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Energy evaluation of AID protocol in Mobile Ad Hoc Networks

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ABSTRACT

Mobile Ad Hoc Networks (MANETs) are communication networks formed on the fly by radio-equipped mobile nodes without relying on any fixed infrastructure. Flooding is the simplest technique for information dissemination in ad hoc based networks, in which nodes disseminate a received message to all their neighbors. This algorithm leads to the broadcast storm problem that severely affects the energy consumption due to redundant submissions. To regulate redundant submissions, which can cause more collisions and requires more energy, recently there have been developed numerous broadcasting techniques. These techniques have been mainly proposed to solve the storm problem by preventing certain nodes from rebroadcasting received messages and/or by differentiating the timing of rebroadcasts. In this paper, we have evaluated and compared an adaptive information dissemination (AID) algorithm with other MANETs broadcasting protocols with respect to the energy efficiency. In AID, each node can dynamically adjust the values of its local parameters using information from neighboring nodes without requiring any additional effort, such as distance measurements or exact location-determination of nodes. Simulation results are reported and show that adaptive broadcasting schemes are most efficient with respect to save broadcast, energy consumption, and reachability.

1. Introduction

The MANETs, being as decentralized type of wireless networks, do not rely on a preexisting infrastructure, such as routers in wired networks or access points in managed (infrastructure) wireless networks. Instead, in MANETs each node participates in routing procedure as a router (not only as a host) by forwarding data to other nodes (Loo et al., 2011; Hamrioui et al., 2014). The forwarding decision is made dynamically based on the broadcasting/routing algorithms. It is worth noting that dissemination/broadcasting is an essential building block for most MANET protocols. For example, most unicast (Johnson and Maltz, 1996), multicast (Lee et al., 2002) and geocast (Camp and Liu, 2003) routing protocols use broadcasting to establish routes or to transmit an error packet for an invalid route (Colagrosso, 2007). Since communication range of nodes is limited and nodes are battery powered, optimizing energy consumption is one of the key factors when developing broadcasting algorithms. In order to save the transmission energy the number of redundantly received messages should be minimized, while, at the same time, maintaining good latency and reachability, since rebroadcasting causes tradeoff between reachability and efficiency under different host densities. Therefore, the selection of relay nodes and their transmission power is a major design consideration in routing and broadcasting algorithms (Bakhouya et al., 2011).

Generally, energy consumption of network devices can be proportional to power and time spent for sending, receiving or discarding the messages. As mentioned in Loo et al. (2011), energy efficiency is equivalent to the ratio of performance, measured as the rate of work done, to the power used and the performance can be represented by response time or throughput of the computing system. In other words, energy efficiency can be measured relatively to the network performance and intensively proportional to consumed power. Consequently, the main approach towards energy-efficiency is efficient power management. Thus, there can be two ways to enhance energy-efficient computing: either improving the performance with the same power, or reducing power consumption without sacrificing too much performance.

Ad hoc network is one of such systems, where the energy efficiency study in design of broadcast protocols has received significant attention in recent years. Due to the fact that mobile nodes are generally battery powered, the energy presents a very scarce resource. Therefore, the limited battery life time imposes

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constraints on the network performance. It is also important to mention that a key consideration for any energy-efficient protocol is the energy consumption at a wireless node (Ahlam Hashim et al., 2012; Wan et al., 2013, 2015). With respect to network activities, each node's radio can be in one of the following three states (Zhang et al., 2010): transmitting (with power TxPower), receiving (RtPower) and idle (idlePower): although no message is being transmitted, the node stays idle and keeps listening the medium, consuming energy at a rate that corresponds to an idlePower. In general, sending is more expensive than receiving, which in turn is more expensive than operating in idle mode. When a node transmits one packet, because of shared nature of wireless medium, all its neighbors receive this packet even if it is intended to only one of them. Hence, in order to maximize the network performance, the broadcasting protocols should be designed in an efficient way that the energy consumption is minimized.

Over the past few years, several broadcasting protocols have been proposed for MANETs (Miranda, 2007; Ni et al., 1999; Williams and Camp, 2002; Wieselthier et al., 2000), and energy efficiency problem has been considered in several studies (Cheng et al., 2003; Li et al., 2004; Ezzedine et al., 2009; Wieselthier et al., 2000). For example, in Cheng et al. (2003) authors introduced energy-efficient broadcast routing algorithms called minimum longest edge (MLE) and minimum weight incremental arborescence (MWIA). Authors achieved longer network lifetime by using MLE, i.e., minimizing the maximum transmission power of individual nodes. Broadcast incremental power (BIP) algorithm developed and then adapted to multicast operation in Wieselthier et al. (2000), exploits the broadcast nature of the wireless communication environment and addresses the need for energy-efficient operation. This algorithm takes into account the wireless broadcast advantage in the formation of low-energy broadcast trees, and it is a node-based spanning tree algorithm, which means transmission power needed to reach all its direct children. Energy and latency efficiencies are targeted in Ezzedine et al. (2009) in the design of ELE-MAC protocol, which attempts to minimize the energy wasted by control packets and to decrease latency.

To achieve maximal performance level in broadcasting process there have been done numerous research in design of protocols in MANETs (Ni et al., 1999), and each protocol presents some advantages and suffers from some drawbacks. In this paper we evaluate and compare the performances of existing protocols with an adaptive protocol for information dissemination for VANETs, presented in our previous work (Bakhouya et al., 2011). The remainder of this paper is structured as follows. We will first present the protocols used in MANETs for broadcasting purpose, a short description of each protocol will be provided in Section 2 followed by a brief description of adaptive broadcasting protocol, called AID, in Section 3. Section 4 presents the simulation results by mainly focusing on energy efficiency in term of reduced number of retransmissions. Conclusions and future work are presented in Section 5.

2. Related work

Broadcasting protocols for MANETs can be classified into two main categories: *static protocols* and *adaptive protocols*. Static protocols can be in turn classified in two sub-categories: *statistical or geometric based* and *network topology based* protocols as shown in Fig. 1. Geometric-based protocols category depends upon certain threshold (e.g. distance, redundant message counts, or broadcast probability) values to estimate the network density while network topology-based protocols use sophisticated structures or neighborhood information to construct the broadcast schedule.

2.1. Static protocols

There are two main categories in this class of protocols, geometric-based and topology-based protocols. The statistical or geometric based protocols are also subdivided into: parameter-based and area-based. Parameter-based protocols use certain parameters, like broadcast probability and hope counters in order to reduce the number of redundantly received packets. The parameter based protocols basically extend the flooding technique, in which the source node disseminates a message to all its neighbors only if this message is seen first time. The classical flooding algorithm has several drawbacks; first it is rather costly in terms of air interface usage, secondly, it is not reliable since most of the nodes are expected to broadcast the message at the same time, thus collusions are likely to occur, thirdly, it causes broadcast storm problem (Ni et al., 1999) that severely affect the energy consumption due to redundant message re-broadcast. An example of optimal broadcasting schedules is depicted in Fig. 2 in which only two transmissions are enough to reach all nodes instead of seven transmissions when using the flooding (Ezzedine et al., 2009).

In counter-based broadcasting, a message will be rebroadcasted only if the number of received copies at host is less than a threshold after RDT (Random Delay Time, which is randomly chosen between 0 and T_{max} seconds) (Kim et al., 2008). In Huang et al. (2006), authors have modified the counter-based protocol and named the new protocol as Hop Count Ad hoc Broadcasting (HCAB) protocol. In probabilistic scheme, mobile hosts rebroadcast messages according to certain probability that is defined at the initial stage. The major drawback of this technique is that setting the probability dynamically in different traffic situations is not an easy task. In Zhang and Agrawal (2005), authors have introduced a scheme for dynamic probabilistic broadcasting in MANETs. The area-based broadcasting techniques, however, exploit the geographical location of the node to calculate the additional coverage area of the sender. More precisely, area-based information broadcasting schemes take advantage of the geo-graphical location of the nodes (Kouvatsos and Mkwawa, 2011). Two main approaches used in this category: distance-based and location-based. In the distance based approach, only the neighbor far away from the current node rebroadcasts the message i.e. a distance threshold value is defined a priori. The location-based scheme, however, uses a more precise estimation of expected additional coverage area in the rebroadcasting decision. The major drawback of this scheme is that nodes have to be equipped with GPS.

The network topology-based protocols are further categorized into structured and unstructured protocols. Structured protocols use geometrical shapes or data structure to make an information dissemination plan. They are classified into two main categories: cluster-based and spanning tree-based. Despite their usage in many applications, the cluster-based approach is also used for broadcasting in which mobile hosts form clusters. Within one cluster, each host is treated as a member, and there is one cluster head and one gateway node responsible for relaying messages. However, maintaining such structure is too costly or even impossible especially when the nodes mobility is very high. Furthermore, in a clustered MANET (Lloret et al., 2008a, 2008b), each node periodically sends ‘Hello’ message to advertise its presence which consume extra transmission energy. In Juttner and Magi (2005), authors have described a spanning tree based algorithm for broadcasting in ad hoc networks. The whole broadcasting mechanism is divided into two parts: i) the maintenance of the broadcast tree, and ii)