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Energy Efficient Greedy Approach for Sensor Networks

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1. Introduction

Applications of sensor networks ranging from environmental/military monitoring to industrial asset management. The development of sensor networks was originally motivated by military applications. However, now a days sensor networks are used in many civilian application areas, including environment and habitat monitoring, healthcare applications, home automation, and traffic control (Lewis,2004). It is mentioned above that the main purpose of deployment of sensor networks is to provide feed back and monitoring of environmental variables in areas, which are intractable to humans. The design of energy efficient routing algorithms is an important issue in sensor networks with such deployments.

In wireless ad-hoc and sensor networks geographic routing is a key paradigm that is quite commonly adopted for information delivery, where the location information of the nodes are available (either a-priori or through a self-configuring localization mechanism). The implication of geographic routing protocols is efficient in sensor networks for several reasons. Firstly, nodes need to know only the location information of their direct neighbors in order to forward packets and therefore the state stored is minimum. Secondly, since discovery floods and state propagation are not required beyond a single hop hence, such protocols conserve energy and bandwidth.

Due to energy constraints in these networks geographic routing in sensor networks has been a challenging issue for researchers. The design of routing strategy may also effect by deployment methodology. Sensors may be deployed randomly or deterministically based on the application in the sensor networks field. These random deployments might result in irregular topologies which in turn affect the routing strategy. Sensors perform both data sending and data routing. Inter-sensor communication is usually short ranged. The nodes in the network cooperate in forwarding other nodes' packets from source to destination. Hence, certain amount of energy of each node is spent in forwarding the messages of other nodes. Lots of work has been done in this respect but still energy depletion of sensor nodes is a big challenge in sensor networks.

The aim of this research is to present such geographic algorithm for sensor networks which will be simple, easy to implement and efficient in terms of energy consumptions. In this research various geographic routing protocols for sensor networks have been studied with their applications to have better understanding of these protocols, This research will explore the paradigm of routing in sensor networks in terms of energy efficiency.

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The chapter comprises of 6 parts, description of each part is given as follow. Part 1 gives the introduction to sensor networks and objective of the research. Part 2 gives the description of sensor networks and different issues related to it. At the end some of the application areas of sensor networks have been discussed. Part 3 contains the details study of some routing protocols for sensor networks and explores their potential limitations. Part 4 presents the motivation of this research and defines the problem definition. Later it describes the proposed solution design and implementation in detail. Part 5 captures the detail of different test results and provides their analysis. Finally, conclusion and future work are discussed in Part 6.

2. Sensor networks and their applications

A number of new applications that benefit a large number of fields have come into existence with the emergence of sensor networks. A key concern in wireless sensor networks is energy efficiency. In a sensor network the nodes did not charged once their energy is drained so the lifetime of the network depends critically on energy conservation mechanism (Chan et al., 2005; Melodia et al., 2004; Wu et al., 2004).

With deployments of sensor networks in mission critical applications, they gained importance and provide for immense potential for research in this area. Two challenging issues are identified in this realm. First, being the reduction in consumption of power by these sensors to increase their lifetime. Second, being the design of routing strategies for communication in the network. In this part a brief description of sensor networks, challenges faced by them and some of the important application of sensor networks has been discussed.

2.1 Sensor nodes

A device that is capable of observing and recording a phenomenon is known us sensor. This is termed as *sensing*. Sensors are used in various applications such as in rescue operations, seismic sensors are used to detect survivors caught in landslides and earthquakes With the advancements in technology it is easy to manufacture low cost and high performance sensors but only with limited resources which include energy supply and communication bandwidth.

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of processing unit with limited computational power and limited memory, sensors (including specific conditioning circuitry), a communication device (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery (Han et al., 2006). A sensor node usually consists of four sub-systems. Computing subsystem, communication subsystem, sensing subsystem and power supply subsystem.

2.2 Wireless sensor networks

Sensor networking is an emerging technology that has a wide range of potential applications including environment monitoring, smart spaces, medical systems and robotic exploration. A wireless sensor network, WSN, is an ad-hoc network with many sensors deployed in an area for a specific reason. A sensor network consists of possibly several hundred sensor nodes, deployed in close proximity to the phenomenon that they are

designed to observe. The position of sensor nodes within a sensor network need not be pre-determined (Zeng et al., 2006). Sensor networks must have the robustness to work in extreme environmental conditions with scarce or zero interference from humans. This also means that they should be able to overcome frequent node failures. Thus, network topological changes become common. Sensor networks must conserve energy since they are limited in energy, usually the battery as the sole supply of energy. Sensor nodes may also have limited mobility, which allow them to adjust to topology changes.

2.3 Challenges

The unique features of sensor networks pose challenging requirements to the design of the underlying algorithms and protocols. Several ongoing research projects in academia as well as in industry aim at designing protocols that satisfy these requirements for sensor networks. In spite of the diverse applications, sensor networks pose a number of unique technical challenges due to the following factors (Akyildiz et al., 2002).

The sensor nodes are not connected to any energy source. There is only a finite source of energy, which must be optimally used for processing and communication. An interesting fact is that communication dominates processing in energy consumption. Thus, in order to make optimal use of energy, communication should be minimized as much as possible. Environmental stress on sensor nodes cause frequent node failures leading to connectivity changes. These require frequent reconfiguration of the network and re-computation of routing paths. The high probability of node failures in sensor networks requires that the cost of sensor nodes is minimal. This will enable redundancy of sensor nodes to account for node failures. In some cases, sensor nodes have the ability to move, although their mobility is restricted in range to a few meters at the most. Mobility of sensor nodes raises the possibility that nodes might go out of range and new nodes might come within the range of communication. The routing protocols for sensor networks must take these changes into account when determining routing paths. Thus, unlike traditional networks, where the focus is on maximizing channel throughput or minimizing node deployment, the major consideration in a sensor network is to extend the system lifetime as well as the system robustness.

A number of solutions propose to one or more of the above problems. The survey focuses on the suggested solutions is energy efficiency which is a dominant consideration no matter what the problem is. This is because sensor nodes only have a small and finite source of energy. Many solutions, both hardware and software related, have been proposed to optimize energy usage. Traditional routing schemes are no longer useful since energy considerations demand that only essential minimal routing be done.

2.5 Important applications of sensor networks

Wireless sensor networks have significant impact upon the efficiency of military and civil applications such as environment monitoring, target surveillance, industrial process observation, tactical systems, etc. A number of applications have been discussed, (Barrenechea et al., 2004; Barett et al., 2003;Braginsky et al., 2002;intanagonwiwat et al., 2000; Krishnamachari et al., 2002; Servetto & Barrenechea, 2002; Ye et al., 2002). There are different potential applications of sensor networks in many areas due to their different communication model. A number of applications are in military where sensors are widely used in applications such as surveillance, communication from intractable areas to base-

stations. Since these are inexpensive and deployed in large numbers, loss of some of these sensors would not affect the purpose for which they were deployed. In distributed surveillance highly mobile sensor networks make it possible to transmit huge amounts of data at low powers. Structure monitoring systems detect, localize, and estimate the extent of damage. Civil engineering structures can be tested for soundness using sensors. Sensors also used to monitor pollution and toxic level. These sensors collect data from industrial areas and areas where toxic spills occur.

3. Literature review

Like mobile ad-hoc networks, sensor networks also involve multi-hop communications. Many routing algorithms have been proposed for mobile networks. Yet, these algorithms are not applicable to sensor networks due to several factors (Akyildiz et al., 2002). Some of these factors are as the size of the sensor network is usually larger than that of ad-hoc networks. High density of sensor nodes are deployed in sensor networks as compared to mobile hosts. Sensor nodes have energy constraints and are highly susceptible to failures. In addition, they are generally static compared to mobile network. Sensor nodes use reverse multi-cast communication while ad-hoc networks use peer to peer communication. These nodes have several constraints with respect to power, memory, CPU processing which prohibits them from handling high data rate. Hence, sensors have low data rate than that of mobile hosts.

All these factors distinguish sensor networks from mobile networks, and make most of the routing protocols of mobile networks inapplicable to sensor networks. Hence, new routing algorithms are investigated for sensor networks.

3.1 Routing mechanism in sensor networks

Generally data centric routing is used in sensor networks (Barrenechea et al., 2004). Unlike the mobile ad hoc networks, in sensor networks sensor nodes are most likely to be stationary for the entire period of their lifetime. Even though the sensor nodes are fixed, the topology of the network can change. During periods of low activity, nodes may go to inactive sleep state, to conserve energy. When some nodes run out of battery power and die, new nodes may be added to the network. Although all nodes are initially equipped with equal energy, some nodes may experience higher activity as result of region they are located in.

As mentioned before, conventional routing protocols have several limitations when being used in sensor networks due to the energy constrained nature of these networks. These protocols essentially follow the flooding technique in which a node stores the data item it receives and then sends copies of the data item to all its neighbors. There are two main deficiencies to this approach implosion and resource management..

In implosion if a node is a common neighbor to nodes holding the same data item, then it will get multiple copies of the same data item. Therefore, the protocol wastes resources sending the data item and receiving it. In conventional flooding, nodes are not resource-aware. They continue with their activities regardless of the energy available to them at a given time. So there is need of resource management in flooding.

Due to such differences, many new algorithms have been proposed for the problem of routing data in sensor networks. These routing mechanisms have considered the characteristics of sensor nodes along with the application and architecture requirements.

Almost all of the routing protocols can be classified as data-centric, hierarchical or location-based although there are few distinct ones based on network flow or QoS awareness. Data-centric protocols are query-based and depend on the naming of desired data, which helps in eliminating many redundant transmissions. Hierarchical protocols aim at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location-based protocols utilize the position information to relay the data to the desired regions rather than the whole network. The last category includes routing approaches that are based on general network-flow modeling and protocols that strive for meeting some QoS requirements along with the routing function.

3.2 Data centric protocols

It is not feasible to assign global identifiers to each node due to the sheer number of nodes deployed in many applications of sensor networks. Therefore, data is usually transmitted from every sensor node within the deployment region with significant redundancy. Since this is very inefficient in terms of energy consumption, routing protocols that will be able to select a set of sensor nodes and utilize data aggregation during the relaying of data have been considered. This consideration has led to data centric routing, which is different from traditional address-based routing where routes are created between addressable nodes managed in the network layer of the communication stack. In data-centric routing, the sink sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute based naming is necessary to specify the properties of data. The two classical mechanisms flooding and gossiping which are used to relay data in sensor networks without the need for any routing algorithms and topology maintenance (Hedetniemi & Liestman, 1998). In flooding, each sensor receiving a data packet broadcasts it to all of its neighbors and this process continues until the packet arrives at the destination or the maximum number of hops for the packet is reached. On the other hand, gossiping is a slightly enhanced version of flooding where the receiving node sends the packet to a randomly selected neighbor, which picks another random neighbor to forward the packet to and so on.

SPIN (Sensor Protocols for Information via Negotiation) is the first data-centric protocol, which considers data negotiation between nodes in order to eliminate redundant data and save energy (Heinzelman et al., 1999). Later, Directed Diffusion has been developed and has become a breakthrough in data-centric routing (Intanagonwiwat et al., 2000). Directed Diffusion is an important milestone in the data-centric routing research of sensor networks (Estrin et al., 1999). Then, many other protocols have been proposed either based on Directed Diffusion or following a similar concept (Shah & Rabaey, 2002; Schurgers & Srivastava, 2001).

3.3 Hierarchical protocols

Scalability is one of the major design attributes of sensor networks similar to other communication networks. To allow the system to handle with additional load and to be able to cover a large area of interest without degrading the service, networking clustering has been purposed in some routing approaches.

The main objective of hierarchical routing is to efficiently maintain the energy consumption of sensor nodes by involving them in multi-hop communication within a particular cluster and by performing data aggregation and fusion in order to decrease the number of

transmitted messages to the sink. Cluster formation is typically based on the energy reserve of sensors and sensor's proximity to the cluster head. LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the first hierarchical routing approaches for sensors networks (Heinzelman et al., 2000). The idea proposed in LEACH has been an inspiration for many hierarchical routing protocols (Manjeshwar & Agrawal, 2001; Lindsey & Raghavendra, 2002; Lindsey et al., 2001; Manjeshwar & Agrawal, 2002), although some protocols have been independently developed (Subramanian & Katz; 2000; Younis et al., 2002; Younis et al., 2003).

3.4 Location-based protocols

Location- based protocols are most commonly used in sensor networks as most of the routing protocols for sensor networks require location information for sensor nodes. In most cases location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated. Since, there is no addressing scheme for sensor networks like IP-addresses and they are spatially deployed on a region, location information can be utilized in routing data in an energy efficient way. Some of the protocols discussed here are designed primarily for mobile ad hoc networks and consider the mobility of nodes during the design (Xu et al., 2001; Rodoplu & Ming, 1999; Li & Halpern, 2001). However, they are also well applicable to sensor networks where there is less or no mobility. It is worth noting that there are other location-based protocols designed for wireless ad hoc networks, such as Cartesian and trajectory-based routing. However, many of these protocols are not applicable to sensor networks since they are not energy aware. In order to stay with the theme of the research, the scope has limited to the coverage of only energy-aware location based protocols.

3.4.1 Geographic and energy aware rotuing

Yu et al. have suggested the use of geographic information while disseminating queries to appropriate regions since data queries often includes geographic attributes (Yu et al., 2001). The protocol, namely Geographic and Energy Aware Routing (GEAR), uses Energy Aware and geographically informed neighbor selection heuristics to route a packet towards the target region. The idea is to restrict the number of interests in Directed Diffusion by only considering a certain region rather than sending the interests to the whole network. GEAR compliments Directed Diffusion in this way and thus conserves more energy.

3.4.2 Geographic adaptive fidelity

Geographic Adaptive Fidelity (GAF) is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to sensor networks as well (Xu et al., 2001). GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity.

4. Design and implementation

In sensor networks, building efficient and scalable protocols is a very challenging task due to the limited resources and the high scale and dynamics. In this realm, geographic protocols [Xu et al., 2001; Yu et al., 2001) take advantage of the location information of nodes, are very valuable for sensor networks. The state required to be maintained is minimum and their overhead is low in addition to their fast response to dynamics.

4.1 Geographic routing

Basic geographic protocol at the network layer has been examined for geographic routing based on greedy mechanisms. Geographic routing provides a way to deliver a packet to a destination location, based only on local information and without the need for any extra infrastructure. It makes geographic routing the main basic component for geographic protocols. With the existence of location information, geographic routing provides the most efficient and natural way to route packets comparable to other routing protocols.

Geographic routing protocols require only local information and thus are very efficient in wireless networks. First, nodes need to know only the location information of their direct neighbors in order to forward packets and hence the state stored is minimum. Second, such protocols conserve energy and bandwidth since discovery floods and state propagation are not required beyond a single hop.

It is based on assumption that the node knows the geographical position of the destination node. This approach to routing involves relaying the message to one of its neighbors that is geographically closest to the destination node of all neighbors, and is geographically closer to the destination. This approach attempts to find a short path to the destination, in terms of either distance or number of hops. It is based on the geographical distances between the nodes.

A node that requires sending a message acquires the address of the destination. After preparing the message, it calculates the distance from self to the destination. Next, it calculates distance from each of its neighbors to the destination. The greedy approach always tries to shorten the distance to be traveled to the destination to the maximum possible extent. Therefore, the node considers only those neighbors that are closer to the destination than itself. The sending node then chooses the node closest to the destination and relays the message onto the neighbor.

A node receiving a message may either be the final destination, or it may be one of the intermediate nodes on the route to the destination. If the node is an intermitted hop to the message being relayed, the node will calculate the next hop of the message in the manner described above.

A sample topology is shown in Figure 1. Nodes A and B are the sender and receiver respectively. Node A sends the message to node Y as it is the closest of its neighbors to the destination node B. On receiving the message, Y calculates its closest neighbor and forwards message to it. This process will continue until the massage reached to the final destination B. The dotted arrows show the shortest path followed by the node.

The basic geographic routing doest not use any data structures stored locally on a node apart from the neighbor table. Thus, no information is stored locally. The sending component doest not differentiate between the source of the message and an intermediate node on its route. The receiving component needs to handle to two different types of messages; one that says that the node is the destination, and the other that specifies the node to be an intermediate node for relaying the message. Both messages are handled in exactly the same way, without any form of distinction.

A typical sensor network consisting of sensor nodes scattered in a sensing field in the vicinity of the phenomenon to be observed is shown in Figure 2 (http://www.acm.org/crossroads/xrds9-4/sensornetworks.html). The nodes are connected to a larger network like the Internet via a gateway so that users or applications can access the information that is sent from the sensor nodes. The dotted circle shows the area where

sensor nodes are scattered to sense the specific task and then route the sensed processed data to the gateway. The main focus is on this dotted area and this research has proposed an Energy efficient greedy scheme for inter-sensor nodes communication where information relay between these sensor nodes. Proposes algorithm will provide simple and effcient path to nodes for forwarding their messages which will furthure conserve total energy of the entire network.

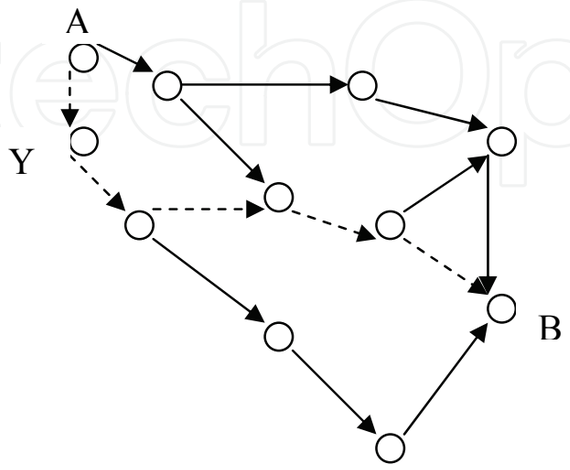


Fig. 1. Sample Route for Basic Geographic Routing

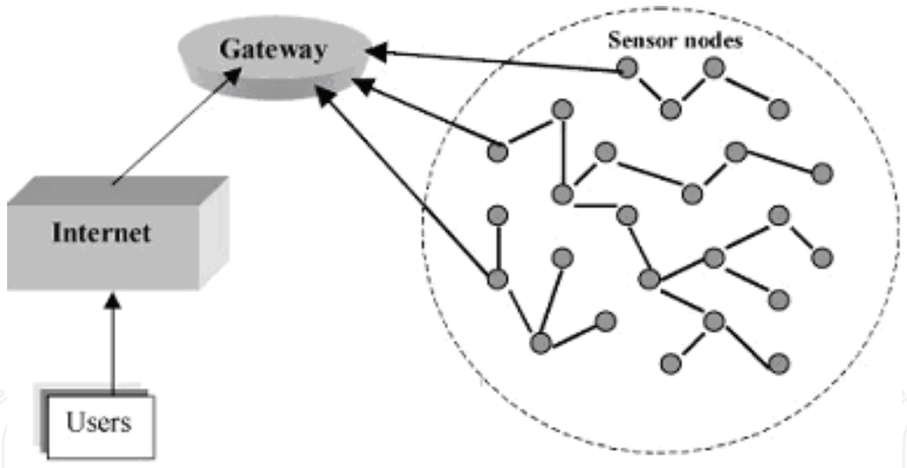


Fig. 2. Sensor Nodes Connected in a Network.

4.2 Routing scheme for inter-sensor nodes communication

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery and have very low energy resources. This makes energy optimization more complicated in sensor networks because it involves not only reduction of energy consumption but also prolonging the life of the network as much as possible. This can be done by having energy awareness in every aspect of design and operation. This ensures that energy awareness is also incorporated into groups of communicating sensor nodes and the entire network and not only in the individual nodes.

4.2.1 Weak node problem

The main component of geographic routing is usually a greedy forwarding mechanism whereby each node forwards a packet to the neighbor that is closest to the destination. However, while assuming highly dense sensor deployment and reasonably accurate localization several recent experimental studies on sensor networks have shown that node energy can be highly unreliable and this must be explicitly taken into account when considering higher layer protocol (Li & Halpern, 2001). The existence of such unreliable nodes exposes a key weakness in greedy forwarding. At each step in greedy forwarding, the neighbors those are closest to the destination may not have sufficient energy to transmit the messages. These weak nodes would result in a high rate of packet drops, resulting in drastic reduction of delivery rate or increased energy wastage if retransmissions are employed.

In sensor networks ,sensor nodes use their energy in forwarding messages in network but at some point when node deplete its all energy it fails to transmit the further messages resulting in loss of data (formation of holes). In this research work, the geographic routing thorough the greedy forwarding (Karp & Kung, 2000) has been considered for implementation. Usually, in the greedy forwarding the closest neighbor node will be heavily utilized in routing and forwarding messages, while the other nodes are less utilized. Due to this uneven load distribution it results in heavily loaded nodes to discharge faster when compared to others. This causes few over-utilized nodes which fail and result in formation of holes in network, resulting in increase number of failed/dropped messages in the network. Energy efficient routing scheme should be investigated and developed such that it loads balances the network and prevents the formation of holes. In this research, the above mentioned problems faced by greedy forwarding approach will be taken care of in sensor networks.

4.2.2 Energy efficeint greedy scehem: basic principle

The concept of neighbor classification based on node energy level and their distances has been used in Energy Efficient Greedy Scheme (EEGS) has been used to cater of the weak node problem. Some neighbors may be more favorable to choose than the others, not only based on distance, but also based on energy characteristics. It suggests that a neighbor selection scheme should avoid the weak nodes. If the geographic forwarding scheme purely based on greedy forwarding attempts to minimize the number of hops by maximizing the geographic distance covered at each hop, it is likely to incur significant energy expenditure due to retransmission on the weak nodes. On the other hand, if the forwarding mechanism attempts to maximize per hop reliability by forwarding only to close neighbors with good nodes, it may cover only small geographic distance at each hop. It would also result in greater energy expenditure due to the need for more transmission hops for each packet to reach the destination. So in both cases energy is not being conserved to increase the lifetime of the network. Therefore, the strategy used in the proposed Energy Efficient Greedy Scheme (EEGS) first calculates the average distance of all the neighbors of transmitting node and checks their energy levels. Finally, it selects the neighbor which is alive (i.e. having energy level above than the set threshold) and having the maximum energy plus whose distance is equal to or less than the calculated average distance among its entire neighbors. Hence, the proposed scheme uses Energy Efficient routing to select the neighbor that has sufficient energy level and is closest to the destination for forwarding the query.

4.2.3 Assumptions for EEGS

Some basic assumptions have been considered for the implementation of EEGS in this research work. Sensor nodes are static in the network (i.e. Once the node has learned its location, its co-ordinates do not change). The central location database has been managed by a central entity which enables each of the nodes to discover its position. In the real scenario, each node would learn its location by some kind of GPS system so the above assumptions can be made without the loss of generality. The irregular random topology for sensor networks has been considered. Single destination scenario is taken into the account. There are infinite-size buffers at each node to support the incoming and outgoing message packets. Hence, buffer overflows and queuing analysis are not the part of this research. In the proposed system the fixed size of packets are used. So the packet sizes will not be considered during the analysis.

4.3 General mechnism of purposed syetem

There are four basic modules have been implemented in the proposed system i.e. network generator, route generator, routing algorithm and router. The platform of Visual Studio 6.0 and OMNET++ network simulator has been used for implementation of purposed system.

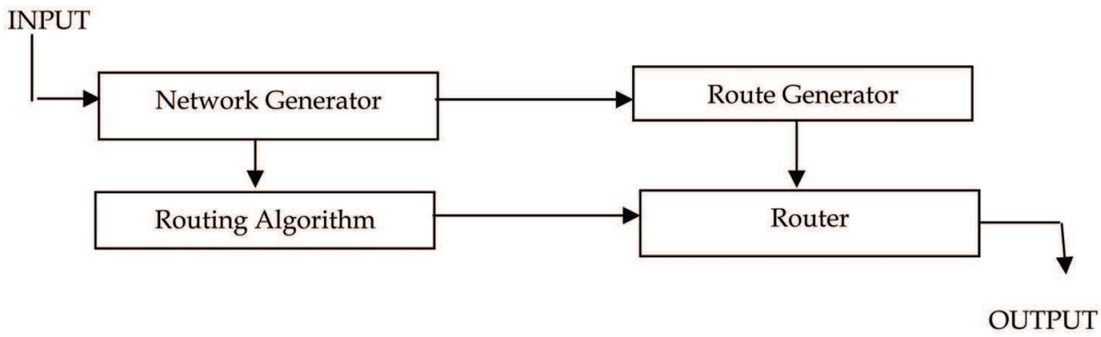


Fig. 3. Block Diagram of the System

The brief description of each module is as follow.

(a) Network Generator: This module generates the network. It has two type of parameters i.e. data rate and number of nodes. It includes a sub module network node which defines structure of single network node. Sub module network node has three types of parameters i.e. address of the node, then number of stations which is equal to number of nodes in this case and data rate. Two types of gates are defines for each node i.e. in gate and out gate. Input and output interfaces of modules are through these gates; messages are sent out through output gates and arrive through input gates, (b) Route Generator: In this module the source and destination are specified for the data sending and receiving. Each node randomly sent the massages to the destination node, (c) Routing Algorithm: This module takes location information of nodes in the network and set their weights. Then it chooses the next hop on the basis of EEGS, (d) Router: This module routes the packet to other nodes and generates the next hop destination map which comes from routing algorithm and then route/forward the received packet to the selected neighbor nodes. This map gives the complete information to each node about its own location and location of its neighbor nodes with their energy levels which are being updates after every transmission. Finally, router module gives the output in the form of packets delivered successfully, packet dropped, remaining energy level and status of the node.

4.4 Energy model

For the implementation purpose, a simple energy model has been used. Each node starts with the same initial energy and forwards a packet by consuming same energy. Initially, all nodes have energy level equal to 1 joule (Yu et al., 2001). Each node depletes energy in transmitting one packet which is equal to 0.1mjoule.

5. Simulations and results

Different simulations results are presented with different number of nodes in order to check performance of the proposed algorithm. Location of nodes has been taken randomly in each network. Performance of two algorithms (i.e. Greedy & EEGS) has been compared in terms of successful delivery rate and number of nodes.

5.1 Implementation with OMNET++

OMNET++ is an object-oriented modular discrete event simulator. The name itself stands for Objective Modular Network Testbed in C++. The simulator can be used for traffic modeling of telecommunication networks, protocol modeling, modeling queuing networks, modeling multiprocessors and other distributed hardware systems, validating hardware architectures, evaluating performance aspects of complex software systems, modeling any other system where the discrete event approach is suitable.

5.2 Simulation model

In simulation model, the numbers of nodes chosen ranged from 16 to 100 sensor nodes. Random topology has been considered in this implementation. The immobile sensor network has been considered, so every sensor node is static. Initially, each node has same energy level as specified in energy model. Any node having energy less than or equal to set threshold will be considered as dead. One node is located as the destination node for all nodes i.e. one node is declared as target node for all data receiving as mentioned in assumptions that one destination scenario has been considered. The packet size is of 562 bytes. Total simulation time is set to 500 seconds and each scenario is repeated ten times with different randomly deployed nodes. As mentioned above discrete even driven simulator OMNET++ has been used in this research for implementation purpose. It simulates routing packets among different nodes in the network.

Figure 4 shows the sample network with 30 nodes. Nodes start sending packets randomly to destination node by choosing the neighbor nodes on the basis of EEGS approach. Initially each node has energy of 1J. EEGS approach calculates the average distance of all neighbor nodes of the sending node and checks their energy levels. Then, it selects the neighbor which is alive (i.e. having energy level above than the set threshold) and having the maximum energy plus whose distance is equal to or less than the calculated average distance among its entire neighbors. This process will continue until the packet reaches to the destination node.

5.3 Evaluation metrics and measurement criteria

There are four performance metrics have been defined in order to measure performance of the proposed algorithm. These metrics includes number of packets delivered successfully, number of packets dropped, number of nodes alive and number of nodes dead.

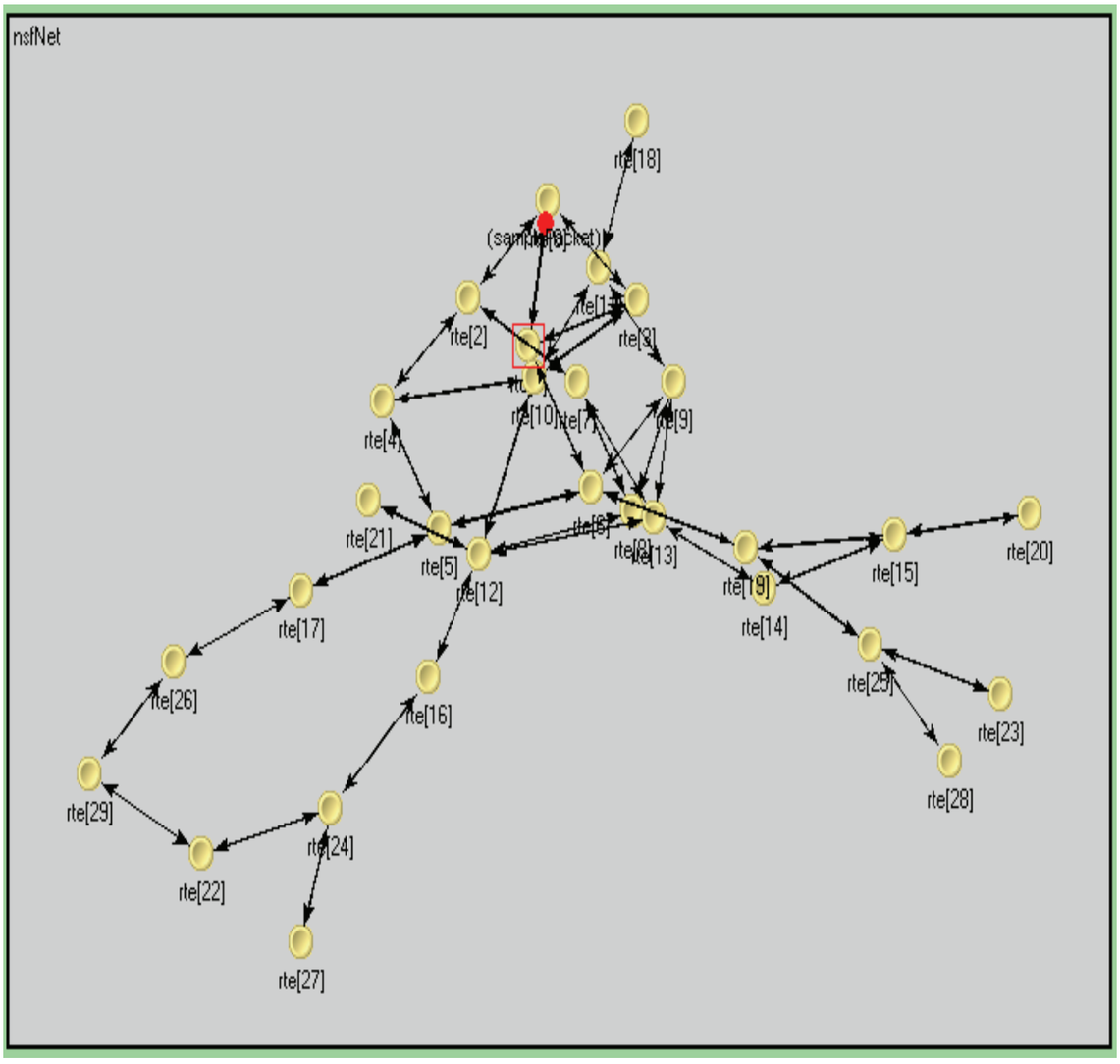


Fig. 4. Sample Network with the Network Size of 30 Nodes.

In Table 1 the results of simulation for network size of 30 nodes has been shown. Each node starts with the energy equal to 1J. These simulation results clearly show that EEGS approach provides better packet delivery rate as compared to Greedy algorithm. In these results it is also worth noticing that EEGS approach is more reliable by having more number of nodes alive, thus it results in longer life of the network as compared to the Greedy algorithm.
Total Packets Generated: 15,000

	Packets Successfully Delivered	Packets Dropped	Nodes Dead	Nodes Alive
Greedy	10500	4500	2	28
EEGS	14536	464	1	29

Table 1. The Simulation Results with Network Size of 30 Nodes

It is evident from Table 2 that the proposed EEGS approach provides better data delivery rate than the Greedy algorithm. The successful packet delivery of EEGS is 90% while Greedy algorithm has 72% on average. The main focus is on varying size of network by keeping other parameters constant. The main aim is to design an algorithm that can scale to thousands of nodes in future sensor networks, therefore the research has been focused on how the algorithm scales and perform better with networks of different sizes. It has been observed that the difference of amount of packets delivered successfully is getting larger as the number of nodes increases. It means that EEGS improves the performance much more as the number of source nodes increases. Also EEGS approach is more reliable in terms of energy consumption as it has less number of nodes dead as compared to Greedy algorithm. Hence, it provides longer the life to the sensor network as compared to the Greedy algorithm.

Number of Nodes		Total Number of Packets Generated by both Schemes	Packets Successfully Delivered	Packets Dropped	Nodes Dead	Nodes Alive
20	Greedy EEGS	10,000	9251 10000	749 0	1 0	19 20
35	Greedy EEGS	17,500	15834 17369	1666 131	1 1	34 34
45	Greedy EEGS	22,500	18877 21599	3623 901	3 1	42 44
55	Greedy EEGS	27,500	21253 23979	6247 3521	5 2	50 53
65	Greedy EEGS	32,500	31019 32500	1481 0	1 0	64 65
75	Greedy EEGS	37,500	25917 26421	11583 11079	3 2	72 73
85	Greedy EEGS	42,500	27325 38468	15175 4032	3 1	82 84
95	Greedy EEGS	47,500	31019 35872	16481 11628	5 3	90 92
100	Greedy EEGS	50,000	32237 40445	17763 4555	5 2	95 98

Table 2. The Complete Simulation Results

5.4 Results and performance comparsion

In geographic routing greedy communication model has been used as the basic comparison model. Greedy algorithm is purely geographic based and does not consider the energy consumption of the nodes. As per the minimum criteria, proposed communication scheme should be having greater successful packet delivery than Greedy algorithm and should have less number of dead nodes.

The results presented in the Table 2 are shown in form of graphs in order to have the clear comparison between the EEGS and Greedy algorithm, which shows that proposed EEGS approach has performance clearly better than Greedy algorithm.
In Figure 5 a comparison has been shown between the total numbers of packets that are successfully delivered in both algorithms. It is clear from the graph that the proposed EEGS approach has much higher successful delivery rate than the Greedy algorithm.

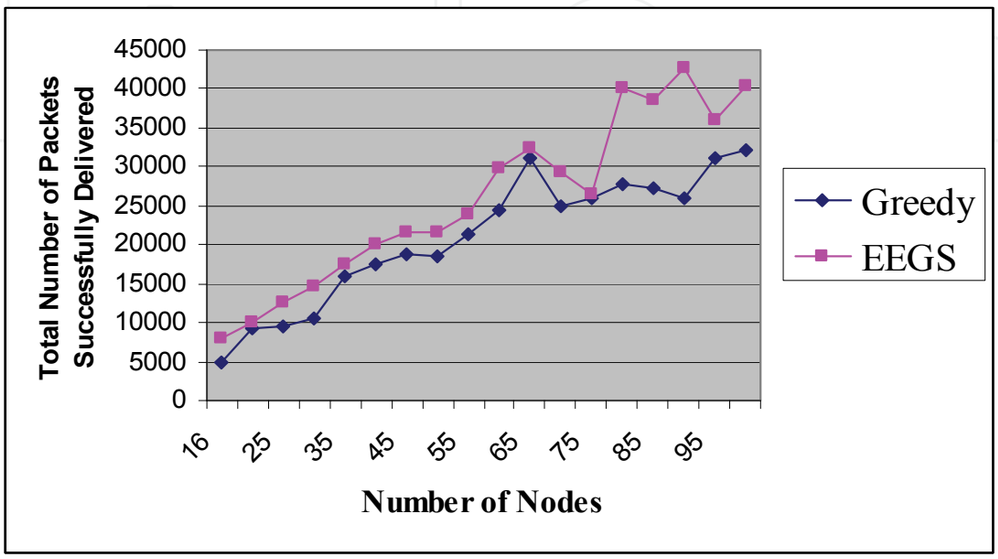


Fig. 5. Successful Packet Delivery in EEGS and Greedy Algorithm.

It is also indicated in Figure 6 that the packet drop rate is very less in EEGS approach as compared to the Greedy algorithm. Hence, EEGS approach conserves more energy and more efficient then Greedy algorithm.

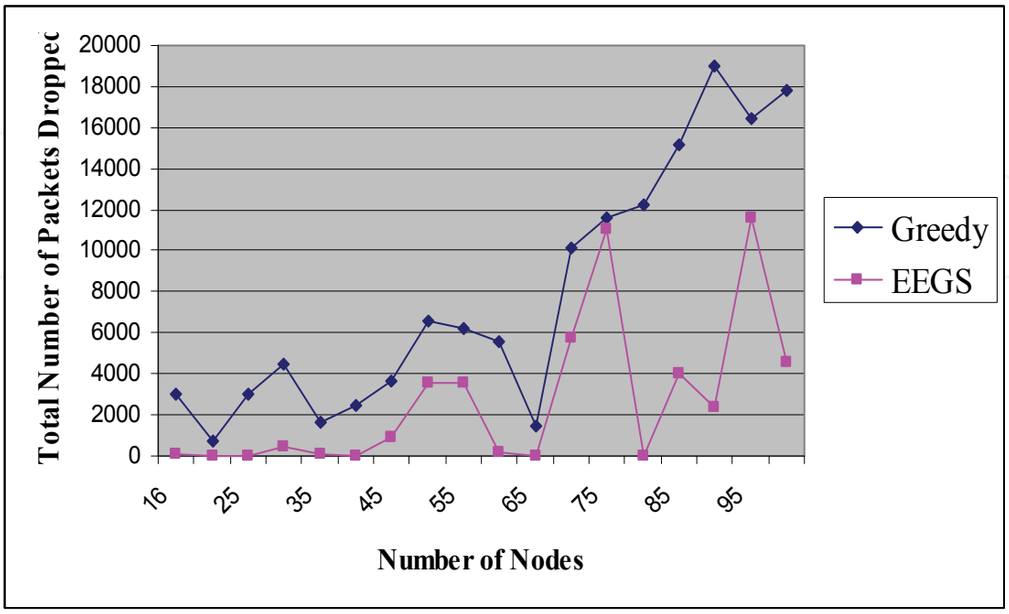


Fig. 6. Packets Dropped in EEGS and Greedy Algorithm.

From Figure 7 it is observed that EEGS approach is more reliable and results in longer life of the network as the total number of nodes which are alive are greater as compared to Greedy algorithm.

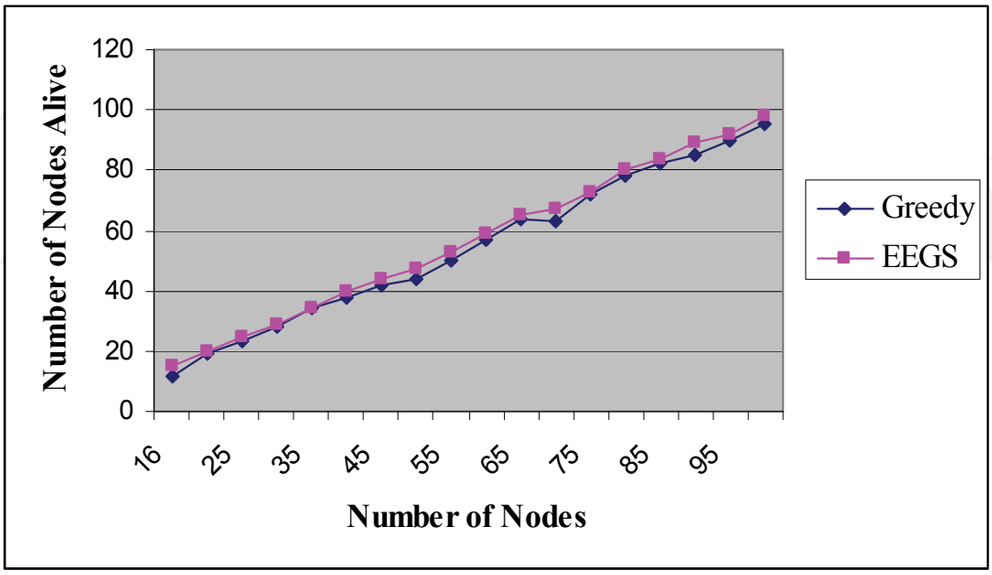


Fig. 7. Nodes Alive in EEGS and Greedy Algorithm.

Figure 8 clearly shows that Greedy algorithm has greater number of dead nodes as compared to EEGS approach. Hence, network lifetime is greater for EEGS than the Greedy algorithm.

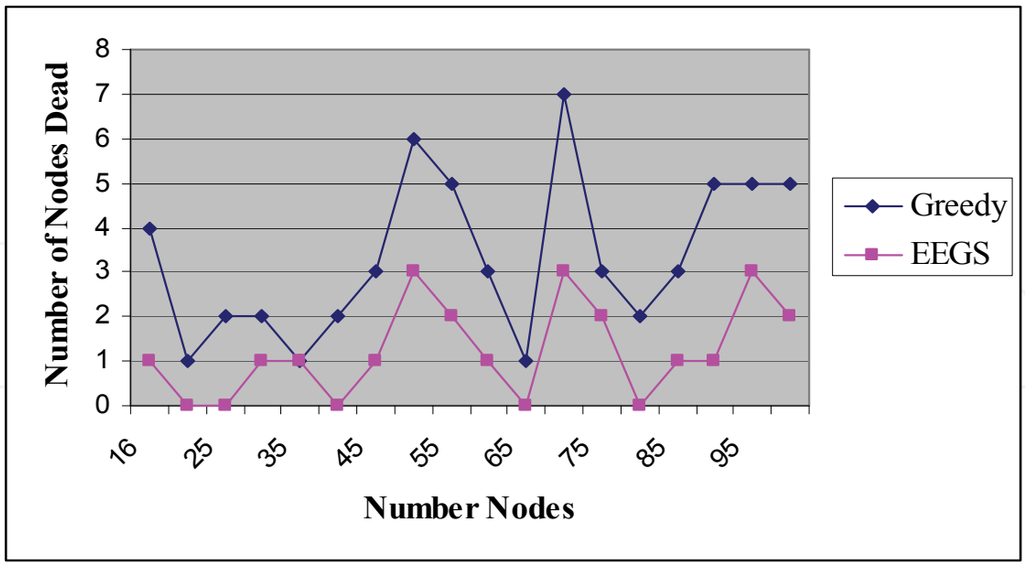


Fig. 8. Dead Nodes in EEGS and Greedy Algorithm.

5.5 Comparison between greedy algorithm & EEGS and analysis

In Greedy algorithm, packets are marked by their originator with their destinations' locations. As a result, a forwarding node can make a locally optimal, greedy choice in

choosing a packet's next hop closest to the destination. Forwarding in this regime follows successively closer geographic hops until the destination is reached. On the other hand, EEGS has the forwarding rule based on location as well as energy levels of nodes. In energy aware algorithm, each node knows its neighbor positions and their energy levels. The transmitting node writes the geographic position of the destination node into the packet header and forwards it to the neighbor which has the distance equal to or less than the average distance of all neighbors of that transmitting node plus having the maximum energy level among all its neighbors.

The geographical position provides the direction when the data is relayed in that direction until being reached to the gateway. The nodes add the geographical position of the gateway in the packet header and forward it to the neighbor who resides geographically closest to the destination and has the maximum energy (from the neighbors which has distance equal to or less than the average distance of neighbors).

During the packet transmission, each node chooses the next hop based on the routing policy used. The procedure repeats until the packet reaches the destination node. The packet transmission energy required between the two nodes is calculated by the energy model specified in 4.4.

The Greedy algorithm and EEGS approach have been run by using different number of sensor nodes with the same energy per node initially. It has been noted that EEGS approach as compared to the Greedy algorithm gives better results in terms of successful packet delivery and less number of dead nodes. Hence, proposed EEGS approach is more reliable as compared to Greedy algorithm and results in longer lifetime of the network.

6. Conclusion and future work

6.1 Conclusion

A sensor network is a promising technology for applications ranging from environmental/military monitoring to industrial asset management. Due to sensor networks communication model, these networks have potential applications in many areas. Sensor networks, similar to mobile ad-hoc networks involve multi-hop communications. There have been many routing algorithms proposed for mobile networks. Yet, these algorithms are not applicable to sensor networks due to several factors. Due to these factors sensor networks are distinguished from mobile networks, and make most of the routing protocols of mobile networks inapplicable to sensor networks. Hence, new routing algorithms are investigated for sensor networks. Almost all of the routing protocols can be classified as data-centric, hierarchical or location-based although there are few distinct ones based on network flow or QoS awareness. Geographic routing in sensor networks has been a challenging issue for researchers considering the energy constraints in these networks. The nodes in the network cooperate in forwarding other nodes' packets from source to destination. Hence, certain amount of energy of each node is spent in forwarding the messages of other nodes. Lots of work has been done in this respect but still energy depletion of sensor nodes is a big challenge in sensor networks. Sensor nodes use their energy in forwarding messages in network but at some point when node deplete its all energy it fails to transmit the further messages resulting in loss of data (formation of holes). In this research work, the geographic routing thorough the greedy forwarding has been

considered for implementation. . In greedy forwarding uneven load distribution results in heavily loaded nodes to discharge faster when compared to others. This causes few over-utilized nodes which fail and result in formation of holes in network, resulting in increase of failed messages in the network. So there was a need of such energy efficient routing strategy that should be balance the load of the network and prevents the formation of holes. Therefore this research work has investigated an Energy Efficient Greedy Scheme (EEGS) for geographic routing in sensor networks. The Greedy algorithm and EEGS approach have been implemented and simulation results have been obtained. From these results it has been shown that proposed EEGS approach performs better and efficiently than the Greedy routing. The simulations based upon the different number of nodes by employing these two algorithms considering different parameters (i.e. the successful packet delivery and number of nodes alive as the performance criterion). Therefore, performance of EEGS approach is much better than the Greedy algorithm in the defined parameters. Consequently, it can be concluded that EEGS can efficiently and effectively extend the network lifetime by increasing the successful data delivery rate.

6.2 Future work

The emerging field of sensor networks has lot of potential for research. In this research work, has considered fixed sizes of packets by using very simple energy model for energy computation purposes. This work can be extended by considering the variable length of packets and the changing distance of transmitting node from its neighbors. For this purpose, there is a need of such an energy model that can calculate the energy consumption of nodes based on their sizes and distances.

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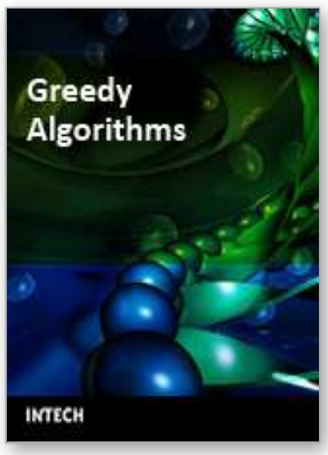
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