UNIVERSITY OF SOUTHAMPTON
FACULTY OF PHYSICAL AND APPLIED SCIENCES
SCHOOL OF ELECTRONICS AND COMPUTER SCIENCE

Cross-Layer Aided Routing Design for Ad Hoc Networks

by

Jing Zuo

A thesis submitted in the partial fulfilment of the requirements for the award of Doctor of Philosophy at the University of Southampton

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ABSTRACT

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In this thesis, we propose a series of cross-layer aided routing algorithms for *ad hoc* networks by jointly exploiting the characteristics of the physical layer, of the data link layer and of the network layer, for the sake of improving the network's throughput, while reducing the normalized energy consumption.

Since the node mobility in dynamic self-organizing *ad hoc* networks may render the routing information gathered during the route discovery process invalid and hence may disrupt the current data transmission, a fuzzy logic aided technique is incorporated into the routing algorithm for mitigating the influence of imprecise routing information. Both the expected route life-time and the number of hops are used as the input parameters of the Fuzzy Logic System (FLS), which outputs the 'stability' of a route. Hence, the specific route having the highest route 'stability' is finally selected for data transmission. The proposed fuzzy logic based routing outperforms the conventional Dynamic Source Routing (DSR) in terms of the attainable network throughput.

Moreover, since near-capacity channel coding aided Multiple-Input Multiple-Output (MIMO) schemes allow a single link to communicate using the lowest possible transmit power at a given Frame Error Rate (FER), multi-antenna aided routing was proposed for reducing the system's total energy consumption, which relied on a three-stage concatenated transceiver constituted by an Irregular Convolutional Code, Unity-Rate Code and Space-Time Trellis Code (IrCC-URC-STTC) equipped with two antennas. It is demonstrated that in a high-node-density scenario the average energy consumption per information bit and per node becomes about a factor two lower than that in the equivalent Single-Antenna Relay Nodes(SA-RNs) aided networks.

Finally, we further exploit the benefits of cross-layer information exchange, including the knowledge of the FER in the physical layer, the maximum number of retransmissions in the data link layer and the number of RNs in the network layer. Energy-consumption-based Objective Functions (OF) are invoked for calculating the end-to-end energy consumption of each potentially available route for both Traditional

Routing (TR) and for Opportunistic Routing (OR), respectively. We also improve the TR and the OR with the aid of efficient Power Allocation (PA) for further reducing the energy consumption. Moreover, two energy-efficient routing algorithms are designed based on Dijkstra's algorithm. The algorithms based on the energy-consumption OF provide the theoretical bounds, which are shown to be close to the bound found by exhaustive search, despite the significantly reduced complexity of the former. Finally, the end-to-end throughput and the end-to-end delay of this system are analyzed theoretically. The simulation results show that our energy-efficient OR outperforms the TR and that their theoretical analysis accurately matches the simulation results.

Declaration of Authorship

I, **Jing Zuo**, declare that the thesis entitled **Cross-Layer Aided Routing Design for Ad Hoc Networks** and the work presented in it are my own and has been generated by me as the result of my own original research. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University;
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- Where I have consulted the published work of others, this is always clearly attributed;
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- Parts of this work have been published.

Signed: .....

Date: .....

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