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A Distributed and Energy Efficient Routing based Game Theory to Congestion Avoidance in Wirelesss Sensor Network

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Abstract— **One of important issues in wireless sensor networks is Routing. The essential function of a WSN is to monitor a phenomenon in a physical environment and report sensed data to a sink. A very common assumption in the analysis and development of routing algorithms is the full cooperation of the participating nodes. However, the reality may differ considerably. The existence of multiple domains belonging to different authorities or even the selfishness of the nodes themselves could result in a performance that significantly deviates from the expected one. The proposal algorithm induces a distributed and energy aware based game theory routing Simulation results show that compared to GEAR, our proposed routing scheme is almost 1.23 times more efficient in terms of network life time and 1.5 times more efficient in terms of data delivery. Simulation results show that this approach performs better than superior in total energy consumption and network lifetime.**

Keywords- game theory, distributed algorithm,wireless sensor network,energy aware routing,fairness

I. INTRODUCTION

A wireless sensor network (WSN) typically consists of a large number of low-cost, low-power, and multifunctional sensor nodes that are deployed in a region of interest. These sensor nodes are small in size but are equipped with sensors, embedded microprocessors, and radio transceivers. Therefore, they have not only sensing, but also data processing and communicating capabilities. They communicate over short distance via a wireless medium and collaborate to accomplish a common task.

The design of routing and data dissemination protocols for WSNs is challenging because of several network constraints. These constraints are imposed not only by the characteristics of individual sensors, the behavior of a network, and the nature of sensor fields, but also by the requirements of a sensing application in terms of some desirable metrics [1].WSNs suffer from the limitations of several network resources, for example, energy, bandwidth, central processing unit (CPU), and storage [3], where energy is the most crucial resource because it determines the lifetime of a sensor. Also, energy poses a big challenge for network designers especially in hostile environments, for example, a battlefield, where it is impossible to access the sensors and recharge their batteries. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Therefore, algorithms designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime while guaranteeing good performance overall [1]. The use of redundant sensors yields additional energy consumption. Therefore, routing and data dissemination protocols should be designed in a way to trade off between energy, fault tolerance, reliability, and delay. Recall that energy is a constraint that should be met by any routing and data dissemination protocol in order to guarantee an efficient usage of the amount of energy available at each sensor [1].

Game theory has recently been applied to telecommunications. Indeed, it is now well known that game theory can be used to analyze interactions between entities such as telecoms regulators, operators, manufacturers, and customers; for instance, game theoreticians have been involved in designing radio spectrum auctions in the US and in Europe. More specifically, the spectrum for the third generation mobile system (3G) in Europe has been auctioned in the UK and Germany [6]. The proposed algorithm based game theory attempts to achieve two objectives at the same time. The first one is to cover all nodes used to model routing under the framework of game theory. Thus, it tries to increase fairness behind approach. The other one is to increase lifetime on these models, which usually requires accurate approach. Hence, the algorithm will found holistic view and model.

As sensor network software and hardware mature, applications which transfer image, video, and structure monitoring data in WSNs are becoming increasingly possible. These applications have different QoS requirements and should be serviced accordingly. We need to consider the fairness issue for packets with different application. In this paper, we propose an efficient approach for multiple routing

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which has a distributed mechanism operating at the network layer.

II. PRELIMINARIES

Extending network lifetime is an ultimate goal in the design of a WSN. Given that most energy of a sensor is mainly consumed in processing, sensing, and communication, an efficient design approach should take into account these three components of energy consumption. A question that network designers are mostly concerned about is how can the lifetime of a network be extended? To address this problem, several energy efficient routing and data dissemination protocols have been proposed, which focus on how to forward the data until they reach the sink regardless of the type of data being transmitted from the source sensors to the sink. Among those protocols, one class does not update the data at intermediate sensors. That is, each intermediate sensor only acts as a pure data relay without altering any of the data it has received. In this paper, the following is assumed for the WSN: a)The sensor nodes are homogeneous and all have a limited power supply, b)the sink and source assumed to have infinite power supply, c)the transmission range is fixed and is small enough so that most nodes will be unable to reach the position of the sink without hoping at least once, d)the nodes have a general idea of their position in the network and position of the sink.

In Game theory, games are strategic situations that are defined and formulated as mathematical objects. a game is formed when a set of player formulates a set of possible moves(known as strategies)along with a number of function that known as payoff function. The people or the entities (decision makers in general) that play the game are called the players. The players take part to the game by performing particular actions (αi) or moves. Each player has preferences for the action profiles. For example, a player may prefer the action profile a to another action profile b. In order to represent this preference, the payoff function is used (it is also called utility function). Since a player is affected not only by its own actions, but also by the actions of the other players as well, a utility function assigns a real value to each action profile of the game. The utility function should fulfill some axioms, but in general, it should assign a larger value to an action profile that is preferred over another one [2]. Thus

$u_i(a) > u_i(b)$, if a is preferred over b. (1)

A very critical assumption in game theory is that a player will always act towards the maximization of its own utility. One of the objectives of the theory is to analyze and predict the effect of different strategies. There are strategies, for example, that result in a state of the game where no player has any incentive to deviate from it. This and similar situations are significant operating points of the game and are called equilibria. The most well known is the NE. A NE is a set of strategies where each player has no incentive to deviate, in other words, given the strategies of all other players, if he changes his strategy he can only decrease his utility. More specifically,

If si is an arbitrary action of player i and s _i is the set of actions of all other players,

Then the action profile $(s^*) = (s_i^*, s_{-i}^*)$constitutes a NE if, for every player i:

$u_i \ (s_i^*, s_{-i}^*) \geqslant u_i \ (s_i \ , s_{-i}^*), \forall \ s_i \ \in$ Si. (2)

The operating point that corresponds to a NE is also referred as Nash equilibrium point (NEP). If the strategies are mixed, then the utility function refers to the expected payoff, which is computed based on the probability distribution functions of the players over the pure strategies and the payoff for each pure strategy.Hence, the utility of the mixed strategy

σ = (σi, σ−i) is computed as follows:

u_i (σ) = $\sum \sigma i(si) u_i(si, \sigma - i)$. (3)

Now, we can define the NE for mixed strategies. Assuming

that σi is an arbitrary probability function of the pure strategies of player i, the mixed strategy profile

σ* = (σ* i , σ* −i) constitutes NE if, for every player i,

u_i (σi , σ* −i) $\geqslant u_i$ (σi, σ* −i), ∀ σi ∈ Σi. (4)

The NE specifies the strategies that will be followed by rational players in a game. If it exists and is unique, it actually provides us with the strategies that will definitely be followed by rational players. Thus, we are able to know the result of the game and the strategies that will be followed before even the game is played for the system designers; this is an objective that they try to achieve [2].

The actual operation of the algorithm is broken down to three steps:

Step1: Each node transmits a query toward the neighbors to receive their energy.

Table 1.Mapping of game theory elements to networks.[10]

Game component:	Entities, processes or elements of wireless networks
Players	Network nodes, service providers or customers Resources All kinds of resources needed by nodes to communicate successfully (spectrum, power, bandwidth, etc.)
Strategies	A decision regarding a certain action of the player, depending on the application field (forward packet, set power level, accept new call, etc.)
Payoffs	Estimated by utility functions, based on QoS merits (delay, throughput, SNR, etc.)

Step 2: when receive a packet if it is for this node destroyed it but if there is another address for sink, calculate utility function and pass through neighbors.

Step3: if all neighbors have depleted completely or packet passes through node more than TTL (time to live) the simulation finished.

III. SIMULATION RESULT

We have used OPNET MODELER 14 in our simulations [8]. In order to analyze the performance of both protocols as

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a function of network size and as a function of energy, we have simulated a variety of different-sized sensor fields with different setup for a variety of cases. During simulations, the structures (shown in Table2) are used for a sensor node. The area was a square area which was 100X100.

Table 2.Sensor Node structure

n.	Field name	Description
1	ID	unique ID of a sensor node
2	Location	Location position of the node in the network
3	NeighborList	the list of each node's neighbors
4	Energy	lifetime of a sensor node
5	PacketList	queue of pending packets to be processed
6	SenseTime	Sense event generation time
7	Send energy	Energy consumed when a packet sent
8	Receive energy	Energy consumed when a packet received

The data packet header structure is shown in Table 3. This packet is defined as type 1. The sequence_number field fill with a sequenced number to show which part of data send. The receiver node uses next hop field to ensure that this is the true next hop of the receiving packet. TTL field is used to prevent missing packet deplete energy of whole network. The source knows location of sink, so x_sink and y_sink filled when a packet generate. We must know how many hops a packet passed to sink, so field hop increase when received to a node. This section describes process models, as shown in Fig. 1.

TABLE 3.Structure of Header Data Packet

sequence_number	
x_source	y_source
x_next_hop	y_next_hop
x_sender	y_sender
x_sink	y_sink
TTL	hop

The event-driven nature of WSNs leads to unpredictable network load. Typically, WSNs operate under idle or light load and then suddenly become active in response to a detected event. When the events have been detected, the information in transit is of great importance. Therefore, we considered a finite automaton when the event occurred the node goes to another state.Fig1.shows the finite automata that OPNET used for synchronized energy of neighbors and selecting next hop.

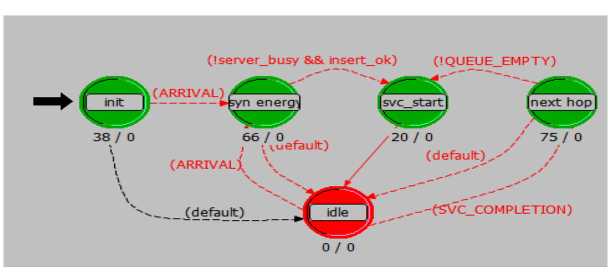

Fig1. Automata of Algorithm

Several tests were carried out using different network parameters of WSNs. The performance of different routing protocols is measured to determine the most efficient one for the scalability. After evaluating several metrics which are throughput, latency, energy consumption, and etc [7].

We have chosen four performance metrics to analyze and compare the performance of both protocols GT and GEAR. These metrics are as follows:

Average energy consumption: It indicates the average amount of energy spent in each node for each individual task. An increased value of average energy consumption indicates more power consumption by each node. In Fig.2 Shows energy of node deplete slowly. Fig.2 shows a comparison.

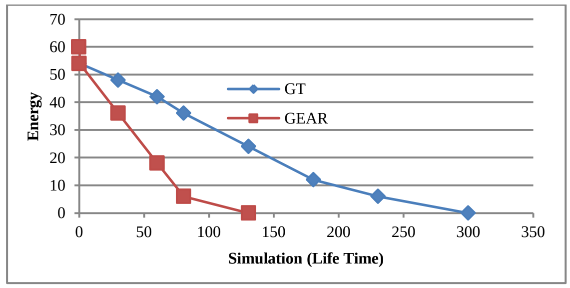

Fig2.Firt Node Died Average Energy

between GT and GEAR node consumed energy. It was expected that GT would outperform the other algorithm.

Number of hop: Fig 3, shows number of hop that one packet must be passing through the sink. If energy related by square of distance ,increasing in hop is excellent, but in our simulation it was not compute ,then as soon as central node increase in energy level, the path change trough outer node .The algorithm tries to use all of node to increase fairness and fault tolerance of whole network. The end to end delay increase because energy of node was finished Fig4.

Average energy of network: In Figure 5 the average of nodes remaining energy in last node of neighbors die based on number of neighbors are shown, respectively. In these figures the vertical axis is the average of nodes remaining energy and the horizontal axes is number of neighbors, respectively. According to the results in the mentioned figures, average of nodes remaining energy for GT protocol is less than other protocols. The lower remaining average energy means the more using energy. If the nodes consume their energy much more before simulations ends, the protocol can be success more and more.

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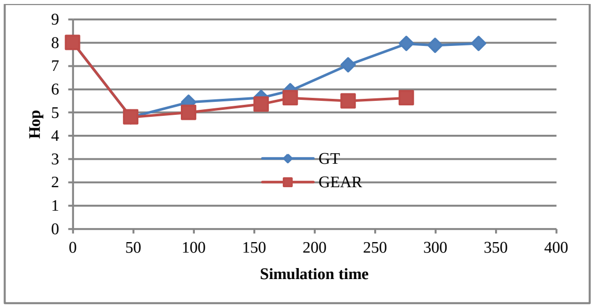

Fig3.Number of Hop

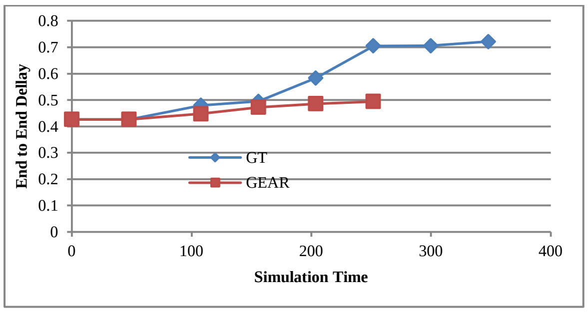

Fig4.End to End Delay

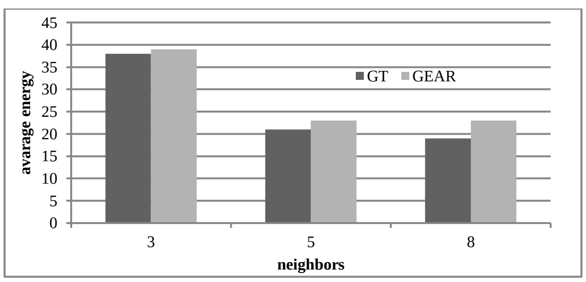

Fig5.Average Energy of Network

Throughput: fig6 shows the number of packet received before simulation end. It is clear that if network could send more packets to sink, it has more efficiency and throughput.

Fainess: Equation (3) calculates the variance of normalized remaining energy of network nodes to average remained energy (Ave) of total network(In worst case half of the nodes get energy empty and half of them remain full, so if we normalize the equation we can achieve normalized fairness equation). In equation (3), Energy is node remaining energy when simulations end.

As it is clear in equation (3) the more fairness parameter, the protocol is much success that it means remaining energy of nodes are closer with each other. If fairness parameter is equal one, the network has the best and the most fairness case (all nodes have the same remained energy), however when it is equal zero we have the most unfairness case of energy consumption. As shown in figure 7, fairness parameter is more successful in GT in rather than the other protocol.

$$\mathrm{DEV} = \sum_{i=1}^{n} (\mathrm{Energy}_i - \mathrm{Ave})^2 \qquad (3)$$

$$\mathrm{Fairness} = 1 - \mathrm{DEV}/\mathrm{DEV}_{\mathrm{Worst}} \qquad (4)$$

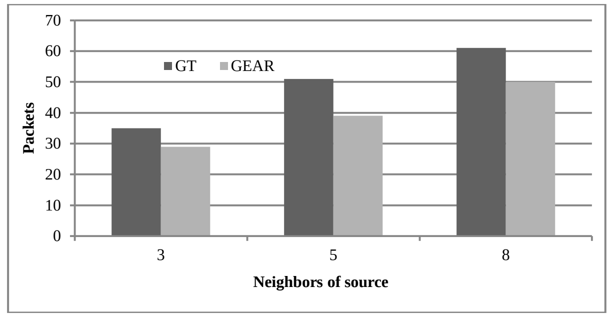

Fig 6.Number Of Packet Recived

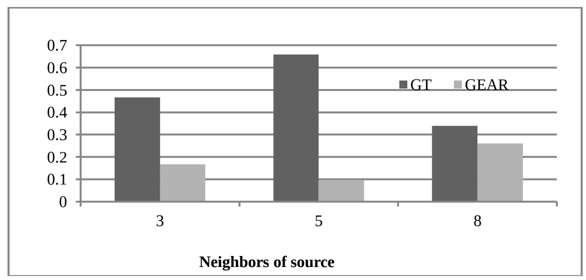

Fig7.Fairness 1

CONCLUSION AND FUTURE WORK

In this paper we introduce an energy aware game theoretic algorithm that induces contested in WSN to achieve that, nodes are made to understand if they did not send packet, they save more energy for themselves. Thus they are forced to rotate the select next hop that has maximum energy and minimum distance in order to extend their life time. Currently the algorithm has no direct dealing with malicious or misbehaving nodes and that is something needs to be implemented. Furthermore, the algorithm work in two dimensional areas, in order to work with three dimensional it can be expanded.

Our future plans include extending our proposed routing scheme to decrease congestion in Wireless Sensor Networks. We are planning to use different routing metrics at the same time to get more energy efficiency and reliability in data dissemination. Achieving energy efficient and reliable routing in mobility environment will further increase the capability of Wireless Sensor Networks.

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