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CASE STUDY AND REPORT

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A Survey on Energy Efficient Multipath Routing Algorithms for Wireless Sensor Networks

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Abstract**—**Routing in wireless sensor networks is a demanding task. This demand has led to a number of routing protocols which efficiently utilize the limited resources available at the sensor nodes. All these protocols typically find the minimum energy path. In this paper we analyze different routing algorithmsfor wireless sensor networks. The aim of these algorithms is to provide on-demand multiple disjoint paths between a data source and a destination.

In Multipath On-Demand Routing Algorithm (MDR), it 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

A wireless sensor network consists of light-weight, low power, small size sensor nodes. The areas of applications of sensor networks vary from military, civil, healthcare, and environmental to commercial. Examples of application include forest fire detection, inventory control, energy management, surveillance and reconnaissance, and so on. Due to low-cost of these nodes, the deployment can be in order of magnitude of thousands to million nodes. The nodes can be deployed 1either in random fashion or a pre-engineered way. The sensor nodes perform desired measurements, process the measured data and transmit it to a base station, commonly referred to as the sink node, over a wireless channel. The base station collects data from all the nodes, and analyzes this data to draw conclusions about the activity in the area of interest [4]. Sinks also can act as gateways to other networks, a powerful data processor or access points for human interface. They are often used to disseminate control information or to extract data from the network.

Key issues like stringent energy constraint and vulnerability of sensors to dynamic environmental conditions, still remain to be addressed. They create a demand for energy-efficient and robust protocol designs with specific consideration of the unique features of sensor networks, such as data-centric naming and addressing convention, high network density and power limitation. Recently, various routing protocols have been proposed for WSNs. Most of them use a single path totransmit data. The optimal path is selected based on the metrics, such as the gradient of information, the distance to the destination, or the node residual energy level. Some other routing protocols that use multiple paths choose the network reliability as their design priority.

In multipath extensions of Dynamic Source Routing (DSR) and Ad hoc On-demand Distance Vector (AODV) were proposed to improve the energy efficiency of ad hoc networks by reducing the frequency of route discovery. Directed transmission is one of the probabilistic routing techniques, which are derived from the flooding. It uses a retransmission probability function to reduce redundant copies of same event data. The hop distance to the destination and the number of steps that the data packets has traveled are used as parameters. The retransmission control mechanism avoids the intensive usage of the shortest path in a certain level. The energy aware routing is proposed in. It uses localized flooding of request messages to find all possible routes between the sources and sinks, as well as the energy costs associated to these paths.

In this paper we discuss different routing algorithms for wireless sensor networks. The aim of these algorithms 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 wireless 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 mul-tipath routing [1]. Multipath routing allows the establishment of more than one path 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.

An important issue in the design of WSNs is to determinean effective sensor placement strategy to meet sensingquality requirements everywhere in the field with acertain flexibility of handling individual sensor failures.This is also known as the Coverage Problem (CP). Sensingquality requirements, or simply coverage requirements, canbe uniform or non-uniform over the sensor field. In the formercase, the resulting problem is a uniform

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CP, while inthe latter case it is a differentiated CP. An effective sensorplacement strategy should also be energy-aware. It shoulddecrease the energy consumption and increase the networklifetime. Apart from the placement of sensors, thereis another way of obtaining energy efficiency in

WSNs:scheduling active and standby periods of the deployed sensors.In a given time period only sensors necessary for thecoverage of the sensor field and for the connectivity of thesensors are required to be active, other sensors can be instandby mode. Determining activity schedules of the sensorsto maximize the network lifetime is a crucial issuein the design of a WSN.

II. PREVIOUS WORK

Several different routing algorithms for sensor networks have been studied until now. The *Temporally Ordered RoutingAlgorithm* (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 sub packets (n is the number of paths available from thesource to the destination) in such a way that only a k subset of sub packets (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:

- ***a.*** ***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.
- ***b.*** ***Route Reply* -** the destination will eventually receive oneof 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 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.

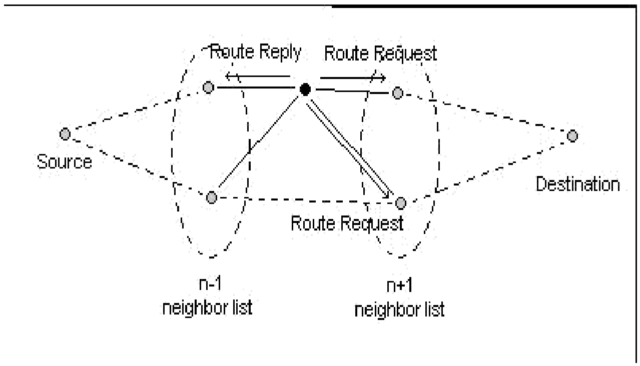

Figure. 1. Algorithm details

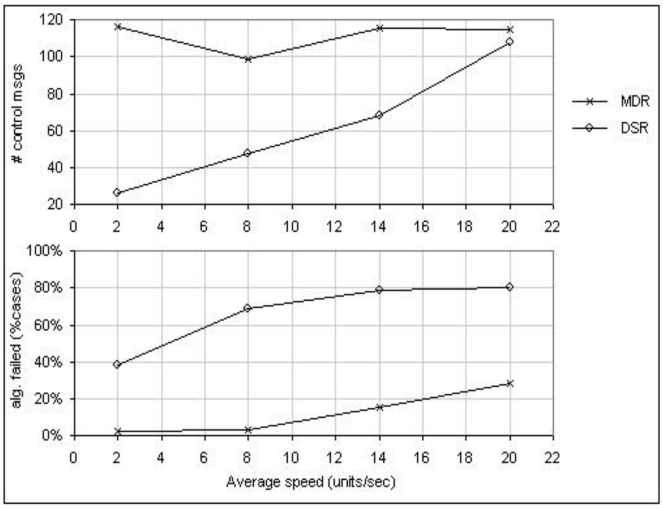

Figure. 2. Comparison MDR/DSR

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

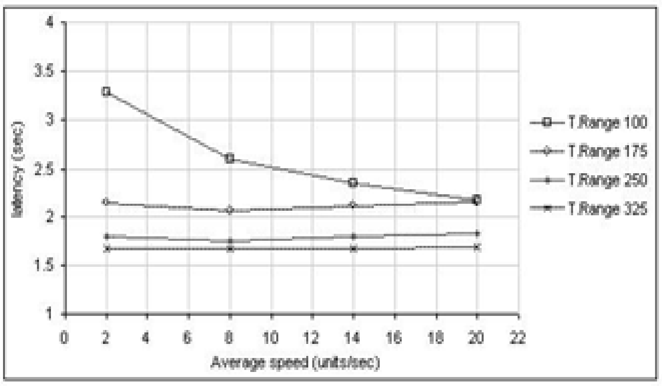

Figure.3. Data delivery latency

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

The mobile ad hoc networks have been a subject of quite a number of investigations in recent years. Most of these investigations have been motivated by the need to design an efficient routing protocol for an ad hoc network. A good routing protocol needs to provide reliability and energy efficiency with low control overhead. To ensure reliability, load balancing and QoS, multipath routing protocols have been proposed for MANET. This paper presented a survey of most recent multipath routing protocols for MANETs. The surveyed protocols showed that multipath routing can improve network performance in terms of delay, throughput, reliability and life time. Yet it is hard to find a single protocol or a set of protocols that can improve all these performance parameters. Selection of a multipath routing protocol depends on a particular application and trade- offs. Some of the objectives are energy efficiency, low overhead, reliability and scalability.

After Analyzing all the different energy efficient multipath routing algorithms we came to a conclusion that multipath routing algorithm (MDR) 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 tradeoff between the number of control messages and the reliability has to be investigated).

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