Efficient and Effective Energy Balancing For Wireless Sensor Networks

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***Abstract*— A decentralized routing algorithm, called Game Theoretic Energy Balance Routing Protocol (GTEB), is proposed to extend the network lifetime by balancing energy consumption in a larger network area using geographical routing protocols (GRPs). The objective of the proposed protocol is to make sensor nodes deplete their energy at approximately the same time, which is achieved by addressing the load balance problem at both the region and node levels. In the region level, evolutionary game theory (EGT) is used to balance the traffic load to available sub-regions. At the node level, classical game theory (CGT) is used to select the best node to balance the load in the selected sub-region. This two-level approach is shown to be an effective solution for load balancing and extending network lifetime. This paper shows the use of evolutionary and classical game theories in designing a robust protocol that offers significant improvement over existing protocols in extending network lifetime.**

Keywords: Energy balance, geographical routing protocols, game theory, wireless sensor networks.

I INTRODUCTION

Wireless Sensor Networks (WSNs) will be very prevalent technology in the near future due to their unique characteristics and to their great number of applications. WSNs consist of a large number of autonomous micro-sensors that are deployed in remote and inaccessible areas to monitor physical or environmental conditions. Although the sizes of sensors are very small, they have their own on-board processor, as well as communication, mobilizing, position finding, and storage capabilities. Sensor nodes have the ability to collect and route data, through one or multi hops, to other nodes, or external base stations. Coordination and cooperation among sensor nodes will provide essential network information collected from monitored physical phenomena. Base Station (BS) basically acts as a gateway between sensor network and end user by receiving the data from sensor nodes and forwarding it to the server hence, it is required to have more computational energy and communication resources than sensor nodes.

Routing data in WSNs very challenging task due to infrastructure-less communications and frequent topology changes. The main drawbacks of the WSNs are the limitation of storage capacity, bandwidth, communication range and power resources.

II RELATED WORK

There were number of techniques proposed to extending WSN’s lifetime. To maximize the network lifetime by balancing energy consumption among nodes in different coronas[1].The energy consumption balancing problem is divided into two sub problems: intra-corona energy consumption balancing (Intra-CECB) and inter-corona energy consumption balancing (Inter-CECB) and network lifetime maximization (NLM).An energy-balanced data gathering (EBDG) protocol is designed to achieve balanced energy consumption among nodes within one corona and among different coronas. In our paper energy balance problem is solved at the region and node levels using Game Theoretic Energy Balance Routing Protocol (GTEB). The number of energy efficient routing protocols [2] have been proposed for WSNs.

WSN consists of a number of sensor clusters and a base-station. Each cluster consists of a number of wireless micro sensor nodes (MSNs) and one aggregation and forwarding node (AFN)[3].The aim is maximize the network lifetime by power control of Aggregation and Forwarding Nodes(AFN).This paper Forwarding node is selected by using CGT and balance the energy at node level.

An energy-balanced routing method based on forward-aware factor (FAF-EBRM) is proposed [4]. In FAF-EBRM, the next-hop node is selected according to the awareness of link weight and forward energy density. FAFEBRM balances the energy consumption, prolongs the function lifetime and guarantees high QoS of WSN. In this paper EGT select the next forwarding region in order to balance the energy consumption. Two protocols RPL(Routing Protocols of LLNs) and GRP [5] were designed to forward collected information to an aggregation point efficiently. Geographic routing protocols [6] eliminate dependence on topology storage and the associated costs. GRPs do not have a global view of the network, including energy information at regions and nodes. Providing this information can incur large overheads and increases complexity. This issue is addressed in this paper by adopting distributed and relatively simple algorithms to balance energy in order to extend WSN lifetime.

Adaptive Load-balancing Algorithm (ALBA-R) protocol [7] is localized and distributed GRP for balancing traffic load on nodes that are located around energy holes so that the nodes do not run out of energy too early. In our case, GTEB can detect the energy hole problem areas and does not forward any traffic towards such areas.

A real-time power aware routing protocol (RPAR) to find balance between end-to end delay and energy consumption using transmission power adjustment[8]. RPAR is considered as a NLEB only protocol. In this paper GTEB is consider both RLEB and NLEB. The mathematical tool evolutionary coalitional game theory [9] is necessary to become WSNs mobile, more autonomous, self organization, self-configuration.

Game theoretic heterogeneous balanced data routing (HBDR) algorithm for WSNs with a tree topology[10]. In this protocol, a hierarchical network is constructed using CGT to provide a load balanced tree that maximizes network lifetime.

In GRP there is congestion around the line between the source and destination.GT based congestion avoidance mechanism[11] is used to avoid the congestion.

GT used to balance energy consumption by alternating cluster head roles among the nodes based on their available energy. Sensor Data Reporting (SDR) Game [12] is used to check the energy level of the nodes.

Game theory based load-balancing routing (GBLBR) protocol [13] is used to Reduce the average end-to-end delay and the percentage of packet loss and find out the best possible route.

EGT is used to solve dynamic networking problems due to changes in energy state, channel state and topology. EGT [14] is used to allocate bandwidth for users based on the service cost of various wireless networks. Population evolution and reinforcement-learning algorithms are used for network selection. EGT for traffic routing over multi-path wireless back-haul networks[15] experiencing rain attenuation. An adaptive cross-layer routing scheme is presented based on the selection of the most reliable path in terms of packet error ratio (unipath routing). EGT based routing protocol [16] is designed for WSNs to control congestion and reliability which were influenced by the wireless channel's characteristics. EGT is implemented to solve the packet forwarding problem [17] when a network consists of heterogeneous nodes operating in networks with different authorities. This shows that the forwarding cooperation among authorities can evolve and provide stable communication. In this paper, both CGT and EGT are used simultaneously for energy balance in geographical routing to prolong the network lifetime.

The main power consumer in a sensor node is its radio transceiver. One of the most effective methods to reduce the data transmission rate is data prediction. Data prediction technique [18] reduce amount of data transmitted, which results in energy saving and the overall network lifetime increases.

Cross-layer strategy [19] is used for energy conservation by balancing the traffic throughout the WSN. Signature-File-based approach [20] is used to answer queries over WSNs,which can answer both aggregative and range queries with high accuracy while significantly reducing the cost of message transmissions. Greedy-Face-Greedy (GFG) and Greedy Perimeter

Stateless Routing (GPSR) Protocols are used to Balance the traffic load on the boundary of holes, this mechanism is called as Distributed Load Balancing Mechanism (DLBM). The Inter-node Interference (INI) mechanism [22] is used to find the minimum number of neighboring nodes. . In this paper, game theoretic (GT) approach is proposed to build a viable load balancing solution to extend the WSNs lifetime. The energy balance problem is solved at the region and node levels. In region level energy balance (RLEB), the objective is to balance the energy consumption around a sender such that all sub-regions around the sender will participate fairly and deplete their energy approximately at the same time. After selecting the participating region, node level energy balance (NLEB) is required to select the most favorable forwarding node in this sub-region. Because the objectives of RLEB and NLEB are different, RLEB employs evolutionary game theory (EGT) and NLEB employs classical game theory (CGT).

III. PROTOCOL DESCRIPTION

The proposed GTEB protocol is designed to provide energy balance to uniformly and randomly deployed multi-hop WSNs with homogeneous nodes where the transmission range is r. Initial energy of a node is E Joules. The nodes know their locations and the location of the destination node. The nodes learn their neighbors' location by exchanging an initialization packet, which includes the location information of the node.

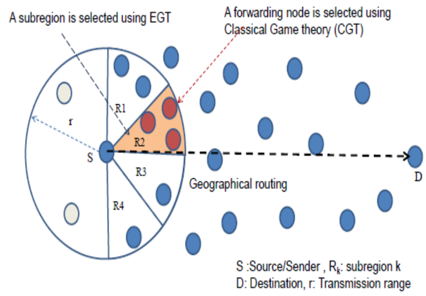


Fig. 1 Sub region and node selection

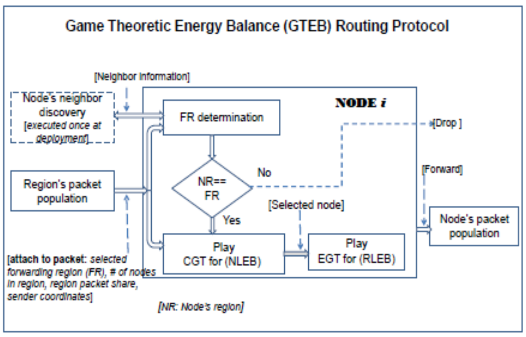
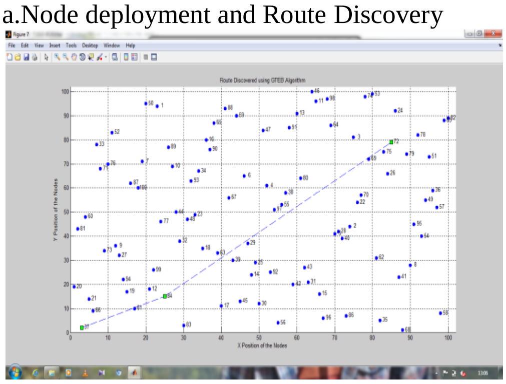


Fig.2 Functional Diagram

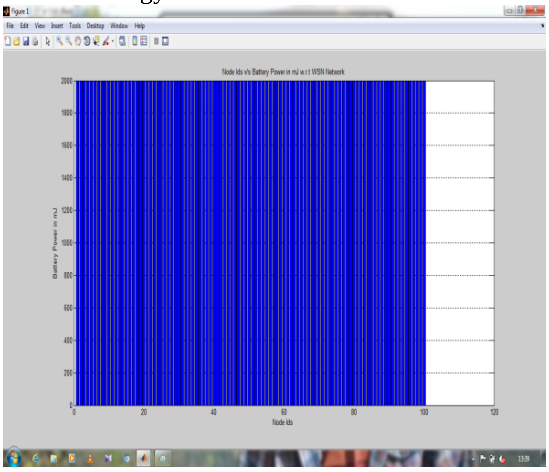
The energy cost of this initialization incurs a one packet transmission cost for each node and one overhearing cost to its neighbors. The GTEB protocol considers geographical routing in a stationary network. If the node is equipped with GPS, the GPS needs to only run in the initialization phase to acquire Fig. 2: GTEB's functional diagram. the location of the node, then it can be turned off. That is why the energy cost of this initialization is not included in this paper. In the network, any node can be a source and can report events periodically or at the instant they occur. The problem of achieving a network wide energy balance is broken down into the following two sub-problems: i) RLEB at sub-regions and ii) NLEB within the sub-region. The energy balance at the
region level is achieved using EGT and the energy balance at the node level is achieved using CGT. The transmission range of a sender is divided into K forwarding sub regions based on the network density . Fig. 1 illustrates this scenario. In the figure, the selected region is shaded and the selected forwarding node is labeled. Based on EGT, a sender forwards a packet to its neighbourhood with the following information: i) angle, which bounds the selected forwarding sub-region, ii) Nk, the number of neighbors in this sub-region, iii) sender's location (x; y), and iv) proportion of packets, k, assigned to this subregion. Carrying these 4 fields requires 5 bytes in the packet header. This information, provided by the packet, will allow the surrounding nodes to identify whether they are in the forwarding sub-region. Then the nodes in the selected subregion will play a Nk-player non-cooperative classical game to identify which one will be the potential forwarding node.
One of the potential forwarding nodes in that sub-region, who wins the game becomes a sender node and plays its own evolutionary game to select the next forwarding region in order to balance energy consumption in its own surrounding.
Fig. 2 shows a schematic functional diagram of the distributed decision making processes in the GTEB protocol. The node neighbor discovery function depicted in the figure is executed once at the deployment time of the network in order to allow nodes to learn the number of single hop neighbors.

IV. SIMULATION RESULTS

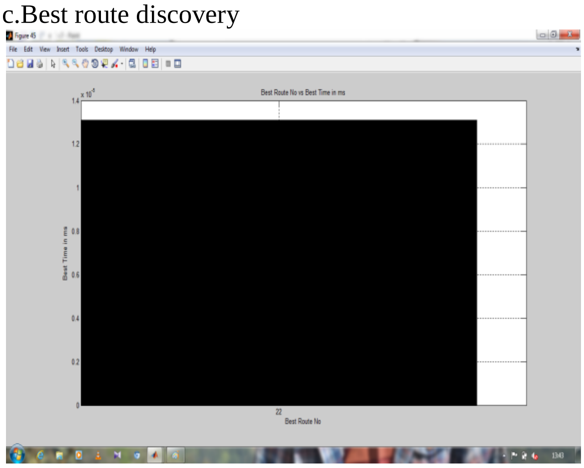
a.Node deployment and Route Discovery



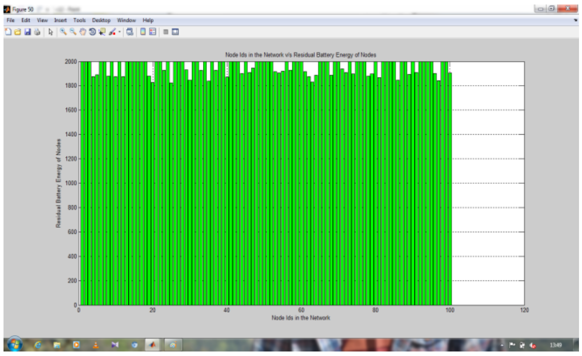
b.Initial Energy for all the nodes



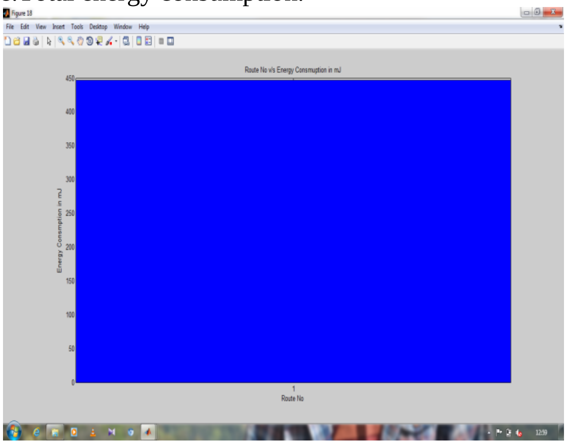
c.Best route discovery



d.Residual energy for the node



e.Total energy consumption.



V. CONCLUSION

This paper proposes a fully distributed routing protocol, called game theoretic energy balance (GTEB), for maximizing the lifetime of WSNs. GTEB utilizes evolutionary game to capture dynamic changes on a macro scale, classical game theoretic to capture selfish behavior of the sensor node, and the geographical routing protocol to minimize routing overhead in the network. The combination of evolutionary and classical game theoretic with geographical routing is shown to be effective in improving lifetime of the network. The simulation results showed that GTEB provides significant improvement in extending network lifetime and delivery ratio over other test protocols and competing geographical protocols. The obtained results showed that GTEB provides excellent adaptation to factors in the network, such as the network density, traffic load and asymmetric energy use. The proposed low overhead protocol can make WSNs operate longer for a given energy resource. GTEB does not currently support mobility. As common to all GRPs, GTEB needs positioning hardware in sensor nodes or alternatively, the pre-programming of node locations.

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