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Energy Efficient Hybrid Topology for Wireless Sensor Networks

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Abstract—*Wireless Sensor Networks (WSN) consists of spatially distributed sensor nodes which are specialized transducers equipped with communication infrastructure. This wireless sensing system can effectively sense, monitor and record physical conditions at diverse locations particularly in hostile locations where human intervention is not possible. The data collected is then forwarded to the main processing centre. Sensor nodes are generally equipped with non-rechargeable batteries, so energy efficiency is a major design issue in order to increase the network lifetime. Energy resource limitation and unbalance energy consumption are inherent problems of WSN. This paper proposes a new energy efficient hybrid topology which is a hybrid of already existing atypical topologies of WSN namely tree topology and chain topology. This hybrid topology can transmit comparatively more data from the sensor nodes to the sink efficiently and effectively. The hybrid topology, tree topology and chain topology are separately implemented in MATLAB using distance source routing and the simulation results thus obtained proves hybrid topology to be better in terms of energy efficiency. The results are then compared.*

Keywords*: WSN; chain topology; tree topology; hybrid topology*

1. INTRODUCTION

WSN which are also sometimes called as wireless sensor and actuator networks [WSAN] consists of spatially distributed autonomous sensors to monitor physical or environmental conditions such as temperature, pressure, humidity, sound level, pollutant levels, illumination intensity, vibration intensity, power line voltage, chemical concentrations etc. These sensor nodes may be connected to only one or several other sensor nodes depending on the type of topology deployed. Typically, each sensor node is made up of transducer, microcomputer, radio transceiver and a power source [1]. A WSN is thus a composition of large number of low cost, low power, multifunctional sensor nodes with good sensing and computing capabilities which are highly distributed inside the system.

These smart sensors senses data from the physical environment, process it and communicate the information to its neighboring nodes which further pass on the information to sink node (or base station). This information can then easily be passed on to the user [2] [3].

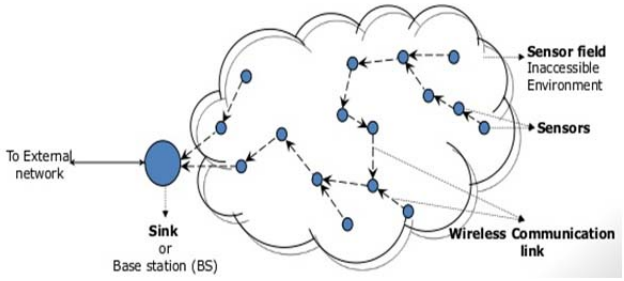

Fig. 1: Wireless sensor network

The disadvantages associated with these sensor nodes are the limited power supply, minimal memory, limited computational power etc. which needs to be overcome. But the biggest disadvantage is the limited energy resource and unequal energy distribution which decreases lifetime of sensor nodes and hinders effective data communication. The hybrid topology is developed to extend network lifetime and lessen energy utilization. The hybrid topology is a hybrid of both tree topology and chain topology. Both these topologies are the types of atypical logical topologies of WSN. The proposed hybrid topology successfully overcomes the energy resource constraints of these sensor nodes.

2. RELATED WORK

Liu et al. in [4] paper makes a first attempt to provide a comprehensive review on atypical routing techniques. This paper provides a detailed classification and analysis of different logical topologies. Various atypical hierarchical routing techniques are described, discussed and quantitatively compared. The advantages and the disadvantages of different logical topologies are analyzed with respect to their significant performances and applications used in day to day life. Finally, they put forward some open issues related to the design of hierarchical WSN. This survey aims to provide useful

guidance in brief for the system designers on how to evaluate and select appropriate logical topologies from variety of other available logical topologies along with effective hierarchical routing protocols for specific applications.

Kumar et al. in [5] this paper defines WSN as wireless sensing system with spatially distributed smart sensors equipped with sensing, computational and communication capabilities. These sensor nodes are light in weight, small in size and have limited energy resources. Due limited energy resources available with these sensor nodes, regular ad hoc routing techniques cannot be directly applied to sensor network domain. Thus, there is need for energy efficient routing algorithms suitable to the inherent characteristics of WSN. The hierarchical routing protocols for WSN, are considered to be much more energy efficient. Therefore, in this paper a comprehensive survey on hierarchical routing protocols for WSN has been discussed.

Hoang et al. in [6] the proposed work focuses on the efficient managing of the energy usage within the cluster which can further be extended effectively for a larger WSN facilitated by different clustering algorithms. To study the effect of different cluster head selection algorithms on the network's lifetime, an experimental study has been conducted and carefully performed. The best results show that the network lifetime is enhanced significantly when a voltage based selection scheme is used for energy conservation as compared to other algorithms. The hierarchical routing protocol for WSN is recognized as a technique that can reduce energy consumption of networks and increase the overall efficiency of the networks. Cluster head selection and network power management plays an important role to improve the overall performance of this hierarchical routing protocol. In this paper, a hierarchical routing protocol for a small scale WSN has been developed and successfully implemented. Cluster head rotation is used to balance the energy consumption and time scheduling of the sensor node operation which is carried out to achieve energy efficiency.

Vhatkar et al. in [7] this paper discusses the design issues faced while using hierarchical routing protocols for WSN by considering its various dimensions and metrics such as mobility, power usage, traffic and the quality of service (QoS). This paper presents a comprehensive and a comparative study on different hierarchical routing protocols for WSN. The modern research has found a variety of useful applications and a number of new characteristics for WSN. The research has led to materialization of various application specific routing protocols which are energy efficient. Energy efficient WSN is the topmost priority for all the researchers. As a result, it is becoming increasingly difficult to discuss the design issue requirements pertaining to both that is hardware and software. Implementation of efficient system in a multidisciplinary research, in field of WSN, is becoming very difficult.

Huang et al. in [8] paper effectively proposed an Energy Efficient Multihop Hierarchical Routing protocol (EMHR) for WSN. Based on energy efficiency strategy, the cluster head decision is made in such a way that the node having surplus energy is selected and is made as the cluster head. This prevents low energy nodes to get selected as cluster heads. During data transmission, the data in cluster head is transmitted by multihop according to the determined weight function which in turn determines the cluster head of next hop. This EMHR protocol effectively balances the load of network topology and reduces the energy dissipation of the cluster heads. The simulation results show that EMHR protocol significantly prolongs survival time of the network and efficiently balances energy load of the cluster heads in WSN.

Wang et al, in [9] this paper shows the energy efficiency as an important issue in designing of WSN. An efficient routing protocol is very critical to prolong the lifetime of sensor nodes. This paper proposes a Hierarchical Multiple-Choice Routing Path protocol (HMRP) for WSN. According to this protocol, the WSN is initially constructed as a layered network and based on this layered network sensor nodes have multipath routes to the sink node/base station (BS) via candidate parent nodes. The simulation results prove HMRP as an effective routing protocol which increases the network lifetime of sensor networks better than other clustering or tree based protocols.

3. PROPOSED WORK

After reviewing several papers we found a need to develop energy efficient hierarchical routing topology. Hierarchical architecture also effectively solves the problem of scalability and energy efficiency to some extent. The biggest disadvantage associated with WSN is the energy resource constraint of the sensor nodes. Sensor nodes have limited battery power resulting in limited computation capabilities. For this both the tree and chain topologies of WSN were analyzed and a hybrid topology was developed out of it. In order to enhance the energy efficiency of these sensor nodes a hybrid topology is designed which successfully outperformed chain and tree topology in terms of energy efficiency.

A Hybrid topology is developed, implemented and tested in MATLAB environment. The type of routing used is Dynamic Source Routing (DSR). This type of routing is designed for use in multihop networks. It allows the network to be self organized without any central administration. The advantages associated with DSR are the reduced bandwidth overhead, minimal battery power and negligible routing updates. It does not make use of the routing table present at each node rather it makes use of source routing. The hybrid model is developed using this DSR. The various steps involved during problem formulation of hybrid model are as follows:

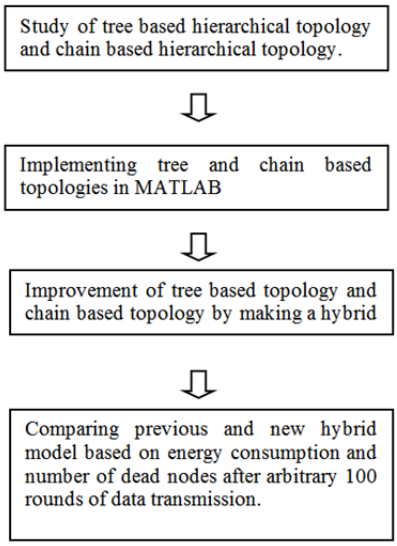

Fig. 2. Proposed methodology

4. HYBRID TOPOLOGY

Hybrid hierarchical topology is developed by combining the advantages of both tree hierarchical topology and the chain hierarchical topology. The results show that the hybrid hierarchical topology is much more energy efficient as compared to individual hierarchical tree based topology and the chain based topology. The features of hybrid topology are as follows:

i. In hybrid topology, route selection energy needed is reduced which is relatively higher in chain based hierarchical topology.
ii. We are able to achieve equal distribution of energy in hybrid technique unlike in tree based hierarchical topology. It boosts the overall efficiency of the network.
iii. After a given number of rounds of data transmissions, hybrid hierarchical topology had relatively lesser number of dead nodes as compared to tree hierarchical topology and chain hierarchical topology.
iv. Hybrid hierarchical topology combines the advantages of both hierarchical topologies that is the tree and chain based topologies.
v. Hybrid hierarchical model improves scalability of the network.
vi. Lifetime of the sensor nodes and energy efficiency improved significantly in hybrid hierarchical topology.

5. MATLAB IMPLEMENTATION

The proposed hybrid model is developed and simulated in MATLAB. The results are then analyzed and compared. The various steps involved during MATLAB implementation for all the three topologies are explained below:

5.1 Creating Deployment Scenario

A hypothetical situation is developed. A total of 200 nodes are deployed. All these nodes are spatially distributed and shown as a 400*400 size image. The nodes are coloured green. The data flows from the nodes to the receiving station.

5.2. Creation of Distance and Location Table

The location table is used for storing the locations of all the 200 nodes which are deployed. When DSR is used the distance of the nodes from the base station is required to be known for efficient data communication. For this the distance table is used. The distance is calculated using simple distance formula that is:

To find the distance between two points (X_1,Y_1) and (X_2,Y_2), the coordinates of these ordered pairs are used and the formula is applied as

$$d= ((X_1-X_2)^2 + (Y_1-Y_2)^2)^{1/2}$$

5.3 Implementation of Chain Topology in MATLAB

To develop chain topology in MATLAB the Availability Factor (av) is set 1 that is av =1. It means that a particular node can be used only once for the purpose of transmitting data. In MATLAB four chains are shown. All of these have equal distribution of energy.

5.4. Implementation of Tree Topology in MATLAB

In tree topology each and every node can be used more that once unlike in chain topology. This results in large amount of unequal distribution of energy. This type of topology in wireless sensor networks has minimal energy efficiency. But the route reselection energy needed in this type of topology is relatively less when compared to chain topology. In this av can be 2, 3, 4…. n, where n can be any number greater than 2 or equal to 2 that is $n\geq 2$. Although a node can be used for any number of times during data transmission in tree topology but for the purpose of implementation its availability is kept 3 that is av = 3.

5.5. Implementation of Hybrid Topology in MATLAB

The logical topologies used in making of a hybrid model are tree hierarchical topology and chain hierarchical topology. Their advantages and disadvantages are analyzed and a hybrid model is then implemented in MATLAB. In this the availability factor is set to 2 that is av = 2. It means that a node can be used only twice for the purpose of data communication unlike in hierarchical tree topology and the hierarchical chain topology. Its availability factor is fixed to 2. The hybrid model helped us to overcome the drawbacks of both the previous topologies.

6. SIMULATION AND RESULTS

In this section we have provided the results and discussions related to our work. A total of 4 different routes are shown for every result. The Fig. 3 shows ordinary Chain based routing. In this chains are formed to send data from the transmitting node to the BS.

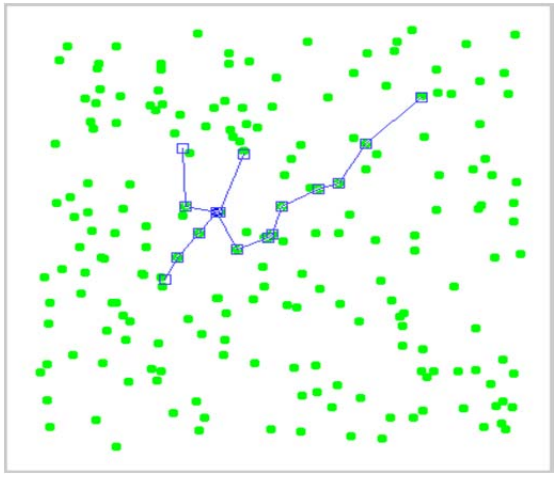

Fig. 3. Chain based routing in MATLAB

In tree based routing shown in Fig. 4, nodes can be used for relatively larger number of times. Unbalanced distribution of energy can also be noticed in this type of topology.

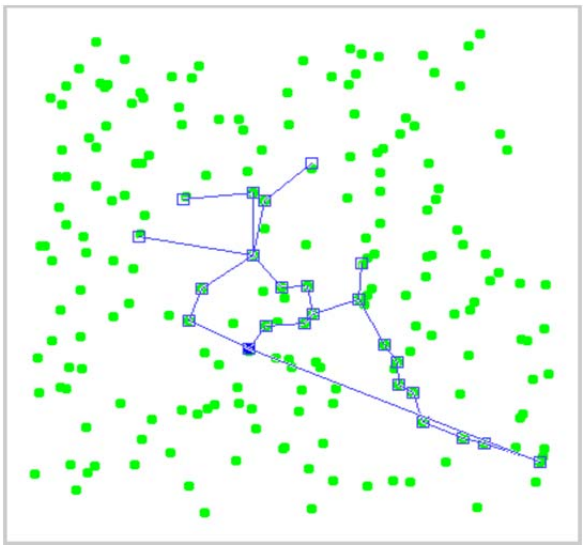

Fig. 4. Tree based routing in MATLAB

Finally, in Fig. 5, the Hybrid based routing is shown which routes data from source to sink.

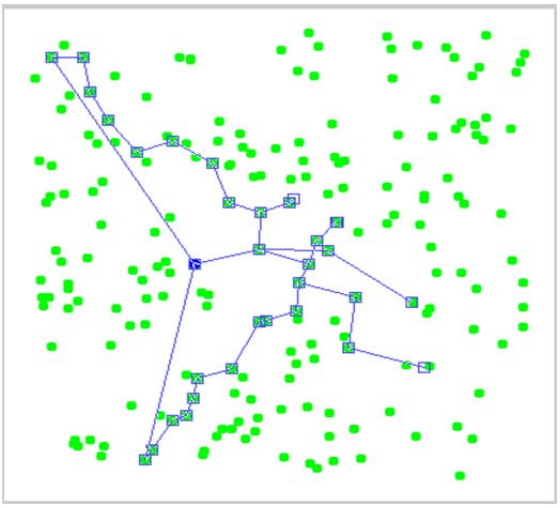

Fig. 5. Hybrid routing in MATLAB

In tree based routing route reselection energy needed is less but the reusability of the nodes is very high. There is high amount of unequal distribution of energy. Where as in chain based topology the reusability is not allowed due to which the path reselection has to be done very often. In hybrid model both the above topologies are used. In Hybrid hierarchical topology reusability is included but with limits. A node can be reused only once. After arbitrary100 rounds of data transmission the results are obtained and analyzed.

In the Fig. 6, comparison is presented based on energy consumption of all the three hierarchical routing topologies after arbitrary 100 rounds of data transmission. Energy consumption is measured in millijoules. In this we can clearly see that the Hybrid approach consumes less energy than original tree and chain algorithms.

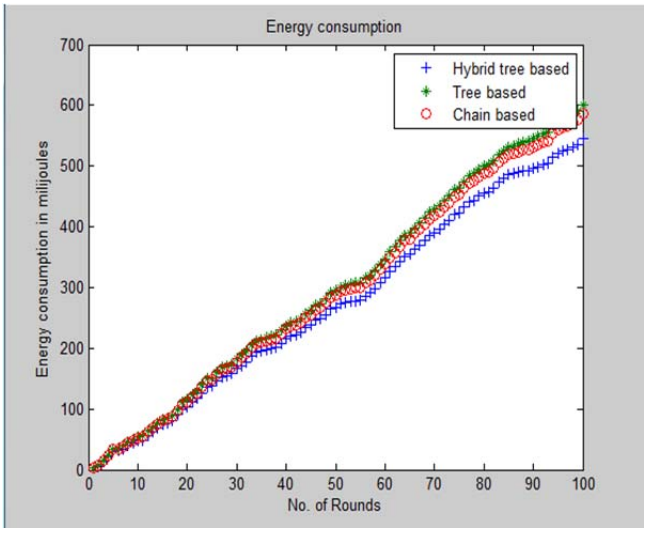

Fig. 6. Energy comparative analysis

In Fig. 7, Network Lifetime is used as comparison metric for comparison among ordinary tree hierarchical topology, chain hierarchical topology and hybrid hierarchical routing topology.

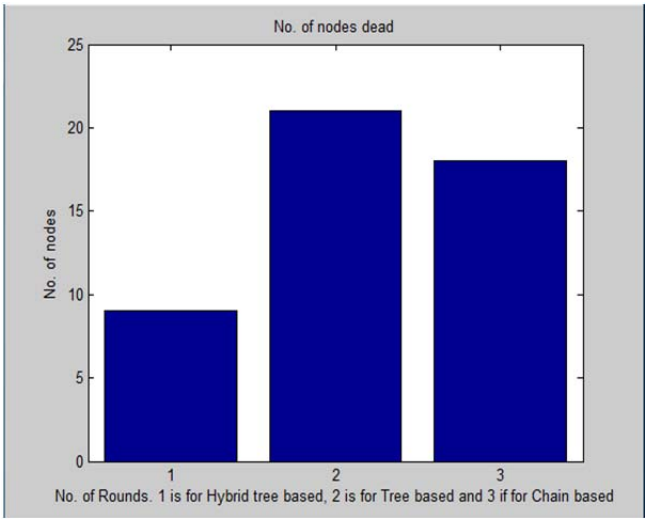

Fig. 7: Number of dead nodes

In this it can be clearly noticed that the proposed hybrid topology has the least number of dead nodes followed by chain and in the end it's the tree topology with highest number of dead nodes after 100 rounds of data transmission. A comparative analysis table is shown below.

Table 1: Comparison table based on energy consumption

Number of rounds of data Transmissions	Energy Consumption in Millijoules in all the three topologies (Approx. values)		
	Hybrid	Tree	Chain
30	170	190	170.8
60	280.2	310.6	300.5
90	480.5	522.2	510.2

It is clear from the above table that the hybrid topology surpasses the tree and chain topology in terms of energy efficiency and performance level.

7. CONCLUSION

In this paper, we have presented a new Hybrid routing topology which uses the concept of tree based routing as well as chain based routing in order to efficiently route the data from source to sink with minimum energy consumption. We have tested our algorithm by simulating the system in MATLAB. The results showcase that hybrid model is better than ordinary tree and chain topologies in terms of energy efficiency and network lifetime.

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