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Fuzzy enhanced Cluster based Energy Efficient Multicast Protocol for Increasing Network Lifetime in WSN

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Wireless Sensor Networks (CWSN) consists of sensor node which is mobile roaming inside and outside the network region. The difficulty in existing models observed is to identify the best routes for forwarding packets. If the balancing of packet arrivals and energy conservation is not achieved, it may lead to reduction of network lifetime. In our research work, Fuzzy enhanced Cluster based Energy Efficient Multicast Protocol (FCEEMP) is developed based on three aspects. First one, the establishment of multicast routing based on the calculation of best route metric and average reliability metric. Second, the cluster is formed based on node stability and route capability. Three set of nodes are formed in the cluster network model i.e. sensor node, cluster member and Cluster Head (CH) to estimate energy consumption. Third, enhancement of fuzzy model is implemented to produce optimal energy and the value of network lifetime. From the simulation analysis, proposed protocol achieves better improvement over existing schemes.

Keywords: CWSN, Energy consumption, Multicast routing, Fuzzy model

Introduction

Wireless Sensor Networks (WSNs)

There are several applications associated with Wireless Sensor Network (WSN) to monitor the events at far region. It contains tiny sensor nodes with several capabilities for advanced processing and high sensitivity. Large number of sensor nodes may be required to monitor real time events but it has some constraints i.e. less power, limited antenna gain, low battery and low bandwidth. The major applications of WSN are environmental monitoring, inventory process, tracking the activity of volcano, weather monitoring and biomedical applications. In cluster based WSN, it consists of three major elements i.e. data monitoring, data aggregation and reporting of data to CH. The role of CH is to manage all cluster members (CMs) and use the available resources whenever it requires. CH is also responsible for monitoring all cluster members, route selection, packet forwarding, channel allocation and broadcasting of power related data. Energy is one of the important factors to determine the lifetime of sensor network. Compared to static sensor nodes, dynamic sensor nodes consume more energy on monitoring and data forwarding. In the cluster based sensor network, cluster members monitor and report the event to CH. If any emergency situations like energy wastage on particular routes, CH advises all CMs to reroute the packets through alternative routes. In existing works, ring based in-network data aggregation method was developed by Jinhuan Zhang *et al*.[1] to minimize the data transmission between two sensor nodes which could increase the network lifetime. In other approach, Fuzzy based evolution algorithm[2] was introduced by Richa Sharma *et al*. to increase the energy efficiency of the network. Based on evolutionary technique and fuzzy algorithm, cluster was formed and the selection of cluster head (CH) was made. Fuzzy based Energy Optimization Routing was introduced by Haifeng Jiang *et al*.[3] to attain the maximum network lifetime in the networks. But the network performance was degraded due to frequent path breaks. The cluster formation and routing was developed by Bhargavi & Saradhi Varma[4] to reach maximum packet deliverability but fails to achieves network connect due to improper route decisions. Naga Ravikiran & Dethe[5] surveyed the important routing algorithms to improve the network lifetime of sensor networks. But it was failed to achieve the network scalability. Sankar & Srinivasan[6] introduced the Internet of Things based fuzzy cluster routing protocol. But it was failed to achieve energy balancing due to dynamic network topology. Ola

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Albeshri *et al*.[7] proposed fuzzy based cluster routing for wireless sensor networks to achieve maximum data gathering. But it fails to achieve network reliability due to loss of data packets. Fuzzy logic based cluster aware routing protocol[8] was developed to improve network lifetime based on hierarchical routing algorithm. Runze Wan *et al*.[9] proposed fuzzy C-means approach for attaining data collection in order to meet the Quality of Service (QoS) requirements. The network performance was not suitable for large deployment. Secure and energy Aware Routing algorithm[10] was explored to balance security and energy efficiency of sensor nodes. Multi-Clustered Energy Efficient Algorithm[11] was developed to form the cluster network based on location of homogeneous and fixed sensor nodes. Location finding algorithm[12] was introduced to find accurate position of sensor node using Received Signal Strength Indicator (RSSI) using triangulation techniques. In the proposed multicast protocol, dynamic and cluster location aware routing is introduced to improve network lifetime without the presence of base station.

Implementation of cluster based energy efficient multicast routing protocol

In the development of the proposed protocol, network environment is given by network model which consists of cluster, cluster head, cluster members and routing protocol. Cluster head plays a major role to monitor the routing behaviour and the communication between cluster members. The multicast routing protocol is deployed to ensure maximum network connectivity which protects network from unbalancing.

Multiple clusters are formed together in the network environment to improve the lifetime. Instead of relying node to node communication, the cluster to cluster connectivity provides reliable and secure data transformation. To provide maximum network lifetime, the proposed protocol is integrated with Fuzzy model. In the first phase, nodes are randomly located which are mobile. Cluster Head (CH) sends (J-MReq) packets to nearby neighbor nodes. If any node closes to CH that is considered as upstream node or else it is known as downstream node in cluster environment. Once the request packets (J-MReq) are received by neighbor node, it will send reply packets (J-MRep) through multiple routes. A route among multiple routes forward the packets within arrival time, it is considered and appointed as primary route by CH. CH floods multiple route request packets to all nodes inside the cluster network environment. All nodes who wish to join as cluster member under single CH or multiple CH will choose the best route to improve the delivery of the packets.

Reliable multicast route discovery

The request packet contains three basic fields i.e. Route ID, path reliability and address of unknown node. The reason for adding these fields in the packet is to assure and protect data packets from selfish or malicious nodes. A node who wants to join multicast group, first it will obtain the reliability of route based on link quality based on following algorithm.

Algorithm 1: Selection of best route

Step 1: Start

Step 2: Cluster member (CM), Data packets, Node ID, CH

Step 3: While (CH is not connected to CM) do

Step 4: CH sends request packets through multiple routes

Step 5: CM replies via best routes to join multicast group

Step 6: The number of best routes $\left(NBR_{\tau}\right)$ is determined based on number of packets successfully carried to number of travelling packets in the route at time $\left(\tau\right)$.

$$NBR_{\tau} = \frac{C_p(\tau)}{T_p\left(\tau\right)}$$

Step 7: CH calculates the number of hops in the particular route and choose the minimum hop to forward the packets.

Step 8: End while

Step 9: Stop

Once all nodes join multicast group, multicast table will be created for all groups. CH monitors the data forwarding behaviours of CM after multicast group setup. If any CM is detected as selfish node or malicious node, CH will stop to send packets and further communication. The detection of malicious node is identified based on packet misrouting, packet tunnelling and altering the packet information. The detection of selfish node is identified from the knowing the information about packets. The address of malicious node or selfish node is immediately added in all messages to broadcast it to all participating cluster members. Such kind of these misbehaving nodes cannot be a group member until it corrects behaviour. The recovering time R(t) is used to restore the node until malicious node becomes genuine node and reliability metric is set to 0.7.

Energy calculation of cluster network model

In this phase, energy utilized by sensor node, cluster member and cluster head is calculated by means of applying population metric b, incremental population metric bi energy metric χ and initial energy E_i to the total number of nodes *n*. Meanwhile density of packets (P_d), average reliability metric (ARM) and link capacity (C_p) are also the key factors used for obtaining energy consumption of sensor nodes, cluster member and cluster head.

Total primary energy introduced in the cluster network model is calculated as E_{tot} ,

$$E_{tot} = E_{SN} + E_{cm} + E_{CH}$$

From this analysis, energy spent by cluster member is greater than m times by energy spent by sensor nodes, whereas energy spent by cluster head is greater than 1+m times by energy spent by cluster members. Always CH is considered as superior node in the network model. In most of the energy efficient clustering protocols, the overhead of network management was reduced by minimizing the chosen CH based on scalability factor. The selection of cluster head must be within time period. There should be no extra loads introduced between sensor nodes to CH. Only the communication between CM and CH is allowed. In our proposed network model, all nodes are equally located with average percentage where the network zone is divided into two zones i.e A and B. This assumption reduces the overhead of network and reduces the energy wastage.

Fuzzy model for decision making

In this phase, fuzzy logic is used as the manipulator for obtaining energy optimization. There are three parts in the fuzzy model i.e. fuzzifier, inference engine and defuzzifier. The fuzzifier takes the input values and maps it to fuzzy set. These fuzzy sets are processed by inference engine using rule base and different methods. In our proposed model, mamdani fuzzy rule is deployed to understand the inference engine. The defuzzifier produces output value from the fuzzy space.

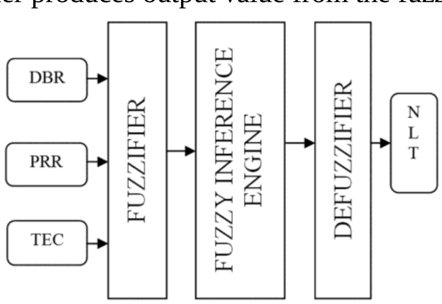

Fig. 1 — Fuzzy model for network lifetime decision

In the proposed fuzzy model, mamdani fuzzy inference engine takes three input values as fuzzy set from the fuzzifier such as degree of best routes, packet receiving rate and total energy of cluster network model. The first two variables represent the performance of routing and third fuzzy set represents cluster energy for decision of network lifetime. The mamdani fuzzy inference system uses IF THEN rule to determine the level of network lifetime. Fig. 1. shows the illustration of proposed fuzzy model for deciding the value of network lifetime. If three fuzzy sets are set to high, the delivery of output value indicates high network lifetime. If any one of the fuzzy sets goes below the average value, it may lead to lower one which may produce medium network lifetime. If any two of the metrics goes below the least threshold value, the network lifetime may be the degraded one.

Performance Analysis

In this phase, Network simulator (NS 2.34) is used to simulate the proposed protocol. For simulation, the tool command language is used as front end and C++ language is written as backend language. In our simulation, 600 sensor nodes are deployed randomly in network model. Each cluster contains 220 nodes are located in the simulation area with the size of 1200 meter x 1200 meter square. The simulation pause time is 100 secs. Nodes are communicated through the transmission range of 250 meters. In this performance analysis, nodes are communicating in the presence of poisson traffic which produces random delay and less overhead. The reason for choosing Low energy Adaptive Cluster Hierarchy (LEACH) protocol is to balance energy conservation in order to increase network lifetime. The simulation settings of network model are illustrated in Table 1.

Network Performance Metrics

The proposed protocol FCEEMP is simulated through the various network metrics to show the performance. It is defined given below.

Table 1 — Simulation and Settings parameters of FCEEMP

No. of Nodes (cluster members)	600
Area Size	1200 x 1200 m^2
Mac	802.15.4
Radio Range	250 meter
Simulation Time	100 sec
Traffic Source	Poisson
Packet Size	256 bytes
Package rate	4 pkt/s
Transmission power	985 mw
Received power	0.785 mw
Protocol	LEACH

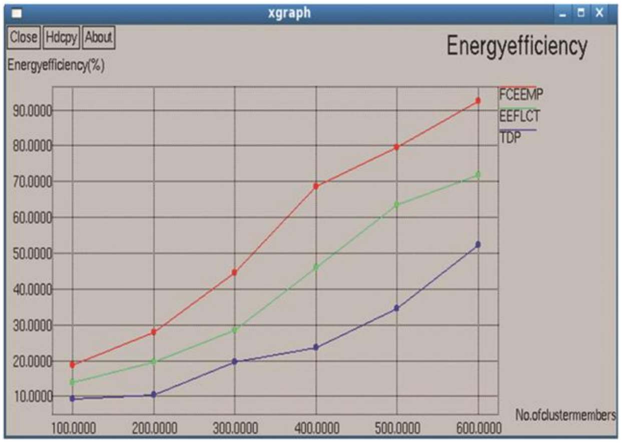

Fig. 2 — No. of Cluster members Vs Energy Efficiency

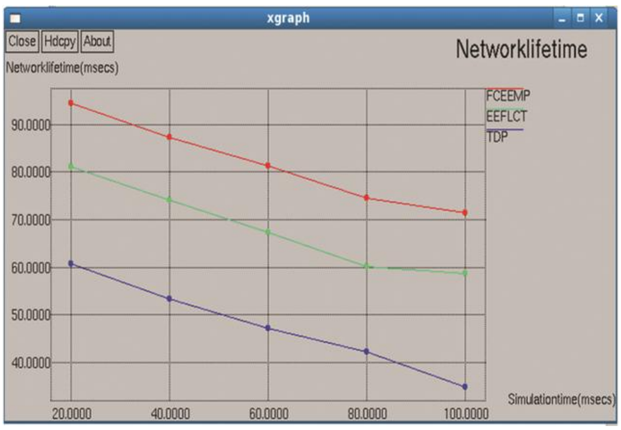

Fig. 3 — Network lifetime Vs Simulation time

Energy efficiency: It defines the energy spent in route to total available energy given to network.

Network lifetime: It defines the time interval between formations of network setup to the expiry of last sensor node.

The simulation results are presented here. FCEEMP is compared with EEFLCT[8] and TDP[10] in terms of network lifetime and energy efficiency. Figure 2 shows the performance of energy efficiency while varying the cluster members from 100 to 600. In existing models, there were no steps taken for CH replacement. In the proposed protocol, the FCEEMP, CH replacement is done after round trip time. From the results, the FCEEMP achieves high energy efficiency than existing schemes. Figure 3 illustrates the performance of network lifetime while increasing the network lifetime from 0 to 100 msecs. In the proposed protocol FCEEMP, the stability period of cluster network is more compared to instability period which increases the network lifetime. From the results, it achieves more network lifetime than existing schemes.

Conclusion

In this research work, fuzzy enhanced energy efficient cluster routing protocol is introduced to balance packet reachability and energy conservation to increase network lifetime. In existing models, selection of CH is based on network parameters. In the proposed model, CH is elected from quality index and average reliability metric of links. Cluster network is divided into two zones which defines the location of nodes with respect to geographic axis. After the estimation of energy consumption model, cluster based multicast network is deployed in the fuzzy decision mechanism which provides low, medium and high network lifetime depends on the input crisp values. Based on the simulation result analysis, the FCEEMP achieves low delay, less instability time, high throughput, high energy efficiency and network lifetime compared to existing models.

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