulation results—the void size distribution w.r.t. node density and the transmission costs induced by different values of TTL.

V. Conclusions and Future Work

In this poster proposal, we outlined Contention-Based Distance-Vector Routing as a topology-based routing protocol for mobile ad-hoc networks and show how it can be used as a recovery strategy for CBF-class protocols in the case position-based greedy forwarding fails. The main advantages we identified are the seamless integration into the CBF contention scheme and potential advantages when dealing with node mobility.

Still, many open issues remain. The most important part is to transform the proposal into a real distributed protocol and evaluate it by means of discrete event simulation (e.g. with the network simulator ns-2). This allows for a quantitative comparison with existing topology-based and position-based protocols using neighbor tables. Also, such simulation results will provide useful input for further design decisions, such as the question if the route reply should be tried greedy, a proper tuning of timeout intervals, etc. Furthermore, the question of unidirectional links has to be considered, which proved to be a major drawback for many existing protocols, but an inherent strength of CBF in position-based greedy mode.

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