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On Dynamically Reducible Transmission Range for Interference-Aware Broadcasting in Wireless Networks

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Abstract. In [1], Tongngam has shown some improvement on minimum latency broadcasting in wireless networks in interference-aware environment by statically reducing transmission range to the farthest receiver of each node at the end of each timeslot. In this paper, we study the broadcasting operation when each node can reduce its transmission range dynamically within timeslot. Doing so not only yields as good results as the previously one's in [1], but also reduces the average transmission range in total which means less power consumed and less interference occurred.

Keywords: interference-aware broadcast, dynamically reducible, minimum latency.

1. Introduction

Ad hoc network is a network where infrastructure is needless. There are many situations that the network is fitted. For example, natural disasters such as flood and storm may destroy major infrastructures, i.e. network and power. Fixing them is a time consumed operation. People in those areas extremely need communications from the relieve center. Also, volunteers and officers must have a channel to talk to each other in order to accommodate their tasks. Ad hoc networks can play an important role in this occurrence since they do not need any infrastructure and they are battery equipped devices. When an important message from a node, called source, is needed to be distributed to all other nodes over the network, a broadcasting operation will be used. However, long range broadcasting is very limitedas Tseng et al. point out in [9]. Moreover, the battery power is a major constraint since network lifetime must be maintained as long as possible. As a result, multi hop broadcasting operation is a good choice.

Not only is a message required to be distributed to all other nodes in the networks, it is also needed to be distributed very quickly. We define the term timeslot to represent a period of time for nodes to broadcast. A node can broadcast after the timeslot it has received the message. The number of timeslots used to have all nodes in the network completely received the message is called latency. Therefore, we want the minimum latency to distribute a message from the source to all other nodes in the network.

Without interference and collision considered, latency can be found simply by constructing a BFS-tree of the graph representing the networks with the source node as a root of the tree and then finding the depth of the tree. That is because all nodes with the message can broadcast in the same timeslot. With interference and collision under consideration, however, two or more nodes could not broadcast simultaneously as simply as described earlier since a node which is receiving the message from one node cannot completely receive the message if it is within transmission range or interference range of other node. A collision is defined by a node within transmission range of two or more nodes broadcasting in the same timeslot. The interference is

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defined in the same manner. However, it can be different from (normally larger than) the transmission range as described in [9].

2. Related Work

The broadcast scheduling problem, where all nodes are defined as points in a plane, the distance between two nodes denotes the Euclidean distance, and all nodes have the same transmission ranger,can be represented by a unit disk graph (UDG). With collision and interference to be aware, Gandhi et al. prove in [6] that the problem is NP-complete. Later in [7], Gandhi et al. present a 12-approximation algorithm for the one-to-all broadcast problem.

Later, Mahjourian et al. propose in [8] an O(α2)-approximation algorithm and greedy heuristics. In almost the same period, Calinescu and Tongngam also develop a few greedy heuristics for interference aware broadcast problem in [2]. With formally defined the problems with interference and collision aware, Integer Programs IPs have been formulated. Their experimental results compared with optimum solution obtained from the IPs and the lower bound (BFS number) show some performance.

All works described above are based on UDG, where all nodes in the networks broadcast a message using an identical transmission range. Qadir et al. propose in [3] four heuristics to improve latency broadcasting performance using multi-radio, multichannel, and multi-rate wireless mesh networks.They apply rate-range relation of 802.11a and 802.11b specifications in their work. Their heuristics use quite complicated transmission combination to select transmitting nodes. They also assume each node will transmit only once and unique rate on the same channel.

Burkhart et al. propose in [4] connectivity-preserving and spanner constructions that are interference minimal. They also assume reducible transmission power in order to minimize interference of the networks. However, its objective is not in the favor of finding minimum latency broadcasting schedule.

Recently, Tongngam proposes in [1] an approach when nodes have an ability only to reduce their transmission range. The experimental result has shown a significant improvement both one time and time transmission reduction. The approach, however, is static meaning that the reduction is performed at the end of each timeslot.

3. Network Model

We consider the Interference-Aware Broadcast Scheduling problem as described in [10], [1], and [2], where the distance between nodes is in the Euclidean distance. Every node in the networks originally has the same transmission range with interference range being a positive factor, α ≥ 1, of the transmission range. The original communication graph representing the networks is UDG and connected. Each node in the networks can reduce its transmission range to the distance as needed. Only an already-received node can broadcast the message. The problem is aimed to broadcast a message from a source node to all other nodes in the networks with minimum latency. As shown in figure 1, node y in the left figure cannot receive the message broadcasted from node xbecause of interference from node a, but node y in the right figure can receive the message because the interference from node a has been reduced due to the reduction of the transmission range of node a. The transmission range is denoted by solid-line circles and the interference is denoted by dotted-line circles.

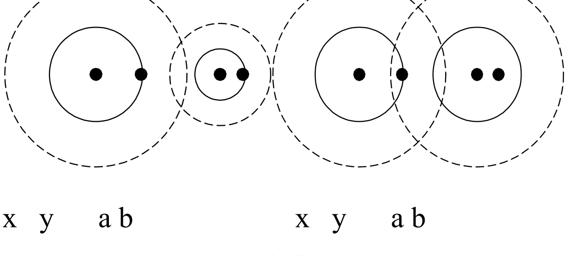

Fig 1: Graph representing network with fixed and reducible transmission range.

4. Dynamically Reducible Transmission Range Approach

As shown in [1], reduced transmission range decreases the interference range. Also, described by N.M.Karagiorgas et al. in [5], static transmission power causes a node spend more energy and induces unnecessary interference, even when its receiving nodes locate at a shorter distance than the fixed transmission range. However, statically reduced transmission range still causes some unnecessary interference. In figure 2 suppose node b can reach node y, if we statically reduce the transmission range of node a and node b as done in [1], it will be easily seen that node y cannot receive the message since it will be interfered while node a and node b broadcasting in the same timeslot. Deploying the greedy algorithm proposed by Calinescu and Tongngam in [2] and breaking tie by less transmission range, we dynamically reduce the transmission range of a broadcasting node if its potential receivers have been covered by other previously selected broadcasting node in the same timeslot. For the case as shown in Figure 2, node b dynamically reduces its transmission to cover only node z since node y has been earlier covered by node a in the same timeslot. Note here that the transmission range is denoted by solid-line circles and the interference is denoted by dotted-line circles.

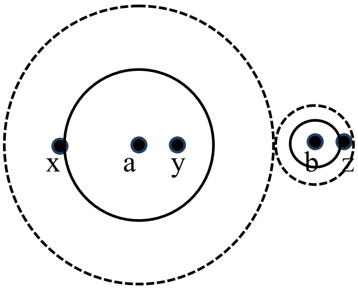

Fig 2: Graph representing network when dynamically reducible transmission range is allowed.

5. Experimental Results

We randomly distribute nodes in the network over a 4 × 4 area and the source node also randomly located within the area. In addition, we vary number of nodes, source included, among 21, 41, 61, and 81. The transmission range of each node is originally set to 1, while the interference range is set to 2. To be comparable, all instances and setting are the same as done in [1].

Table 1 shows the results of applying our approach to IA-MAA greedy heuristic proposed in [2] compared with one obtained from [1]. Both static and dynamic approaches give the same average results. More importantly, with the same number of average broadcasting nodes, we have found that the dynamic approach yields about 5% better performance in term of average transmission range of all broadcasting nodes resulting in less energy consumption and less interference as a whole. The reason is that a node can dynamically reduce its transmission range regarding its potential receivers as described in the previous section. Note that this experiment is done by allowing nodes to reduce their transmission range in every timeslot.

Table 1 : Experimental results from static and dynamic approach

#nodes	Static approach			Dynamic approach		
	Latency	#bcastNodes	Tx-range	Latency	#bcastNodes	Tx-range
21	7.4	9.8	0.84	7.4	9.8	0.80
41	8.2	12.9	0.83	8.2	12.9	0.78
61	8.5	13.5	0.89	8.5	13.5	0.85
81	8.2	14.7	0.88	8.2	14.7	0.83

6. Conclusion

We propose the dynamically reducible transmission range approach to the interference-aware broadcasting problem. Compared to the static approach proposed earlier in [1], this approach has shown some significant performance in lessening overall transmission range of broadcasting nodes. With equal latency, the dynamic approach performs better than the static does in the sense of lower interference and power consumption. This is because broadcasting nodes can dynamically reduce their transmission range when their potential receivers have been covered by broadcasting node previously selected earlier in the same timeslot.

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