Internet Connection Protocol for Ad Hoc Wireless Networks

L Xue, M S Leeson and R J Green

Communications & Signal Processing Group, School of Engineering,
University of Warwick, Coventry CV4 7AL

Abstract: *This paper addresses the open issue of Internet connection for ad hoc wireless networks. The concept of "Gateway Awareness" is introduced into an existing proactive ad hoc routing protocol (DSDV). In this new approach a subset of nodes may contact Internet gateways and make this fact known to all mobile nodes. By so doing a route to the Internet is efficiently and quickly established. Simulation results show that this techniques displays comparable packet delivery ratios to current routing protocol philosophies in all circumstances and offers several times the throughput of existing schemes when optimised.*

1 Introduction

An ad hoc network is a highly dynamical wireless network without the use of any existing network infrastructure or centralised administration. In an ad hoc network, mobile nodes of similar transmission power and computation capabilities act both as terminals and as routers, forwarding packets for other mobile hosts whose destination may be out of their direct propagation range. The mobility of the nodes and consequent lack of topological stability make it necessary to develop routing protocols since those widely applied in fixed networks, such as Open Shortest Path First (OSPF) [1], are unsuitable for ad hoc networks.

In recent years, many ad hoc routing protocols have been developed. These may generally be categorised as table-driven, for example Destination Sequenced Distance Vector (DSDV) [2], or source-initiated, also known as demand-driven, such as Ad hoc On-demand Distance Vector AODV [3]. In addition, it is possible to adopt a hybrid approach, where nodes proactively maintain link information for nodes within a variable-sized local neighbourhood, whilst reactively sending out route queries distant destinations [4]. Both methods have specific advantages and disadvantages that make them suitable for the specific scenarios. Table-driven routing protocols attempt to maintain consistent, up-to-date routing information from every node to every other node in the network. This will minimise the delay before the data is sent but a periodical update has to be made among the network that consumes time, bandwidth and energy. On the other hand, source-initiated protocols route only when desired by the source node. A node requiring a route to a destination initiates a route discovery process within the network. This process is completed once a route is found or all possible route permutations have been examined. However, the route discovery process for an unknown destination will cause considerable delay.

If a node in an ad hoc network also has connectivity to the Internet, it is advantageous for that node to offer this to other nodes. Maximum use of the fixed network can considerably benefit the ad hoc network by allowing access to information on the Internet and by increasing network reliability. To enable it to operate as a router, a mobile node must discover the gateway to the fixed network. This paper introduces a new method for use in routing protocols, known as the *Gateway Aware* scheme, where only certain nodes that are within range of the fixed network receive and convey fixed gateway information. This subset of nodes has the ability to discover an Internet gateway within propagation range and is in charge of all the internetwork communications.

Here, simulation results are presented for an implementation of global ad hoc network connectivity using gateway aware nodes in a modified version of DSDV. The simulation is detailed and at the packet level, implemented using the ns2 simulator [5], including the accurate model behaviour of IEEE 802.11 MAC and PHY standards [6].

2. Overview of Internet connectivity for ad hoc wireless networks

The Internet draft "Global connectivity for IPv6 Mobile Ad hoc Networks (02 Nov 2002)" [7] has specified the Internet connection method for ad hoc wireless networks. An Internet router is used as the Internet Gateway and comes into play if nodes in the ad hoc network request connection to the Internet. Two methods for Internet Gateway discovery are proposed. The first is a proactive scheme, which allows periodical gateway advertisements to all nodes in the Ad hoc Network from the Internet Gateway. The second is a reactive scheme, which utilises solicitation and advertisement signalling between a wireless node and the Internet Gateway. Any Ad hoc routing protocols can be used inside the Ad hoc Network. Since DSDV is proactive, the same approach was adopted in the gateway discovery scheme used in the simulation work.

DSDV maintains a routing table for all the destinations of each node so that packets can be routed to the destination nodes whether or not within direct range. These routing tables are updated frequently concerning the topology changes in a wireless Networks. DSDV can fulfil the task of Internet access using the proactive gateway discovery protocol, with periodic advertisement to acknowledge the mobile nodes from the Internet Gateway. Every node will receive the advertisement and record the route to the Internet Gateway with up-to-date information. However, this scheme has some drawbacks. Firstly, the Internet Gateway information will create a large number of unnecessary data packets circulate in an ad hoc network whose main purpose not Internet Access. Secondly, maintaining up-to-date route information for an Internet Gateway depends on the advertis ement period of the Internet Gateway and the data update period of the ad hoc network. Given the dynamically changing network infrastructure, these data packets may consume a lot of bandwidth and energy. Finally, the creation of a defined route from the ad hoc network to the Internet will improve transmission performance by immediately providing a path of known reliability between the networks.

To address these issues a significant modification of DSDV may be made, namely the introduction of Gateway Aware nodes. Unlike DSDV, these nodes are the only nodes in the ad hoc network which are aware of the Internet Gateway when they are within the propagation range of each other. Together with the Internet Gateway they will be the intermediaries between the two networks and deal with all communications. Upon receiving the advertisement from the Internet Gateway, these nodes will identify themselves to all the other members as the access point to the Internet. When moving out of the direct range, they will stop their function as Gateway Aware nodes and notify the other nodes of this via the regular network updates. Nodes requesting Internet access go through the nearest Gateway Aware nodes and are not confined to a particular Internet Gateway. By using the Gateway Aware nodes, unnecessary data transmission is removed, as Internet Gateway information will only be maintained in the routing tables of certain nodes. Packets routed can change their targeted Gateway Aware nodes during transmission by using the routing criteria, improving network performance.

3. Routing criteria of Gateway Aware DSDV

The packet broadcast through the Ad hoc Networks contains the elemental parameters of DSDV such as the destination address, number of hops required to reach the destination and the sequence number of the information received. To perform Internet connection using Gateway Aware technology, the following data will be added into the packet:

- Gateway Aware node mark
- Announcement type

The mark is to identify the Gateway Aware nodes and will be called when the destination address is out of the routing table, which is assumed to mean that it is in another Network. In the routing table, the addresses of the Gateway Aware nodes are among the destination list. With the mark, the address of those service nodes will be easily located when Internet connection is required. For nodes forwarding the packets, the current status of that destination node which has been marked is examined and if it changes, the packets can be routed to the next available Gateway Aware node. Another important parameter is the information for the Gateway Aware node to announce or cancel its function. Wireless topology changes in Ad hoc Networks make the take-over between Gateway Aware nodes occur frequently. This parameter helps the mobile nodes know the changes as soon as possible, providing more reliable transmission channels with Internet connection.

When ad hoc nodes receive the packets with destinations outside the their network, these will be routed to the Gateway Aware node first and then pass to the Internet Gateway. A Gateway Aware node's information can be read from the routing table through the Gateway Aware node mark. When more than one Gateway Aware node exists, multiple paths can be used. The one with the newest sequence number will be chosen first. When the sequence numbers are the same, the path with a smaller distance metric will be used.

4. Simulation scenario

The simulations used 30 wireless nodes forming an ad hoc network and 3 wired nodes, of which one acted as the Internet gateway. To evaluate the performance of the Internet connection, the proactive gateway discovery scheme was employed and the broadcast period from the Internet Gateway was varied from 1 to 50 seconds.

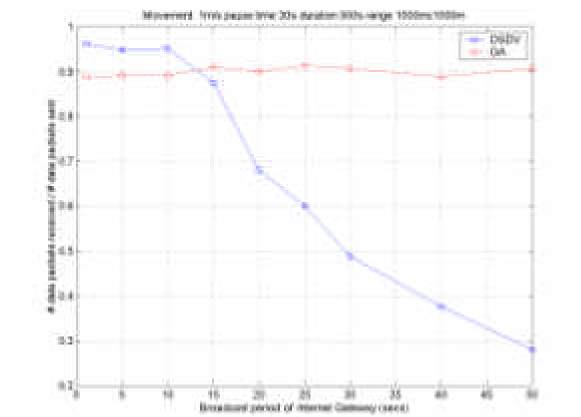
The wireless nodes moved around a square flat space (1000m×1000m) for 500 seconds of simulation time. The node movement model in the simulations was generated by the network simulator ns2 using its "random waypoint" model. In this, each node stays stationary for a pause time and then starts to move to a randomly selected destination in the 1000m×1000m range at a speed distributed uniformly between 0 and the maximum speed. Upon reaching the destination, the node remains stationary for the pause time again and then repeats the same movement until the end of simulation. A constant bit rate (CBR) was used to remove any traffic effects and concentrate on the protocol performance alone. One of the wired nodes was chosen as the destination, and a randomly selected mobile node as the sender.

To compare the performance of DSDV and the Gateway Aware technology, the parameters for routing inside the ad hoc network were the same in both cases. Three metrics were examined: packet delivery ratio (the ratio between the number of packets originated by the CBR source and the number of packets received by the destination), routing overhead (the total number of routing packets transmitted during the simulation) and average end-to-end delay.

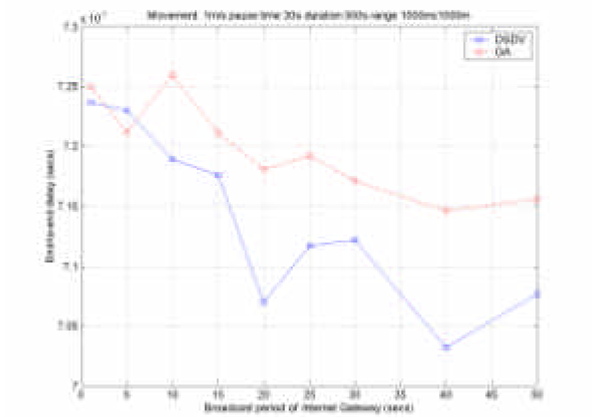
5. Simulation results

The simulations used two different node movement speeds: 1m/s and 20m/s, with a mean time for nodes to pause in the ad hoc network from 1 to 30 seconds. These parameters were chosen to represent congregations of mobile users on foot and in their vehicles. Since the proactive gateway discovery scheme was employed here, the period broadcast time of Internet Gateway played very important roles when network topology changes frequently. Figure 1 shows the results of a comparison between DSDV and the Gateway Aware approach for 30s mean pauses and with an Internet Gateway broadcast period of varying from 1s to 50s.

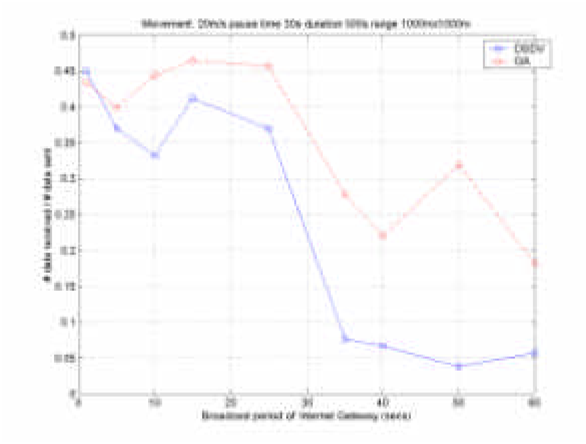
In the low node movement scenario (Figures 1(a) and 1(b)), as the broadcast period of Internet Gateway increased, DSDV failed to deliver the packets and the data deliver decreased substantially. The Gateway Aware technology performed better, offering a relatively stable data deliver ratio as the broadcast period increased. DSDV had a fairly constant routing overhead and the Gateway Aware technology had the same routing parameters within the ad hoc network, so that the routing overhead is also nearly constant. The Average end-to-end delay time with Gateway Aware technology is generally longer than DSDV for higher data deliver ratio and some packets may take longer to arrive.



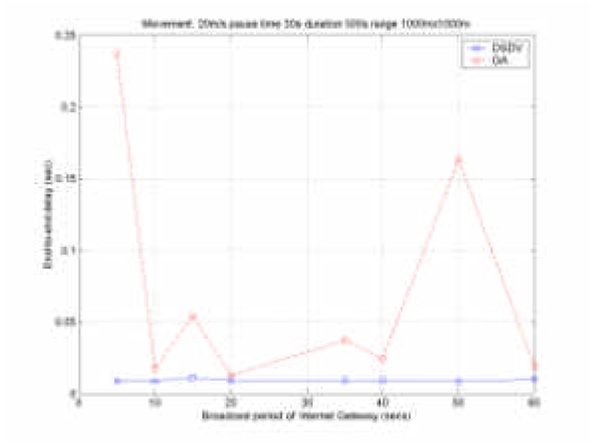
(a) 1m/s mean node movement speed



(b) 1m/s mean node movement speed



(c) 20m/s mean node movement speed



(d) 20m/s mean node movement speed

Figure 1: Performance for 30 seconds pause time: (a), (c) data delivery ratios; (b), (d) end-to-end delays.

In high node movement scenario (Figures 1(c) and 1(d)), as the broadcast period of Internet Gateway increased, the data deliver dropped for both DSDV and the Gateway Aware method. The Gateway Aware technology offered a higher delivery ratio but the advantage over DSDV was less marked. However, the Gateway Aware protocol achieved substantially better results when the broadcast period was over 30 seconds. The average end-to-end delay time with Gateway Aware technology was again generally longer than DSDV. The results for higher node movement show that the original parameters of DSDV (also used in Gateway technology) are not ideal for the new method.

6. Conclusions

This paper has described a significant modification to the DSDV routing protocol for ad hoc networks offering enhanced Internet connectivity for such networks. The essence of the new method is to designate a subset of nodes Gateway Aware, in that they provide the interface to Internet gateways. To assess the performance of this idea, simulations have been carried out using the *ns2* network simulator, which has been modified to provide a suitable simulation environment. The simulations compared the performance of DSDV and the Gateway Aware technology for different node movement speeds. At lower node movement speeds, Gateway Awareness had a significant advantage, providing higher and more stable data deliver ratios because of its flexible route selection ability. The advertisement period of the Internet Gateway had less of an effect on the Gateway Aware method than on DSDV. The primary parameters used for DSDV and the Gateway Aware technology need to be reconsidered to improve the performance, particularly for higher movement speeds.

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