An Energy Efficient Multipath Routing Algorithm for Wireless Sensor Networks

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***Abstract*— In this paper we introduce a new routing algorithm for wireless sensor networks. The aim of this algorithm is to provide on-demand multiple disjoint paths between a data source and a destination.**

Our Multipath On-Demand Routing Algorithm (MDR) improves the reliability of data routing in a wireless mobile network while maintaining the amount of overhead traffic at a low value.

An important feature of MDR is that it is very robust against the average speed of the nodes in the network. Even for very high values of the mobility, the algorithm succeeds in delivering the data to the destination.

I. Introduction

In this paper we introduce a new routing algorithm for wireless sensor networks. The aim of this algorithm is to provide multiple disjoint paths between a data source and a destination. *Multipath On-Demand Routing* (MDR) is an on-demand algorithm, meaning that a new path from a source to a destination is created only when a data packet has to travel between them. It is well suited for wirelless sensor networks because it requires small communication overhead and low processing power.

MDR can also be used in general purpose ad-hoc wireless networks. Usually, such a network has a highly dynamic topology due to mobility and failures. As the network diameter grows, data generated by one or more sources usually has to be routed through several intermediate nodes to reach the destination due to the limited range of each node's wireless transmission. Problems arise when intermediate nodes fail to forward the incoming messages.

To prevent this, acknowledgements and retransmissions are implemented to recover the lost data. However, this generates large amount of additional traffic and delays in the network. The reliability of the system can be increased by using multipath routing [1]. Multipath routing allows the establishment of more than one paths between source and destination and provides an easy mechanism to increase the likelihood of reliable data delivery by sending multiple copies of data along different paths.

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II. Previous work

Several different routing algorithms for sensor networks have been studied until now. The *Temporally Ordered Routing Algorithm* (TORA) [6], *Dynamic Source Routing* (DSR) [4] and *Directed Diffusion* [3] are only some of them. All these algorithms focus on reliable delivery of data to destinations. But they are sensitive to a large number of communication failures and to high average speed of the nodes.

To diminish the effects of node failures (both communication and hardware failures) multipath routing schemes have been developed based on these algorithms [5][2]. They are a solution against failures but the amount of control and data traffic usually increases a lot.

We have already developed a data-splitting method that can be used together with a multipath routing algorithm [1]. The main idea behind it is to split the original data packet in n subpackets (n is the number of paths available from the source to the destination) in such a way that only a k subset of subpackets ($k < n$) are necessary to reconstruct the original data packet.

MDR was designed with the goal of providing several disjoint paths between the source and the destination. It proved that it is tolerant to failures and more than that, it is almost immune to topology changes due to mobility. High average speeds of the nodes produce negligible negative effects.

III. Multipath On-Demand Routing

MDR follows the main ideas behind the DSR algorithm. It is based on an initial flooding of the network with the route request and then generates route replies from the destination back to the source (see Figure 1). There is no route maintenance phase and the control messages have fixed length.

We present bellow some more details about the two phases:

- *Route Request* - when the source wants to find a destination it floods the network with a short message announcing this. The message contains the source ID, the destination ID and the ID of the request. Thus, the length of the message remains constant during the route request.
- *Route Reply* - the destination will eventually receive one of the route request messages. It only knows that there exists a path and it is not interested in what the path is. The destination just returns a route reply to the neighbor from which it received the route request message. The

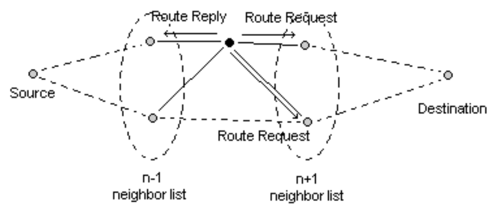

Fig. 1. Algorithm details

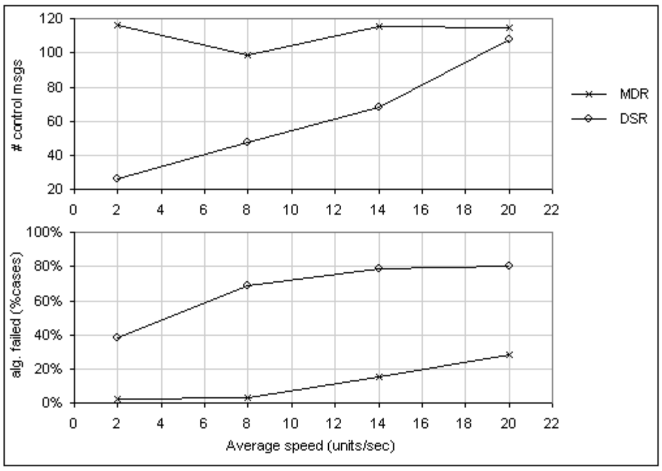

Fig. 2. Comparison MDR/DSR

message contains a supplementary field that indicates the number of hops it traveled so far. Each node that receives a route reply, increments the hop count of the message and then forwards the message to the neighbor from which it got the original route request.

This mechanism reduces the size of the messages considerably when compared to the original DSR. In fact we are moving the information stored inside the messages to the sensor nodes themselves. The sensor nodes are responsible to ”remember” where the flooding message came from.

IV. RESULTS AND DISCUSSIONS

We have implemented the MDR algorithm in order to get a better understanding of it. For example, in Figure 2 we show a comparison between DSR and MDR. The first observation that we can make is that the algorithms works for mobility values at which the DSR algorithm gives an unacceptable rate of errors. The price is paid in the amount of control traffic.

Figure 2 also shows that the number of overhead messages is higher for the MDR algorithm. A closer look at the message sizes shows that the MDR traffic compared to the DSR traffic varies from a 4.04:1 to a 1.02:1 ratio (from the lower average speed to the higher one).

The simulations involved networks of 50 nodes distributed randomly within a rectangle area (800x500 units). We have considered Random Way Point Algorithm to model the nodes

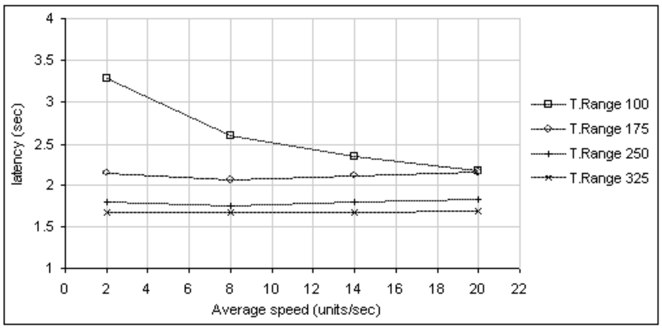

Fig. 3. Data delivery latency

mobility. The simulations were repeated for several transmission ranges of the nodes (100-375 units) and for several values for the average speed of each node.

The study involved several parameters of the algorithm. We have studied the influence of mobility on the number of control messages, on the number of paths discovered, on the data latency (for example see Figure 3), and on the number of cases the data packet does not reach the destination. Other parameters such as the period for which the source waits for route replies and different failure modes were also taken into consideration.

V. CONCLUSIONS AND FUTURE WORK

In this paper we have introduced a new multipath routing algorithm (MDR). It is a viable solution against mobility and failures in wireless sensor networks and in ad-hoc network in general. From the point of view of reliability, it performs better when compared with single path routing algorithms such as DSR.

The future work will focus mainly in improving MDR by modifying the Route Reply phase to better deal with failures. The caching of routes will be taken into consideration as well (the trade off between the number of control messages and the reliability has to be investigated).

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