An energy efficient routing algorithm (X-Centric routing) for sensor networks

Goktug Atac, Tamer Dag
Computer Engineering Department
Kadir Has University, Istanbul, Turkey
goktugatac@yahoo.com, tamer.dag@khas.edu.tr

Abstract—Recent developments in wireless communications and electronics technologies have enabled the progress in low cost sensor networks. Sensor networks differ from traditional networks in several ways, such as the severe energy constraints, redundant low-rate data and many-to-one flows that the sensor networks require. One of the major challenges facing the design of a routing protocol for Wireless Sensor Networks (WSNs) is to find the most reliable path between the sources and the sink node by considering the energy awareness as an essential design parameter. This paper introduces a new routing protocol called as X-Centric routing by considering the above parameters. Under the X-Centric routing, the decision making mechanism depends on the capacity of the sink node by switching between address-centric routing (AC-Routing) and data-centric routing (DC-Routing). The design tradeoffs between energy and communication overhead savings in these routing algorithms have been considered by considering the advantages and performance issues of each routing algorithm.

Keywords: Wireless sensor networks; AC-Routing; DC-Routing; X-Centric Routing

I. INTRODUCTION

Artificial sensors have become an important part of ordinary and industrial part in the second part of the twentieth century. Sensors of a great variety of types have been established in process industries, agriculture, medicine, military services and many other areas. And still, the development of new sensing capabilities is currently proceeding at an unprecedented rate. This technology grows by various factors including a growing concern for the protection of the environment, for the improvement of fossil fuel economy for the enhancement of safety and security [1].

It has been observed that, during the recent years sensor markets in developed countries have been growing at an average rate in excess of %10 per year. As a result, there has been a correspondingly high level of investment in sensor research, and development as the demand has arisen for sensor performance to catch up with the signal processing capabilities. [2]

A general sensor network is made up of multiple detection stations called as sensor nodes. A sensor node is small, lightweight and portable physical quantity. Each sensor node is equipped with the following basic components:

- Transducer – responsible for generating electrical signals based on sensed physical effects and phenomena
- Microcomputer – responsible for processing and storing the sensor output
- Power source – responsible for the power requirement of a sensor node from an electrical utility or from a battery

A sensor network can also be considered as a group of specialized transducers with a communications infrastructure intended to monitor and record conditions at diverse locations. For a sensor network, the most common monitored parameters are temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions.

A sensor's sensitivity indicates how much the sensor's output changes when the measured quantity changes. For instance, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C. Sensors that measure very small changes must have very high sensitivities. Sensors also have an impact on what they measure; for instance, a room temperature thermometer inserted into a hot cup of liquid cools the liquid while the liquid heats the thermometer. For this reason, sensors need to be designed to have a minimal effect on the parameter that is being measured. Having smaller size sensors often has a positive impact on this aspect and it may introduce other advantages. Technological progress allows an increasing number of sensors to be manufactured on a microscopic scale such as micro sensors using MEMS technology. In most cases, a micro sensor reaches a significantly higher speed and sensitivity compared with macroscopic approaches [2,4].

Routing is the act of moving information across an internetwork from a source to a destination. Routing is needed for sensor network because the main idea of sensor network is to transfer information from source to destination so routing becomes the most important element for sensor networks. [3,4,5,6]

In this paper, a new routing algorithm for sensor networks called as the X-Centric routing algorithm for is introduced. The X-Centric routing algorithm can be considered as an approach, which tries to combine address-centric (AC) routing, and data-centric (DC) routing by taking into advantage of the positive aspects of both algorithms. The X-Centric routing algorithm has a decision making process which makes transitions between AC-Routing and DC-routing by considering the sink occupancy levels for desired conditions.
The rest of the paper is organized as follows: Section 2 introduces AC-Routing and DC-Routing used in sensor networks. Section 3 described the proposed X-Centric routing briefly. Section 4 presents some simulation results performed on X-Centric routing by presenting the performance in terms of sink occupancy, total average delay, total packets lost and also total energy saved. The paper concludes with the conclusions made in Section 5.

II. ROUTING ALGORITHMS FOR SENSOR NETWORKS

This section describes the main routing protocols used for sensor networks such as AC-Routing and DC-Routing along with their basic properties.

In order to connect networks together so that they may exchange information and in order to move traffic through these networks efficiently, a method is needed whereby a specific path thus a route is found among the many available nodes (routers, servers, workstations) and routes that connect two or more network together. In other words Routing is the act of moving information across an internetwork from a source to a destination. But usually it is not just a route that allows traffic to be exchanged between the users; it is the “best” route between these users.

The term “best” might vary based on the requirements of the application traffic. For instance, while a real-time video conference considers the best route as a route which offers the lowest and most consistent delay, a funds transfer to a bank considers the best route which offers encryption services. [6,7]

For sensor networks the routing protocols can be grouped into address-centric and data-centric routing. Although both routing protocols aim to find the shortest path between the source and destination pairs, the data-centric approach differentiates from the address-centric approach in terms of data aggregation as explained in the following subsections.

A. AC-Routing

In the AC-Routing approach, each source node sends its information separately to the sink. This model is known as the traditional end-to-end routing model. In this protocol, the main idea is to find the shortest path between pairs of addressable end nodes and transmit information along the shortest path.

The example network of Fig. 1 illustrates an example on the behaviour of AC-Routing where there are two source nodes trying to transmit information to the sink. Source 1 is transmitting data “labeled 1” through node A and source 2 is transmitting data “labeled 2” through nodes C and B. These paths are the shortest paths between the individual sources and the sink node. [8,9]

B. DC-Routing

In the DC-Routing approach, the source nodes transmit information to the sink as well. However, in this case, data is aggregated along the path to the destination. Different from the AC-Routing protocol, the nodes on the path of data flow examine the data content and apply some aggregation functions on the transmitted information. The data-centric paradigm results in some positive outcomes in terms of data redundancy, energy consumption and ultimately helping the optimum usage of sensor networks, so that this method becomes an alternative answer to the question of how to transform data in sensor networks.

Fig. 2 illustrates the behaviour of DC-Routing on a small scale network where 2 source nodes are transmitting information towards the sink. In this case, the data originated from the two sources is aggregated at node B, and the combined data “labeled 1+2” is transmitted from node B to the sink. As a result, considerable amount of energy is saved by transmitting less number of packets. [8,9]
III. X-CENTRIC ROUTING

Both routing algorithms (AC-Routing and DC-Routing) described in the previous section have the disadvantage of using the occupancy of sink when the observations has done in the parameter of, total average delay, total packet lost, total sink occupancy usage. The main idea of XC routing had born regarding of the disadvantage of using the sink occupancy. Using the occupancy effective gains energy save because of less delay and less packet lost.

In addition, the main problem is to gain a low cost energy saving sensors, the new algorithm is try to determine in which condition it has to use the address centric algorithm or data centric algorithm to make fewer transmission. Because the sink has limited capacity and has a limited energy to process the coming messages to make fewer transmission, sink has to decide the right algorithm to gain this energy save. Figure 3 illustrates the process flow of the message from source to sink, but the main purpose is how the sink process the incoming messages. As we told that it has limited capacity and energy. But in other side it has to respond all incoming messages by processing and forward them to the real destination. We say the sink process the incoming messages, what means? In sensor processing means, first deciding it where to forward, and second controlling the message.

When sink receives a packet or let’s say message it doesn’t forward it directly to destination, it first try to optimize the packet and if needed consolidate it with other messages. Because the received message can be same so it has to make it separate.

In addition, the sink has limited capacity not all the messages can be received by sink, for this reason delays and energy loose will be obtained in each sensor and sink. Here the routing algorithm effects this condition, next section will observe first, what if sensors choose only address centric routing for routing algorithm in wireless sensor networks and second observe what if sensors choose only data centric algorithm, and last what will happen if the sink decide which routing algorithm to use in different conditions using simulations.

IV. SIMULATION RESULTS FOR X-CENTRIC ROUTING

This section presents the simulations and their results conducted to compare the various characteristics of AC-Routing, DC-Routing and X-Centric routing protocols.

In order to evaluate and compare the performance of these routing protocols, two main parameters have been used:

- Sink Refreshment Time (SR) - the time interval that the sink refreshes itself to process the packets which have arrived and waiting in the sink,
- Periodic Time Intervals (PT) - the periodic time interval that a packet is produced at a source node while the source node collects information.

For the simulations various values for SR and PT have been used to evaluate the response of AC-Routing, DC-Routing and X-Centric Routing to the relative values in between SR and PT. The following values have been used during the simulations:
- 0.4 sec, 1 sec and 1.2 sec for SR,
- 0.2 sec, 1 sec and 1.8 sec for PT,
- In addition, it has been assumed that the maximum occupancy for the sink was 5 units thus capable of holding 5 packets.

By changing the PT and SR values, the following characteristics of sensor networks have been measured for the indicated routing algorithms:
- Sink occupancy
- Number of lost packets
- Number of processed packets
- Average delay

Fig. 5. The example network used for simulations

Fig. 5 shows the network on which the simulations are conducted. It is assumed that two source nodes A and B are transmitting the collected data to the sink node. Under AC-Routing, the path for data flow is A-C-E-G-Sink for source A and B-D-F-Sink for Source B. Under DC-Routing data is aggregated at node G, thus the path for data flow is A-C-E-G-Sink and B-D-F-G-Sink for source A and B respectively.

Fig. 6. Sink occupancy for AC-Routing, DC-Routing and X-Centric Routing

Fig. 6 illustrates the sink occupancy for AC-Routing, DC-Routing and X-Centric Routing vs. time when SR=1.2 sec and PT=1.8 sec. In this figure, it can be observed that under the AC-Routing the sink fills up with packets immediately and stays at the maximum occupancy level causing packet losses. On the other hand, under DC-Routing the sink does not fill up as the SR is less than PT and the number of packets arriving at the sink is much less compared to AC-Routing.

Under the XC-Routing, the sink occupancy fluctuates in between minimum and maximum occupancy levels as the algorithm switches between AC-Routing and DC-Routing.

Fig. 7. Number of lost packets under AC-Routing, DC-Routing and X-Centric Routing

Fig. 7 presents the number of lost packets for AC-Routing, DC-Routing and X-Centric Routing vs. time when SR=0.4 sec and PT=0.2 sec. In this case, more traffic arrives to the sink during each SR period as the value of PT is decreased. As expected, the number of lost data for AC-Routing is the most, while for DC-Routing is the least, as the number of packets arriving at the sink is the most for AC-Routing and is the least for DC-Routing because of the data aggregation. The behaviour of X-Centric Routing falls in between the other two because of the decision making mechanism applied under the X-Centric Routing.

Fig. 8. Average packet delay under AC-Routing, DC-Routing and X-Centric Routing

Fig. 8 illustrates the average packet delays for AC-Routing, DC-Routing and X-Centric Routing vs. the number of packets for P.T equal 0.2 sec and S.R equal to 0.4 sec. Y axis is the average delay time (T/P) and X axis of the diagram shows number of packets. The average delay value for XC is between AC and DC. But simulation shows that when the network scale increase XC routing has greater performance and delay is decrease.
V. CONCLUSIONS

In sensor networks the scarcest resource is energy, and one of the most energy-expensive operations is route discovery and data transmission. For this reason, algorithmic research in WSN mostly focuses on the study and design of energy aware algorithm for routing and data transmission from the sensor nodes to the destination.

The goal of this paper is to propose an energy efficient routing algorithm (X-Centric routing) for sensor networks and it had modeled and analyzed the performance of the X-centric routing comparing with AC and DC routing.

The XC routing algorithm is also tries to gain maximum efficiency from a network topology, because it tries not to waste energy. The simulation shows that with the given energy XC routing try to make maximum work. [10]

Day by day, the importance of wireless sensors are increase and current technology try to overcome the demands, but this is not easy enough because to reach the best solution, technology needs new inventions. As the near future technology, for wireless sensor nodes are typically low-cost, low-power, small devices equipped with limited sensing, data processing and wireless communication capabilities, as well as power supply XC routing try to open a new window in routing method and try to gain maximum efficiency with minimum resources. The next step for XC routing, can be integrating this method with other new inventions and try to accomplish other technologies disadvantages. [11]

As the technology needs new inventions XC routing can be a new way to follow and develop.

REFERENCES


[8] Ivan Stojmenovic “Algorithms and Architectures of Sensor Networks” @2005

