Multipath Routing for Data Dissemination in Energy Efficient Sensor Networks

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Abstract

In wireless sensor networks (WSN) data produced by one or more sources usually has to be routed through several intermediate nodes to reach the destination. Problems arise when intermediate nodes fail to forward incoming messages. We increase the reliability of the system by providing a new routing mechanism that specifically takes into consideration possible failures on the communication paths. The new algorithm computes several paths from the data source to the destination and sends, over each path, a fragment of the initial data. Only k fragments of the total n fragments (k<n) are necessary to build the initial data packet. The path construction is based on the reputation coefficients of the nodes, computed on how the nodes acted in the past.

1. Introduction

Sensor nodes have many failure modes [3]. Each failure decreases the performance of the network. Our approach to assure that the gathered data will reach its destination in the network is by designing an algorithm that assumes as a regular fact that nodes may be not available during the routing procedure. Additional energy will be required only for a small amount of computations; this is almost negligible compared with the energy used for communications [6].

The algorithm starts by discovering multiple paths from the source to the destination [7]. These paths are calculated taking into account the *reputation coefficient* of the nodes (a coefficient that shows the way a specific node behaved in the past). A low reputation coefficient of a node means that the node failed to route messages in the network in the past and it will be avoided from the routing scheme. The reputation coefficient is increased with each successfully routed packet.

Sending the same data over multiple paths is a solution in case of node failures but it requires large quantities of network resources (such as bandwidth). Our contribution is to split the data packet into several pieces and to send these parts instead of the whole packet. To avoid path failures that make the received data useless we introduce also redundancy (if the data packet was split into n parts, only k parts (k<n) should be enough to reconstitute the original packet).

This paper briefly describes the main characteristics of computing the reputation coefficient, designing the multipath routing and splitting the data into small parts. Some simulation results and future directions are also described.

This work is performed as a part of the European EYES project (IST-2001-34734) on self-organizing and collaborative energy-efficient sensor networks [2]. It addresses the convergence of distributed information processing, wireless communication and mobile computing.

2. Description of the algorithm

This section will describe aspects of the multipath routing, data splitting and reputation coefficient computation. We will focus on the main ideas and not on the implementation of the algorithm.

2.1. The multipath routing

The multipath routing algorithm described by Romer [7] solves a certain number of problems related to the temporal order event delivery in WSN. Romer's algorithm is almost 20 times more energy efficient than algorithms implemented in classical distributed systems. The failure of nodes or the presence of nodes that are not able to accomplish the routing mechanism due to low energy is covered by this algorithm.

Our work extends Romer's algorithm as follows. We maintain the idea of subscription groups (SG) to ensure temporal order delivery of events. A subscription group is a group of nodes whose events must be delivered in temporal order. Romer's solution to construct multipaths is the following: the main path is constructed by arranging all the source nodes, the intermediate nodes and the destination nodes in a ring (using shortest-path considerations). Splitting the ring in two half-rings gives us already two paths from source to destination. More paths can be constructed by dividing each half-ring into several segments.

The covering multipath construction uses a modified version of Dynamic Source Routing protocol (DSR) [1]. Our modification consists in transforming DSR from an address-centric algorithm to a data-centric algorithm. This protocol assures that even when high mobility is required, it delivers 95 to 100% of the messages, across routes with a length of 1.01 times larger than the optimal path, with a routing packet overhead of 1% of the total packets sent [1].

2.2. The reputation coefficient

Romer's multipath construction can be improved by using the information on how nodes succeeded to deliver messages in the past. This way, the modified DSR protocol will run only across nodes with the reputation coefficient larger than a certain thresh-hold. During the run of the protocol the nodes will update the information about their neighbors.

The mechanism of testing that a node cooperates is simple. Assuming bidirectional communication, suppose that node A needs to send a message to node C via node B. A will be able to listen to what node B transmits, getting some feed-back on B. There are several situations where node B transmits the message and node A does not receive the confirmation or where node B tricks node A by making it believe it transmitted the message. Examples include changing the transmission range or sending information during another transmission so nothing will be understood.

We compute the reputation coefficient by using a *watchdog-pathrater* mechanism as described in [3]. The watchdog gets information about the neighbors and the pathrater updates the path information. Several authors have improved this algorithm to cover more conflicting situations [4][5]. The main purpose is to find a formula for computing the reputation coefficient in a way that watchdog errors will not decrease it too much while real misbehaving has important influence.

2.3. Data splitting across multiple paths

One of the disadvantages of multipath routing is that it sends the same information over multiple paths. In the end, several copies of the same data-packet will reach the destination. This means that we can reduce the bandwidth by splitting the initial data packet into several subpackets such that only a smaller number of these subpackets will be necessary to create the original information. On each path we will send one of these subpackets. Even if some of the paths may fail during the algorithm, the received subpackets should be enough to reconstitute the original information.

The total number of subpackets as well as the redundancy used is a function dependent on the multipath degree and on the estimated number of failures. As the multipath degree can change according to the source and destination positions in the network, each source must be able to decide on these parameters at each transmission.

3. Simulation environment and results

The simulations we are performing assume that nodes are placed in a 2D matrix structure. This scenario has the advantage of maintaining a constant connectivity across the whole network. The connectivity can be changed by specifying the transmission range of a node. The number of nodes is 100. To be able to test different network topologies, we have placed these nodes inside a matrix with variable size (for example: 10x10, 15x15, 20x20) while making sure the network is not split in several clusters.

We have simulated the routing algorithm in the presence of failures. We assume that 10%, 20%, 30% or 40% of the nodes can stop forward messages (each one for 10% or 20% of the simulation time). The results are presented in Figure 1. The graph shows the worst case when the watchdog is not enabled and the best case when the watchdog can detect that a node failed after the first message it does not deliver. There are 4 paths between the source and the destination with an average length of 10 nodes/path.

Figure 1 helps us getting an empiric formula for how much information a subpackets must contain. For example, when 30% of the nodes are expected not to perform their function for 10% of the time (and the watchdog is set to off), only 2.98 out of the four paths succeed in delivering messages.

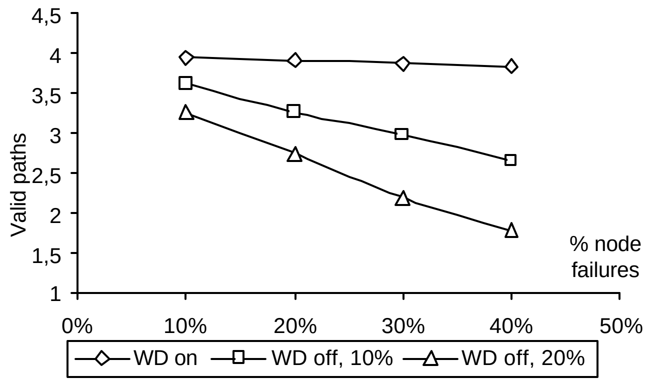

Figure 1 Number of valid paths

Splitting the data packet in 4 subpackets, each of them carrying 1/3 of the original information (plus the overhead) should work. This means an almost 3 times traffic reduction. Future work concerns the way data should be split into subpackets, such as a given smaller number of received subpackets could compose the original data (by using the XOR function, error correcting codes, etc.).

4. Conclusions and future work

We outline ideas for a new robust algorithm for WSN routing. The main goal is to make sure that data from the source will reach the destination even if failures/intrusions occur in the network. The described algorithm combines the notions of multipath routing and reputation coefficient ([3][7]) and adds the idea of sending subpackets of the main data packet through the multiple paths.

Future work is related to improving the described algorithms and to find how to combine them in the best way. This implies also designing new algorithms because the existing algorithms related to routing and reliability are not well suited to the WSN (the sensor nodes do not have enough resources for them).

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