Energy and Delay-Constrained Routing in Mobile Ad Hoc Networks: an Initial Approach

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ABSTRACT

Energy conservation is a critical issue regarding wireless mobile ad hoc networks, since the nodes are battery restrained and the depletion of their power defines the lifetime of the network. In this work a mechanism for energy saving and timely delivery of data packets is incorporated into the route discovery phase to select paths with lower cost. The proposed algorithm utilizes two metrics: residual energy and queue length at each node. Buffer information is considered as a traffic load characteristic and its use is twofold: limitation of battery power consumption and end-to-end delay. A simulation-based performance comparison between a routing ad hoc protocol and its modified energy and delay-constrained version demonstrates that the latter one improves system performance for certain network scenarios.

Categories and Subject Descriptors

C.2.2 [**Computer-Communication Networks**]: Network Protocols – *routing protocols*

General Terms

Design, Performance

Keywords

Energy efficiency, delay, routing protocols, ad hoc networks

1. INTRODUCTION

An algorithm for energy and delay-aware routing is introduced in this work. A cost function for residual battery power and number of packets waiting to be served is elaborated so that energy efficient routes are chosen during the process of path discovery and a mitigating effect on the experienced delay by the data packets is obtained.

In our study the feasible multi-objective cost function is restricted to twofold. The Energy and Delay-Constrained (EDC) routing algorithm maintains the parameters as follows:

Residual battery power is considered as an indication of the capabilities of the observed node to forward more new traffic and is a mandatory part of every energy-aware routing protocol.

Current size of the queue at each node is exercised in order to restrict the end-to-end delay of the data packets. We regard buffer information as an important metric in the process of finding a path since when taken into account it helps avoiding routes with congested nodes, which on the one hand add to the end-to-end delay of the data traffic and on the other hand have their battery power dissipated with rapid pace.

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2. DESIGN AND PERFORMANCE EVALUATION

2.1 Cost Function

A heterogeneous cost function (CF) consisting of the above mentioned parameters should be defined with a set of values [0, 1]: zero depicting the lowest achievable cost and one reflecting the highest cost of the observed route. When the battery power of the nodes along the path is preserved and little traffic has been forwarded through them the cost of the path is close to the lowest one. The cost of the studied route increases with the growth of the traffic introduced in the nodes and with the enlargement of their queues and tends to reach its maximum value when the network gets congested.

As a firs approximation of the cost function we have adopted the one as follows:

$$\cos t = \alpha \sum_i \frac{1}{1 + ER_i^t} + (1-\alpha) \sum_i (1 - \frac{1}{1 + Q_i^t}) ,$$

where E_i^t represents the residual battery power at node *i* at time *t* and Q_i^t is the number of packets waiting to be served at time *t* in the buffer of node *i*.

The first part accounts for the energy value, while the second one expresses the cost depending on the buffer size. In order to strike a balance between the two components of the cost value a parameter α is introduced, with values between 0 and 1.

The calculation of the heterogeneous CF is implemented in the selection of a route so that the path to be optimal from an energy and delay-efficient point of view.

The CF is implemented in the route discovery phase of the AODV protocol. We make use of the reserved fields of the RREQ and RREP control packets to transmit the cost of a given route. For the format of these control packets the reader is referred to [3]. The choice of the underlying protocol is based on its applicability and logic [1], [2].

2.2 Performance evaluation

2.2.1 Simulation environment

The results reported further are obtained by network simulator ns-2. The area of the network is rectangular: 700 m. x 700 m. field and a random waypoint model is used to generate node movement. It is characterized by two main parameters: maximum speed set to 2 m/s and pause time set to 2 s. The network is formed by 50 mobile nodes, each node being a source of one connection at a maximum. 20 CBR connections of 3 packets/s are generated. Only data packets of size 512 bytes are used. Simulations are run for 300 simulated seconds. Each data point represents an average of five runs. For the calculations made, 95% confidence intervals are assumed.

2.2.2 *Simulation results*

A performance comparison of AODV protocol and its modified version denoted by us as EDC-AODV is conducted. Their evaluation is carried out in terms of: packet delivery fraction, end-to-end delay and residual energy.

Simulation results show that EDC-AODV outperforms AODV for α smaller than 0.4 when packet delivery fraction is considered. Not only that for all different values of the weighted parameter ECD-AODV performs better than AODV when end-to-end delay is regarded (Fig. 2), but even in terms of dispersion around the mean value does the modified algorithm outperform AODV. In Fig. 3 the total residual energy of the network at the end of the simulation time is presented. It has greater mean value for all α for the EDC-AODV in comparison with AODV. Fig. 4 gives another presentation of the total residual energy: when AODV is run the difference between the residual energy of the node with the highest and that with the lowest battery power is bigger than the corresponding one for the EDC-AODV protocol.

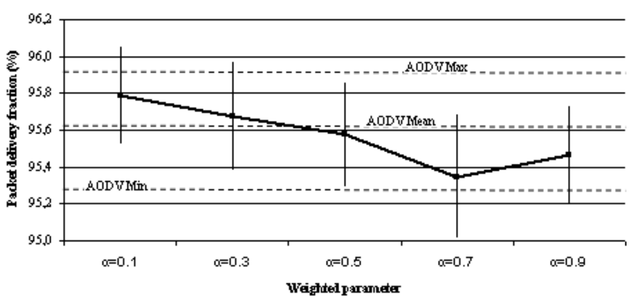

Figure 1. Packet delivery fraction

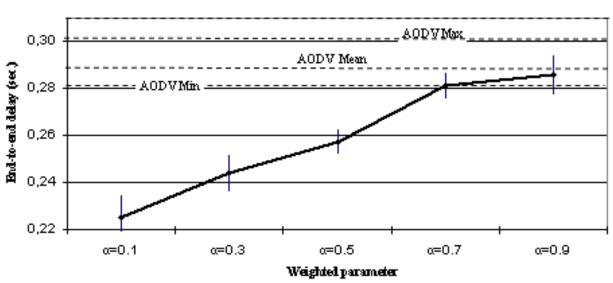

Figure 2. End-to-end delay

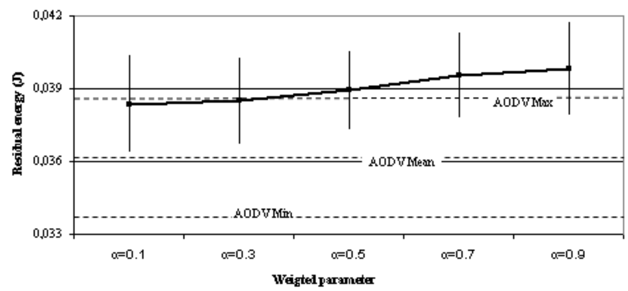

Figure 3. Residual energy

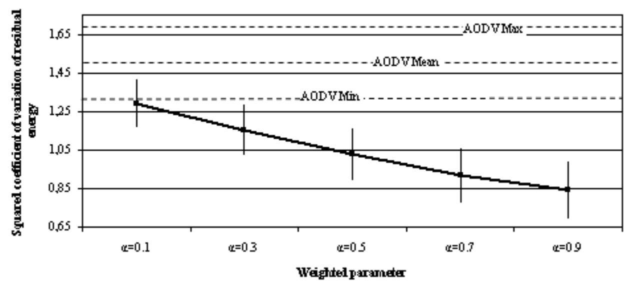

Figure 4. Squared coefficient of variation of residual energy

3. Conclusions

An initial approach for energy and delay-efficient routing for MANETs is outlined. The proposed solution takes into account two parameters – residual energy and buffer information – in order to achieve its paramount goals: to prolong system lifetime and to minimize the end-to-end delay. The results for the defined simulation scenario demonstrate that the AODV protocol is outperformed for all the parameters observed.

4. ACKNOWLEDGMENTS

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