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An Efficient Game Theory Utilized Routing Algorithm For Wsns

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Abstract

In the realm of wireless sensor networks, many cluster based routing algorithms have been suggested, in which groups of nodes are organized into clusters. Based on factors like remaining battery life, network coverage, and the number of hops between nodes, a cluster head is chosen to coordinate the collection of data from individual sensor nodes and send it either directly to the base station or to a relay node (another cluster head) for further transmission. To solve this problem, we present a Game Theory-based Energy Utilization Algorithm (GTEUA) for networks' routing needs. The cluster-head in GTEUA is chosen using a game-theoretic decision-making procedure that takes into account the values of three metrics: residual energy (RE), Received Signal Strength Index (RSSI), and Packet Reception Rate (PRR). The suggested method enhances the network's lifetime by finding a path to the destination that uses the least amount of energy. Through an inter-cluster routing approach, the packets in GTEUA are sent further to the base station. The simulation results show that the network's throughput, longevity, and power consumption are all improved with the use of GTEUA.

Keywords—Cluster head, Energy utilization, Game Theory, LEACH, Sensor network.

INTRODUCTION

Multiple sensor nodes are interconnected to form a wireless sensor network. Distributed sensor nodes collect data on phenomena like temperature, sound, and pressure, and the network has many uses in areas as varied as the military, target tracking, interior and outdoor environmental monitoring, health monitoring, power monitoring, forest fire warning, and more. [1], [2].

As well as allowing for two-way communication, the modern design of networks allows for command of sensor operations. An electrical circuit for communicating with the sensors, a power supply (often a battery or an incorporated type of energy harvesting), and a radio transceiver are the main components of a sensor node [3]. It is not necessary to engineer or predetermine the placement of these sensor nodes prior to deployment. Researchers face a hurdle in delivering data with minimal energy use due to the nodes' dynamic architecture, in which communication between sensor nodes and the base station consumes more power. [4]

Scalability, topology, power consumption, operating environment, media, and hardware restrictions all play a role in the design of sensor networks [5]. To get the most out of the electricity, it's important to pick the transmission path wisely. One of the main challenges in wireless sensor networks for energy management is packet routing under changing topology [6]. Decision making is crucial in routing since it determines where the packet will be handed off to next. The deployed sensor nodes in a given environment may have a layered or clustered structure. In a layered design, the strongest node acts as a base station and radiates signal outward. The result is a network with several levels, each of which has the same total number of hops to the base station. In cluster architecture, a number of groups are created, and a leader is elected to oversee the sharing and collection of information from within each group.

There are a variety of potential causes for sensor network failures. Possible causes [7] include: connections failing when obstructed by an external item or environmental circumstance; batteries running down from excessive communication; alterations to the network's structure as a result of nodes' dynamically relocating. The failure of a link may be detected by measuring residual energy, signal intensity, PRR, RSSI, and SNR [8].

This paper uses game theory, a mathematical/analytical tool of strategies for dealing with competitive situations in which the outcome of a participant's choice of action depends critically on the actions of other participants, to propose the efficient routing approach GTEUA, in which the nodes are framed in clustered architecture and the cluster head gets elected. If a game contains at least one saddle point, it is said to be rigidly decided. The reward (profit, utility) at the "saddle point" is achieved after all possible moves have been made by both players. The proposed approach treats players as nodes in a cluster and tactics as network performance characteristics. In GTEUA, the payout is the appearance of a cluster head, which is the desired outcome.

Related Work

Most of the studies examining approaches for election of cluster head and routing focus on stationary sensor nodes.

By designating a new root node at the beginning of each iteration and communicating this decision to all sensor nodes, the General Self-Organized Tree-Based Energy-Balance routing protocol (GSTEB) proposed by Zhao Han et al. [9] creates a routing tree that maximizes energy efficiency. GSTEB is a dynamic protocol because each node chooses its parent based on information about just itself and its neighbors.

To improve the stability of the connections between WSNs and IWSNs, Jianwei Niu et al. [10] propose the Reliable Reactive Routing Enhancement (R3E). R3E is meant to improve upon preexisting reactive routing methods by exploiting local path diversity to ensure packets are delivered reliably and efficiently despite the unreliability of wireless networks. R3E drastically increases the packet delivery rate while keeping energy consumption low and delivering packets quickly.

Two effective routing algorithms, LayHet and EgyHet, are presented by Xiao Chen et al. [11], both of which are based on a framework protocol called reverse path (RP) to handle asymmetric connections. LayHet is a layer-based routing protocol that guarantees performance, conserves energy by reducing broadcasts and forwarding probabilities, and embeds the shortest path information. The enhanced version, EgyHet, takes into account the energy still presents in the nodes.

Forward-aware factoring is used by Degan Zhang et al. [12] to suggest an energy-balanced routing strategy (FAF-EBRM). Here, consideration is given to the link's weight and the forward energy density when deciding which node should serve as the network's next hop. Additionally, a technique for spontaneously reconstructing the local topology is developed.

According to Chen et al. [13], "ProHet" is a distributed probabilistic routing protocol that makes use of asymmetric networks to provide assured delivery rate with minimum overhead. The ProHet protocol generates a bidirectional routing by discovering an alternate path for each connection. Next, forwarding nodes are selected using past data as a guide.

There has been a lot of discussion recently on how to best regulate power consumption in sensor networks, and a number of different approaches have been presented. In the event of mobility, it is imperative that each node in the network be capable of autonomously adjusting its settings. It should be highlighted that such topology is not quantifiable due to its sudden alterations caused by the movement of nodes. As a result, reducing network-wide instability requires giving thought to the decision-making process.

Problem Definition

Most of the power in a wireless sensor network is used up inefficiently. If network energy is handled appropriately, proper routing may be performed, lengthening the lifespan of the network. Cluster leadership may be determined by factors such total power, node location, network coverage, movement velocity and pattern, and cluster orientation [15]. As the first influenced cluster head election mechanism [16], LEACH elects each node as cluster head with a predetermined probability of energy levels throughout several rounds. Concerns concerning how sensed data is routed to the cluster head when a node leaves its coverage area, and whether or not it is sufficient for a node to operate as the cluster head if a cluster head is elected according to several criteria, arise when a node leaves its coverage area [17]. This study aims to use game theory, a decision-making process, to efficiently choose the cluster head based on the residual energy (RE), Received Signal Strength Index (RSSI), and Packet Reception Rate (PRR) characteristics. Power loss during mobile node operation as a result of poor routing is significantly reduced using this method.

Proposed Methodology

The proposed technique utilizes a cluster-based routing strategy, with a focus on identifying the most important node in each cluster to route packets and collect data. Game theory, a mathematical concept that explains competition and cooperation amongst intelligent rational decision-makers, is used to choose who will lead each cluster [14]. In the context of wireless sensor networks in particular, the hypothesis has been shown to be quite helpful. The cluster head is selected using a number of criteria, including Residual Energy (RE), Received Signal Strength Index (RSSI), and Packet Reception Rate (PRR), all of which are derived from game theory [21].

Cluster Formation

If we have 'n' sensor nodes, then Si = s1, s2, s3, s4, sn. Taking into account the transmission radius as 'Ri' for exchanging messages during the construction of clusters, which is provided by, a square region of length 'L' containing 'n' deployed sensor nodes is partitioned into l clusters [14].

$$L^2 = \sum^{S} nR^2 + \sum^{n} \Delta d_j - \sum^{n} \Delta 0_k$$

where d is the smallest feasible gap between clusters, m is the smallest number of gaps, O is the smallest possible overlap between clusters, and n is the total number of clusters.

If the transmission range of clusters are same, Ri=R

$$L^2 = \ln R^2 + \sum^{n} \Delta d_j - \sum^{n}$$

In particular, it specifies the normative transmission radius used to create 'l' clusters. The metrics Residual Energy, Received Signal Strength Index (RSSI), and Packet Reception Ratio are utilized in a game-theoretic (saddle-point) approach to selecting Cluster Heads (PRR).

Residual Energy

Consider Eelec to be the energy lost in transmission, amp to be the power lost by the amplifier in the transmitter, and d2 to be the route loss [18].

$$P_r = P_t \times G_t \times G_r \times (h_r \times h_{t)})^2 \times d^{-2} \times L^{-1}$$

The variables Pr and Pt represent the received and sent wireless power, respectively; d represents the distance between the transmitting and receiving nodes; Gt and Gr represent the antenna gain at the transmitter and receiver, respectively. Where hr and ht represent the heights of the transmitter and receiver antennas and L represents the total system loss.

Packet Reception Ratio

The success rate of data transmission between two nodes is quantified by a metric called the Packet Reception Rate [20]. If the PRR is high, the link quality is strong and the likelihood of a mistake is low.

GAME THEORY BASED ENERGY UTILIZATION ALGORITHM

As defined by [21], [22], "game theory" refers to a method of strategic decision making in which a variety of rules, tactics, and consequences are included. Parameters like residual energy, Received Signal Strength Index (RSSI), and Packet Reception Rate (PRR) are taken into account while selecting a cluster head using a variety of game-theoretic approaches.

Players, who are the people making decisions in a game, can set up the parameters to ensure that they will reach the best possible outcome given the following conditions.

- There is a limited number of players in the game.
- The participants can assess the scenario and make decisions independently of one another.
- All players in a game are familiar with the regulations that were laid down during the procedure.
- A player's payout, regardless of the game's final result, is predetermined.

In Fig. 1 we see the high-level design of the game-theoretic approach of the suggested method.

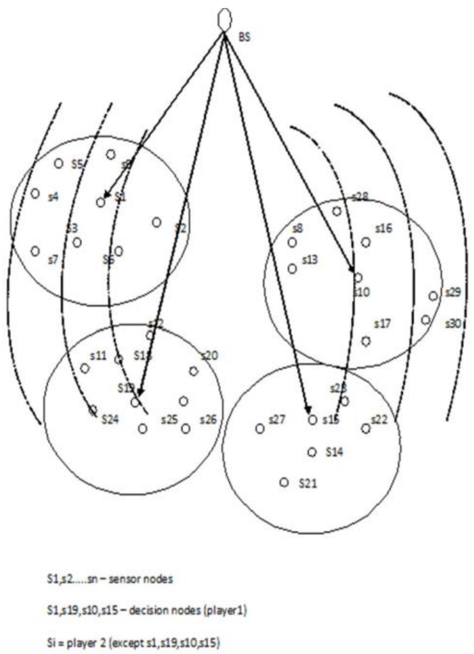

Figure 1: Structure of Game Theory Approach for GTEUA

Cluster Head Election with Saddle Point

1. Begin:
2. Initialization of parameters.
3. For(iteration=1; do clustering 'k'; i++)

{

compute (P_{RR}, R_{ssi}, E_R)

broadcast "HELLO" message to BS

if $(P_{RRi} > P_{RR(i=1,2...k)})$ except for S_i then

elect CH = $S_i \forall$ k

endif

4. process: collect messages from nodes S_k ; $k = 1,2 \ldots n$; $\neq i$;
5. if $(E_{si} < E_{th} \parallel Cov_{area} \neq R_i)$

re-elect CH(P_{RR}, R_{SSI}, E_R)

cal(opt_value)

elect CH = S_i

else

CH = $S_i \forall$ k

Endif

6. Goto process

PERFORMANCE ANALYSIS

The GTEUA method was tested several times, and the results were compared to those of the established LEACH technique in a MATLAB simulator. Number of packets transferred to the base station, number of dead nodes, and overall amount of node energy are all compared against the number of rounds required to pick the cluster head. The acquired results are depicted in Figs, and they demonstrate that the suggested method is superior to the LEACH procedure under all conditions.

Algorithms are tested using a number of different measures to see how well they function. Packets transmitted to the base station using the GTEUA algorithm are seen to be higher than those delivered by LEACH in Fig. 2.

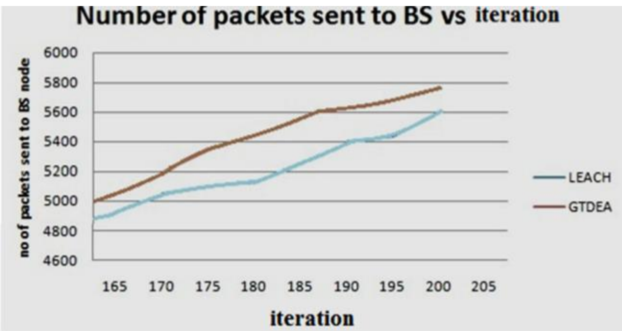

Figure 2: Comparison of throughput using LEACH and GTEUA

Network lifespan is depicted in Fig. 3; it is seen to be longer for GTEUA than for LEACH. It is important to notice that although the initial node in LEACH dies in the 138th round, in our proposed GTEUA it dies in the 177th round.

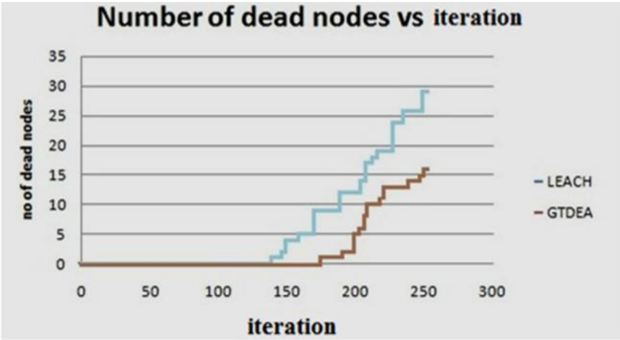

Fig. 3 Comparison of network life time in LEACH and GTEUA

Using LEACH and GTEUA, Fig. 4 compares the power consumption in each round. It has been seen that GTEUA uses less energy than LEACH does.

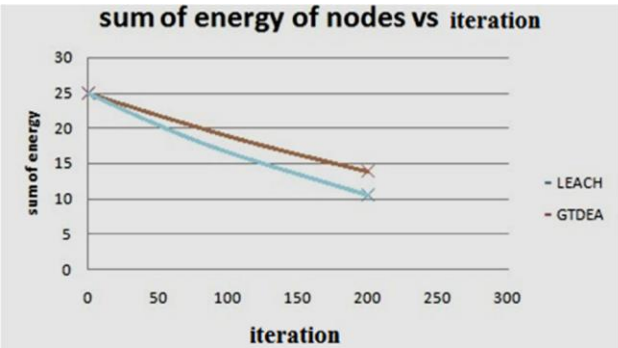

Fig. 4 Comparison of energy consumption in LEACH and GTEUA

Conclusion

Nodes in a cluster-based wireless sensor network don't talk to one another; instead, the cluster head is chosen based on a number of parameters, and all of the nodes send their sensed data to the base station individually. However, this highlights the whole network's inability to effectively control an individual's energy use. Using Residual Energy, Received Signal Strength Index (RSSI), and Packet Reception Rate (PRR) for iterative cluster-head election, this work presents a Game Theory based Energy utilization Algorithm (GTEUA) for WSNs. Inter-Cluster Routing Technique is used to send data packets from Cluster-Heads to the main hub. In comparison to the LEACH algorithm, simulations demonstrate significant improvements in energy efficiency, throughput, and longevity of the network.

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