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Survey Paper

A survey on probabilistic broadcast schemes for wireless ad hoc networks

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ABSTRACT

Broadcast or flooding is a dissemination technique of paramount importance in wireless ad hoc networks. The broadcast scheme is widely used within routing protocols by a wide range of wireless ad hoc networks such as mobile ad hoc networks, vehicular ad hoc networks, and wireless sensor networks, and used to spread emergency messages in critical scenarios after a disaster scenario and/or an accidents. As the type broadcast scheme used plays an important role in the performance of the network, it has to be selected carefully. Though several types of broadcast schemes have been proposed, probabilistic broadcast schemes have been demonstrated to be suitable schemes for wireless ad hoc networks due to a range of benefits offered by them such as low overhead, balanced energy consumption, and robustness against failures and mobility of nodes. In the last decade, many probabilistic broadcast schemes have been proposed by researchers. In addition to reviewing the main features of the probabilistic schemes found in the literature, we also present a classification of the probabilistic schemes, an exhaustive review of the evaluation methodology including their performance metrics, types of network simulators, their comparisons, and present some examples of real implementations, in this paper.

1. Introduction

Broadcasting is a widely used dissemination technique in which nodes send out the same information simultaneously to all their neighbors. Broadcasting is used in ad hoc networks such as Wireless Sensor Networks (WSNs) [7,121,106], Mobile Ad Hoc Networks (MANETs) [48], and Vehicular Ad Hoc Networks (VANETs) [107,116]. In routing protocols for ad hoc networks, broadcasting is part of the discovery phase, which is responsible for finding a communication path to route the application data from a source node to one or more destination nodes (unicast [18] or multicast routing protocols [6,5,26]). Broadcasting is also used in the maintenance of routes since nodes exchange Hello packets to collect neighboring information. In addition, broadcasting is also employed to disseminate emergency or warning messages in disaster scenarios, which is one of the main applications of MANETs [96,95,92]. In such harsh conditions, an efficient broadcast mechanism is vital and may be the only possible way to disseminate crucial information [40,97]. Furthermore, in VANETs the dissemination of warning messages is also important to warn the motorists of congestions due to traffic accidents.

The simplest way of broadcasting is flooding, in which each node in the network retransmits an incoming message once. The main benefit of using flooding is the ease of implementation. However, this technique also has several issues, one of them being its inefficiency in terms of resource consumption such as bandwidth and energy. While the former impacts the network in terms of efficiency and capacity, the latter is crucial for the lifetime

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of the network. The main problem of flooding in wireless ad hoc networks is that it causes the well-known broadcast storm problem [109] due to collisions and contention. Since all the nodes share the same wireless medium, the broadcast storm problem leads to dramatic deterioration of the performance in wireless ad hoc networks. In order to alleviate the broadcast storm problem many broadcast protocols have been proposed in the last decade [31]. A basic classification of broadcast schemes divides them into two categories, deterministic schemes and probabilistic schemes. In deterministic techniques, only a subset of nodes are allowed to take part in the broadcasting process. Multi Point Relay (MPR) [65] and Connected Dominating Set (CDS) are some examples of deterministic broadcast algorithms. However, this could lead to repeated use of the same nodes. In addition, under mobility conditions this set of nodes should change very frequently because of the topological changes. Probabilistic broadcast schemes however balance the power consumption among all the nodes in the network by selecting well balanced routes over the network lifetime. In probabilistic broadcast, nodes forward the incoming broadcast packets according to certain probability value, so all nodes are allowed to participate in the broadcast process. Moreover, probabilistic schemes are more robust against failures, attacks, and are unaffected by the mobility of nodes like the deterministic schemes.

This paper surveys the main probabilistic schemes proposed in the literature for wireless ad hoc networks. As fast as we know, this is the first survey of probabilistic broadcast in ad hoc networks. The main contributions of this paper are:

- A classification of probabilistic broadcast schemes in wireless ad hoc networks.
- A thorough review of the proposed schemes found in the literature.
- A review of the evaluation methodology for probabilistic broadcast, including performance metrics, simulation platforms, comparisons and real implementations.
- To provide a set of open challenges of probabilistic broadcast schemes that have not been covered yet.

This survey continues as follows, the proposed classification of probabilistic broadcast schemes is presented in Sections 2, and 3 reviews all the probabilistic schemes found in the literature that fall into the proposed classification. The methodology used to evaluate and compare the probabilistic schemes is reviewed in Section 4. Section 5 presents a discussion on the main findings of the proposed survey and provide a set of open challenges that have not been sufficiently covered in the literature so far. Finally, Section 6 includes the main conclusions of this survey.

2. Classification of probabilistic broadcast schemes in wireless ad hoc networks

The objective of this section is to classify the probabilistic broadcast schemes found in the literature. We have classified the probabilistic broadcast schemes into two main categories, (1) fixed probability schemes and (2) adaptive schemes (see Fig. 1). These main categories can be further divided into different subcategories as shown in Fig. 2 and explained below.

2.1. Fixed probability schemes

These schemes use a constant forwarding probability value so every node has the same forwarding probability in the network. Fixed probabilistic schemes have been studied using percolation theory and the phase transition phenomenon used in random networks [102,101,42,104]. However, there are important differences from random networks and ad hoc networks so the results observed in random networks cannot be said to be true for ad hoc networks. Consequently, there is not an optimal forwarding probability for all possible scenarios. This optimal forwarding probability may depend on many parameters such as density, distance among nodes, and speed.

2.2. Adaptive schemes

In adaptive schemes local or global parameters, such as density metrics, speed, energy are used to determine the

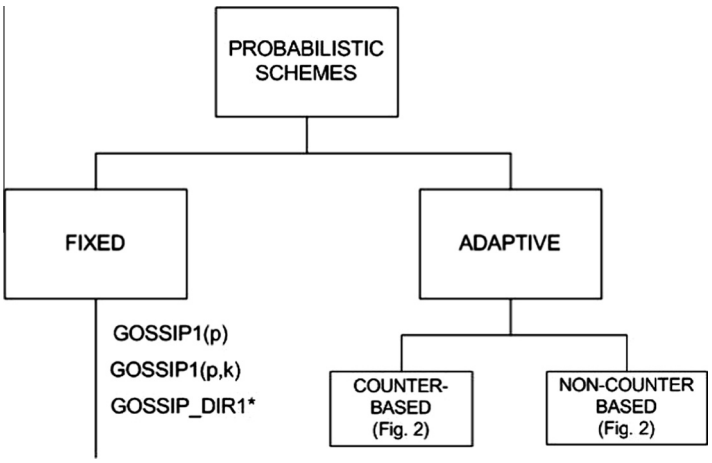

Fig. 1. Classification of probabilistic schemes.