DESIGN AND IMPLEMENTATION OF NEW ROUTING STRATEGY FOR ENHANCED ENERGY EFFICIENT IN WSN

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ABSTRACT

Energy consumption is a key element in the Wireless Sensor Networks (WSNs) design. Indeed, sensor nodes are really constrained by energy supply. Hence, how to improve the network lifetime is a crucial and challenging task. Several techniques are available at different levels of the OSI model to maximize the WSN lifetime and especially at the network layer which uses routing strategies to maintain the routes in the network and guarantee reliable communication. In this paper we intend to propose a new protocol called Combined Energy and Distance Metrics Dynamic Routing Protocol (CEDM-DR). Our new approach considers not only the distance between wireless sensors but also the energy of node acting as a router in order to find the optimal path and achieve a dynamic and adaptive routing.

The performance metrics exploited for the evaluation of our protocol are average energy consumed, network lifetime and packets lost. By comparing our proposed routing strategy to protocol widely used in WSN namely Ad hoc On demand Distance Vector(AODV), simulation results show that CEDM-DR strategy might effectively balance the sensor power consumption and permits accordingly to enhance the network lifetime. As well, this new protocol yields a noticeable energy saving compared to its counterpart.

KEYWORDS

Energy saving, Routing protocol, lifetime, WSN, power consumption, Sensor node, NS2.

1. INTRODUCTION

In the last few years, wireless sensor networks have increasingly attracted considerable attention among researchers in the field of Telecommunications. They are considered as one of the most active areas of technology development due to their unique characteristics, low cost, easy deployment and flexibility [1].

WSN help human to perform many tasks such as habitat monitoring, industry application, collaborative and distributed computing, military, agriculture, emergency operations and health care application [2] [4]. Although wireless sensor network is employed in various fields, it has many constraints such as limited storage capacities, limited communication abilities and especially limited energy resources due to the finite battery-power available [5]. In this type of networks, each wireless sensor is able of acting as a router along with being a source node or destination node. Hence, when sensor cannot achieve correctly its task, the performance of WSN can be greatly impeded and eventually the basic availability of the network such as routing approach can be affected.

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On the other hand, reload or replace sensor nodes battery after their exhaustion is very difficult especially in unreachable areas such as desert or battlefield [6]. So a careful energy resource management is needed to increase the lifetime of wireless sensor networks. Substantial researches have been carried out to analyze and overcome the constraints of WSNs.

Hence, several routing protocols have been designed and implemented to improve the performance of these types of networks.

Indeed, routing protocols play an important role in WSNs. They permits to determine the optimal path to a destination, ensures successful connectivity and guarantee reliable communication. But the problem in existing energy aware communication protocols is that they try to find an optimal path and then repeatedly use this best route for every communication, which conducts to rapid energy diminution of the wireless sensors on the selected path. Substantial researches have been carried out to analyze and overcome the constraints of WSNs. Hence, several routing protocols have been designed and implemented to enhance the performance of these types of networks.
Authors in [8] proposed a new protocol called MAODV derived from AODV mechanism. Their idea was to take into account the bit error rate as the metric to be reduced for route selection. The simulation results showed that MAODV improves the packet delivery ratio at the cost of a delay increase.

In addition, in [9] authors considered the transmit power control as a metric to improve the performance of AODV routing technique. The same authors proposed in [10] a new strategy to set a timeout for a path in order to remove the stale paths after a certain timeout period and minimize the number of control packets. Hence, this approach permits to reduce the power consumption of the network. A small change in the traditional AODV protocol which integrates local routing of intermediate sensors in order to improve energy consumption of the network is proposed in [11] and called E-AODV approach.

Among these works, most of them just integrated one cost metric (as energy or BER or transmit power, etc.) to optimize the energy consumption of the wireless network.

In this paper, we propose a new routing strategy which considers not only the distance between wireless sensors but also the energy of node acting as a router in order to find the best path and achieve a dynamic and adaptive routing to increase network lifetime as long as possible.

Performance analysis of both reactive and proactive routing protocols namely DSR, AODV, DSDV was studied in our earlier work [3] on the basis of various performance metrics and under various traffic scenarios. Through extensive simulations, we deduced that AODV and DSR yielded better performance than the DSDV even when the network has a large number of sensor nodes. The results also disclose that AODV routing technique becomes more effective in providing better performance when the studied metrics are simulated. So we concluded that AODV technique can be considered as the most energy efficient protocol.

In this regard, we suggest a new energy efficient communication protocol for wireless sensor networks based on the AODV platform. The main goal of our approach is to enhance the network lifetime as well as discover the optimal path from the source sensor to the destination based on combination of two most important metrics to evaluate the optimal path namely: distance relative to the sink and energy available in each sensor node acting as router. Our new algorithm extends and optimizes the routing AODV approach.

This work is arranged into five sections. Section II covers a brief overview of routing strategy. Section III describes the considered performance metrics. Section IV provides a detail description of the design and implementation of our proposed routing approach. In section V we compare the performance of CEDM-DR protocol with its counterpart routing technique. Finally the conclusion of the work and future directions are provided in the last section.

2. OVERVIEW OF WSN ROUTING PROTOCOL

In wireless communication we can distinguish two categories. The first needs to have direct access to the base station (BS) for the transmission of communications. While the second has the opportunity to access to the BS via the intermediate nodes using a communication hop by hop [17]. The most important problem for an ad-hoc network is the delivery of data packets between the mobile nodes. Since the node topology changes frequently this makes routing very problematic.

Low bandwidth, limited battery capacity, and proneness to errors add to the complexity of the design of an efficient routing protocol. A routing technique in WSN presents many challenges compared to data routing in wired networks.

Indeed, the choice of the route is done by routing algorithms. Different routing methods are proposed for wireless sensor networks. These protocols are classified according to many parameters and to the strategies of discovering and maintaining routes.

Protocols can be classified [20] as reactive, proactive and hybrid, depending on their operation and type of requests. Proactive protocols control peer connectivity to ensure the availability of any path between the active nodes. In order to maintain a common network topology, sensor nodes announce their routing state tables of the entire network.

On the other hand, reactive protocols establish paths only on request. Meanwhile, the sensors are inactive in terms of routing behavior. Nodes transmit each routing request to their peers until comes to a sink node and the last answer on the reverse communication path.

2.1. DSDV Routing protocol

Destination Sequenced Distance Vector (DSDV) [12] is a hop-to-hop distance vector routing protocol. It is characterized by each host maintaining a table consisting of the next-hop neighbor and the distance to the destination in terms of number of hops.

In order to obtain the optimal path, the protocol DSDV guarantees loop free routes to each destination node, this is based on an average settling delay, which is a delay before advertising a route. All the hosts periodically broadcast their tables to their neighboring nodes in order to maintain an updated view of the network.

2.2. DSR Routing Protocol

The DSR protocol is a reactive protocol that aims to limit the bandwidth consumed by packet routing in wireless ad-hoc wireless networks. Dynamic source routing protocol [13] is based on the concept of a routing algorithm from the source node to discover routes.

This means that every node needs only forward the packet to its next hop specified in the header and need not check its routing table as in a table-driven algorithm. Determining source routes requires accumulating the address of each device between the source and destination during the route discovery.

2.3. AODV Routing Protocol

The ad-hoc on demand distance vector is an on demand algorithm, meaning that it builds routes between nodes only as desired by source nodes. It maintains these routes as long as they are needed by the sources. AODV [8] [12] uses sequence numbers to ensure the freshness of routes. This routing protocol builds routes using a route request on a route reply query cycle.

AODV uses a reactive approach for finding routes and a proactive approach for identifying the most recent path. This protocol uses the same route discovery process to DSR protocol for finding fresh routes.

3. PERFORMANCE METRICS

The technical performance of our proposed routing algorithm is evaluated based on various performance metrics [3].

3.1 Average energy consumption

The energetic consumption is the average of the total energy consumption of the entire network to transmit data packets from a source to destination. We obtain the energy consumption by calculating the ratio of the sum of the total energy consumed by each node to the total number of nodes [21].
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So a protocol that uses less energy during the simulation is considered more effective [12].

3.2 Lifetime

Network lifetime is the time span from the deployment to the instant when the WSN is considered non-functional. It can be, for example, the instant when a percentage of sensors die and consequently the loss of coverage occurs [6] [14].

3.3 Packet Lost

It represents the total number of data packets dropped during the simulation. The loss of a packet may be due to a collision during transmission process.

$$PL = NP_s - NP_r \tag{1}$$

Where:

- PL: The number of packet lost
- NP_s: The number of packet send
- NP_r: The number of packet received

4. CEDM-DR PROTOCOL DESIGN AND IMPLEMENTATION

4.1 WSN Energy Consumption Model

In this work, the energy consumed by both the transmitter and the receiver blocks was evaluated for calculating the total energy consumption in the network. We perform the transmitter and receiver hardware model as introduced in [3] [19].

The total energy consumed by a wireless sensor S is the consumed energy by its communication block (transmitter / receiver), sensing block and processing block [15].

We consider that transceiver circuit of a wireless node operates according to three modes. Indeed, when there is information to send the sensor node operates in the communication mode so all these circuits are active.

But, if there is no data to communicate the sensor circuits switch to standby mode. During this mode, wireless node is in a state of listening and sensing.

This strategy contributes to reduce energy consumption that's why the power consumption in this mode is small enough to be neglected.

In this study we assume that the energy consumed by the sensing and the processing block is neglected because it is quite negligible with respect to the energy consumed by the communication block [17] [18].

$$E_{tot-c}(s) = E_{c-sens} + E_{c-proc} + E_{c-com} \tag{2}$$

Where:

- $E_{c\text{-}sens}$ is the energy consumed during sensing process.
- $E_{c\text{-}proc}$ is the Energy consumed during the processing phase
- $E_{c\text{-}com}$ Energy consumed during communication phase.

$$E_{tot-c}(s) \approx E_{cp-com}(s) \tag{3}$$

We considered the energy model as introduced in [19] and shown in the following Figure.

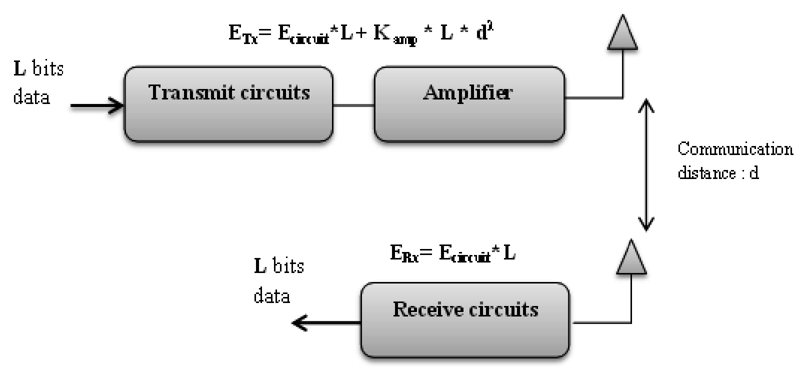

Figure 1. Energy model adopted

The total energy consumption of the communication process is expressed as follows [18]:

$$E_{tot-c}(s) = E_{Tx}(L,d) + E_{Rx}(L,d) \tag{4}$$

Where:

- E_{Tx} represents the energy consumed during the transmission process.

- E_{Rx} represents the energy consumed during the reception process.
- L is the number of bit transmitted.
- d is the distance between transmitting sensor and receiving sensor

Expressing each terms:

$$E_{Tx}(s) = E_{circuit} * L + k_{amp} * L * d^{\lambda} \quad (5)$$

$$E_{Rx}(s) = E_{circuit} * L \quad (6)$$

Where:

- $E_{circuit}$ represents the energy consumed by the electronic circuits.
- K_{amp} *:* is the transmission amplification coefficient
- λ *is* the path loss exponent.

4.2 CEDM-DR Algorithm

In this section, we describe the algorithm of our new routing protocol which is based on combination of two major metrics: distance and energy.

- **Step 1**: Each network node(s) transmits hello messages to discover neighboring nodes to one hop.
- **Step 2**: Verification that the sink and the source node own neighboring nodes. (If true go to Step3 else Stop)
- **Step 3**: All network nodes discover neighboring nodes through the Step 1.
- **Step 4**: All network nodes evaluate the distance between each neighbor and the sink. This distance is expressed as follows:

$$D_{Sink}(s) = \sqrt{(X_s - X_{\sin k})^2 + (Y_s - Y_{\sin k})^2} \quad (7)$$

Where the X_s and Y_s are respectively the coordinate of the node "s".

- **Step 5** : The weight is calculated using two parameters which are the remaining energy in the node receiver and the distance between the receiver node and the sink.

$$Weight(s) = Energy\,\mathrm{Re}\,maining(s) + \frac{1}{D_{Sink}(s)} \quad (8)$$

- **Step 6 :** When one of the sensor nodes needs to transmit data it will choose the node with the highest weight among these neighbors.

The setting parameters considered in our simulations are summarized in Table II.

To simulate different routing protocols we choose network simulator 2 (Ns2) since it is open source free software in which different specifications in the environment can simply modified and changed. Figure 2 presents an example of wireless sensor network under NS2.

Performance of the routing protocols AODV and the new protocol CEDM-DR are evaluated based on different performance metrics, average energy consumption, the lifetime of the network and total dropped data packets.

Table 1. Simulation Parameters.

Parameters	**Values**
Routing Protocols	AODV, CEDM-DR
Number of Nodes deployed	25 to 200
Environment Size	400*400m2
Nodes Placement Strategy	Random
Transmission Range	100m
Initial Node Energy	2.5 Joules
Tx Power	0.07mw
Idle Power	0.03mw
Sleep power	0.01mw
Energy circuit	50nJ/bit
K amplification coefficient	100pJ/bit/m2
Simulation Time	150sec
Antenna Model	Omni Antenna
Propagation Model	Two Ray Ground
Transport Protocol	TCP/UDP

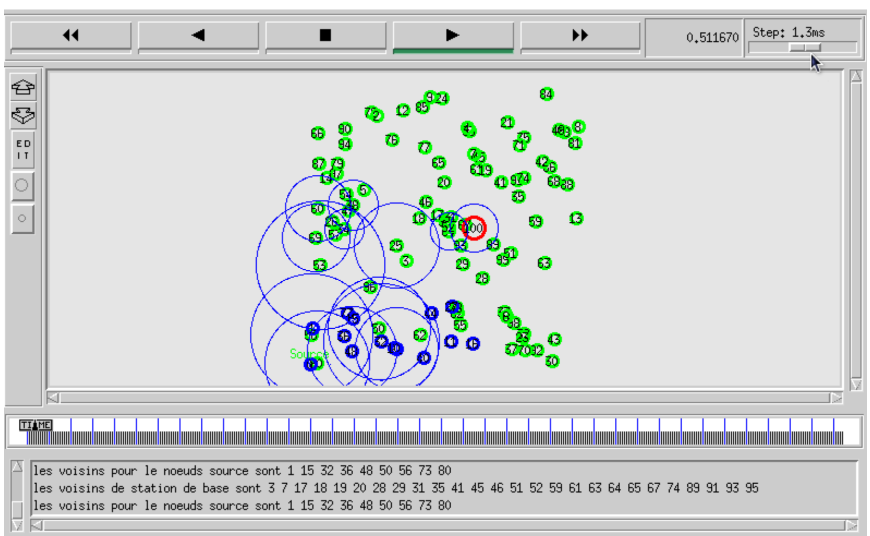

Figure 2. Simulation on NS2

Figure 3. Total average energy consumption

The average energy consumed by the sensor nodes as a function of the number of nodes is illustrated in Figure 3. We note that for all variations of the number of node the new routing protocol implemented still consumes less than the traditional AODV protocol using CEDM-DR, we observe between 0% and 66% energy savings when compared with AODV.

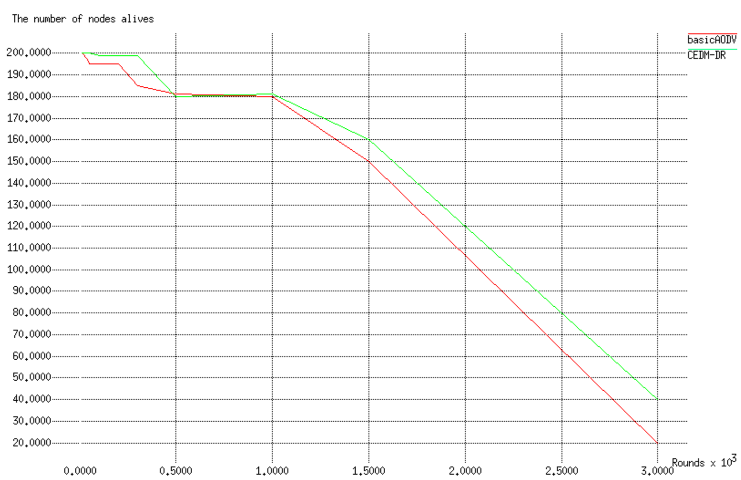

Figure 4. Lifetime of the network

Figure 4 depicts the number of nodes living on a total of 200 nodes with respect to the number of transmissions during the simulation. These curves show that the new protocol CEDM-DR improves the entire network's lifetime. This is mainly due to the dynamic priority-weight adopted.

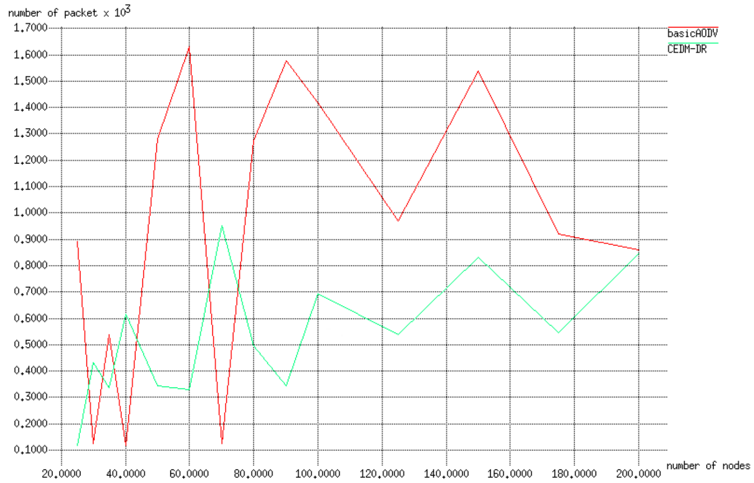

Figure 5. Total of dropped packet

The total number of packet lost as a function of the number of sensor nodes is drawn in Figure 5. From this plot, we confirm that our new approach allows to obtain lower number of packet lost than its counterpart. The CEDM-DR protocol reduces between 0% and 50% of packet lost.

5. CONCLUSIONS

In this paper, the performance of a new routing protocol using two important cost metrics has been evaluated through extensive simulations verifying that our proposed algorithm is effective in saving energy and leads the system to overall enhancements.

Indeed, implementation and experimentation of Combined Energy and Distance Metrics Dynamic Routing Protocol (CEDM-DR) using network simulator reveals that our new approach is better than AODV in energy consumption, Packet Lost and especially in Lifetime.

To sum up, the above results illustrate that the CEDM-DR strategy works well when compared with AODV. Hence, our future plan is to evaluate security issues in this new routing approach CEDM-DR.

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