Rumour-based Broadcasting for Mobile Ad Hoc Networks

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Abstract: Broadcasting is at the heart of many routing algorithms in mobile ad hoc networks (MANETs), and provides a simple yet effective method for one-to-many information dissemination in these networks. In this paper we describe a new algorithm for broadcasting in MANETs which is inspired, by the way rumours spread in social networks. We examine aspects of our algorithm through simulations.

1 Introduction.

Mobile ad hoc networks (MANETs) are created by mobile devices equipped with short-range radio transmission. Communication is possible between devices within each other's radio range. Mobility can lead to frequent topology changes in such networks. This, and the finite transmission range of the nodes, hardens classical networking tasks such as routing and information dissemination in MANETs. Broadcasting is the process in which one node sends a packet to all other nodes in the network. Broadcasting is often necessary in MANET routing protocols. For example, many unicast routing protocols, such as Dynamic Source Routing (DSR) and Ad Hoc On Demand Distance Vector (AODV) use broadcasting, or a derivation of it, to establish routes [1]. Broadcasting is also important for one-to-many information dissemination in such networks [2].

In this paper we describe a new broadcast scheme for MANETs, which is inspired by the way rumours propagate in social networks. Unlike previous schemes, our approach is simple, it does not require any exchange of control messages between nodes, and can adapt in a natural way to local changes in node density and mobility patterns. In a series of papers [3,4] we investigated our scheme in the context of peer-to-peer networks built on top of the Internet. Our study showed that the use of rumour mechanism greatly improves the efficiency of simple flooding in such networks. In this paper we describe a modified version of the scheme which is suitable for mobile ad hoc networks, and demonstrate aspects of it through simulations. The rest of the paper is organised as follows. In section 2 a brief overview is given of the most important of broadcasting schemes for MANET. This is followed by a description of our rumour-based broadcasting algorithm for these networks. In section 4 preliminary results are presented for both static and mobile ad hoc networks. The paper is concluded in section 5.

2. Broadcasting in mobile ad hoc networks

The most commonly used form of broadcasting in MANETs is simple flooding in which each node forwards a newly received message to all its neighbours. However, flooding can cause unnecessary and often harmful bandwidth congestion [5], as well as inefficient use of node's resources (CPU time and, more importantly battery power). Recently, a number of research groups have proposed several broadcasting techniques whose goal is to minimise the number of unnecessary retransmission while attempting to ensure that the broadcast package is delivered to each node in the network. Following [6], these approaches can be broadly divided into three categories. Probability Based Methods, Area Based Methods and Neighbour Knowledge Methods. Probability Based Methods use some basic understanding of the network topology to assign a probability to a node to rebroadcast. Area Based Methods assume nodes have common transmission distances; a node will rebroadcast only if the rebroadcast will reach sufficient additional coverage area. Neighbour Knowledge Methods maintain state on their neighbourhood, via "Hello" packets, which is used in the decision to rebroadcast. A recent study of these schemes was performed by Williams and Camp [6], and their results indicate that in static networks Neighbour Knowledge Methods perform best. However, in order to maintain a high delivery ratio when mobility is introduced these schemes require frequent exchange of Hello packets, resulting in a high communication overhead.

3. Rumour-based Broadcast

Rumour-like mechanisms provide a highly efficient way for distributed dissemination of news and fads in social networks, and are also being used in advertising campaigns (the so-called viral advertising). While more conventional social networks (such as friendship networks) are more or less static, those mediated by computer and communication networks, such as chartrooms and peer-to-peer groups, can be highly dynamic. Rumour mechanisms are effective in both static and dynamic social networks [7]. This suggests that such spreading mechanism could be a suitable starting point for efficient and distributed broadcasting in mobile ad hoc networks.

The broadcast protocol we describe here was inspired by Daley-Kendal mathematical model of rumour spreading in social networks [3]. The basic algorithm works as follows. Each of the nodes in the network can be in one of three possible states. We call a node holding an update and willing to rebroadcast it a *spreader*. Nodes that are unaware of the update will be called *ignorant* while those that already have received it but are not willing to rebroadcast the update are called *stiflers*. Each spreader waits for a random time before broadcasting an update. In this time the state of the node could change from spreader to stifler due to its interaction with neighbouring nodes, in which case the node refrains from broadcasting the update altogether. Otherwise at the end of its waiting time the spreader node senses the communication channel and transmits once it becomes available. Upon receiving a broadcast message an ignorant node changes its state and becomes a spreader. On the other hand, a node that is already a spreader can become a stifler, with probability α , if it hears a broadcast message that it already knows about. The broadcasting terminates when no spreaders are left in the network.

We note that, unlike other broadcasting schemes for MANET, in our algorithm a node can broadcast a message more than once. As we show later, this is particularly useful in mobile networks which are only partially connected. In such networks mobile spreaders can carry the update between isolated clusters hence increasing delivery efficiency. Another important feature of our scheme is its inherent adaptability to local topologies, which is achieved without the need for exchanging Hello packets. This is a direct consequence of the fact that changes in the state of a node are dictated (through broadcast messages) by the state of its neighbouring nodes. Such short-range coupling between nodes, when chosen judiciously, can result in a long-range order in the network, hence resulting in desired global performance.

4. Simulations

Three characteristics of mobile ad hoc networks, which distinguish them from fixed networks, are the finite transmission range of the nodes, the use of a shared medium for communication, and finally node mobility. A finite transmission range limits the number of direct connections (or links) that each node can have at each instance (the number of links is roughly given by $\pi R^2{}_t\ \bar{n}$, where R_t is transmission range and $\bar{n}$ is the average node density). The use of shared medium causes interference. Hence the success of a transmission between a pair of nodes at a given instance strongly depends on other transmissions in the network at that instance. In order to reduce the impact of interference, transmissions in MANET are controlled using various MAC protocols. Finally, mobility of nodes results in a time-dependent connection topology.

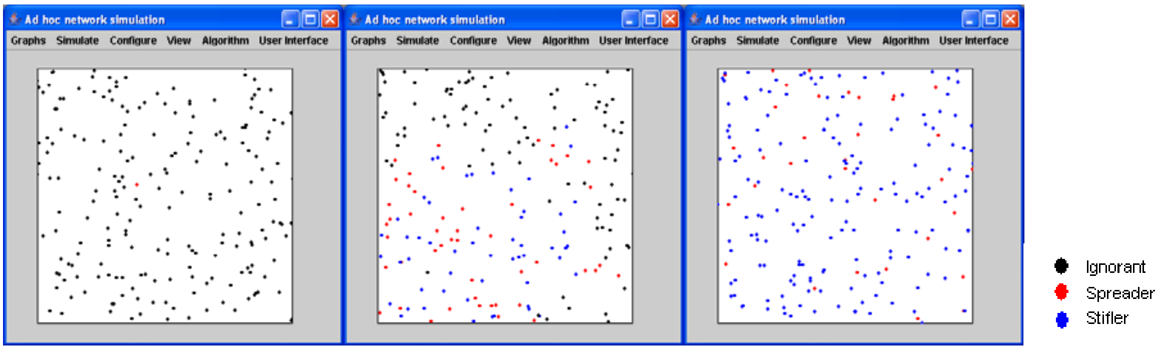

Fig. 1 Snapshots of a simulation of rumour-based broadcast in a mobile ad hoc network comprising 200 nodes. A random walk mobility model is used.

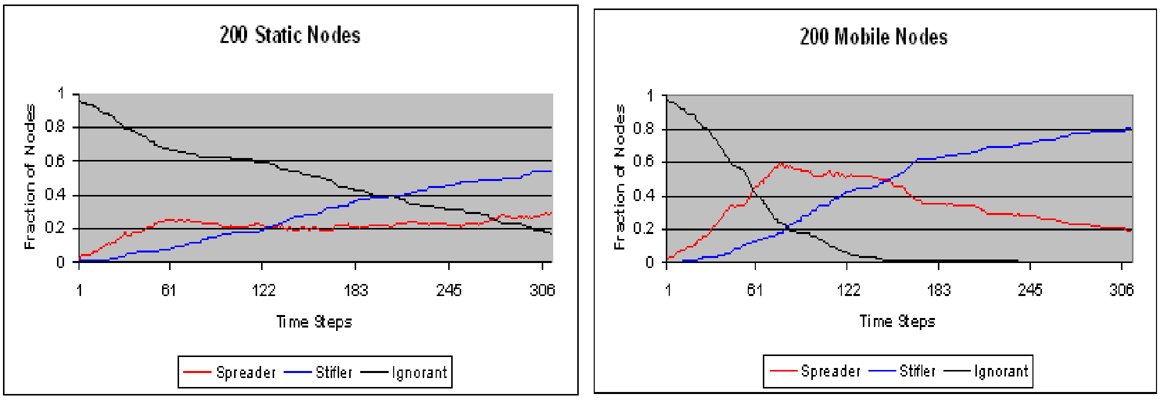

Fig. 2 Time evolution of the fraction of spreaders, ignorants and stiflers in rumor-based broadcasting. Left panel shows results for a static ad hoc network of 200 nodes. Right panel shows results for the same network but with node mobility switched on.

We have written our own JAVA simulator (called JANS) for MANET and have implemented our broadcasting scheme into the simulator. In its current state JANS incorporates generic features of mobile ad hoc networks, as described above, without including the whole complexity of various communication layers. In this section we illustrate the working of the basic algorithm through a set of simulations. All the simulations reported here were performed using a system consisting of 200 nodes, which were initially distributed randomly in a $300m \times 300m$ plane. This corresponds to an average density of $\bar{n} = 0.0022 m^{-2}$. The transmission range of the nodes was set equal to $R_t = 30$ m, and the interference range was set equal to $2R_t$. The impact of MAC layer on transmission was mimicked by requiring that at each simulation timestep only those nodes that do not cause interference to any neighbouring node, which is already transmitting at that timestep, can transmit. This is achieved in the following way. At each simulation timestep we go through the list of all potential transmitters at that timestep, in a random sequential order, and select a node for broadcasting if its transmission does not interfere with any other node that is already transmitting at that timestep.

In figure 1 we display snapshots of our simulation of rumour spreading in a mobile ad hoc network where nodes follow a random walk. The simulation starts with one randomly chosen node being “infected” with the update. As time evolves the number of spreader nodes increases but this process is slowed down due to spreader-spreader interactions, which turns some of the spreader nodes into stiflers. It can be seen that at the end of the process all nodes in the network have received the update, i.e. they are either in the spreader or stifler state (most of the remaining spreaders die out quickly due to spreader-spreader interactions).

Next we consider partially connected ad hoc networks and perform our simulations for two cases. In the first case nodes are static while in the second case they move according to a random walk model. Figure 2 shows time evolution of the fraction of ignorant, spreader and stifler nodes in both the static and the dynamic network. In the static network only 80% of the nodes have received the update at the end of the process. In contrast in the mobile networks the rumour spreads throughout the network with the aid of mobile spreaders, and reaches 100% of the nodes in the network. Furthermore, it can be seen that mobility also greatly increases the speed of spreading.

5. Conclusions

In this paper we described a new algorithm for broadcasting in mobile ad hoc networks, which is inspired by the way rumour spreads in social networks. Our preliminary simulation studies showed that node mobility could greatly enhance the performance of the algorithm. Interestingly, we found that when the network is fragmented into isolated clusters our scheme can still achieve a high delivery ratio since it utilizes the ability of mobile spreaders to carry the update between these clusters. Another important feature of our scheme is its inherent adaptability to changes in density and mobility of the network, which is achieved without the need for complex algorithms, and/or frequent exchange of control packets.

We are currently investigating our algorithm over a range of network conditions, including node density, node mobility and broadcast traffic rates and comparing its performance with other proposed schemes. Furthermore, the two basic parameters of our scheme, the spreader-stifler transition rate α and the maximum waiting time were fixed a priori in the current study. We plan to investigate how to make these adaptable to network conditions.

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