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An Energy Efficient Multicasting Routing Protocol for Wireless Sensor Networks

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Abstract:

Wireless sensor network consists of hundreds to thousands of nodes that communicate among themselves using radio signals and any node can leave or join the network when required. In Wireless sensor network no central controller is present. Sensor nodes deployed in the network are responsible for data routing in the network. Wireless sensor network is used to monitor the environmental conditions such as temperature, pressure, humidity, sound, noise etc. Wireless Sensor nodes have very small size and have limited resources. In far places, it is very difficult to recharge or replace the battery of the sensor nodes. In such conditions, focus is to reduce the battery consumption of the sensor nodes. In this work, a new technique is proposed to enable efficient battery consumption in a multicasting routing protocol. In this technique, the cluster heads are selected on the basis of dynamic clustering using neural network. Simulation results show that the proposed technique is more reliable, energy efficient and provide better results as compared to the existing technique.

Keywords **— Multicasting, energy efficiency, clustering, neural network.**

I. INTRODUCTION

A Wireless sensor Network (WSN) is a wireless network consisting of large number of sensor nodes which is deployed for monitoring physical or environmental conditions [1]. WSN are employed for applications such as monitoring of environment, traffic surveillance, building structures monitoring, military sensing and gathering of information, monitoring of habitat, wildfire protection, pollution monitoring, etc. [1], [2], [3]. Designing of routing protocol in WSN poses many challenges due to limited resources offered by it like limited energy, short memory, and limited processing. To prolong the lifetime of WSN with limited energy resources, multicast can better meet the requirement of network resources. Multicast is the process of transfer of same message to multiple receivers simultaneously within the transmission range of the sender. Multicast is an essential component in many wireless sensor networks applications. Multicasting is a more efficient and reliable method of supporting group communication as compared to unicasting or broadcasting mechanisms.

Applications of multicasting are conference meetings, military control operations and multicast tactical operations [4]. Multicasting routing protocols can be divided into four categories:

- Tree Based multicasting routing protocol
- Mesh based multicasting routing protocol
- Group Location based multicasting routing protocol
- IP based multicasting routing protocol.

Tree Based Multicasting Routing Protocol: The basic idea of tree based multicasting routing protocol is to build a multicast tree which is used to send data from base station to any other node in WSN [5]. The base station on establishment of a tree, broadcasts request packets to discover the child nodes and these child nodes find their child nodes in the same manner. In tree-based multicast protocols, there is only one path between a source-receiver pair. Tree-based multicast protocols can be classified into two types:

- Source-tree-based multicast routing protocols.

- Shared-tree-based multicast routing protocols.

In a source-tree-based protocol, a single multicast tree is maintained per source, whereas in a shared-tree-based protocol, a single tree is shared by all the sources in the multicast group. The shared-tree-based multicast protocols are more scalable as compared to source-tree-based multicast protocols. Here, scalability refers to the ability of the protocol to work well without any degradation in performance when the number of sources in a multicast session or the number of multicast sessions is increased. In source-tree-based multicast routing protocols, an increase in the number of sources gives rise to a proportional increase in the number of source-trees. As a result, there is a significant increase in bandwidth consumption in the already-bandwidth-constrained network. But in a shared-tree-based multicast protocol, this increase in bandwidth consumption is not as high as compared to source-tree-based protocols. The main drawback of these protocols is that they are not robust enough to operate in highly mobile environments [5].

Multicast routing protocols improve the network performance by optimizing the parameters such as bandwidth, channel utilization, throughput rate and quality of service (QoS). Geographic multicast routing (GMR), uses stateful geographical attributes and multicast group size, establishes the multipath connectivity in the network. Data forwarding node selects the neighbour node based on cost-aware greedy approach towards the destination nodes. The limitations of GMR are network scalability and node mobility [6]. Distributed geographic multicast routing (D-GMR) is a stateless protocol based on reduction ratio heuristic based Euclidean Steiner trees (rrSTR) and constructs radio-range familiar Euclidean Steiner trees. The source node performs functions such as: (i) create a virtual Steiner tree (ii) partition the tree towards the destination node and (iii) select the destination node in next hop. The limitation of D-GMR is unbalanced network density [7]. Demand scalable geographic multicast routing (DS-GMR) uses weighted Steiner trees and multicast reduction ratio. It is used when destination nodes are adjacent to each other and improves multicast end-to-end delivery ratio [8]. Hierarchical geographic multicast routing (HGMR) uses forwarding efficiency of GMR and scalability of hierarchical rendezvous point multicast (HRPM). Large geographic area is divided into cells on basis of HRPM. Multicast trees are constructed within each cell and selection of neighbouring nodes done on basis of localized GMR greedy approach. The limitation of HGMR is varying cell size and node density [9]. Optimal multicast (oCast) routing protocol for wireless sensor networks considers centralized and distributed approaches for small scale destination nodes [10]. Dijkstra - based localized multicast routing applied in large scale sensor networks uses energy- efficient shortest paths and covers maximum geographical area towards the destination node. It uses radio range of multicast group members to estimate the average route cost and delay in multicast trees [11]. Gradient based traffic aware routing uses multiple sink nodes in the network. Routing paths are established from source to sink node using gradient search method based on attributes like hop count, distance and delay between the nodes in the network [12]. On-demand multicast routing uses the cluster head node to act as intermediate multicast source node and forward data towards the destination. This approach increases the connectivity rate and establishes a reliable network [13]. Core network supported multicast routing (CNSMR) protocol; a stateful based distributed multicast routing protocol for sensor networks consists of heterogeneous nodes such as cluster head (CH) nodes, core nodes (CN) and sensor nodes (SN). CH nodes and CN nodes form the core network, and CNs with core network and SNs form the multicast tree which helps to balance the load in network and improve the network performance. However, in this protocol selection of cluster heads is static, done on the basis of nodes having maximum energy is being selected as cluster head in every transmission round. Due to this, issues of energy inefficiency are raised [14].

In this paper, an improved version of core network supported multicasting routing (CNSMR) protocol in wireless sensor networks is presented. In this enhanced version of CNSMR, dynamic clustering of nodes using Boltzmann neural network is done where cluster head selection is done to perform required data transmission by minimum energy consumption.

II. CORE NETWORK SUPPORTED MULTICAST ROUTING (CNSMR) PROTOCOL

CNSMR is a stateful multicasting routing protocol which uses heterogeneous nodes (HNs) such as cluster head (CH) nodes, core nodes (CN) and sensor nodes (SN). In stateful multicasting approach, multicast group members which participate in the multicast session store the alternate paths and maintain the multicast tree during link failures. The sensor network is grouped into clusters that comprise of cluster head (CH) node, core nodes (CNs) and sensor nodes (SNs). CHs and CNs have more computing ability, energy and storage resources as compared to SNs. In sensor networks, SNs forward the data to CH nodes using techniques such as data dissemination, directed diffusion and data gathering. This protocol uses data gathering technique to forward the data to neighbouring CNs and minimises the routing complexity. In multicasting, source node primarily initiates the multicast session and invites a set of nodes with REQ signal to join the session. After receiving the REPLY signal from target nodes, source node forms the multicast group and confirms the path. CH node controls the operations like topology control, routing and monitors the energy status of SNs in the network. CNs with CH form the core network and the SNs with CNs and core network form the core network supported multicast tree. Within each cluster the following tasks are performed: (i) the CH node maintains the route path with adjacent CNs and neighbouring CHs (ii) the CN maintains the route path with neighbouring CNs and adjacent SNs.

The formation of core network and multicast network is shown in figure 1. The steps to be followed are given as follows: (i) CHs and CNs exchange control signals (CORE-PATH-REQ and CORE-PATH-REPLY). The message CORE-TREE-CREATE is sent by CH node to CN nodes to form the core network. within each cluster, if the CH node and CNs are far away, then additional CNs are deployed in the wireless sensor network to form the core network, (ii) SNs send the control signal ROUTE- REQ to the neighbouring CNs. The CNs updates the multicast group membership and confirms the route with ROUTE-GRANT leading to formation of routes between CNs and SNs in the network. This process is repeated until multicast trees are formed with the core network. (iii) The SNs, neighbouring CNs and CH exchange multicast data in the network.

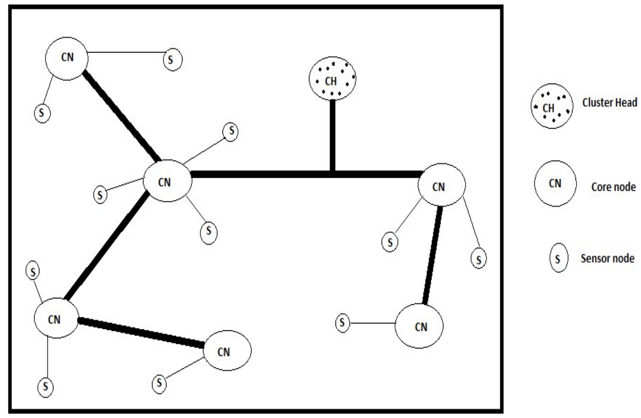


Fig. 1 Formation of CNSMR

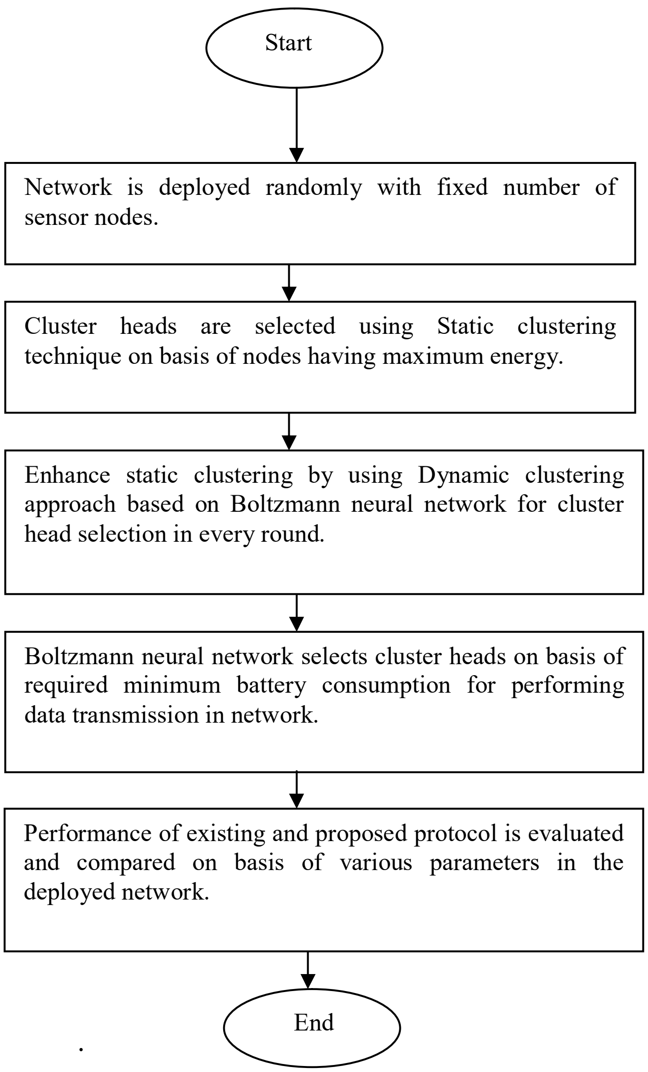
III. PROPOSED PROTOCOL:

The existing CNSMR protocol performs static clustering of nodes in the network where nodes with maximum energy were selected as cluster heads resulting in energy inefficiency in the network which results in shorter lifetime of network. The proposed protocol is an improved version of CNSMR protocol where clustering of nodes is done in a dynamic way with the help of Boltzmann neural network. In existing protocol, nodes having maximum energy were being selected as cluster heads whereas in proposed protocol, cluster heads will be selected to perform required data transmission in network using minimum energy requirement.

Boltzmann neural network is a type of supervised learning methods. It is a recurrent neural network consisting of visible layers and hidden layers. The neurons in input layer are connected to hidden layer and hidden layer neurons are connected to output layer neurons. It consists of binary units, +1 for on and -1 for off. In addition to the system output, state of each individual neuron is taken into account.

Every pair of neurons has weight connected between them. Boltzmann learning adjusts weights until the desired output is produced by the network. It uses an error signal to train the network during any iteration similar to error correction learning. But as compared to error correction learning where we consider the direct difference between result value and desired value, difference between the probability distribution of the system is taken.

Proposed Algorithm: For achieving energy efficiency in the network through proposed algorithm, the steps to be followed are listed in the flowchart:



IV. SIMULATION AND RESULTS:

The whole scenario has been implemented in MATLAB R2013a software. MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. It has development environment for managing code, files and data and tools for building custom graphical user interface.

Simulation Environment: - The sensor nodes are deployed randomly in a 100*100 m area to make a heterogeneous network comprising of nodes with different energy levels. Both the existing and proposed protocol are compared in this same network .The network is assumed to have only one base station present, nodes are energy constrained and a node is considered dead when it is not capable of transmitting data to base station. The various simulation parameters used while implementation is listed in the table below:

TABLE I
SIMULATION PARAMETERS

S. No.	Parameter	Value
1.	Field Dimensions	100*100
2.	Base Station location	X=50, Y=50
3.	Number of nodes	100
4.	Energy required for transmission(ETX)	50 nJ
5.	Energy required for reception(ERX)	50 nJ
6.	Free space model parameter ε_{fs}	10 pJ/bit/m^2
7.	Multipath fading model parameter ε_{mp}	0.0013 pJ/bit/m^4
8.	Number of rounds	5000

The parameter ETX corresponds to energy required for transmission of data in the network and ERX corresponds to energy required for reception of data in the network. The parameter ε_{fs} is the amplifier energy parameter corresponding to free space model and ε_{mp} is the amplifier energy parameter corresponding to multipath fading model. The network performance is analyzed over 5000 rounds. The performance of proposed scheme is compared with the existing technique through assessment of following metrics:

1. **Number of Dead nodes**: It is defined as the number of nodes which stop operating

during rounds of transmission of data in deployed network. If the nodes deployed die at a slow rate in the network, network will have longer lifetime.

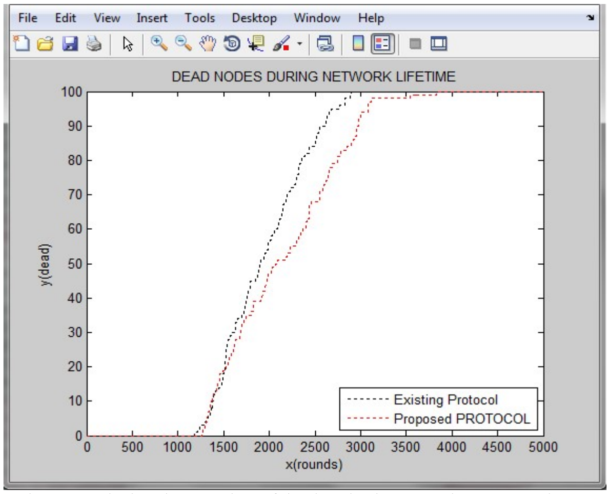


Fig. 2 Graph showing number of dead nodes in network w.r.t rounds

Figure 2 shows that nodes die more early with respect to transmission rounds in existing technique than proposed technique. So, nodes in proposed technique live longer than existing technique hence showing improvement in network lifetime.

2. **Packets sent to base station:** It is defined as number of packets transmitted to base station by cluster heads with respect to rounds of data transmission in network.

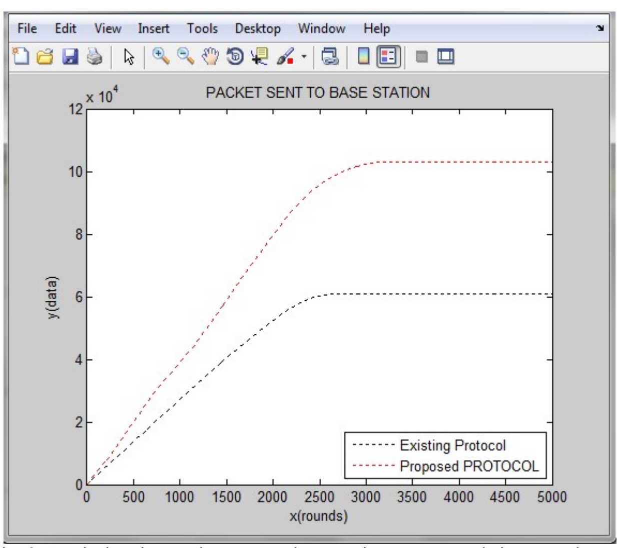


Fig. 3 Graph showing packets sent to base station w.r.t. rounds in network

The Figure 3 shows numbers of packets sent to base station over the rounds are more in proposed technique as compared to existing one resulting in improvement in throughput of network. As a result improves the network performance and reliability.

V. CONCLUSION

In this paper, an improved version of CNSMR protocol is presented to increase network lifetime and energy efficiency of network. It is based on dynamic clustering approach using Boltzmann neural network. The network consists of clusters comprising of cluster head, core nodes and sensor nodes. Cluster heads are selected using Boltzmann neural network to perform data transmission using minimum energy required to do it. The simulation results show the comparison between existing CNSMR protocol and new proposed protocol in terms of number of dead nodes in network and number of packets transmitted to base station. Proposed protocol offers better results as nodes in the network die later than existing protocol resulting in increase in network lifetime and also numbers of packets transmitted to base station are more as compared to existing protocol. In future work, focus can be made on increasing number of levels of hierarchy in multicasting protocol for making the multicasting protocols more robust for future use.

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