Multi-Metric Routing Decisions for Ad Hoc Networks using Fuzzy Logic

Susan Rea & Dirk Pesch

Adaptive Wireless Systems Group
Department of Electronic Engineering
Cork Institute of Technology, Cork, Ireland
E-Mail: {srea, dpesch}@cit.ie

Abstract

On demand routing protocols for mobile ad hoc networks, such as Dynamic Source Routing (DSR), generate routes for unknown destination paths on an as needs be basis. So as to avoid the continual demand for route discovery in DSR, network nodes record previously determined routes in either path or link caches. A route discovery attempt can possibly result in several paths being uncovered for a single destination. As nodes often have a finite capacity path cache, it may not be possible to store all paths. In order to make intelligent decision with regard to the caching of paths or links it is necessary to attach weightings to links that are indicative of their quality. This paper presents a fuzzy logic based decision algorithm that weighs either a single link or a complete source destination path in order to instruct caching decisions and to optimise route selection.

1. Introduction

In an ad hoc network nodes cooperate in dynamically establishing wireless networks and maintaining routes through the network, forwarding packets for each other to facilitate multihop communication between nodes not in direct transmission range. Dynamic Source Routing (DSR) [1,2] is used in this paper to illustrate the effect of multi-metric decisions making using fuzzy logic for caching decisions. A node initiates route discovery when it wishes to transmit a packet to a destination that it does not have a cache record for. To do so, the node broadcasts to its local neighbourhood a route request for the necessary destination. Any node receiving such a packet adds its own address to the route record and rebroadcasts the packet to its neighbour zone if it has not already processed this packet or its address is not already listed in the route record. This route request packet will arrive at the required destination or at some intermediate node that has knowledge of a path to that destination whereupon a route reply is returned to the route request initiator node that lists the path from source to destination, which is then cached by the source node. A single route discovery can lend itself to result in possibly multiple routes for a destination. However, the flooding nature of a route request can harshly influence the performance of a network, as several nodes may initiate floods concurrently, generating bursts of broadcast traffic through the network resulting in collisions and retransmission attempts that can cause congestion in a network. By implementing effective caching the need for route discovery can be minimised and the performance of the network improved. This paper presents a multi-metric decision algorithm that enables a node to select effective routes for caching thereby reducing the necessity for route discovery.

2. Fuzzy Logic Decision Making

In DSR as a route request is flooded through the network, nodes append their own address to the route record and rebroadcast the request. It is proposed here that nodes that appear in this route record should add to a cumulative weight function an assessment of the link over which this packet was received. Route metrics that can be used to determine the associated link and overall path cost are link strength, link capacity, energy available at a link vertex, and number of hops in a path. Current

routing protocols are typically optimised with regard to one of these metrics, for example DSR selects paths that consist of the shortest number of hops [3] and the Associativity-Based Long-Lived Routing protocol [4] selects paths that exhibit long lived connectivity between nodes, with nodes periodically transmitting beacons as a means of identifying themselves. These beacons are counted and used as a measure of connectivity, nodes with a high beacon count are considered to be stable and as such can be used to route packets through.

It is proposed here that a number of metrics will be combined into a single decision thereby optimising a routing protocol over a number of metrics and making it more robust. The link cost will be determined via a fuzzy logic system with the caching parameters being applied to a fuzzifier that translates them into fuzzy sets. The fuzzy sets are used to appraise each constraint as being Low, Medium or High, assigning each a value between {0,1}. These evaluations are passed to a fuzzy inference engine that applies a set of fuzzy rules that determines if a route is apt for caching or not. If a route is deemed suitable a route reply is generated and sent to the initiator of the route request by reversing the path stored in the route record. Example fuzzy rules for both *To cache* and *Not To Cache* conclusions are given below:

IF (LS=HIGH) AND (LC=HIGH) AND (NE=HIGH) AND (NH=LOW) THEN CACHE
IF (LS=LOW) AND (LC=HIGH) AND (NE=LOW) AND (NH=HIGH) THEN NO CACHE
Where, LS = Link Strength
LC = Link Capacity
NE = Node Energy
NH = Number of Hops

The decision to cache or not is made by using the min-max rule [5], with the minimum value of the *To Cache* rule set being taken as the outcome and likewise for the *Not To Cache* set. The maximum value of these two outcomes is then selected as the conclusion for the decision. Also, to limit the flooding of route requests over the network it is necessary that a node self-monitors with respect to its remaining battery life and current traffic load before committing to advance packets for others.

Conclusion

This paper proposes a fuzzy logic based caching decision as a route selection method. This facilitates the generation of effective caches that limits the necessity for route discovery floods. In conjunction with this, nodes can decide to end a route discovery flood if they select themselves as being unsuitable for routing through self-monitoring. This cumulative path fuzzy logic system also generates route replies only for routes suitable for caching and not for all available routes as is usual with DSR. The final paper will present results demonstrating the effective of this fuzzy logic decision-making algorithm on network performance.

References

[1] C. E. Perkins, Editor, *Ad Hoc Networking*, Addison-Wesley, Boston etc., December 2000.

[2] D. B. Johnson, D. A. Maltz, H. Yih-Chun, *The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR)*, IETF Internet Draft, http://www.ietf.org/internet-drafts/draft-ietf-manet-dsr-08.txt, work in progress.

[3] Y. C. Hu., D. B. Johnson, *Caching Strategies in On-Demand Routing Protocols for Wireless Ad Hoc Networks*, Proceedings of the Sixth Annual International Conference on Mobile computing and Networking, MobiCom 2000 August 6 – 11, Boston, MA, USA.

[4] C. K. Toh, *Ad Hoc Mobile Wireless Networks protocols and Systems*, Prentice Hall PTR, New Jersey, 2002.

[5] L. Reznik, “Fuzzy Controllers”, Newnes Publishing, 1997.