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Genetic Algorithm based Multicast Routing in Wireless Sensor Networks - A Research Framework

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Abstract*—Wireless sensor networks contain hundreds or thousands of small sensor nodes. These sensors are capable of communicating either among one another or directly to an external base station. Multicast based routing methods are challenging tasks in a wireless sensor network. It is due to various factors such as energy efficiency, QoS etc. Therefore it is important to have methods based on genetic algorithms. Though sufficient works have been done on the survey of genetic algorithm and multicasting based routing in wireless sensor networks, this paper presents an updated survey of genetic algorithm based multicast routing as a classification. Localization, mobility, query based, energy efficiency, data aggregation and QoS are the metrics used for the genetic algorithm based multicast routing in wireless sensor networks classification. Finally, a comparative study of all genetic algorithm based multicast routing techniques in wireless sensor networks is presented.

***Index Terms*— Cluster, Genetic Algorithm, Multicast, Wireless Sensor Networks.**

I. INTRODUCTION

Wireless sensor networks consist of small nodes with sensing, computation, and wireless communications capabilities [1]. Wireless sensor networks are composed of a set of devices that communicate without using any permanently installed infrastructure by transmitting radio signals. The devices, also called as nodes of the network, generally use omnidirectional antennas and their transmission range is determined by the power they employ in the transmission of the messages [2]. Sensors gather information about the state of physical world [3]. These sensors are limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, using some local decision process it can transmit the sensed data to the user. A variety of mechanical, thermal, biological, chemical, optical, and magnetic sensors may be attached to the sensor node to measure various properties of the environment. Since the sensor nodes have limited memory and are typically deployed in difficult-to-access locations, a radio is installed for wireless communication to transfer the data to a base station [4]. In a wireless sensor networks which is organized by cluster, there are two statuses of nodes: cluster heads and cluster nodes [5]. The clustering approach is done by cluster heads, in which the cluster heads are selected from sensor nodes and then the nodes become member of the nearest cluster head [6]. The nodes in the sensor networks comprise sensor nodes, sink gateway nodes and management nodes. Nodes having the ability of forming networks through self-organization are deployed in large numbers inside or close to the monitoring area. Multiple nodes handle the monitored data, and after the multi-hop routing, it is sent to the sink gateway node and via internet or satellite, it reaches the management node [7]. The total number of sensors in the network and their placement determine the degree of network coverage. Based on the application, a higher degree of coverage may be required to increase the accuracy of the sensed data [4]. Energy awareness is a central and prominent one among design issues in WSN [8]. Mobility of the network entities changes the load distribution and causes processing and memory bottlenecks in some parts of the network. However, since the network routing elements are also mobile, their movement can be used to distribute the load [9]. The process of finding the spatial location of nodes in a wireless network is often called localization [10]. A query is delivered to the sensor network and data are collected according to the query's requirements [11]. QoS provisioning entails the development of several essential techniques of multicast routing protocols [41].

A. Characteristic of Wireless Sensor Networks

The node mobility, node failures, and environmental obstructions cause a high degree of dynamics in WSN. It includes frequent network topology changes and network partitions. Despite partitions, however, mobile nodes can transport information across partitions by physically moving among them. The resulting paths of information flow are potentially unidirectional and might have unbounded delays. Besides there is a communication failures is also a typical problem in WSN. Another issue here is heterogeneity. WSN may consist of a large number of rather different nodes in terms of sensors, computing power, and memory. This large number raises scalability issues on the one hand, but on the other hand provides a high level of redundancy. Also, nodes have to operate unattended, causes node localization problem, because it is impossible to service a large number of nodes in remote and possibly inaccessible locations like mountains, sea and mine, and remote geographic areas [12]-[14].

B. Routing Challenges and Design Issues in WSN

Despite the innumerable applications of WSNs, these networks have several shortcomings, such as limited energy

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supply, limited computing power, and limited bandwidth of the wireless links connecting sensor nodes The routing challenges and design issues in WSN are, node deployment, Energy consumption without losing accuracy, Data reporting method, Node/link heterogeneity, Fault tolerance, Scalability, Network dynamics, Transmission media, Connectivity, Coverage, Data aggregation, Quality of service[1].

II. MULTICASTING

Sometimes it is necessary to distribute data to a subset of previously known nodes. This process is called multicast [15][16]. Multicast routing protocols in wireless sensor networks are required for sending the same message to different and multiple different destination nodes. Since it is not always convenient to identify the sensors in a network by a unique identification number, but using the location information to identify the nodes and sending messages to the target locations is a more efficient approach [17]. Multicasting reduces the network parameters like bandwidth consumption, sender and router processing, and delivery delay and communication costs for applications that send the same data to multiple recipients [18]. In multicast routing the centralized and distributed methods are optimal when number of destination is small [42]. Multicast routing protocols are divided into three categories, namely, IP multicast, application layer multicast, and overlay multicast [19]. The management for multiple groups and multicast trees requires memory and processing power, which is limited on sensor nodes [20].

A. Genetic Algorithm (GA)

Genetic algorithm (GA) is a global optimization search algorithm which simulates the biological genetic and evolutionary processes in the natural environment [21]. Each GA is an individual of the population which is also called as chromosome. It represents a potential solution to problem to be solved. Each piece of chromosome is called gene [22]. The "fitness value" is used in order to evaluate the good or bad chromosome in each generation. The next generation chromosomes produced are called offspring. Offspring chromosomes were generated from the previous generation by crossover or mutation operation. During the new generation process, the large generation is selected and the small generation is eliminated according to fitness value. This is done with a purpose of maintain the population size top a fixed value. According to this principle, the algorithm converges to the best chromosome after several generation operations, which in turn can achieve global optimization [21].GA emphasizes the combination of the most promising candidates for the solution of the problem [22]. GA routing introduces and uses sub-optimal paths randomly at times to reduce and distribute energy consumption in routing with a view of increasing the lifetime of the network [23]. Selection, Mutation and crossover are the operators of genetic algorithm [5]. The initial groups are then distributed based on the fitness proportion [24].

III. EXISTING MULTICAST ROUTING IN WIRELESS SENSOR NETWORKS

In the case of multicast there are several situations where it is important to transmit the same information to a group of sensor nodes. The configuration procedure of a group of sensors is an instance here. Middleware is another situation where multicast can offer an efficient solution. Because whenever it is necessary to update a group of nodes with the latest version of a component (e.g. light module) it is not advisable to send the module to every sensor in a point-to point fashion. In this situation, multicast can provide WSNs with the necessary routing tools to perform an efficient software component distribution. These tasks are necessary for correction of software bugs or for the application of nodes reconfiguration. Since code distribution protocols are, in general, quite traffic-intensive and should be performed without disturbing other critical traffic, it is critically important to employ multicast procedures. In this study it is aimed to evaluate the use of some standard multicast protocols and to propose new extensions. Multicast has significant advantages in WSN environments, over broadcast and unicast. It reduces the number of transmitted packets required to update a specific middleware component. Therefore, there will be represent a decrease in the energy spent by each node. Most of the routing protocols for sensor networks require location information for sensor nodes and when the receivers are more then multicast routing is efficient in WSN [25]. In most cases location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated [26]. A comparative study on different multicast routing protocols in WSN have shown in Table-I. Nodes in sensor networks have only local knowledge due to lack of an infrastructure, so routing algorithms should be distributed. Since the number of nodes can be very high and networks can be dense, routing algorithms should be scalable. Sensor nodes have limited power; routing algorithms should be energy aware [17]. The main characteristics for multicast routing protocols evaluation are Packet Delivery Ratio, Number of packets transmitted per packets delivered, Number of packets and control packets per packets delivered [27].

A. Geographic Multicast Routing For Wireless Sensor Networks (GMR)

Geographic Multicast Routing for Wireless Sensor Networks proposed by Juan A. Sanchez, Pedro M. Ruiz and Ivan Stojmenovic in the year 2007. It is a fully-localized algorithm and it does not require any type of flooding throughout the network. In this routing method each node propagating a multicast data message needs to select a subset of its neighbours as relay nodes towards destinations. GMR optimizes cost over progress ratio. The cost is equal to the number of selected neighbors, while progress is the overall reduction of the remaining distances to destinations. The selected subset is the one that reduces most of the total distance to destinations besides cost per unit. When several

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neighbors are selected, each of them takes care of routing towards part of the overall set of destinations. When for some destinations no neighbor of the current node can reduce the distance, the algorithm uses face routing to exit the local minima until a new node providing advance is found. When multicast data is being forwarded, only those neighbors who are selected by the current node have to process the message. They add a GMR header to data messages to allow neighbors to realize that they are selected as relays. It is also used to mark which destinations are required to be routed in perimeter mode [28].

B. Hierarchical Geographic Multicast Routing For Wireless Sensor Networks (HGMR)

Hierarchical Geographic Multicast Routing for Wireless Sensor Networks suggested by Dimitrios Koutsonikolas, Saumitra Das, Y. Charlie Hu and Ivan Stojmenovic in the year 2007 is a new location-based multicast protocol that seamlessly incorporates innovations in location-based multicast and optimizes them for wireless sensor networks by providing both encoding efficiency (and hence energy-efficiency) as well as scalability to large networks. HGMR starts with a hierarchical decomposition of a multicast group into subgroups of manageable size (i.e. encoding overhead) using HRPM's (Hierarchical Rendezvous Point Multicast) key concept mobile geographic hashing. Within each subgroup, HGMR uses GMR's (Geographic Multicast Routing) local multicast scheme to forward a data packet along multiple branches of the multicast tree in one transmission. Thus, HGMR can simultaneously achieve energy efficiency (through higher forwarding efficiency utilizing multicast advantage) and scalability (through low overhead hierarchical decomposition) [29].

C. Energy-balancing Multicast Routing Protocol for Wireless Sensor Networks (EMRP)

Energy-balancing Multicast Routing Protocol for Wireless Sensor Networks was presented by Taehee Kim, Hosung Park, Min-Sook Jin, Batzorig Sambuu and Sang-Ha Kim in the year 2008. The main goal of the proposed protocol is to balance the network energy consumption by changing the routing paths which should be taken into account at the beginning of the routing process. Routing paths in the data delivery paths are never changed unless topology changes. Therefore, the nodes on the routing paths can be dead owing to continuous energy consumption. Consequently, the lifetime of network might be shortened. A dynamic location-based multicast protocol is proposed in order to balance the network energy consumption by changing the routing paths so that the lifetime of wireless sensor networks is prolonged [30].

D. Distributed Geographic Multicast Routing in Wireless Sensor Networks (GMP)

Distributed Geographic Multicast Routing in Wireless Sensor Networks shown by Shibo Wu, K. Selçuk Candan in 2006 proposes an efficient Euclidean Steiner tree based geographic multicast routing protocol. The underlying idea of GMP is that each transmitting node constructs a heuristic Euclidean Steiner tree including the source and all destinations. The tree is virtual in a sense that it may include interior vertices that do not correspond to any actual wireless sensor nodes. It is noted by them that due to the lack of up-to-date global knowledge of the state of the wireless network, (a) the Steiner tree points computed by any algorithm are not likely to be actual hops that will be used in the resulting route and (b) each receiving node in the network will have the opportunity to readjust the Steiner tree based on its own position [31].

E. An Overlay Multicast Protocol for Wireless Sensor Networks (SNOMC)

An Overlay Multicast Protocol for Wireless Sensor Networks recommended by Gerald Wagenknecht, Markus Anwander and Torsten Braun in the year 2012 is to design a protocol that supports multicast in WSNs in an efficient and energy-saving way. The protocol should support bulky traffic, which is characterized by data arrivals in bursts. They use UDP as transport protocol. It does not support any reliability since it is stateless, but it benefits from low complexity. Acknowledgments on the application layer can be positive or negative and information can be had about the reception status of messages. It is proposed in this protocol that sensor node overlay multicast to support reliable, time-efficient, and energy-efficient dissemination of bulky code data from one sender node to many receivers [32].

TABLE I: Comparative Study on Multicast Routing in WSN

Protocol	Localization	Mobility	Query Based	Energy Efficiency	Data Aggregation	QoS
GMR[28]	Yes	No	No	Yes	No	No
HGMR[29]	Yes	Yes	Yes	Yes	Yes	No
EMRP[30]	No	No	No	Yes	Yes	No
GMP[31]	Yes	Yes	No	Yes	No	No
SNOMC[32]	Yes	Yes	No	Yes	No	No

IV. EXISTING GENETIC ALGORITHM BASED MULTICAST ROUTING IN WIRELESS SENSOR NETWORKS

Genetic algorithms work with a population of chromosomes, each representing a possible solution to a given problem. Each chromosome is assigned a fitness score as to how good a solution to the problem it is. The highly fittest chromosomes are given opportunities to reproduce, through crossover with other chromosomes in the population. This produces new chromosomes as offspring's, which share some features taken from each parent. The least fit chromosomes of the population are less likely to be selected for reproduction, and so they die out. A whole new population of possible solutions is thus produced by selecting the best chromosomes from the current generation, and mating them to produce a new set of chromosomes. This new generation

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contains a higher proportion of the characteristics possessed by the good chromosomes of the previous generation [33][34].

A. Finding Agent-Based Energy-Efficient Routing in Sensor Networks using Parallel Genetic Algorithm (PGA)

Finding Agent-Based Energy-Efficient Routing in Sensor Networks using Parallel Genetic Algorithm proposed by E. Rahmani, S. M. Fakhraie, and M. Kamarei in the year 2006 is a new method to find an energy efficient data routing scheme in sensor networks. They have used parallel genetic algorithm to find the optimum parameters of the new scheme. Simulation results show that the proposed scheme has improved the load balancing and traffic spreading over the network, through the usage of proposed scheme with optimum parameters. Data centric protocol has been used in which the sink sends queries to certain regions and waits for data from the sensors located in the selected region. A sensor that is located in central part of the region is considered as source. Sink can run GA without any problem because it normally does not have any limitations on power and memory [35].

B. A Multi-objective Genetic Algorithm based Approach for Energy Efficient QoS Routing in Two-tiered Wireless Sensor Networks (EEQSRT)

A Multi-objective Genetic Algorithm based Approach for Energy Efficient QoS Routing in Two-tiered Wireless Sensor Networks presented by G. Hossein EkbataniFard, Reza Monsef, Mohammad-R. Akbarzadeh-T, Mohammad H. Yaghmaee in the year 2010 considers a two-tiered wireless sensor network, with *n* relay nodes acting as cluster heads and one base station (sink). It is assumed that each sensor node belongs to exactly one cluster and the routing schedule is computed by some centralized entity (e.g., the sink), which is not power constrained. Sensor nodes transmit their data directly to their respective cluster head nodes (relay nodes), then cluster head nodes perform the initial fusion of the received data and send them to the sink by the routing tree. According to the energy reserved in the node, the requested delay and the reliability, the sink node determines a routing tree in order to optimize QoS parameters (delay and reliability) and energy consumptions of wireless sensor network. The proposed protocol efficiently optimizes the QoS parameters, reliability and end to end delay, reduces average power consumption of nodes and in effect extends the lifetime of the network [36].

C. A Quantum Genetic Algorithm based QoS Routing Protocol for Wireless Sensor Networks (QG-QoS)

In the year 2010 Weizhong Luo and Changsha came up with an algorithm called a Quantum Genetic Algorithm based QoS Routing Protocol for Wireless Sensor networks. In this paper, they proposed QoS based protocol for wireless sensor networks, which can run efficiently with best effort traffic. QG-QoS is the first quantum genetic algorithm based QoS routing protocol in wireless sensor networks. The algorithm is characterized by the representation of the individual, the evaluation function, and the population dynamics. So that QGA can treat the balance between exploration and exploitation easily and effectively. The problem solution is a set of links that connect all nodes to the sink. Initially the links should be converted to Q-bit representation. QG-QoS uses binary system to for encoding the links. There are two rules that are used in the encoding process: (1) If there is no a link between two nodes, then the link's corresponding gene value is 0; (2) The input links of the source nodes and the output links of the destination nodes need not be considered. The problem of finding routing paths to satisfy different metrics of the QoS routing is NP-complete. The quantum genetic algorithm can solve this kind of problems effectively, especially when the scale of the network is large [37].

D. Genetic algorithms applied in routing protocols for wireless sensor networks (GARS)

Genetic algorithms applied in routing protocols for wireless sensor networks introduced by Ioana Apetroaei, Ionut-Alexandru Oprea, Bogdan-Eugen Proca and Laura Gheorghe in the year 2011 is a spanning tree topology for the WSN that dynamically changes according to the nodes residual energy, in order to maximize the usage of the network. The main processing is done using genetic algorithms, which are most appropriate solution for optimization problems. Initial topology gathering is a very important step during the routing process. Here the base station has to get knowledge of the network topology, because this is the base information processed with the genetic algorithm. To achieve this, at the network fresh start, the sensors first determine their distances to the neighbors, then send a message containing the list of neighbors and distances. After receiving the neighbor lists from all nodes, base station proceeds with the topology calculation. At this stage edges in wireless networks are considered to exist between any two nodes that are located so that they can send messages to one another. The cost of the edges is represented by the distances between the nodes. Since it is not feasible to equip the sensors with GPS, or other localization system, another way of determining the distances has to be used. And then a topology discovered message is broadcasted by each node, including the power level it was sent with [38].

E. A genetic algorithm based on extended sequence and topology encoding for the multicast protocol in two-tiered WSN (GAEST)

A genetic algorithm based on extended sequence and topology encoding for the multicast protocol in two-tiered WSN suggested by Jiliang Zhou, Qiying Cao , Caixia Li and Runcai Huang in the year 2010 proposes GAEST framework in two tiered WSN for both global and local topology discovery of shared multicast trees that selects the best output power and determines the optimal transmitting distance for all cluster head nodes, which can maximize the overall network lifetime. Moreover, the extended ST (Each pair of S and T chromosomes represents a multicast tree) encoding method

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and three associated operators, namely, selection, topology and node mutation, which utilize node cost information for reducing the search space, helps the GA find the optimal solution in far fewer evaluations and is far more reliable in comparison with the GA using a Prüfer number encoding. Simulation results demonstrate better performance of GAEST, especially when the number of nodes becomes larger [39].

F. Location Based Hierarchical Secure Multicast Group Building in Wireless Sensor Networks (LBHSM)

In the year 2011, Jin Myoung Kim, Hae Young Lee, In Geol Chun, Won Tae Kim, Seung Min Park and Tae Ho Cho put forward an algorithm called as Location Based Hierarchical Secure Multicast Group Building in Wireless Sensor Networks which is a hierarchical multicast group building method. By considering the location information of the sensor nodes, They exploit genetic algorithms (GA) exploited to build a multicast group. Their method will be applied to applications that use not only multicast communications but also clustering based sensor network. It is proposed a hierarchical secure multicast group building method. In order to build the groups, they exploit genetic algorithms by considering the location information of the sensor nodes. The efficiency of the proposal is shown through simulation, in terms of the standard deviation among group members. The redistribution of cryptography keys is important for the robust secure communication within the multicast group [40]. The Table-II depicts the comparison between different GA based multicast routing protocols in WSN on various parameters.

TABLE II: Comparative Study on Genetic Algorithm Based Multicast Routing In WSN

Protocol	Localization	Mobility	Query Based	Energy Efficiency	Data Aggregation	QoS	Multicasting	Security
PGA [35]	Yes	No	Yes	Yes	No	No	No	No
EEQSR T[36]	No	No	No	Yes	Yes	Yes	No	No
Qg-QoS [37]	Yes	No	No	Yes	No	Yes	No	No
GARS [38]	Yes	No	No	Yes	Yes	No	No	No
GAEST [39]	Yes	Yes	No	Yes	No	No	Yes	No
LBHSM [40]	Yes	No	Yes	No	No	No	Yes	Yes

V. FUTURE RESEARCH DIRECTIONS

Present routing protocols optimize for the limited capabilities of nodes and the application-specific nature of networks. Some protocols have been designed with security as a goal, but it is not up to mark. One aspect of sensor networks that complicates the design of a secure routing protocol is in-network aggregation. The requests from the user should be made to the BS through the Internet. Since the routing requirements of each environment are different, further research is necessary for handling mobility management and reliable link management with minimal bandwidth usage. The challenges are formidable and extensive research from multiple disciplines is needed before QoS-enabled WSNs become reality. There are still many issues to be resolved around WSN applications such as communication architectures, security, and management.

VI. CONCLUSION

In this paper, an up to date survey on genetic algorithm based multicast routing in wireless sensor networks has been presented. The benefits and the issues caused due to the genetic algorithm based multicast routing have been reviewed. A thorough overview of the parameters such as localization, mobility, query based, energy efficiency, data aggregation and QoS for the GA based multicast routing in wireless sensor networks is provided. A performance comparison of the entire genetic algorithm based multicast routing has been stated and their strengths and drawbacks are summarized in order to enunciate the variety of approaches proposed**.** Most of the genetic algorithm based multicast routing techniques consider largely on the energy consumption. Developing a new protocol for genetic algorithm based multicast routing in wireless sensor network which would provide increased energy efficiency with security is our future work.

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