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Impact of noise and interference on probabilistic broadcast schemes in mobile ad-hoc networks

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ABSTRACT

Broadcasting is a vital part of on-demand routing protocols to discover new routes in mobile ad-hoc networks (MANET). Pure flooding is the earliest and still widely used mechanism of broadcasting for route discovery in on-demand routing protocol. In pure flooding, a source node broadcasts a route request to its neighbors. These neighbors then rebroadcast the received route request to their neighbors until the route request arrives at the destination node. Pure flooding may generate excessive redundant traffic leading to increased contention and collisions deteriorating the performance. To limit the redundant traffic, a number of probabilistic broadcast schemes have been proposed in the literature. However, the performance of those probabilistic broadcasting schemes is questionable under real life MANETs which are noisy in nature. Environmental factors like thermal noise and co-channel interference may have adverse effects on the system performance. This paper investigates the effects of thermal noise and co-channel interference on the performance of probabilistic schemes employed in the route discovery mechanism in MANETs. Based on extensive ns-2 simulations, this paper discovers that, contrary to the findings of previous studies, these schemes do not outperform pure flooding scheme when thermal noise and co-channel interference are taken into account.

1. Introduction

A mobile ad-hoc network (MANET) consists of a set of mobile nodes that can connect to each other over multi-hop wireless links on ad-hoc basis. These networks are self-organizing, self-configuring as well as self-healing without requiring any infrastructure or central administration [1–4]. These properties make a MANET an excellent candidate for a number of applications ranging from communication in battle fields to rescue operations in disaster areas.

MANET nodes can arbitrarily be located within an area and are free to move. The movement of MANET nodes changes the network topology dynamically. MANET nodes adapt to the changing topology by discovering new neighbors and establishing new routes to destinations [5].

Due to the limited transmission range, a node may not communicate directly with a distant node and may have to rely on its neighboring nodes to relay the message along the route to the final destination node. Therefore, each node acts not only as a host node but also as a relay node to extend the reachability of other nodes. When a node needs to send data to a remote node, first, it finds out a set of relay nodes between itself and the remote node. The process of finding the optimal set of relay nodes between the source node and the destination node is called routing. Node mobility, limited battery power and the error-prone nature of wireless links are the main challenges in designing an efficient routing protocol in MANETs.

A number of routing protocols have been proposed in the literature [6]. These protocols generally fall into three categories namely table-driven (proactive), on-demand (reactive) and hybrid routing protocols. Table-driven routing protocols

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aim to maintain routes to all possible destinations in the network at all times. Examples of table-driven routing protocols include OLSR (Optimized Link State Routing) [7] and DSDV (Destination-Sequenced Distance-Vector) routing [8]. In contrast to table-driven approach, on-demand routing protocols, e.g., AODV (Ad-hoc On-demand Distance Vector) routing [9], DSR (Dynamic Source Routing) [6], and ABR (Associativity-Based Routing) [10], discover a route only when it is needed. Hybrid routing protocols, e.g., ZRP (Zone Routing Protocol) [11] and CEDAR (Core-Extraction Distributed Ad-hoc Routing) [12] combine the features of both proactive and reactive routing protocols.

In on-demand routing protocols, the routing process consists of two phases namely route-discovery and route-maintenance. These protocols rely on broadcasting for route discovery. For example, in case of AODV routing protocol, a source node that needs to send data to a destination node triggers route discovery mechanism by broadcasting a special control packet called Route Request (RREQ) to its neighbors who then rebroadcast the RREQ packet to their neighbors. The process continues until the RREQ packet arrives at the destination node. The destination node sends a control packet called Route Reply (RREP) that follows the path of RREQ in reverse direction and informs the source node that a route has been established. Since every node on receiving the RREQ for the first time rebroadcasts it, it requires N-2 rebroadcasts in a network of N nodes assuming the destination is reachable. This kind of broadcasting is called pure flooding and is depicted briefly in Fig. 1 while details can be found in [13].

Pure flooding often results in substantial redundant transmissions because a node may receive the same packet from multiple other nodes. This phenomenon, commonly known as the broadcast storm problem (BSP) [14], triggers frequent contention and packet collisions leading to increased communication overhead and serious performance complications in densely populated networks. The broadcast storm problem equally affects the route maintenance phase during which routes are refreshed by triggering new route discovery requests to replace the broken routes. To elevate the damaging impact of pure flooding, a number of improved broadcasting schemes have been proposed in the literature [14–16]. These techniques generally fall in two categories namely deterministic and probabilistic broadcasting. Deterministic schemes (e.g., MPR [17] and Self Pruning Scheme [18]) exploit network information to make more informed decisions. However, these schemes carry extra overhead to

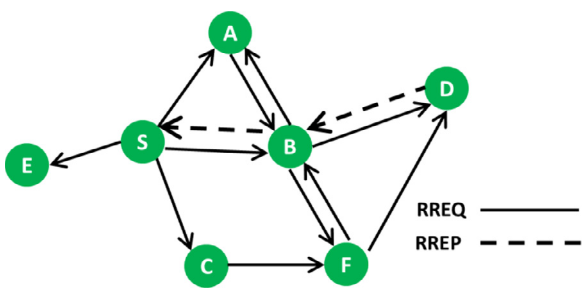

Fig. 1. Route discovery mechanism in AODV.

exchange location and neighborhood information among nodes. On the other hand, the probabilistic schemes, e.g., fixed-probabilistic [19], distance-based [20], counter-based [21] and location-based [14] schemes, take a local decision to broadcast or not to broadcast a message according to a predetermined probability. All these schemes try to minimize the number of rebroadcasted RREQ packets. In fixed-probabilistic scheme, a node receiving the RREQ packet rebroadcasts it with a fixed probability. In case of distance-based scheme, a node receiving the RREQ packets decides to rebroadcast by considering its distance from the sending node.

Real life MANETs are noisy and the communication is not error free. A number of channel impairments like noise, co-channel interference, signal attenuation, fading and user mobility affect the transmission. Previous studies have shown that routing protocols based on probabilistic broadcast schemes outperform the traditional pure flooding based routing protocols [14,22]. However, the results of those studies can be challenged for real MANETs. It is because those studies either ignored the noise and the interference at all [16,23] or they used a simplified model by translating the effects of noise and interference into a simple packet loss probability [24].

This paper investigates the effects of thermal noise and co-channel interference on the performance of probabilistic schemes by using realistic models of thermal noise and co-channel interference at physical and MAC layers. The investigations have been carried out for the fixed-probabilistic [19] and the distance-based [20] broadcast schemes. The performance is evaluated by considering routing overhead, application layer throughput, end-to-end delay and energy consumption. Through extensive ns-2 simulations and analysis of the simulation results, this paper reveals that, in contrast to the previous studies, the fixed-probabilistic and the distance-based broadcasting schemes do not show promising results when realistic thermal noise and co-channel interference at the physical and the MAC layers are taken into account. The rest of the paper is organized as follows. Section 2 highlights the related work. Section 3 presents the simulation setup, performance evaluation and discussion of results followed by conclusion in Section 4.

2. Related work

Cartigny and Simplot [25] proposed a probabilistic scheme where the retransmission probability is calculated from the number of neighboring nodes which are considering rebroadcasting. This work showed that a fixed parameter could be derived to enhance the reachability and demonstrated a substantial reduction in broadcast traffic yielding encouraging results. However, this work did not consider the effects of interference and thermal noise.

Zhang and Agrawal [22] suggested a probabilistic scheme that dynamically modifies the rebroadcasting probability based on the node distribution and the node movement by considering local information but without needing any distance measurements or exact location determination devices. Their results showed an improvement in performance when compared to both pure flooding and static probabilistic schemes. However, the effects of noise and interference were ignored. The same authors (in another work [26]) suggested